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Mapping productivity, energy and wellbeing: interdisciplinary explorations of falling productivity growth, energy transitions and implications for wellbeing

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Mapping Productivity, Energy and Wellbeing

Interdisciplinary explorations of falling productivity growth, energy transitions and implications for wellbeing

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Abstract

Productivity growth has been failing for several decades in many of the wealthiest economies. Conventional economics and policy making sees this as a crisis because they assume that productivity growth is linked to material standards of living and that reductions in the growth of living standards will lead to reduced wellbeing. The ESRC funded *Powering Productivity: Exploring links between energy, wellbeing and the UK's productivity puzzle* research project investigated the problem of falling productivity growth and its relationship to both energy and wellbeing. The research used a participatory system mapping method and two thematic literature reviews to integrate perspectives across disciplines. A possible explanation for failing productivity is the declining access to high quality energy in (i.e. traditional fossil fuel). This explanation subsequently raises fundamental questions. With the transition to sustainable renewable energy driven societies, will falling productivity growth rates be the new normal? If so, what does this mean for wellbeing, standards of living and general levels of prosperity? Can we raise productivity growth rates with sustainable energy sources? And finally, how does this ongoing fall in productivity growth influence wellbeing? In this paper we describe the research methods and process, reflect on the insights generated in the interdisciplinary explorations, and speculate how it might inform the design of sustainable transitions.

1. Introduction to the Powering Productivity Research

Productivity growth has been falling for several decades in the UK (McCann 2018, Jackson 2019 – see figure 1) and other wealthy economies (Askenazy et al., 2016, Manyika et al., 2017). In mainstream economic theory, reductions in the growth of productivity are linked to reductions in material living standards and are assumed to lead to reduced wellbeing. Ecological economists argue that failing productivity growth may be associated with declining access to high quality energy (Fagnart and Germain, 2016, Brandt, 2017, Jackson, 2019a). Reductions in the quality of energy can be due to both declining access to easy to access reserves of fossil fuels and to a transition away from fossil fuels (Brand-Correa et al., 2017, Hall and Klitgaard, 2018). This explanation subsequently raises fundamental

questions. With the transition to sustainable renewable energy driven societies, will falling productivity growth rates be the new normal? If so, what does this mean for wellbeing, standards of living and general levels of prosperity? Can we raise productivity growth rates with sustainable energy sources? And finally, how does this ongoing fall in productivity influence wellbeing?

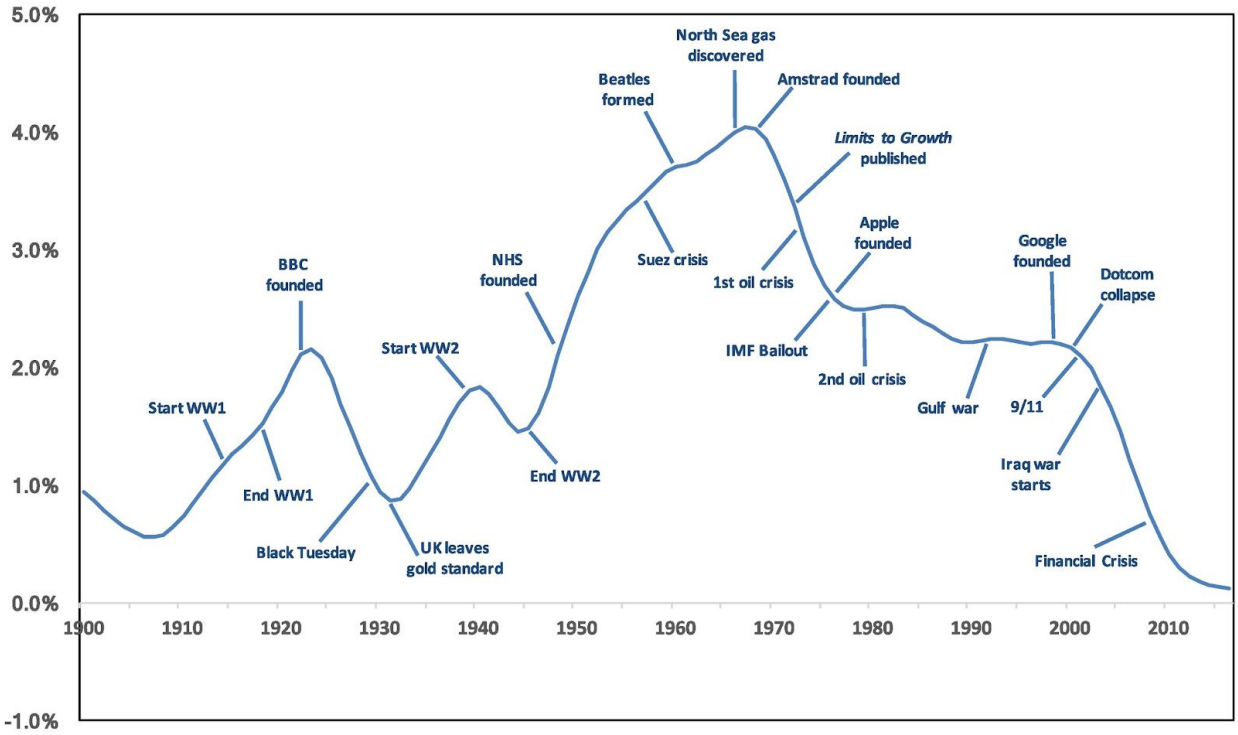


Figure 1: **Labour productivity growth in the UK 1900 – 2016**. Source: Jackson 2019.

Falling productivity growth and its relationship to both energy and wellbeing were investigated in the ESRC funded *Powering Productivity* research project. The research used a mixed method combination of thematic literature review with expert elicitation in a participatory systems mapping process. The mapping method enabled interdisciplinary explorations of the research problems. This paper will describe the methods and processes and then review the knowledge generated using two knowledge maps as focal points for reporting on research findings: the Energy-Productivity Map (figure 3) and the Wellbeing-Productivity Map (figure 5). The topics under discussion have wide-reaching implications and the paper will conclude with reflections on how the research insights might inform the design of sustainable transitions.

2. Research Design

Two parallel research projects were conducted, each with its own mapping workshop: 1) Energy and Productivity and 2) Wellbeing and Productivity. The research design consisted of a combination of two thematic literature reviews with two participatory systems mapping workshops with subject experts. The information gathering and co-production activities were followed by the development of two topic reports – literature reviews: *Energy and Productivity* (Elkomy S, S Mair and T Jackson, 2020) and

Wellbeing and Productivity (Isham A, S Mair and T Jackson, 2020); the design of interactive knowledge maps, and a *Mapping Method Report* which describes the mapping process in greater detail (Boehnert, Mair & Landa-Avila, 2020). Stages in the research design are illustrated in Figure 2.

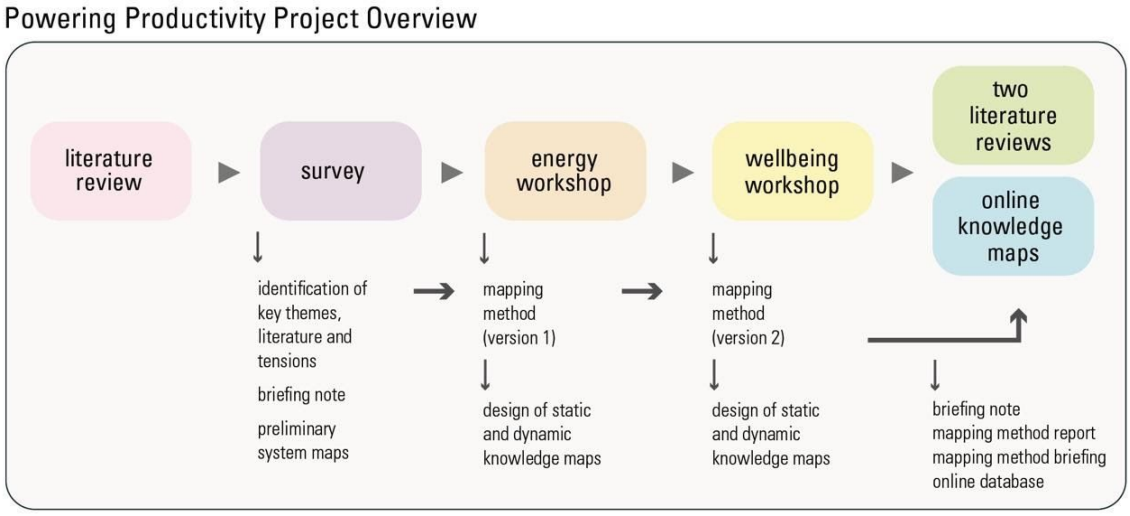


Figure 2. **Powering Productivity Project Overview** - research design

The participatory processes began with questionnaires sent to subject experts to identify key themes, literature and research groups. Two systems mapping workshops were organised to facilitate interdisciplinary discussions and participatory mappings on the two topics. In the mapping workshops, specific attention was paid to significant relationships and tensions within the subjects under investigation. Workshop participants created the system maps on large pieces of paper with guidance from design facilitators. The literature review group used the initial system maps to guide their writing and searching processes. Post-workshop, the co-produced system maps were used to inform the thematic literature reviews to highlight new linkages that emerged within the interdisciplinary mapping. The system maps were refined by the mapping methods research group at Loughborough University in an iterative process with feedback from the wider research group at the University of Surrey. This process informed the development of two knowledge maps (figures 3 and 5) published online as interactive digital visualisations linked to a database of the literature review (figures 4 and 6).

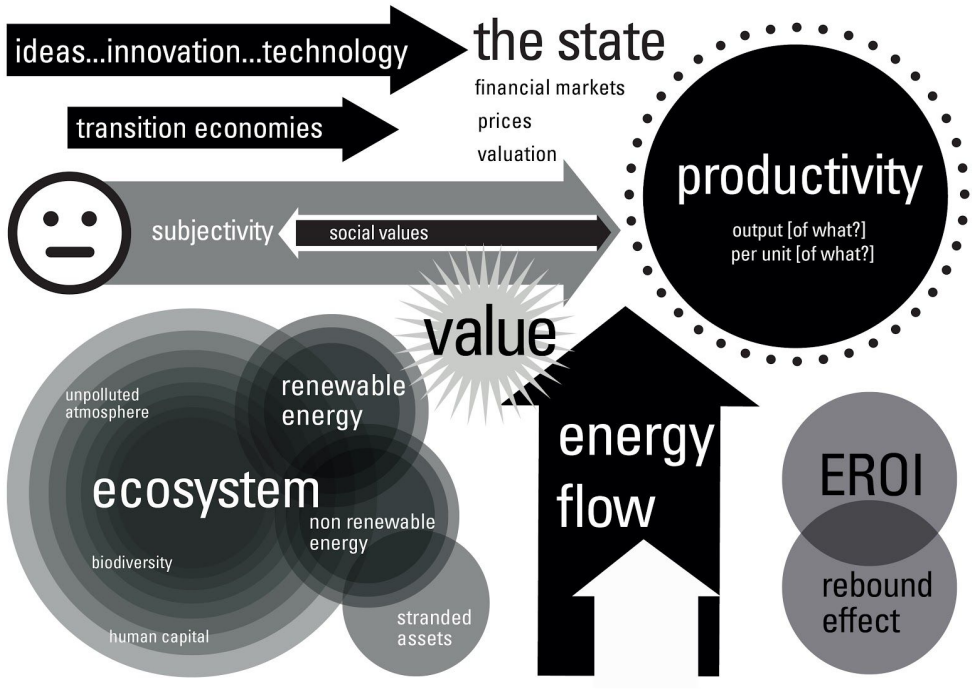


Figure 3: **Energy-Productivity Knowledge Map** v.1.

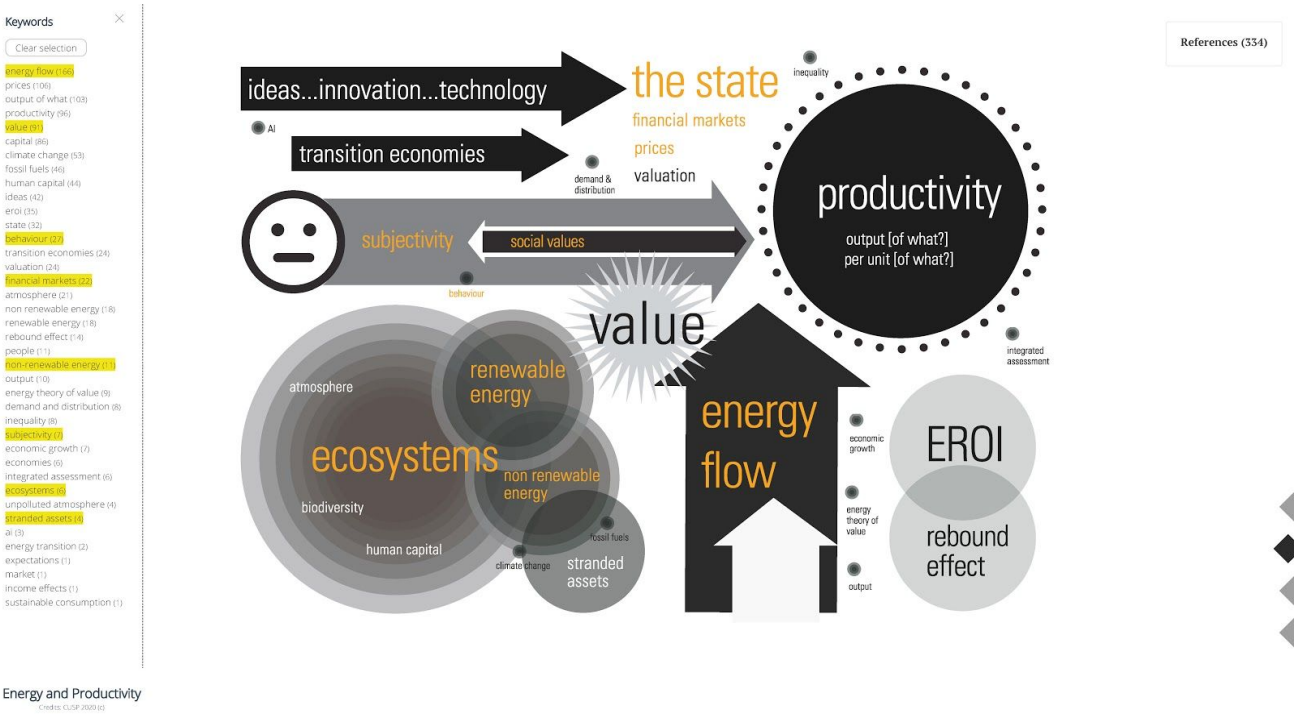


Figure 4: **Energy-Productivity Map** online with link to database – click here to access online map.

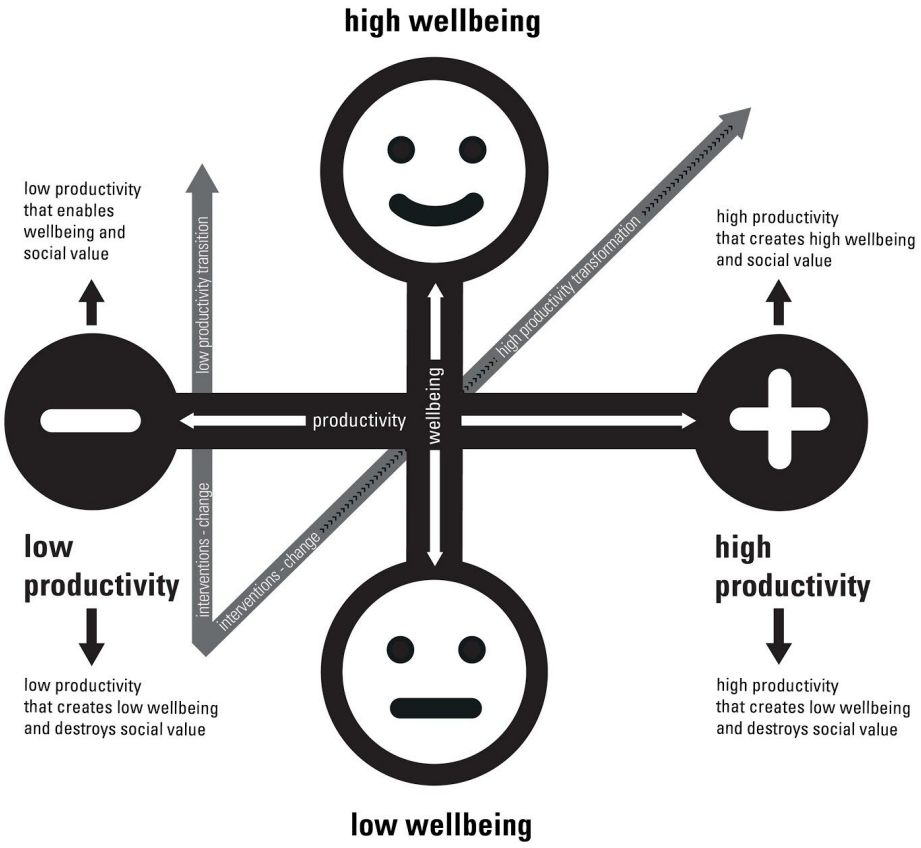


Figure 5. **Wellbeing-Productivity Knowledge Map**, v.1.

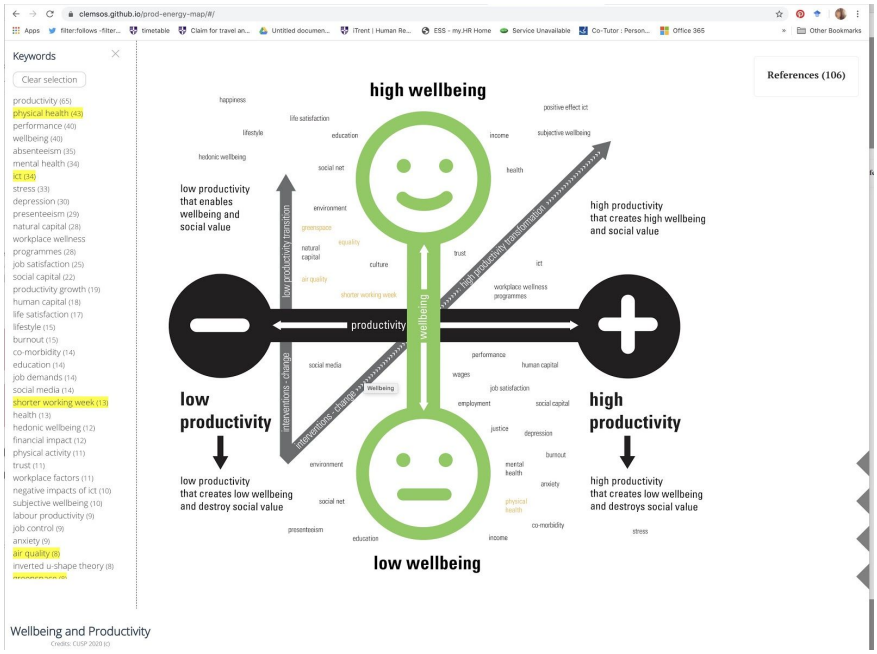


Figure 6. **Wellbeing-Productivity Map** online with link to database – *click here to access online map*.

3. Transdisciplinary Knowledge Generation with Systems Oriented Design

The relationships between productivity, energy and wellbeing are complex and inherently inter-disciplinary. Productivity is a contested concept, but sits principally within economics. Productivity is constructed and used by economists as a measure of the productive capacity of an economy (how much can we produce for a given set of inputs) *and* as a measure of the standard of living (how rich are we, on average). It deals with market activity measured in monetary terms. Labour productivity, for instance, is typically measured as the value of market output per person employed. On the other hand, energy is a physical concept constructed and used by engineers and natural scientists. Common measures of energy include primary energy (energy at the point of extraction such as tonnes of coal) and exergy (the amount of energy that is available to do physical work). Wellbeing adds yet another dimension to the inquiry. As a concept wellbeing can be constructed and used from economic, sociological, or psychological viewpoints. Examples of wellbeing measures include those that are relatively 'objective', such as physical or mental health; through to those that are explicitly subjective, such as self reported life satisfaction. Communicating across all these different disciplinary vocabularies, assumptions, epistemologies and priorities is extremely difficult.

3.1 Systems Oriented Design

Systemic design offers visual strategies and design methods to bridge disciplinary silos. The system-oriented design community has developed mapping strategies that capture complexity by visualising relationships, dynamics and tensions across knowledge traditions. Systemic design (Sevaldson, 2013; Jones & Bowes, 2017) combines design practices and systems work in ways that are especially well-suited to capture complex interactions across domains, sectors, spaces and scales. This project uses participatory systems mapping methods in the systemic design traditions to facilitate interdisciplinary discussions and knowledge exchange. For this research, a process was designed to review what information should be prioritised, organised, visualised and documented in the mapping processes. During the mapping workshops, the maps functioned as a focus for criticism, discussion and as a catalyst for the emergence of new ideas. With participatory structured mapping processes and open mapping processes, new relationships were made visible and documented. The mapping workshops helped to integrate knowledge from different domains into the research project in ways that would be difficult to achieve through a standard literature review.

3.2 Systems Mapping Methods

Systems mapping is an umbrella term that refers to different strategies for synthesising knowledge within complex system approaches. Using visual strategies and devices to graphically display relationships between elements, spaces, actors and ideas – systems maps reveal contextual and dynamic information. Mapping supports relational reasoning (Corner, 1999, 251, Boehnert 2014, 2018a) by making visible what is otherwise inaccessible (Corner, 1999, 225). Mapping facilitates sense-making (Dervin 1998) and can build shared understanding across knowledge boundaries (Comi, Bischof & Eppler, 2014, 8). Mapping is a means configuring and reconfiguring existing conditions in ways that facilitate the emergence of new ideas (Corner 1999; Boehnert 2018, 371-372). Ultimately systems mapping aims to increase the quality of knowledge on issues of complexity.

Within this research project, participatory processes enabled knowledge exchange where system maps provided a common conceptual focus. The mapping processes used drawing techniques to capture ideas

and interactions. In these ways mapping practices can increase mutual understanding, foster experiential knowledge, and allow participants to connect tacit with explicit knowledge in ways that nurture new capacities to externalise and communicate tacit knowledge (Comi *et al*., 2014, 7; Mengis, Nicolini, & Swan, 2018, 298). Systems mapping is made more robust by including contributions from diverse stakeholders, fields and sectors relevant to the themes or problems under investigation. With this research workshop participants were drawn from diverse academic disciplines. The systemic design approach in this project employed a variety of mapping methods, including participatory gigamapping and knowledge mapping.

Gigamapping aims to increase the richness and diversity of knowledge on issues of complexity with large-scale maps that work across scales to display relationships and interactions. Gigamapping is an open and participatory mapping method that creates rich contextual information by avoiding preconceived structure. Design facilitators here do not strive for refined, logical and ordered maps – but to reflect the messiness of wicked problems. This mapping practice is used in management, academia, knowledge organisation, planning and implementation. Design facilitators are not looking to achieve consensus within the gigamap, but rather to acknowledge multiple perspectives and dynamics in intersecting systems (Sevaldson, 2015, 5). The participatory mapping process captures dialogue across communities, disciplines and sectors in ways that are well-suited to capture dense information, dynamics and complex relationships (Jones & Bowes, 2017, 230; Sevaldson, 2011, 2, 4; 2015, 3). Systems maps aim to display states of affairs and build problem fields or *problematiques* (Sevaldson, 2015, 3) and function to uncover leverage points, tense relationships and opportunities for interventions.

Post-workshops, the gigamaps were transformed into knowledge maps. Knowledge mapping is a method that graphically represents elements from different domains in a structured manner to reveal relationships, to suggest particular narratives, and to develop meaning (Hashemi *et al*. 2013, 45; Robinson & Petchenik, 1976, 74). Knowledge maps "capture not just (descriptive) facts or numbers, but contain also prescriptive and prognostic insights, principles, basic assumptions and relations. They are used as communication devices in order to trigger sense making activities and to motivate viewers to re-construct meaning" (Eppler and Burkhard, 2007, 113). Organising complex information in ways that helps audiences to identify relationships and links to pre-existing knowledge, often with visual metaphors, facilitates sense-making, generates new meanings and makes it easier for new knowledge to become applied (Boehnert, 2018, 176). Examples of knowledge maps are: concept maps, mind maps, cognitive maps, topic maps, causal loop maps and flow maps.

The mapping methods in this project combine the participatory system mapping elicitation phase and a representation phase (post-workshops) as described in the *Mapping Methods Report* (Boehnert, Mair & Landa-Avila, 2020). The gigamaps developed in the workshops were used as the basis for two static knowledge maps and the design of two online interactive knowledge maps with links to the literature database (figures 4 and 6). With this method new knowledge generated at the workshops was captured and transformed linking to the text referenced in the literature reviews.

3.3 Integrating the Mapping and Review Processes

The *Mapping Productivity* research process integrated the thematic literature reviews and mapping workshops in two ways. First, preliminary literature searches (partially based on the surveys) were used to produce briefing notes which framed initial discussions at the mapping workshops. Both briefing notes followed the same structure: identifying a number of core themes (12 in the energy project and 9

in the wellbeing project), summarising key arguments, providing indicative references and raising questions for discussion. Secondly, the maps and discussions at the workshops were used to guide subsequent stages of literature search and report development. Workshops were facilitated by the design facilitators, leaving the literature review research group free to take notes and participate in map construction. At each workshop, the two literature review authors participated in the mapping process. Each was in a different mapping group to ensure coverage of all discussions. (There were two groups of 4-6 people working on two different maps in each workshop). This provided a level of immersion in the mapping process which contributed to the co-production and helped to ensure the mapping process influenced the literature reviews.

Figure 7 & 8. **Challenges in the energy-productivity mapping process -** There was no overall consensus on the energy-productivity relations. Discussions quickly turned to fundamental concepts – such as: 'what is value?'

With regard to integrating learning, the energy-productivity workshop was the more challenging topic. Some complications were due to the research process itself. The energy workshop occurred at an earlier stage in the review process. Consequently, the literature search was less complete, resulting in greater scope for the workshop to move into uncharted territory. The more consequential dilemma emerged from the fact that the broader scope of the discussions were further driven by the diversity in participants and the controversy of the subject matter itself. Discussants had very different worldviews which on occasions created tensions – particularly notable between mainstream and heterodox economists. Additionally, there was no overall consensus on the energy-productivity relation in the room. Given the space and diversity in perspectives, it is perhaps not surprising that discussions quickly turned to fundamental concepts, such as 'what is value?' All these aspects re-affirmed the need for further research in this understudied field. The breadth and complexity of conversations in the energy workshop made its integration with the review process more difficult.

Figure 9 & 10. **Energy-productivity mapping process -** Two dominant dynamics emerged in the map: 1) the relationship between subjectivity, social values and economic value; 2) the role of energy in productivity.

The wellbeing workshop was less controversial. There was notably more of a shared understanding of the subject matter amongst participants, although perspectives differed on a potentially adverse relationship between productivity and wellbeing. All in all, the discussions at the wellbeing workshop were more focused and less fundamental. This workshop served to clarify gaps and ensure all relevant literature had been covered.

The energy workshop was more creative and had more breadth. These are important and desirable qualities – but these features made the review process considerably more challenging. By contrast the wellbeing workshop was less expansive and creative. Discussions were narrower. This focus gave the wellbeing-productivity mapping process it greater depth – and enabled the mapping processes to feed more easily into a review process.

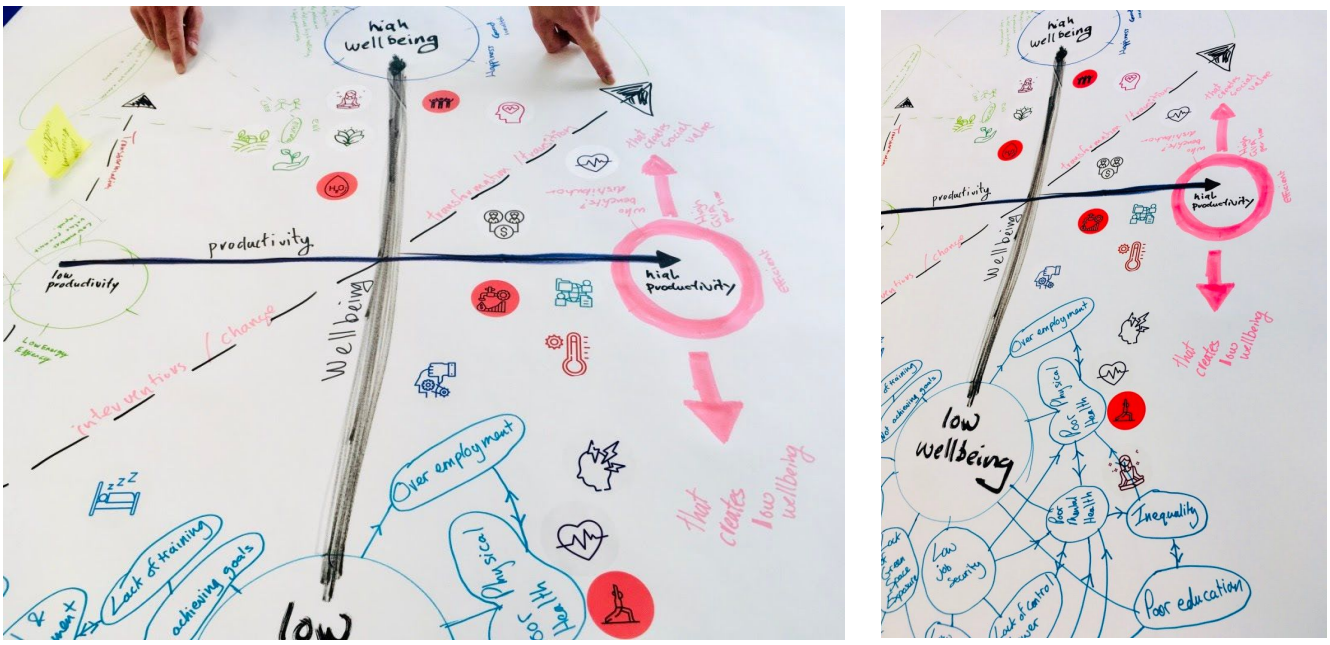


Figure 11 & 12. **Wellbeing-Productivity Mapping process**. Perspectives differed on a potentially adverse relationship between productivity and wellbeing.

4. The Energy-Productivity Relationship

In the following two sections we provide a narrative discussion of the relationship between energy-productivity and wellbeing-productivity. The aim here is to draw out key insights from the mapping exercises and literature reviews. To structure our narratives we highlight key elements from the two maps. We begin by focusing attention on the energy-productivity map, drawing attention to its use of 'value', then exploring the interplay between its 'political-economic' and 'physical-energetic' elements.

4.1 The importance of economic value and social values

The concept of 'value' is at the heart of the productivity question. The term is an abstract one and has a variety of meanings and interpretations. One the most famous examples of different forms of value is the distinction between exchange value and use value set out by Marx (1873/2013). Exchange value is the form of value most commonly referred to by productivity metrics. The UK government often speaks of 'GDP per person' (a measure of the market values ascribed to goods and services produced in a given year) i.e. in it's Industrial Strategy (BEIS 2018). In other words, the value of goods when exchanged for other goods. Use value has its own distinct logic. Use values describe the reason we want a particular good seperate from our ability to exchange it. There are still other types of value: ecological economists discuss 'intrinsic' values for instance: the value something has purely by virtue of its existence (Curry, 2011). Intrinsic value functions as a concept that draws attention to the fact that value exists outside market exchange processes.

The way that we choose to define 'productivity' is a reflection of what we believe 'value' is and how we believe it is generated. Productivity is a measure of how much value is produced per unit of input. 'Value' is the output measure. The thing we believe is important in generating that value is the input measure. There are as many forms of productivity as there are forms of value.

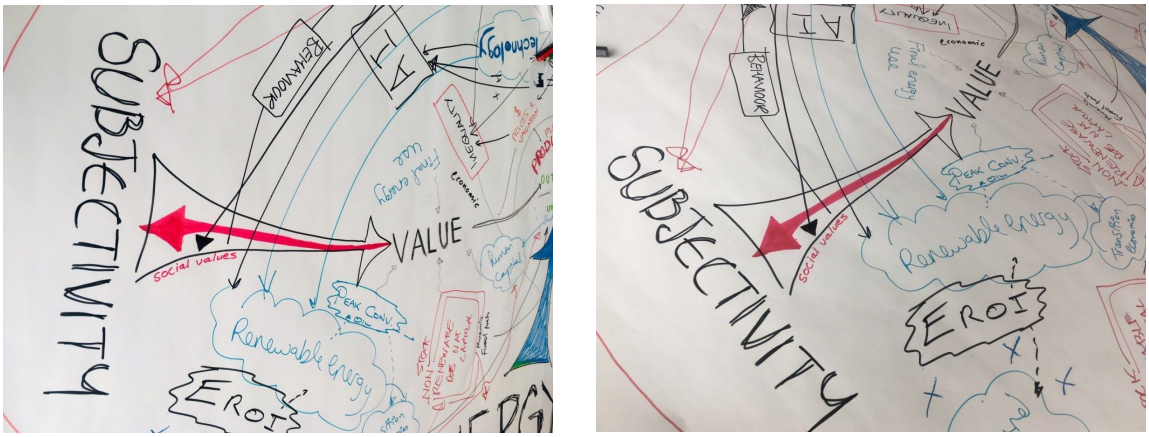
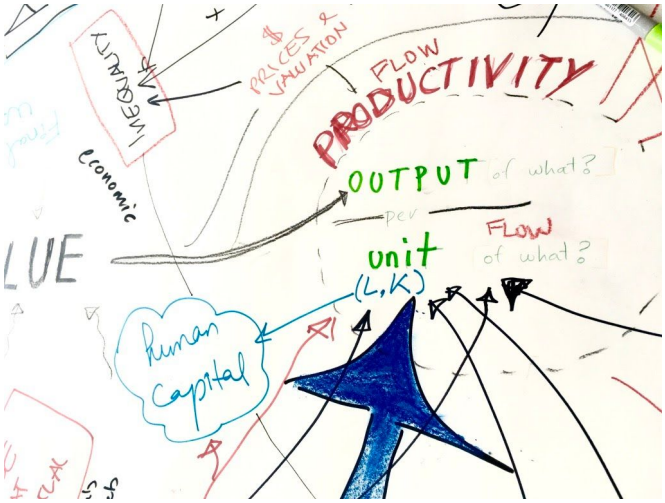


Figure 11 & 12. **Energy-Productivity Mapping.** Mapping the subjectivity, social values and economic value where value is understood and produced according to different social values.

In the energy map, the terms 'value' and 'productivity' are employed in ways that suggest the multiplicity of ways the terms are interpreted, and consequently the multiplicity of ways value and productivity are understood. The 'value' starburst in the energy map is placed in the centre of the composition in between the social values/subjectivity arrows and the material elements including

energy flow below. The arrow marked subjectivity and social values connect the individual (represented by the 'face' in the final wellbeing productivity map (figure 5)) to productivity. The multiple meanings associated with productivity are made explicit by the 'output [of what?] per unit [of what?]' inside the productivity bubble (see figure 13 & 14). In the mapping process, participant mappers sought to emphasise the understanding that the concept of 'productivity' is conceptualised and used in ways that reflect how the notion of 'value' is constructed and used – which in turn reflects perceptions on how value is created.



Figures 13 & 14. **Energy-Productivity Map: 'Output [of what?] per Unit [of what?]' in the Productivity Bubble**

4.2 Between the economic and the physical

The "subjectivity - values - value" elements form the central axis of the energy-productivity map (figure 15 & 16) and divide the economic from the physical. The area above this axis can be understood to represent the political economy of value production. The area below represents the physical and energetic aspects of value production (figure 17 & 18). The combination of these two dynamics (the economic and the physical) is itself novel and represents one of the strengths of the mapping process. Typically, communities that emphasise political and economic elements of productivity and those that emphasise energetic elements are distinct from one another – and rarely do these discourses meet. Kallis and Sager (2017), for instance, argue that ecological economists have focussed principally on the physical work that energy brings to the production process, at the expense of their understanding of the ways this physical work intersects with elements such as price and (social) power. At the same time, conventional economists have very little to say about the importance of physical work done by energy (Elkomy et al 2020). The narratives emerging from the combination of energy-physical and political-economic elements in this mapping process is very different from heterodox productivity discourses.

The productivity narrative in conventional economics does not include energy. Modern growth theory, says that productivity growth comes primarily from the abstract concepts of 'research' or 'human capital' (Romer, 1994). Because these drivers of productivity are considered in a way that is disembedded from material reality, all links to energy are overlooked. This dismissal of the material circumstances that enable productivity constitutes a fundamental and consequential error according to ecological economics. Environmental scholars have long described how the ignoring of the ecological as a foundation for human prosperity constitutes a severe error with grave consequences.

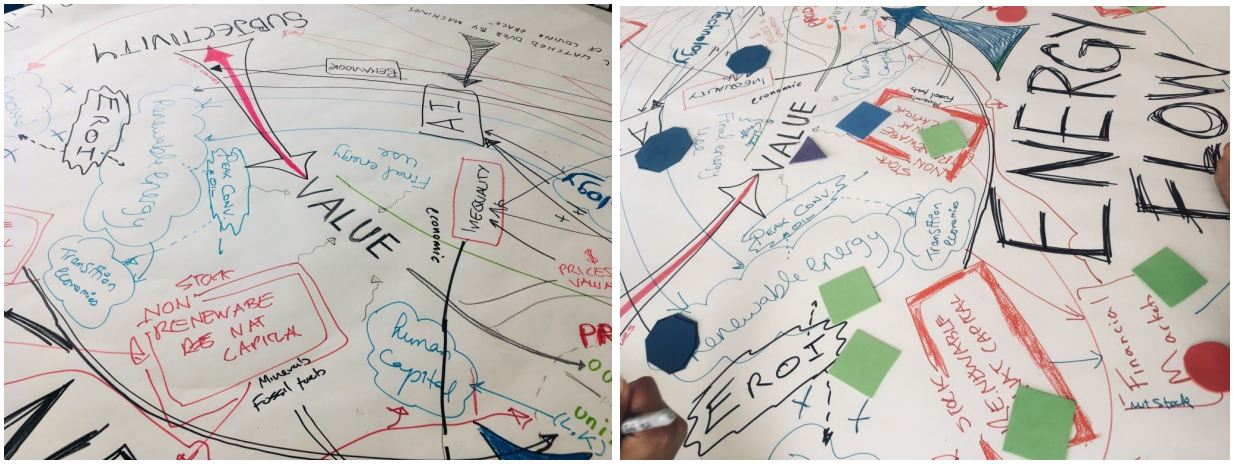
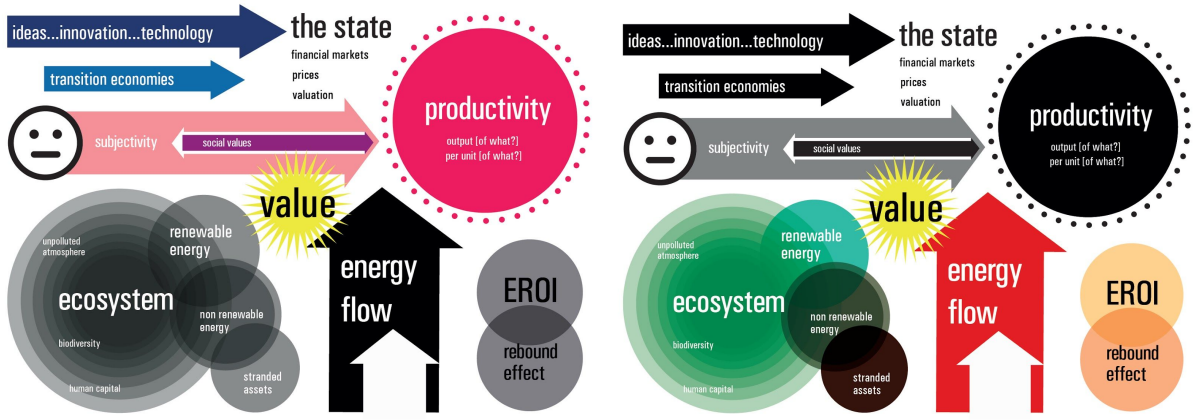


Figure 15 & 16. **The Energy-Productivity Map**. The "subjectivity - social values - value" central axis.

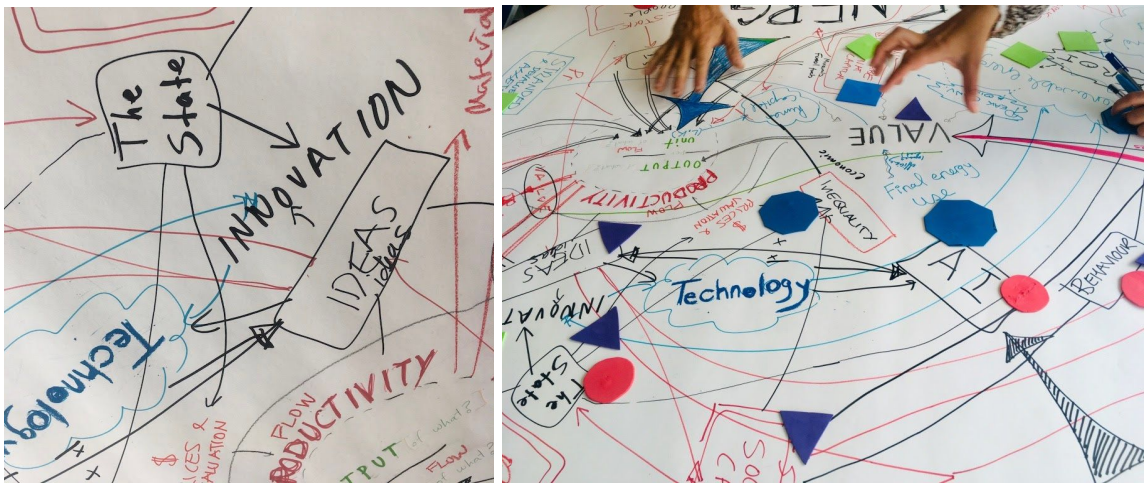


Figures 17 & 18. **Energy-Productivity Map.** The the central axis (the subjectivity - social values arrow) divides "the economic" (top) from the physical/energetic (bottom) of the map. The area above this axis can be understood to represent the political economy of value production. The area below represents the physical and energetic aspects of value production. Productivity is influenced by dynamics from both the top and bottom of the map.

The problem extends to media and policy documents that refer to labour productivity almost exclusively erasing the role of energy and ecological circumstances. For example, the UK industrial strategy only provides productivity figures in terms of GDP per hour worked or GDP per capita (BEIS, 2018). Ecological economists argue that this dismissal of the role energy plays in productivity is a fundamental mistake. For ecological economists, energy is defined as the potential to carry out work. Consequently, without energy there can be no work. As Keen et al., (2019) quip: capital without energy is a statue, labour without energy is a corpse. As a clarifying metaphor, if the energy supply is cut off to an office block or factory, the computers and machines (physical capital) cease to function. If workers have no access to food, they will stop working. From this perspective, it is clear that all production and productivity requires energy. These basic facts are obscured in mainstream economic theory on productivity.

At this point it is worth returning the question of value. If energy is required for the production of value, as described above, an important question becomes how energy is channelled and what kind of value it is used to produce. The top section of the energy-productivity map displays ideas and institutions that

inform the dominant construction of productivity today – the political economy of value production. This is productivity as in terms of exchange value. Ideas, innovation and technology (figures 19 & 20) are employed by institutions with the means to take abstract ideas and apply them. Engineers and designers are employed to design and develop new energy systems, technologies and ways of living. These new systems are shaped by both political economies and the priorities of governing institutions: including the state and the market. Consequently their form and purpose is shaped by these institutions. The economic and the physical can be theorised by synthesising the top and bottom of the map (figures 17 & 18). The political economy and energy economy have coevolved. This is evident in the history of the concept of energy return on energy invested (EROI).



Figures 19 & 20: **Energy-Productivity map**. The top of the map represents the political economy of value production. Pictures of the mapping process situating ideas, innovation and technology elements in relation to governing structures (the State).

EROI is a measure of energy quality. It tells us the amount of energy we have to use in order to generate energy in a particular process. For example, before a wind turbine can be used to generate energy it must be built. This requires metals to be mined, heated and shaped. The EROI of a wind turbine is the energy it generates, divided by the energy that goes into its construction and maintenance. The more energy that goes into production and maintenance, the lower the EROI. Energy analysts suggest that EROI is falling across all energy types (Hall et al., 2014, Brockway et al.,2019). This is happening because the easy to access sources of energy have been used, and current sources of energy that are harder to access. For example, traditional oil and gas has an EROI of around 18:1, while shale oil and tar sands have EROIs of 7:1 and 4:1 (Hall et al., 2014). Lower EROI means less energy is available to us for a given energy expenditure. At lower EROIs we have less net energy available for non-energy production.

The challenge of falling EROI is a result of geological and technical realities as well as the political economy of productivity growth. EROIs are determined by the energy efficiency of the technologies available to extract energy, as well as the difficulty of accessing the energy source. If EROIs do decline, as some trends suggest and analysts fear, we may face a future with less energy available for productive uses. Sers and Victor (2019) show that if EROIs fall low enough it is possible that just to maintain current levels of energy generation, we have to channel most of that energy back into energy production.

Lower productivity associated with falling EROI is an undesirable situation. However, the consequences of these dynamics will be primarily determined by the political economy and the types of value that are prioritised by the political economy. Particular questions arise in these circumstances. Are high energy lives necessary? Is it possible to arrange things differently? These wicked problems will fundamentally shape future living conditions. This aspect of the productivity puzzle must be accounted not only in energy policy but in the design of future ways of living.

5. The link between wellbeing and productivity

In this section we focus on the wellbeing-productivity research. The question of the definition of productivity continued to be a primarily concern and was captured prominently on the map (figure 22) The socially constructed nature of the notion of value and its ambiguous relation to productivity is illustrated in the wellbeing-productivity map. Here increasing and decreasing social value is explicitly labelled to emphasise the (supposed) ultimate purpose of productivity growth in enabling greater wellbeing (Figure 5 and 23). At either end of the horizontal 'productivity' axis are labels suggesting alternate relationships between social values and productivity (Figure 22 & 23). The map captures a variety of components that may contribute to social value and wellbeing (or, low wellbeing): over employment, poor physical health, etc. (figure 24).

Figure 21. **Wellbeing-Productivity Map**. The (central) diagonal line "interventions / change" moves from low to high productivity and wellbeing" (as the normative goal).
Figure 22. **Wellbeing-Productivity Map**. How is productivity defined? is identified as a central question.
Figure 23. **Wellbeing-Productivity Map**. High productivity can create both high and low wellbeing illustrated as arrows emerging from the high productivity circle.

In the context of the trend of lowering productivity growth, a central question of the productivity-wellbeing mapping exercise was the consequences of low productivity growth on wellbeing. Two alternative responses to this question were captured with the map. The two axes on the map are productivity and wellbeing. Over these axes the group situated two intervention pathways (see figure 5 & 21 - although only one pathway is visible in figure 21). Both intervention pathways travel from low wellbeing to high wellbeing. The difference is on the X axis - one intervention takes us to a high productivity area, the other a low productivity area. These two lines draw attention to a key tension in questions of productivity. Does the pursuit of productivity growth deliver wellbeing? Is high wellbeing possible with low productivity growth (which may well become the new normal)?

It is well established that high levels of wellbeing lead to high levels of worker productivity in the workplace (Isham et al. 2020). Both physical and mental health are linked to the ability to work, with ill-health being associated with absence from work and 'presenteeism' - where people are present, but operating below full capacity (Mind, 2014; Hafner et al., 2015). However, it is less well established how the pursuit of productivity growth impacts wellbeing. In fact, there is very little research into this relationship.

Figure 24. **Wellbeing-Productivity Map**. A network of undesirable conditions surrounds low wellbeing.

As described in 4.1 and 4.2, the dominant political economy can be understood to define productivity in terms of exchange value. From this perspective, increases in productivity are seen as essential to the delivery of the conditions for wellbeing. Increases in exchange value associated with increases in consumption, and consumption are perceived as the route to wellbeing (Cushman, 1990, Fisher, 2009, Jackson 2017). The interdisciplinary mapping processes encouraged critical investigation of this productivity – wellbeing intersection, that was further developed in the wellbeing–productivity literature review as summarised below.

There are a number of ways that chasing exchange-based productivity growth can actively damage wellbeing – some of these impacts are captured in the culture around low wellbeing on the map (figure 24). First, in an effort to improve the output of workers, companies and governments have taken actions which increase both job demands and job insecurity. For example the widespread uptake of zero-hours, fixed term contracts, and the 'gig' economy increases job insecurity for many workers Blanchard & Landier, 2002, Taylor et al., 2017). Job insecurity is linked to reduced worker productivity (Van Den Heuvel, et al., 2010). Secondly, the adoption of ICT is a key driver of productivity growth (Jalava, & Pohjola 2007, Miller and Atkinson 2017) but it creates a perceived need for constant availability and promotes sedentary lifestyles (Parry et al., 2013). Sedentary lifestyles are associated with reduced health and therefore reduced productivity via a reversal of the mechanisms discussed above. Finally, the pursuit of exchange based productivity is implicated in the over-production that drives ecological crisis (Jackson, 2017, Mair et al., 2018, Mair, 2019). As suggested in 4.2, use of high quality energy from fossil fuels intersects with the pursuit of exchange based productivity growth. Yet, climate change is itself expected to reduce productivity substantially (e.g. Day et al., 2019). Consequently, productivity (in its current form) is both a driver of climate change and impacted by climate change.

The exchange-based productivity mindset has diffuse and pernicious effects. Productivity has come to be seen as a market concept. Almost all productivity metrics and frameworks start from a market perspective (Diewert, 2018). Consequently, a common approach to improving productivity in non-market sectors is to treat them as though they were markets. For example, efforts have been made to turn the NHS into a market (Gilbert et al., 2014, Krachler & Greer, 2015). In some cases, these approaches not only failed to improve productivity but actually reduced health-care outcomes. For example, Elkomy et al., (2019) find that contracting out of cleaning services reduces immediate cleaning costs but also reduces levels of cleanliness and increased hospital-acquired infections. The requirement to grow productivity within the healthcare sector therefore appears to lead to poorer quality care services being provided, which in turn will negatively impact upon individual health and wellbeing.

6. Concluding insights for the design of sustainable transitions

The Powering Productivity research took a whole system approach to the intersection of productivity, energy and wellbeing. The research findings suggest a need for a more critical approach to productivity. The multiplicity of productivity measures has important implications for design. When designing productivity boosting initiatives, we must ask what kind of value the productivity measure is enhancing, and why. Different forms of value suggest different ways of creating productive societies. A society that values care, for instance is likely to have fundamentally different structures than a society that values market output. As the latter dominates today's political economy, this is how productivity is typically defined and mobilised as a concept. Designers need to ask whether this frame is appropriate.

This work has wide reaching implications on current debates including automation, the future of work, energy transitions. Since all design must consider decarbonisation imperatives, future oriented designers must also consider this energy-wellbeing-productivity puzzle. When thinking about productivity, we must consider what is being produced and why is it valued. Today's dominant construction of productivity growth has sown the seeds of its own destruction. Productivity in standard economic discourse is dependent on energy use, but energy quality is declining. These trends have implications for climate change due to energy use. New conditions of lower EROIs combined with climate change imperatives suggests exchange based productivity has had its day. Policy makers and designers engaged with future energy transitions both need to think of ways to create broader forms of value that enable wellbeing but require less energy.

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