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Power in Practice: Insights from Technography and Actor-Network Theory for Agricultural Sustainability

Saurabh Arora and Dominic Glover

Power and Practice

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In this paper, we use conceptual insights from two distinct traditions within the social studies of science and technology, namely actor-network theory (ANT) and technography, to explore the relationship between power and the reconfiguration of agricultural practices toward sustainability. Noting the generative (productive) and repressive aspects of power, we examine how power manifests in practice by generating and enforcing rules and norms, creating and implementing regulations, driving the adoption of specific technologies, determining how resources are used, and (de) skilling labour. In particular, the conceptual frameworks of ANT and technography help us to discuss how power is refracted through socio-material settings, oral and written discourses, organisational frameworks and cultural institutions. We consider how agency is distributed, through power in practice, among collectives constituted by human/social and nonhuman/material entities. Our discussion highlights the importance of configuring, enlarging and nurturing spaces in which small farmers and marginalised people are empowered to adjust and adapt, or resist and reject, modern and non-modern technologies, in order to practice the kinds of agriculture they consider sustainable, appropriate and valuable. In conclusion we relate our discussion to a distinction, made earlier by other STEPS Centre researchers, between strategies for achieving sustainable agricultural transformations that aspire to a fantasy of control and those that are based on an ethic of care.

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Acronyms

ANT	Actor-network theory
FSR	Farming systems research
HYV	High-yielding variety
NGO	Non-governmental organisation
SRI	System of Rice Intensification

Abstract

In this paper we use conceptual insights from two distinct traditions within the social studies of science and technology, namely actor-network theory (ANT), and technography, to explore the relationship between power and the reconfiguration of agricultural practices toward sustainability. Noting the generative (productive) and repressive aspects of power, we examine how power manifests in practice by generating and enforcing rules and norms, creating and implementing regulations, driving the adoption of specific technologies, determining how resources are used, and (de)skilling labour. In particular, the conceptual frameworks of ANT and technography help us to discuss how power is refracted through socio-material settings, oral and written discourses, organisational frameworks and cultural institutions. We consider how agency is distributed, through power in practice, among collectives constituted by human/social and nonhuman/material entities. Our discussion highlights the importance of configuring, enlarging and nurturing spaces in which small farmers and marginalised people are empowered to adjust and adapt, or resist and reject, modern and non-modern technologies, in order to practice the kinds of agriculture they consider sustainable, appropriate and valuable. In conclusion we relate our discussion to a distinction, made earlier by other STEPS Centre researchers, between strategies for achieving sustainable agricultural transformations that aspire to a fantasy of control and those that are based on an ethic of care.

Keywords: power, practice, agricultural sustainability, transformations, technography, actor-network theory

1. Introduction

Agriculture is a socio-material practice. It involves humans interacting with each other and with material objects such as tools, machines, seeds, fertilisers, and pesticides, as well as non-human living organisms – plants, animals and microbes. The development and use of inputs and resources in agricultural production is generally understood as the domain of 'technology' and 'innovation'. However, studies of technology and innovation in agriculture tend to overlook the social and material processes through which resources and inputs are actually put into practical use (assembled, configured, modified, produced and conserved), both on the farm and beyond its boundaries (Glover *et al*. 2017; Arora *et al*. 2013). Mapping these processes is crucial to grasping the dynamics of agricultural technology and innovation as forms of practice that are undertaken on fields and in laboratories. Moreover, transformations to agricultural sustainability are only achieved when they are practical, on fields and in laboratories.

Critical for understanding such transformations is an appreciation of power, particularly in a global context where efforts to realise the dream of an African Green Revolution continue to gather pace (Pingali 2012; Brooks 2014), and where agricultural intensification has been relabelled as 'sustainable' (FAO 2011; The Montpellier Panel 2013). In this paper we examine how power manifests in practice by enforcing rules, implementing regulations, driving the adoption of specific technologies, shaping how resources are used, and (de)skilling labour. Incumbent relations of power favour techniques of agricultural intensification that are driven by the latest chemical and genetic technologies, the extension of profit-driven agro-capitalism, and institutions of international development that promote technological innovation through neoliberal market mechanisms. But while these perspectives on power are useful for appreciating its repressive effects in closing down alternative pathways to agricultural sustainability (Leach *et al*. 2010), they suffer from two limitations.

First, in addition to tracking the repressive and prohibitive effects of power, we must also account for the ways in which power is productive and generative (see Foucault 1988: 118). Power aligns and directs people's actions, resources and technologies, along specific pathways of socio-technical change (Leach *et al*. 2010). In this way, some courses of action are opened up, while some others are repressively closed down. At the same time, power shapes people's subjectivities (e.g., as progressive farmers who adopt new technologies for practicing agricultural intensification). Power often works through an association with cultural norms, cognitive routines, civic rules and government regulations (Giddens 1984).

Second, while being attached to social norms and governmental regulations enacted widely across a society, power changes form from material to symbolic (and *vice versa*) as it moves across different social settings. For instance, this change in form might mean that economic power associated with the flow of capital gets *refracted* as cultural or discursive power that shapes people's (neoliberal) subjectivities (Brenner *et al*. 2010). This changing form, or refraction, implies also that power becomes immanent to a social setting. While power may be impressed on a setting from the outside, through refraction it takes a form that is specific to the setting. In this paper we consider how forms of power attached to new regulations and modern technologies are refracted as they attempt to reshape existing practices in agriculture. We also consider how this refraction is a function of the availability and utilisation of resources and biophysical forces, rules and procedures, social norms and customs, knowledge and skills, plants and animals constituting a social setting.

Following Foucault (1988), we adopt a relational perspective on power, according to which, power is not an essence belonging to an individual or an organisation, but rather manifests in relations within and across social settings. In terms of the making of its repressive and generative effects through relations, power can be observed as an asymmetrically structuring agency (Stirling 2014a). Agency is

asymmetrically structured by existing social norms, customs, rituals, rules and procedures, as well as by resources, technologies, knowledge and skills (Giddens 1984). In turn, this agency works on the resources and on norms and procedures to structure them asymmetrically, in an attempt to reproduce unequal relations of power. Thus, as asymmetrically structuring agency, power is about influencing the conduct of other interrelated humans and nonhumans including technologies, resources, rules, norms, procedures and customs. And as we note above, power is also refractive. While power might be associated with supposedly durable norms and rules spanning entire societies, and with technologies and resources, it also mutates in uncertain and indeterminate ways as it moves through different social settings, in each of which power becomes immanent.

Studies of power in agricultural practices have a long lineage. Yet most studies have directed their attention to the workings of power only along one or two sets of relations (e.g., between agricultural research institutions and small farmers). For instance, early studies in farming systems research (FSR), while mapping interactions between the economic, social, cognitive, technical and material (biotic and abiotic resources) components of farming systems (Collinson 2000; Byerlee *et al*. 1982), typically focussed on transfers of technology from laboratories to farmers' fields, and thereby located innovative agency asymmetrically with agricultural scientists rather than with farmers (Chambers and Jiggins 1987). Correctives to this bias were provided by various alternative approaches, including Biggs' (1990) 'multiple sources of innovation' model, Chambers *et al*.'s (1989) work on participatory research and technology development, and later by studies of farmers' learning and technology selection practices (Douthwaite *et al*. 2002; Douthwaite *et al*. 2010) and the collective nature of agricultural innovations systems (Hall *et al*. 2003; Hall 2009). These latter studies have shown in detail how learning for innovation is distributed among a network of actors, including researchers, farmers, extension officers, non-governmental organisations (NGOs), credit providers and firms, while their activities are governed by a range of formal and informal institutions including public policies and social norms. However, the implications of technological change in concentrating or distributing, entrenching or weakening power in farming worlds is left largely out of the accounts (Thompson and Scoones 1994; Doss 2006; Arora 2012). Existing approaches therefore yield limited understandings of how pathways to agricultural sustainability may be opened up through the restructuring of power relations achieved by transforming socio-material practices (Leach *et al*. 2010).

In this paper, we use conceptual insights from two distinct traditions within the social studies of science and technology, namely actor-network theory (ANT) and technography, to explore the relationship between power and reconfiguration of agricultural practices. Technography is an ethnographic approach to the study of technique that draws on insights from the work of anthropologists and sociologists such as Marcel Mauss and Emile Durkheim. ANT is built on the methodological dictum of 'following the actors' to appreciate how science and technology are entangled in society and ecology. We bring the two sets of insights into conversation with each other to compare their articulations of power. Building on this comparative understanding of power in practice, we aim to derive implications in a final section of the paper, and raise some questions about the scope and challenges to achieve transformations to sustainability in agriculture.

2. Technography

Technography is a conceptual framework and methodology for studying technology. The technographic approach has roots in the disciplines of sociology and anthropology and may be summed up very roughly as the ethnographic study of technology-in-use, or the ethnography of technique. In popular discourse, the terms 'technology' and 'technologies' are generally used to refer to specific technical tools, instruments, machines, engines and complex systems. Technology is often understood to refer especially to devices and gadgets that are modern, contemporary or 'high-tech' items, such as smart mobile phones and tablet computers, the Internet, voice recognition software, artificial intelligence, drones, transgenic organisms and nanomaterials. People rarely think of quotidian items such as crockery, floorboards and bedlinen as being technological in an equivalent sense. Technography has been developed largely by scholars working within a French and Francophone intellectual tradition, where the word *technologie* has retained a historical meaning (that has largely been lost to its English relative 'technology') as 'the *study of* tools, machines, processes and methods employed in diverse branches of industry', the '*coherent body of knowledge and practice* in a certain technical domain', or the '*general theory of technique*'.[1] As these definitions imply, *technologie* relates to technique in the same way as musicology relates to music, linguistics to language or sociology to society. In this section, we use the term technique to refer to forms of practice that are characteristically technical, material, mechanical or physical, involving bodily gestures, the manipulation of objects or the application of physical forces, to delineate them compared to practices that are chiefly social, mental, cultural or symbolic – while recognising that many real practices have simultaneously social, psychological, symbolic and material aspects.

The French term *technographie* is easier to convey in English because the combination *techno* and *graphy* readily evokes the study of technology/technique. The French mathematician and physicist André-Marie Ampère (1775—1836) defined the domain of *technographie* as knowledge relating to the procedures, instruments and machines used to process and convert materials and resources from their raw forms into diverse useful products, to transport them where they are needed, and to conserve them until the moment of use.[2]

Marcel Mauss's classic definition of techniques as 'traditional efficient (or effective) acts' (*actes traditionels efficaces*) is a particularly important touchstone, meaning 'an ensemble of movements or actions […] which are organised and traditional, and which work together towards the achievement of a goal' (Schlanger 2006: 149). Mauss used the term traditional in a specific sense, meaning acts that were taught and learned by people within communities and cultures, and passed on between individuals and groups and especially from one generation or cohort to the next. For Mauss, 'traditional effective acts' were coordinated actions, directed towards human purposes that were socially shaped and which were embedded within social structures and cultural institutions. Here, Mauss invoked the

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[1] The online Larousse Dictionary, *technologie* (emphasis added), http://www.larousse.fr/dictionnaires/francais/technologie/76961 (6 May 2017).

[2] '*Technographie.* Pour approprier les corps aux divers usages auquels ils sont destinés, il faut leur faire subir diverses transformations ; par exemple, changer successivement la laine en fils, en draps, en habits ; un lingot d'acier en ressorts, en instruments tranchans ; les substances alimentaires en mets qui puissent flatter notre goût ; un sable grossier en verres et en cristaux, etc. : il faut les transporter des lieux où ils sont en abondance dans ceux où la consommation les réclame, les conserver jusqu'au moment de les livrer au consommateur. Des instrumens et des machines sont nécessaires pour opérer ces transformations. Or, la connaissance des procédés par lesquels on les opère, des instrumens ou des machines qu'on y emploie, constitue une science du troisième ordre, que j'appelle *technographie*, de Τέχνη, *art.*' André-Marie Ampère (1834), *Essai sur la philosophie des sciences, ou Exposition analytique d'une classification naturelle de toutes les connaissances humaines,* Chez Bachelier, Imprimeur-Librairie pour Les Sciences, Quai des Augustins no. 55, p. 80. Translation: [Second author].

concept of *habitus* to convey the combination of tacit knowledge and bodily movement that shapes the distinctive techniques of individuals and cultures (Schlanger 2006: 79–80).

In *Techniques of the Body* Mauss explored how all kinds of techniques, even seemingly instinctive actions such as sleeping or walking, are culturally shaped (Schlanger 1935). He related how, as a soldier of the French Army serving alongside British troops on the First World War's Western Front, he had observed that British soldiers were unable to dig with French spades, and *vice versa*. When British and French units relieved one another the spades would have to be changed at the same time. Mauss's insight was to see that, though the goal was ostensibly the same – digging trenches – both the tool used and the corresponding techniques employed were different, not to mention the ways the soldiers organised themselves to carry out the task. These differences were significant enough that they could serve as cultural markers to identify distinct national cultures and assign individuals to their respective groups. Since the British and French troops were unable to adapt readily to their counterparts' tools and methods, effective work could easily grind to a halt until the appropriate type of spade was provided. Culture thus was not just symbolic, but also material and observable as praxis.

Mauss's ethnographic approach to the study of technique implies that the observer should pay attention to three components: the actions (movements, gestures, etc.) being performed; the tools being used, if any (and how they are used); and the purpose or intention of the actions. This approach is essentially compatible with the one adopted by the French development agronomist, historian and museologist, François Sigaut. Sigaut defined the key unit of technographic study as the 'operation', comprising 'actions' that were 'material' (i.e. bringing about material transformations) and 'intentional' (i.e. purposeful or oriented towards a particular goal). We use the term 'material transformation' here to encompass any change in the physical status of an object or material, such as its location, orientation, size, physical form or composition. Material transformations may involve many diverse processes, such as displacing or re-orienting objects or artefacts in space, connecting, separating, mixing or decomposing them, applying force to alter their shape or dimensions, or subjecting them to chemical or biological reactions. An individual operation could be identified as the smallest such transformative step within a sequence of steps, which Sigaut called a path (*filière*). This approach implies that any productive process could be decomposed into a series of discrete operations that could be studied individually or as a set. Sigaut further explained that different technical paths (*filières*) would intersect with one another so that, altogether, the universe of technical paths in a given society would form a network, 'which is in fact the economic organization of that society' (Sigaut 2002: 426). He identified the operation, the path and the network of paths as instruments to 'locate the technical facts within the social space' (Sigaut 2002: 426).

Sigaut's work offers an interesting perspective on the importance of understanding the purposes of action as a key component of any operation. Sigaut emphasised that the operation cannot be defined by its physical or chemical properties alone, but by its position along a path; in other words, it is necessary to understand *why* and not only *how* a material transformation is accomplished. This appears at first a rather obscure point, but Sigaut insisted that one could not identify a technique without first identifying the operation in which it appeared – including the purposes driving it. He criticised the habit of technicians and engineers to talk always about the effects of action, as if those effects were definitive of the operation or the technique:

> […] An effect is not a technique, it is only one of the components of a technique. Centrifuging, for example, is an effect involved in operations as dissimilar as separating uranium isotopes, testing blood, separating milk, spinning the wash[…]the only thing they have in common is centrifugal motion, and[…] the 'centrifuge effect' can be used to identify a technique only once the operation concerned has itself been unambiguously identified.
> Sigaut 2002

Sigaut drew a distinction 'between categories of action', such as cutting, crushing, kneading and ploughing, and their effects. In a further step, he distinguished between the 'workings' of a technical object (how it works) and its function or purpose (what it is for). For example, he noted that an anthropological museum might classify a collection of diverse objects as 'knives', based on the rationale that they all possess sharp blades and they all 'work' by cutting. But he insisted that the specific function or purpose of a particular kind of knife is determined by the specific cutting of particular materials, using an observable technique, within a definite operation, and carried out for an identifiable purpose by a certain person or group. Sigaut's insistence on this point may seem pedantic, but it emphasises that an action's (operation's) purpose or function is determined chiefly by the people or society carrying it out. It is not discoverable within the technique itself, nor is it an intrinsic property of the technical artefacts used, although those artefacts' material characteristics are intimately and reciprocally connected to the techniques by which they are put to use. That close association between a particular tool and its special techniques is essential to Mauss's idea of tradition as the cultural repertoire of social groups, within which particular actions and artefacts that have evolved together are passed between generations. Just as Mauss understood that digging with a spade is not the same activity in all cultures, being made up of particular spades and their distinctive techniques, Sigaut recognised that the action of cutting with a knife, as well as the material form of the knife and its symbolic meanings, are culturally shaped (Sigaut 1996; Sigaut 2002). Sigaut's approach gives attention to human agency and goals, which are socially defined. However, in Sigaut's writings on technique the question of precisely how individual agency interacts with broader cultural frameworks is less well developed. While Sigaut makes it clear that techniques and their associated tools, operations and pathways are inextricably connected threads of a common social and cultural fabric, belonging to identifiable human groups, his work lacks an explicit account of how the performance of tasks is governed by, and also helps shape, wider social institutions and structures. In other words, Sigaut's work leaves open the question, how does individual volition intersect with motives and intentions that are socially selected, collectively sanctioned or culturally shaped?

A British anthropologist, Paul Richards, and his colleagues at Wageningen University in the Netherlands took up the thread of technography without a deep awareness of the way it had been developed by scholars such as Sigaut, but with a much stronger emphasis on the ethnographic approaches of Mauss and Durkheim, as well as the cultural theory of the anthropologist, Mary Douglas (Richards 2000; Jansen and Vellema 2011). The technographic approach developed by Richards and his colleagues also focuses on the practices of material transformation or 'making, but with a more substantial elaboration of how the performance of tasks is connected to modes of social organisation and larger frameworks of social and cultural institutions.

According to Jansen and Vellema (2011) technography has three components: a) a study of making or *material transformations*; b) a study of *distributed cognition*; and c) a study of task- and performance-related *rules and routines* and how they are constructed. The making component is all about how material transformations are accomplished. In this aspect, the primary focus is on techniques, that is, interactions between people and the tools and materials they employ. These interactions are key to the study of making because they both enable and constrain the capacity of the human actors involved to accomplish their goals. A technographic study may employ a range of different research methods including qualitative and quantitative tools, but with a strong emphasis on direct observation of techniques and tasks. The technographer should observe and record who is doing what, and what materials are being transformed and how, using what tools and resources. Quantification might appear in the form of measurements such as the weight lifted, area covered or volume produced, the number of repetitions, or the time and energy expended, during the performance of a task. While recording the activities of the people involved in the process of making as well as the timing and sequence of those activities, the technographer should pay attention to the material properties of the tools and other resources employed (e.g. aspects such as their size and weight, and subjective perceptions such as their

ease of use), as well as key features of the biophysical setting where the activities are taking place (e.g. in an study of agriculture these would include rainfall, soil quality, temperature, hours of sunshine).

Material transformations alter an object's affordances, which are the potential uses to which they lend themselves or the opportunities they offer for human interaction. An affordance may be thought of as something like an invitation or proposition, or a perceived way in which an object might be taken up and applied to some purpose. Affordances are perceived by potential users of objects and materials. These perceptions are influenced not only by sensory appreciation of the objects' material properties such as size, weight, texture, but also by an individual's personal characteristics (e.g. height, strength, dexterity) and social and cultural norms (e.g. rules governing appropriate forms of behaviour for workmen, maidservants, neighbours or owners of property). The technographer therefore needs to attend carefully to the material characteristics and the symbolic meanings of objects and artefacts, alongside the social relations that connect them with users (Pfaffenberger 1988; Pfaffenberger 1992; Hutchby 2001; Dant 2005).

The sociologist Tim Dant has applied the phenomenology of Martin Heidegger and Maurice Merleau-Ponty to explain why material interactions, embodied knowledge and bodily skill are central to the study of techniques and practices (Dant 2005). This conceptual framework recognises that practices are interactions between human agency, human bodies, artefacts and the natural world. In other words, practices are expressed through interactivity; they depend not only on the volition and skills of the actor but also on the material properties and cultural symbolism (affordances) of the objects and artefacts with which she interacts. Without the actor and the objects interacting together, there is no technique or practice. For as long as the activity is in process, we can appreciate the actor and the objects as a single entity – the 'sailor—windsurfer' or the 'cyclist—bicycle'. While the complete beginner may be incompetent with even the most basic tools, her gradually increasing bodily skills and accumulating embodied knowledge open up the affordances (both cultural and material) of more advanced and sophisticated tools, which become more accessible to her, and thus her field of practice and the range of achievement available to her also increase (Dant 1999).

The second aspect of technography, distributed cognition, is concerned primarily with social interactions and relationships and how they contribute to the process of making (Jansen and Vellema 2011). The observation of the techniques should identify how individual tasks are carried out in time and space and how the tasks are distributed and organised across a group of people. Technographers use the 'task group' as an important conceptual unit of analysis. The distribution of tasks within the group entails a parcelling out of physical and cognitive responsibilities and burdens, which has consequences for the generation and distribution of information among the people involved. An individual's access to information and their knowledge about the performance of a collective task will depend heavily upon that person's contribution to the task and their role or roles within a task group. In other words, the exigencies of the task to be accomplished and the position of that task within a wider process of material transformation will exert a structuring influence on how information and knowledge are generated and distributed within the task group.

Tom McFeat (1974) illustrates this insight with the example of a traditional whale hunt. Chasing down and harpooning the whale required the intricate coordination of tasks among the whaleboat's crew. The individual roles, skills and physical abilities demanded from oarsmen, steersman and harpooner were quite different, and so were their positions in relation to the task and the flow of information reaching each person. No more than one steersman and one harpooner were needed to accomplish the task, whereas a large number of oarsmen was needed to provide the power required to catch up with the whale and, at a crucial moment, the rapid steering necessary to keep the boat safe from the thrashing tail of the struck whale. The oarsmen carried out their work with their backs turned on the whale. The harpooner did his work from the prow of the boat, with his face turned towards the whale. Only the steersman in the stern of the boat had a full view of the group and the progress of the attack.

This disposition made it logical and functional for the steersman to take charge. The harpooner relied completely on the oarsmen, guided by the steersman, to get him into position to make his thrust, but the success of the whole attack still depended almost entirely on his individual technique – though not quite, because the attack could and often did still fail because of the whale's determination to escape or the unpredictable surges of waves and wind.

The case of the whaleboat can be expanded to the scale of a large modern warship that is piloted safely through hazardous waters despite nobody on board having a complete grasp of everything going on (or going wrong) aboard the ship, or on nearby vessels (Hutchins 1995). The juxtaposition of the whaleboat and the warship reveals how the task group concept can be conceived and applied at different scales of analysis. The term 'distributed cognition' was used by Hutchins (1995) but it can be applied easily to McFeat's (1974) exposition of how 'task ordering' works to organise flows of information and structure social relations within small groups. Both cases show how the exigencies of the task to be performed influence the configuration of social relations. The members of the task group cooperate with one another to organise and coordinate the deployment of material objects and delivery of biophysical forces, in an attempt to achieve a collective goal. These social and material interactions encourage a certain disposition of people, tools and material resources, which leads to the creation of specialised roles, an uneven distribution of information, asymmetrical communication flows, and an emergent hierarchy of authority governing the performance of the task. This insight points towards the third component of technography: the study of how rules and norms emerge from, and are constructed through, the performance of tasks.

It is important to observe at this point that the concept of task ordering refers to the way rules and norms may emerge from the way people and resources are organised and deployed to achieve tasks, however, not all of the rules and norms governing the task group are internal to the task or task-related. For example, the initial selection of a task (or goal) and the convening of a task group (to pursue the goal) may occur through the operation of pre-existing shared cultural values or relations of power. The authority of the steersman over the crew of a whaleboat might not emerge solely from his special role within the task group, but might already have existed because of his place in the hierarchy of a tribe of hunters or a whaling ship's crew. Also, technical efficiency is likely to be only one of the principles determining the configuration of the task group and the disposition of its people, equipment and information. The configuration of technical practices occurs within a wider social, political, economic, cultural and institutional context. Nonetheless, the notion of task ordering plays the useful role of highlighting the ways in which technology (technical practices) may influence those wider frameworks, and give a structure to the field in which social relations of power are played out.

In the Wageningen technographic approach, rules and routines that govern technical practice (and therefore discipline the members of task groups) are seen to emerge from the process of making, which is embedded within a particular social and cultural (as well as biophysical) context (Jansen and Vellema 2011). In other words, social relations are influenced, and institutions are formed, out of the way technical tasks are organised and carried out. However, technical practices and their power relations do not arise from a void. Tasks, task groups and their associated techniques and tools are also shaped from without, by wider relations of power that exist in the society where they are performed. These relations of power are refracted through the situated performance of technical practices by particular communities at certain times. In this way, changes in technical practices can cumulate into transformations in the way power and agency are distributed in society. To explain how this works, the Wageningen technographers use the key concept of *sodality*, borrowed from Durkheim and especially his works, *Professional Ethics and Civic Morals* (Durkheim 1957) and the more famous book *The Elementary Forms of the Religious Life* (Durkheim 2001). Sodality is a term for an association formed on the basis of shared skills and expertise, such as a craft guild, fraternity, or professional organisation. As a task group is configured, specialist roles may be created. For example, in a technographic study of the System of Rice Intensification (SRI) in northern India, Sen (2015) showed that the new paddy cultivation

method instituted novel specialisms in the management of seedling nurseries, enlarged a niche role for the few farmers in the communities who still owned bullocks for ploughing, and conferred both burdens and influence on certain farmers, designated 'village-level resource persons', who were called upon by SRI farmers to carry out certain specialised tasks on their rice fields. The occupants of roles such as these may acquire privileged access to information and develop special skills and competences that are critical to the successful performance of the task. Social and economic relationships will be (re)configured as power and privileges may accumulate to these specialists. As a consequence, hierarchical relationships of power and authority may emerge, or existing power structures may be changed. Formal rules may be created or strengthened, which define membership of the sodality along with special procedures, such as apprenticeships, examinations and graduation ceremonies, to initiate new members and certify their professional knowledge and skills (Jansen and Vellema 2011). It follows that sodalities may also lose power and privileges during processes of technological change, for example, when the technical practices with which their skills and authority are associated are replaced by different technologies, or when new patterns of ownership or systems of governance take away their influence. A historical example is the transition that occurred during the Industrial Revolution, which transferred power from craft guilds and skilled workers to factory owners and capitalists.

Sodalities may exercise authority over the ways tasks are to be carried out in different places, for example by determining protocols and standards. These rules and routines will be interpreted, applied and enforced locally by sodality-members, who exercise power within local communities of practice (Jansen and Vellema 2011). This is akin to the role of a parish priest who represents and speaks on behalf of the universal church within a particular community. A sodality-member operating within a local community or task group claims authority over a given domain, and plays a critical role in determining how the general norms and rules of the sodality will be applied in local practice. Local variations in practice may emerge through the way formal rules are interpreted and enforced locally. Emerging local variations will depend not only on the specific interpretations given to rules by the sodality-members who speak on their behalf, but also from the sodality-members' effectiveness in securing local compliance. This will be conditioned by the quality of their social relations with members of the local community – such as whether they are held in esteem or whether their threats of sanctions are treated seriously.

Once they have come into existence, the institutionalised rules and norms themselves form key parts of the kit of tools and resources available for the formation of task groups and performance of tasks (Jansen and Vellema 2011). Moreover, by creating a stable framework for the routine performance of tasks, they also exert a strong, structuring influence over what tasks get performed and what goals should be pursued.

It is evident that a technographic approach to the study of technology brings into focus the intentions of human actors as they employ social and material resources (and even biological ones, such as crops, livestock and enzymes) to achieve their goals. However, it is clearly understood that human agency in relation to technical practice is by no means unconstrained. First, the individuals in the situation have to grapple with the materiality of the tools and objects around them, as well as the biophysical context of their work. Second, for any task beyond the capacity of one person, they must rely on social relationships. These material and social interactions both enable and constrain their capacity to achieve material transformations. But, according to a technographic analysis, the exigencies of the task as well as the disposition of people and other resources required to achieve it have definite implications for the configuration of social and socio-material relationships. Human intentions matter, but since the outcomes of human technical projects are not fully under control – for example because a whale resists being harpooned or because weather intervenes to ruin a carefully planted crop – a premium is placed on the ability of humans and task groups to manage risks and improvise, within the constraints and limitations imposed by materiality and uncertainty.

The capacity to improvise successfully in the moment is a type of skill embedded in performance. Performance is a key concept within the Wageningen approach to technography, first articulated by Paul Richards in a paper that referred to small-scale farming in West Africa and compared the farmers' skills to the skills of a musician performing for an audience (Richards 1989). Richards argued that the visible results of the farmer's work should not be understood as the outcomes of a coherent plan or blueprint conceived in advance and implemented in a systematic manner, but as contingent results emerging from a performance situated in time and space, conditioned by resource constraints and by the uncertainty inherent in a dynamic flow of events. Like a musician improvising a tune, the farmer draws on a repertoire of skills, experiences and decision making tools to create the unfolding performance. She reacts to problems and opportunities and tries to cope and adapt when things start to go wrong. At the start of each season, the farmer may have a general plan and goals in mind, including long-term (multi-season) plans to improve the land or develop new cropping systems, but the performance realised through practice will be the outcome of interactions between the skilled performer, the tools and resources available to her, and the effects of rain, wind, pests and pathogens (Batterbury 1996).

To say that the performer is 'skilled' is not to say that she is necessarily competent ('skilful'). A successful outcome will surely require skill as well as a measure of good luck, but farmers, like musicians, can be good or bad at their craft. From a technographic perspective, skill can be understood as embodied knowledge, expressed through practice. Just like technique or practice itself, skill is not only an individual attribute but a property of ongoing performance within a dynamic flow of social and material interaction, in other words an environment where 'skilling' (the ongoing renewal of craft competence through practice and rehearsal) might be healthy and functional, or badly disrupted (Stone 2007; Stone 2011; Stone 2016).

3. Actor-Network Theory

Arguably the cornerstone of Actor-Theory (ANT) is its refusal to maintain sharp divides between subjects and objects, humans and nonhuman, words and worlds, culture and nature. A refusal of these divides leads to a conceptualisation of action that is distributed between interrelated subjects and objects, humans and nonhumans. Yet ANT is not a bland theoretical claim that nonhuman objects play a role in action, but rather an assemblage of concepts and methods to trace which role things actually play (Latour 1999: 116). ANT was developed in the 1980s through empirical analyses of processes of making knowledge and artefacts in science and technology (Callon 1986; Law 1987; Latour 1988). In this section, we provide an overview of these early ANT studies as well as later work, by focussing on three concepts that are central to appreciating the role of things in the making: translation, de-scription and performativity.

To account for the difference things make to human agency of knowing, of making artefacts, and exchanging goods, in ANT, it is proposed that things be given the capacity to act (Latour 2005: 71). However, to act is not to be equated with *ex nihilo* production of knowledge, meanings, decisions, artefacts and exchange. Nor should it be treated solely as cause to effect determinism. Making a difference refers also to a whole range of non-deterministic and non-linear effects. To account for the making of these effects, Latour (2005) argues that any entity should be approached as a mediator. As a mediator (rather than an intermediary), any entity can be an agent, which mediates between other entities, transforming in the process what it transfers from one entity to another. Treating things as mediators means that their, 'input is never a good predictor of their output; their specificity has to be taken into account every time' (Latour 2005: 39). This opens up a new perspective on agency as distributed in collectives constituted in action by interrelating humans and nonhumans. It is these hybrid collectives that attempt and accomplish tasks, in practice (Callon and Law 1995).

Hybrid collectives are assemblages of social, ecological and technical entities. Such collectives are, however, not already in existence. Instead they are constituted in actual processes of doing. By observing the doings in detail, an ANT analyst is able to map the collectives in making, as relations between different mediators are formed and modified. In a classic paper, Callon (1986) conceptualises this (re)making of relations as 'translation' processes. The concept of translation attempts to capture the various strategies and objects involved in the making of relations. It directs attention to how the interests and values associated with mediators change in the process of (re)making relations. In the following, we refer to mediators simply as actors.

The conceptualisation of translation is underpinned by two core methodological principles. First, it demands that the researcher 'follow' the human (and nonhuman) actors she studies (Latour 1987), refraining from censoring the actors' voices and from fixing their identity as members of a particular class of 'subjects' or 'objects'. Identities and interests are considered to be under negotiation.[3] Second, any *a priori* distinction between effects produced by humans and nonhumans, between social and natural processes, is abandoned. The researcher, 'follows the actors in order to identify the manner in which these define and associate the different elements by which they build and explain their world, whether it be social or natural' (Callon 1986: 201). Researchers are thus asked to practise, 'generalized

[3] In studies that are not methodologically individualist, interests and identities of human subjects are often determined on the basis of their socioeconomic class, nationality, ethnicity and gender. Callon's (1986) conceptualisation of translation begins by treating these interests and identities as negotiable/adjustable in relations with other humans and nonhumans. Similarly, in the natural sciences, nonhuman objects may be given an identity of (classified as) organic, inorganic, animal, plant, microbe, mammal, tool, technology, concept, indicator etc. Rather than treating these categories as fixed, ANT directs attention to the fluidity of their boundaries and heterogeneity within them. This fluidity and heterogeneity becomes particularly apparent when the categorised entities' relations with others are taken into account.

symmetry', according to which we must not, 'change registers when we move from the technical to the social aspects of the problem studied' (Callon 1986: 200). The same terms must be applied to all human and nonhuman actors (Callon 1986: 221).

Callon (1986) outlines four 'moments' or phases of translation between heterogeneous entities. The first moment of translation is problematisation of an existing situation by some *primum movens* (first mover). In Callon's narrative these are three French scientists newly returned from Japan, where they had encountered the intensive cultivation of scallops. This cultivation is done by immersing into the sea collectors to which larvae can anchor while being protected from predators. The problem framed by the three scientists centres on the question whether the successful experience with the cultivation of scallops in Japan can be transferred to the Bay of St. Brieuc in France. Yet the question is only one element of problematisation. Equally important is the identification of a group of relevant (potentially interested) actors. And so begins the process of establishing relations between them, in order to address the question.

The second moment of translation is *interessement*, which Callon (1986: 207–208) defines as the, 'group of actions by which an entity (here the three researchers) attempts to impose and stabilize the identity of the other actors it defines through its problematization'. *Interessement* involves the use of devices that can drive a wedge between potential allies and others interested in maintaining connections with them. The potential allies in Callon's narrative include the scallops and the St. Brieuc fishermen. To interest the scallops, the devices of *interessement* deployed by the researchers include towlines with collectors immersed in the sea.

The third moment, enrolment, points to the multi-sided negotiations and trials that allow *interessement* to succeed in practice. In the case of scallops, this success depends on their willingness to anchor to the collectors. This willingness is constituted through relations with other forces including tidal currents and predators. It is easier for the scallops to anchor in areas with weak tidal currents. The material used for the collectors (broom, horsehair or straw) also matters. Eventually in the St. Brieuc experiments, some collectors attracted no scallops at all. Even those collectors that did anchor a few scallops never reached the levels observed by the three researchers in Japan.

The fourth moment of translation is the mobilisation of allies in order to be able to speak in their name. This mobilisation is critical for discerning if the speaker is representative. For instance, can a few anchoring larvae be considered representative of all scallops living in the Bay of St. Brieuc? Can the three researchers be considered effective spokespersons on behalf of the scallops? Are the fishermen who aligned with the researchers, representative of other fishermen? To be able to answer these questions, attention must be devoted to mapping the series of alterations undergone by actors in the translation process.

It is also critical to note that during any moment of translation, one or more of the involved entities may betray the goals that the *primum movens* want to achieve. In Callon's scallops narrative, the few larvae that initially anchored to the collectors immersed by the researchers may at some point stop anchoring (as they are carried away by tidal currents and other forces). In this way, they end up betraying the researchers. Such dissent or betrayal may lead to re-problematisation, or to the annulment of the scientists' program of action. Crucially the possibility of dissent also shows that any alliances forged through a translation process may, 'be stable only for a certain location at a particular time' (Callon 1986: 222). Translation thus is a process that is 'situated' in time and space, in a specific hybrid collective, underpinned by the attempted inclusion of the outside world into the hybrid collective assembled for knowing and making artefacts.

Callon’s (1986) narrative of translation shows how the three scientists attempted to assemble their agency (of knowing and speaking on others' behalf) by translating dispersed and non-aligned entities into allies in a hybrid collective. By allowing some actors to direct others and speak on their behalf (e.g.,

scientists speaking on behalf of scallops and fishermen), successful translation asymmetrically structures agency. The latter agency is power (Stirling 2014a), expressed in relations of the scientists with the fishermen, the scallops and their scientist colleagues. At the root of this power lie acts of knowing, made possible by translations involving scallops and fishermen with a range of objects such as towlines and collectors. Power, as the asymmetrically structured agency of knowing, is thus (unevenly) distributed across the relations of a hybrid collective that is composed of scallops, fishermen and their interests, towlines, collectors and mathematical models etc., which are entangled with each other.

Callon's narrative, however, gives the impression that it is only the scientists as *primum movens* who interest and mobilise other actors. This obscures that other involved actors such as the fishermen may simultaneously be carrying out their own problematisation and *interessement*, to enrol other entities into alternate hybrid collectives. Taking the latter into consideration makes it possible to appreciate relations of power between different collectives, as agency is asymmetrically structured in favour of some collectives (e.g., those assembled by the three scientists in Callon's narrative). These collectives become more powerful through successful translation processes. In Latour's (1987) words, these collectives become 'centres of calculation' where knowledge is progressively accumulated.

Furthermore, for our present purposes of agricultural practices, it is useful to distinguish between inanimate and animate nonhumans in hybrid collectives. In Callon's narrative, for example, scallops are living organisms, dispersed and not readily accessible, so it is easy to imagine that intensive efforts are required to interest and enroll them into the scientists' collectives. In contrast, tools and technologies such as towlines and collectors are designed to be easily accessible to their users. Clearly the *interessement* and enrolment of these inanimate objects is likely to be different from scallops. This difference is critical to appreciate in agriculture where living beings (e.g., livestock, insects, plants) and inanimate objects such as ploughs and pumps play distinctive roles in farmers' practices.

In order to understand the role of inanimate objects in practice, it may be useful to focus on their flow across time and space (Star and Griesemer 1989). As objects flow, they are changed to different extents, and adjusted in/to the hybrid collectives that they encounter and help re-constitute (Callon 2007). To appreciate this process, focussing in particular on technical objects, Akrich (1992) proposes the concept of 'de-scription'. The starting point of Akrich's conceptualisation is the recognition that the making and using of objects is a heterogeneous activity. A wide range of forces are implicated in this activity including economic interests, sociocultural values, government regulations, standards, natural resources, knowledge, skills, tools, devices, components, and input from eventual users (Joerges 1999). Such an approach to making and using technical objects acknowledges that they are made real in and through relations with diverse other human and nonhuman entities in hybrid collectives (Latour 1991).

As an object circulates, it may move from the hybrid collective of its designing/making to others in which it is used. Alongside the motive of their own profit or fame, and responding to wider societal or environmental concerns, designers imagine and anticipate how the object they are designing will be used. They do this by defining the projected users' needs, resources, competences, aspirations, affinities and prejudices. During the Green Revolution in Asia, designers of high-yielding varieties of rice and wheat attempted to imagine and anticipate how small farmers in Asia would cultivate the new varieties (e.g., under irrigation and using chemical fertilizers). Attempts were then made to 'inscribe' this imagined context of use into the object being designed. In general, designers attempt to translate an imagined context of use into the 'content' of the object (Akrich 1992). This in-scription process is never straightforward. Designers' actions are constrained by the materiality of the artefacts (e.g., tools, soils, plastics, chemicals, computers, microbes) involved in the design process (Joerges 1999). Materiality redirects attempts by designers to use or mould objects. This produces disjunctures between what is imagined (as the context of use) by designers and what is achieved (as the designed content of the object).

Out of the process of in-scription emerges the designed object that 'delegates' certain roles and responsibilities to its end-users, other human actors (e.g., installers, repairers) and interdependent objects. For example, the script of a key delegates to the locksmith the role of installing the lock in such a way that the key is usable, and to user the task of rotating it to lock or unlock the door (Latour 1992). The door and the lock have clear roles to play too, in order for the key to succeed in keeping unwanted elements out of a room. The key prescribes what actions are permitted in use and what should be excluded. In this way, the keys' script attempts to pre-determine the ideal user (and the skilled locksmith), as the one who acts in accordance with its script together with a functioning lock and door. To facilitate this use, prescriptions may be given to the users and installers in the form of instruction manuals, codes of conduct, and best practice protocols.

To appreciate the actual use of technical objects, Latour (1992) argues that it is misleading to separate objects (imbued with scripts that delegate) from their human users and designers. He, along with other ANT scholars, advocates that attention be devoted to the hybrid collectives in which objects are used. The latter collectives do not however exist *a priori*, they are constituted and re-constituted in the process of use of an object, through which the object is de-scripted. De-scription thus depends on relations constituted in the user collectives. And depending on the relational composition of user collectives, many different de-scription processes are realisable with the same object/script. While some collectives such as those associated with a resource-rich farmer may be successful in carefully adapting an object to their needs and settings, poorer farmers' collectives may even fail to adapt an object that is supposedly user-friendly (Arora *et al*. 2013). This variable adaptability of an object is a function of the object's script and realised in processes of de-scription, which we illustrate using a few examples from ANT studies below.

Consider Akrich's (1992) analysis of the photovoltaic lighting kit developed by French industry, which was dispatched for adoption and diffusion in less developed countries. Despite the fact that this kit was to be installed in user homes, the script of the kit circumscribed the users' ability to adapt it to their homes. For instance, the wires that connected solar panel with the batteries and the fluorescent tubes were of fixed length. In user collectives, as part of de-scription, the fixed length of wires made it rather difficult to adapt the kit to rooms of different sizes and shapes (Akrich 1992: 210). Additionally, the kit's components (fluorescent tubes, water-tight batteries) were unavailable in most regions. They could not be easily replaced once they had been used or broken. Also, local maintenance and repair of the kits was prohibited by the engineers who did the installation. The engineers were concerned that a mistake in connecting the kits might damage them. Overall, with this rigid script, it is apparent the aim of the designers and engineers was to make the kit foolproof. Only the most resourceful households were able to successfully adapt the kits to their homes, with the help of local technicians.

As a counterpoint to the rigid script of the French photovoltaic kit, consider the Zimbabwe bush pump where the success of the technology was not contingent on, 'an engineer who masters the situation and subtly subdues everyone and everything involved (de Laet and Mol 2000: 227). In the first place, the pump's installation was community-based. Local water diviners were consulted regarding the location of the pump, and the drilling of the bore well was done by users themselves assisted by the Vonder rig that is hand-driven and portable (de Laet and Mol 2000: 233). This empowering of users was central to the bush pump's script that was made as flexible as possible, to allow the pump to be adapted and adjusted into diverse user settings. The script of the pump was aimed at serving, rather than controlling, user communities. The aim was to make the bush pump locally serviceable. Repair using locally available materials was encouraged and facilitated by the pump's designer. Eventually, in and through various de-scription processes, multiple user-led redesigns of the same pump were realised. Yet this multiplicity does not mean that the bush pump could be just about anything. In all its manifestations, the bush pump was installed on top of a concrete slab and it required a bore-hole; it was not a bucket pump nor was it a rig used to dig bore wells; it was never a water diviner nor was it general 'infrastructure' (de

Laet and Mol 2000). The pump's multiplicity was thus constrained and facilitated by its script, alongside many other entities in the user collectives, through different de-scription processes.

This potential multiplicity of an object, in de-scription, allows us to question the dominant uses it might be put to. It also opens up the space to imagine and realise alternate uses of the object. Similar multiple enactments of the same material objects may be encountered in farmers' hybrid collectives. It is well-documented that the same variety of seeds routinely produces disparate crop yields on different farms in the same region (Munshi 2004; Nziguheba *et al*. 2010) depending on the relational composition of a farm's hybrid collective including the type of soil, irrigation, weather, labour and skill of the workers, contracts, standards, access to credit, fertilisers, pest management and so on. The varying yields result from diverse de-scription processes of the same seeds, in and through relations with many human and nonhuman forces in farming collectives. These hybrid on-farm relations, and the alterations involved in producing crops from seeds, produce a multiplicity of enactments of the same seeds (on multiple enactments, see Mol 2002). This multiplicity is not just inherent to the script of a seed variety, but rather emerges out of dynamic relations forged in hybrid collectives during de-scription processes.

A seed thus works in relation to other human and nonhuman forces that compose farming collectives. Actions by these other forces gradually change a seed into a crop. This process, manifesting as changes in the reality of a seed and indeed of a farm, 'does not precede the mundane practices' of farmers, but 'is rather shaped within these practices' (Mol 1999: 75). Crucially, however, this changing reality is circumscribed by the script of the seed variety. For example, high-yielding or genetically modified varieties delegate specific roles to farmers (who are given instructions to use the seeds 'correctly') as well as to pesticides and fertilisers. They also implicate other nonhuman entities on the farm such as soils and water in specific ways. Now, by circumscribing and delegating action, a script becomes political during de-scription processes (Mol 1999). It makes some alterations of reality more likely, while helping to close down other possible changes (cf. Leach *et al*. 2010 on closing down of pathways to sustainability). For example, high-yielding varieties (HYVs) of rice might respond to chemical fertilisers much more effectively than local 'traditional' varieties (Rakshit *et al*. 2008). The use of chemicals was anticipated in the HYVs' scripts, which makes it more difficult not to use them if investments made by farmers in HYVs are to be recuperated and any desired effects achieved. Resulting higher yields closes down the use of local varieties, which has critical implications for farmers' skills, knowledge and agricultural sustainability.

To develop a fuller understanding of how scripts intervene in reality, explication of another ANT notion is necessary. Callon (2007; Callon 2008) proposed the notion of performativity to describe the reconfiguration of reality, in the form of hybrid collectives, as a new entity with a designed script is included. This new entity can be a material object or a discursive concept or a procedural rule (Callon 2007; Arora *et al*. 2013). Having focussed on material entities (above) we continue by focussing on the relational agency of concepts, models and standards.

Callon (2007) developed the concept of performativity by studying the role of economics in the making of markets. Callon argues that it is inadequate to treat economists' models and indicators as being merely descriptive. They do not simply describe economic production and exchange, but actually help perform it. In Callon's view, the economy is not just embedded in society (socio-cultural relations and conventions or rules), but also in economics. Models and other representations produced by economists help format the reality of market exchange in the economy. Involved in this formatting, alongside economists' representations, are many other actors such as policymakers, managers, workers and consumers, as well as tools, technologies and resources (Callon 2007; Callon 2008). This formatting takes the form of relational reconfiguration of hybrid collectives in which the exchanged object becomes entangled.

As an illustration, consider the manufacture, sale and purchase of a car (Callon 2005). In the process of its manufacture the car is relationally entangled with natural resources such as iron and steel, polymers

and other materials, component suppliers, warehouses, workers and robots on the assembly line, safety regulations, technical standards, as well as engineers and managers. In order to be sold to a retailer as a finished product, the car is (partially) disentangled from this complex heterogeneous world that is characterised by its own everyday concerns and uncertainties. Additionally, in order to be sold to a user/driver, the car must also be discursively disentangled, to the extent possible, from issues such as air pollution, traffic congestion, accidents and climate change. These disentanglements may be crucial for the exchange of the car (and money) to take place. They also help ensure that the 'protagonists are quits', once the transaction is completed (Callon 2005: 6).

At the same time as the disentanglements are materialised in the process of market exchange, the car gradually becomes entangled in the world of the buyer. It is adjusted into the buyer's everyday mobility practices, which include the use of roads and petrochemical infrastructures. Meanings of social status, comfort and luxury associated with the car are actualised in use. In addition, the car is entangled with a range of socio-technical practices of repair and maintenance. All these practices are performed by a diverse set of hybrid collectives. Callon (2007) aims to direct attention to the performative role played by economic descriptions in these practices. In the first place, economists' ideas of private property rights are central to the exchange. After sale the car becomes the private property of a buyer. Equally important are economic ideas of calculative rationality that help constitute the agency of both buyers and sellers. The buyers attempt to satisfy their needs and desires, by making economic calculations that allow them to achieve what they might consider a 'good deal', while the sellers calculate and set prices that are aimed at making a 'good profit'. Overall, Callon argues that this is true for all commodities. For their circulation they must be disentangled from the hybrid collectives of their producers/sellers and simultaneously entangled into the collectives that use them. Economic representations thus play a performative role, not just in the reality of exchange of commodities, but also in their production and use.

Callon's conceptualisation of performativity of economics has been heavily criticised for failing to distinguish between economists' representation of market exchange with its reality (Miller 2002). And for failing to conduct empirical analyses that allow Callon to connect the actual realities of market exchange with their economic representations (Fine 2003). Both Fine and Miller have also accused Callon of complicity with neoclassical economics and its assumptions of calculative rationality. In this way they argue that Callon ends up supporting, or at least glossing over many problems associated with, neoliberalism and its deregulated markets. However, in Callon's work, economic representations only come to matter (or not) in actual realities of market exchange. Through their performativity, the models and indicators constructed by economists become an integral part of market practices. They are critical to the functioning of the markets we participate in. If the models and indicators were different, the practice of market exchange might be different too. Yet the models are not blueprints or plans on the basis of which markets are constructed. For Callon, they do not define markets from the outside. Instead they are directly, 'implicated in the practical management of the market, in the definition of its standards, in the surveillance of exchange processes, in the constant adjustments, refinements, and reconstructions that are required to keep the exchanges flowing' (Holm 2007:235). Being implicated in practical management does not however mean that economic representations produce concrete and expected effects in markets. Meaning of economic representations in performativity is not necessarily imposed, but rather translated and adapted (entangled) into the hybrid collectives of markets in many unpredictable ways. So the arguments about the multiplicity of an object, in its de-scription processes, apply equally to an economic model, to a technical standard and to a government regulation.

The concept of performativity has been shown to have relevance far beyond economic representations. For example, it has been used to study the performativity of standards, in agricultural value chains (Arora *et al*. 2013; Ouma *et al*. 2013); of values, in organisations (Gehman *et al*. 2013); and of policy, in governance for realising urban resilience (Wagenaar and Wilkinson 2015). In combination with the concepts of translation (of interests and identities) and de-scription (of material objects' scripts),

performativity helps bring to the fore how entities such as models and standards reconfigure relations between humans and nonhumans in hybrid collectives, and thereby help format actual practices. Together the three ANT concepts provide a framework for studying the active constitution of agrarian practices by multiple divergent interests, desires, identities, rules, resources, technologies, knowledges, meanings, standards and human bodies. They also help appreciate how relations are made and unmade in the process of assembling the hybrid collectives that perform practices.

4. Power in Technography and ANT: A Dialogue

Technography and ANT both offer useful conceptual tools with which to approach the entanglement of technology and society, in the performance of practices. Yet there are important differences between the two sets of tools. As we outline below, the two frameworks emphasise different aspects of the socio-material interactions involved in technology. They use different idioms, which can be obscure and can make it hard to compare them or relate them to one another. Nonetheless, both are useful in helping us to analyse how agency and power are distributed across individuals and groups, and how the organisation of technical practices is shaped by, and helps to shape, rules and routines both within tasks (or task groups) and beyond them.

In this Section we compare the conceptual apparatuses of ANT and technography to shed light on the constitutive role of power, particularly as it is attached to rules and routines, within socio-material practices. The section is organised according to three points of comparison, in relation to power. First we focus on how relations of power are manifested in material interactions underpinning socio-technical practices. Second, we discuss the emergence of rules governing the distribution of roles and responsibilities among the interrelated entities involved in agricultural practices. And third, we examine how these rules and procedures are extended beyond the practices from which they emerge. In the concluding Section of this paper, we discuss whether and how our comparative understanding of power within technical practices has implications for agrarian transformations to sustainability.

4.1 Power in Material Interactions

In the technographic approach to the study of practices, material transformations are achieved by humans through purposeful and skilful interactions with tools and resources as well as with other people and groups. The agency of individuals and groups is configured through the social relations and material interactions involved in practical activity. Social relations are intimately connected to material practices: on one hand, social relations help people to initiate, organise and coordinate technical activity; on the other hand, social relations are also configured and modified by the way tasks are organised and performed by individuals and cooperating groups. The possibilities of action that are available to an individual or group in a practical situation are partly an effect of the way task ordering distributes information and responsibilities among the people involved in the task, leading to the progressive accumulation of specialised knowledge and skills to different individuals and groups. The possibilities of action are expressed or observable as a range of affordances found in a situation, which are qualities that emerge from relations between specific (groups of) people endowed with skills and capacities, and the objects and resources that surround them. These relations are dynamic; they also have both material/physical and cultural/symbolic aspects. In this way, the technographic approach suggests mechanisms by which agency is asymmetrically (re)structured, as power, between people and groups, through the practice of technical skills and the performance of tasks.

Technography's focus on affordances emerging out of material and symbolic interactions is comparable to the construction of alliances with materials, through translation, in ANT. By tracing the moments of translation from problematisation to enrolment, ANT allows power to be mapped as the formation of asymmetrically structured agency (e.g., of the scientists, fishermen, scallops and towlines in the scallops story). This agency is relational, it manifests in specific relations through which actors (the scientists) formed alliances with materials such as towlines and collectors in an attempt to influence the conduct of others (scallops and fishermen). The establishment of such relations of influence, and the resulting emergence of asymmetrically structured agency, is contingent on the success of translation processes. Thus, ANT suggests that relations of power involving materials are 'outcomes' of translation processes. Power does not reside in human intentions and purposes or within skilled human bodies, nor is it simply attached to rules and procedures prior to action, but rather it emerges from the development of relations between human actors and various tools and resources, through doing and knowing.

Translation represents an alternative approach to understanding the relations that technographers call affordances. From an ANT perspective, the affordances are not found within prior frameworks of socio-cultural norms and shared meanings. Instead, the sharedness of norms and meanings may be achieved in and through translation processes, if the latter are successful.

It is also important to note that ANT uses the same means to explain the emergence and dynamics of power over both materials and human beings. By achieving the power to influence the conduct of nonhumans, actors may secure influence over other humans, and *vice versa* (Latour 1992). Translation thus entangles humans and non-humans in and through relations of power. Yet, any translation process is uncertain and unpredictable, and can fall apart if the mobilisation of allies fails and dissent takes over. Translation thus depends on human or nonhuman actors, such as scallops, who may be able to resist power that emerges out of translation processes (Callon 1986). Such resistance may lead to a partial change in the form of power from material (e.g., power in-scripted into a technology to delegate tasks and control user actions) to symbolic (e.g., power embedded in oral discourses that shape practices in particular settings), and vice versa. It is this change in form that we term refraction. Arguably, objects in technography are more like mere 'intermediaries' than mediators, in the sense that an intermediary only, 'transports meaning or force without transformation: defining its inputs is enough to define its outputs' (Latour 2005: 39). Objects in technography thus appear to play modest roles as refractors of power. Human actors are identified in technography as possessing some sort of, and a variable degree of, power to influence material objects. The quality and dimension of this relationship are defined by dynamic attributes such as physical capabilities, bodily skills, embodied knowledge and existing socio-cultural institutions, such as gendered identities. In ANT, such power is seen to emerge from and is contingent on a sort of trial of strength, enacted through translation.

4.2 Power in Distribution of Roles and Responsibilities

In technography, individuals' access to information and their specialist knowledge are structured by the respective roles and responsibilities they undertake or are assigned within task groups. Together the members of the task group, coordinating and cooperating with each other, practise techniques and process information in order to accomplish a task. In many if not all cases, and especially in the performance of complex tasks, flows of information within the task group are likely to be asymmetrical and knowledge and skills are likely to be distributed unevenly. Work may become hierarchically organised, based on centralisation of authority by individuals occupying key positions, who, as a consequence, acquire specialist skills that are considered critical for the 'efficient' performance of a task. Rules and routines are thus argued to emerge within and through the performance of tasks; these emergent rules and routines are specific to their task group and not necessarily widely shared across society. Pre-existing socio-cultural institutions such as gender roles may be observed empirically within technographic studies, but technographic theory focuses more on the mechanisms by which rules and routines emerge within practical activity, rather than the ways in which the rules are also co-constituted by the wider socio-economic, cultural and political contexts within which social goals are selected and tasks are performed. On the other hand, task-linked relations of power that originate within a specific task or task group are theorised to have potentially wider ramifications beyond individual task groups, if performers of specialised roles within tasks become organised into sodalities that are able to govern the performance of similar or related tasks in other communities and places.

In ANT, the power gained by some actors to speak on behalf of other actors and actants does not emerge out of the rules and routines of a task at hand, but rather is constituted directly as relations (of power) are established through translation. This translation is the task at hand, which points to the relational ontology of ANT. Acting is the making of relations and vice versa. Power is made manifest when action (or agency, as the capacity to act) is asymmetrically structured, when some actors are able to influence the conduct of others. Thus, as compared to technography, power in ANT appears to be more clearly relational. And the relations in question are not confined to relations of hierarchy and authority within a predefined 'task group'. To achieve an outcome, relations may be constructed between disparate and

widely dispersed entities, including humans and nonhumans, in hybrid collectives which always have porous boundaries. Furthermore, relations may change over time as (material) resistance and dissent come into play. Many of these relations involve humans such as scientists who have political and cultural authority behind them. However, prominent ANT studies, such as the ones reviewed above, do not explicitly account for extant authority, and the rules and routines associated with it, which is often historically accrued. Any form of power associated with cultural authority as well as rules and routines is viewed as constructed and performed with disparate relations established through translation.

This does not however imply that ANT is an ahistorical approach. As well as accounting for time within the translation process, from problematisation to mobilisation, the continuing role of the past within the present is clearly accounted for, in relation to power, through the notion of de-scription. Extant rules and routines, associated with the authority of 'experts' as designers of objects, are in-scribed into the objects that move into 'user' settings where they are de-scribed. Rules and routines, in-scribed into objects, attempt to delegate roles and responsibilities to different actors engaged in using the object (and re-making it). In this sense, a script represents an attempt to enact a relation of power between the designers/makers of an object and its proposed users. However, the actualisation of this relation of power between designers and users depends on the de-scription process undertaken by hybrid collectives assembled in user settings. In the de-scription of 'rigid' scripts, such as the ones built into the solar PV kits studied by Akrich (1992), the rules and routines in-scribed into objects attempted to control users in a deterministic manner. They were difficult to de-script. In contrast, de Laet and Mol (2000) argue that the Zimbabwe bush pump they studied had a more 'flexible' script that allowed more space for user collectives to adapt the original design.

The rules and routines that are inscribed into objects, and intended to delegate roles and responsibilities to various users, may be enacted differently within a particular hybrid collective and across multiple hybrid collectives. The power expressed in the form of rules and routines and in-scribed into objects, is thus refracted through the hybrid collectives which the objects encounter.[4] In this way, power emerges within and becomes immanent to specific hybrid collectives. It is also fluid and variable, across time and space, within and between collectives. These features of emergence, fluidity and variation are conceptualised relationally in ANT. Different relational configurations, in particular hybrid collectives, allow the same rule, routine and object to be differently enacted, by different communities of practice and in different places (Mol 2002). Instead of focussing on difference and multiplicity, technographers seem to focus on how emergent rules and routines become shared across communities of practice, in particular the concept of sodality and the power it bestows upon certain actors to speak on behalf of and enforce rules of practice. In this sense, ANT and technography appear complementary. While one may yield a better understanding of how rules and routines emerge from technical practice and are made durable, the other focusses more on their relational particularity and, consequently, their multiplicity across space and flexibility through time. To account for such variability, the technographer would need to study how sodality-members speak and act in particular settings on behalf of the standardised rules and routines, as laid down by the sodality, and so plot a course between the established formal rules and changing local needs. Arguably, the variation and multiplicity of rules becomes harder to observe if rules and routines are disentangled from material objects and concrete practices, and made more dependent upon distinct sociocultural institutions (i.e. formal norms and rules) as theorised in technography.

[4] This applies also to the in-scription process itself, which entails the mutation of the symbolic power associated with rules and routines into material power in-scribed into an object. In-scription is also refractive due to changes in courses of action arising out of resistance posed by materials in the design process (Joerges 1999).

4.3 Extension of Power Attached to Rules and Procedures

We have argued that ANT and technography both suggest mechanisms through which rules and procedures (which underpin routines) emerge from the performance of technical practices. In technography, these rules and procedures are immanent to a task and emergent from the way the task is organised, but influenced by wider economic, social, cultural and political institutions. In ANT, any emergent rules and routines are immanent to relations in a hybrid collective, which may include links with wider societal forces that have been translated into the collective. Yet this immanence of rules and routines raises the question how they extend beyond a specific task group or hybrid collective, and become institutionalised in wider society. It is through such institutionalisation that power associated with rules and routines gets dispersed in society, while being concentrated in centres of governing, knowing and doing (Stirling 2016), within and across individual practices.

According to technography, the answer to this question lies in the study of sodalities. Sodalities, based on shared skills and knowledge, may establish generalised rules and standards out of the particular rules and routines that emerge, originally, from task groups. These formal rules are codified as procedures and protocols that are supposed to govern how tasks are performed and by whom. Through apprenticeship, sodality-members acquire the power to speak on behalf of a body of knowledge, interpret the rules, make rulings on specific cases, and enforce the protocols within and across task groups, allowing them to exercise power in society. Armed with specialised knowledge and skills, and with formal rulebooks and regulations at their disposal, sodality-members may extend and institutionalise their relations of power into (new) task groups and similar domains elsewhere.

The rules require spokespeople because the actualisation of rules and procedures in the practice of new task groups is not smooth or straightforward. As demonstrated by Richards (1989), formalised rules and procedures are enacted within constraints arising out of materiality and uncertainty in practice. The rules and procedures interact with a repertoire of particular skills, tools and resources that are exercised within a dynamic flow of events. This flow is not predictable, for example as rainfall patterns change, soils become infertile, pesticides become unreliable, pest populations change, and skilled farmworkers become hard to find. In order to perform their actions more or less effectively, practitioners (performers) often need to adapt their practices and improvise to meet new situations. They may be led to adjust the formalised rules and procedures imported into their practice from other times and spaces, thereby refracting the power associated with those rules and procedures. Sodality-members are like judicial and practical experts whose specialism is to navigate and negotiate – and to help task groups and communities to navigate – between the institutionalised rules and particular cases. This is a refractive space of interpretation, communication and improvisation.

Moving to ANT, the extension of formalised rules and procedures in space and time is appreciated through the notion of performativity. The rules and procedures addressed by ANT are either embedded in objects (as discussed in the previous section), or written down in 'best practice' manuals, in codebooks of standards, or in economic models. Moving across time and space, these rules and procedures are translated into active hybrid collectives. In this process, new relations are established and extant relations may be dismantled (Callon 2007; Arora *et al*. 2013). Thus, by influencing the reconfiguration of hybrid collectives, the rules and procedures (as nonhuman entities) enter into relations of power with other material and symbolic entities in hybrid collectives. Yet, in the same process, the rules and procedures may themselves get reconfigured, adjusted and adapted to work in relation with other entities participating in hybrid collectives that enact practices. This means that power is not centred on the rules and procedures themselves. Instead it is distributed in action, across different relations within and between hybrid collectives. And as these relations link actors as mediators, rather than intermediaries, the institutionalisation of rules and procedures is uncertain and unpredictable, entailing multiple adjustments (as well as the making and unmaking of relations) between the rules/procedures and other material/discursive entities in hybrid collectives. The

extension of power associated with the rules and procedures is therefore refractive, rather than linearly repressive or productive.

5. Conclusions and Implications

In this paper, we have explored and compared two sets of conceptual tools for thinking about practices, technology and innovation. Both sets are concerned with activities that are socio-material, or socio-ecological-technical, meaning that they involve humans interacting with materials of various kinds (such as natural resources, technical objects, designed artefacts), as well as nonhuman living organisms such as crops, farm livestock and marine animals. Accordingly, both approaches also agree that the inter-activity involved in using and producing technology includes social aspects alongside material ones. That is to say, cognitive and communicative dimensions, which have bodily, symbolic, cultural, discursive and regulatory aspects. In both approaches, kinds of agency (the power or capacity to act) are distributed across a diverse ensemble of entities that interact with each other.

Both approaches also help to show that innovation is an intrinsic feature of socio-material practice, and not a discrete type of activity. Innovation is revealed as not merely invention or the doing of radically new things, it is also a regular feature of everyday socio-ecological-technical practices, which require the continual remaking of relations, exercise of bodily skills and embodied knowledge, and the ongoing enactment of techniques. Whereas innovation, as it is commonly understood, may entail a higher proportion of novel techniques, activities and material objects compared to established or familiar practices, this is a difference of degree rather than an essential difference in kind. The everyday practices of using and producing technology involve an ongoing, continuously unfolding sequence of socio-material adjustments and adaptations to changing circumstances.

It follows that technical practices may be thought of as situated performances or 'improvisations', which draw upon a repertoire of skills and resources (including knowledge and technological artefacts), while being governed by norms, values, rules and procedures. From this perspective, the everyday practices from which culture is made are expressions of, 'an adaptive process that accumulates partial solutions to frequently encountered problems' (Hutchins 1995: 354). The solutions are partial and cannot fit all situations, therefore the creativity and improvisational work of skilful practitioners are essential features of everyday practices, making them innovative. Recognising this opens up the possibility of fostering an inclusive and vibrant innovation democracy, rather than a knowledge economy driven by technocratic expertise (Stirling 2015). An innovation democracy allows the distributed innovative capacities of society to interact and conjugate, enabling wider deliberations and negotiations among alternative technological practices, and opening up spaces where debates about what constitutes successful innovations, conducive to achieving transformations to (agricultural) sustainability, may take place.

The possibility of achieving agricultural sustainability, in and through innovation democracies, is however conditioned by the productive and repressive dimensions of power. Power, expressed in rules and routines, in-scribed into material objects and promoted through discourses, structures agency and distributes it asymmetrically in and between practices. This asymmetrically structured agency is on one hand productive. It enables certain socio-material practices to become dominant through institutionalisation, driven by the extension of their constituent rules, routines, materials and discourses in society. The practices (technologies) so enshrined are often those that further the interests of certain incumbent powers in society, dominant companies, nations, and industrial sectors, for example. This extension of productive power also generates the repressive effect of closing down alternative socio-material practices. Technography and ANT offer different yet complementary ways of understanding this repressive effect of power. In technography, this happens as rules and procedures associated with technological practice are extended across society by sodalities. In ANT, the extension of power across practices is achieved through de-scription and performativity of circulating discourses and objects into which rules and procedures have been in-scribed. However, both technography and ANT apprehend how the extension of this repressive aspect of power is refractive rather than linear. As new rules,

procedures and materials (such as modern seeds, pesticides and fertilisers) discipline agricultural practices across different settings, they do so through multiple adjustments and adaptations to socio-ecological-technical relations that constitute hybrid collectives (ANT), or to local ecological conditions and repertoires of skills (technography). In ANT, refractions of power are manifested through processes of translation (in which actors may resist enrolment, forcing adjustments in the programme) and de-scription (whereby actors may be able to resist or subvert the proposed script, substituting their own ways of working). In technography, the refraction of power is seen in the way the affordances within a technological proposition offer the opportunity for different local actors to respond in various ways. Some of these ways may not have been anticipated or perhaps desired by the designers and promoters of the technological proposition.

In order to build innovation democracies capable of achieving sustainability transformations, it may be critical to counter the repressive effects of power refracted through practices, while opening up new pathways to sustainability constituted by a diverse range of socio-material practices (Stirling 2007; Leach *et al*. 2010). In order to appraise the social and ecological sustainability of practices, deploying a plurality of perspectives may not only yield more robust appraisals but also help to build legitimacy and accountability (Stirling 2015). Enabling this opening up to the diversity of socio-material practices and a plurality of appraisal perspectives may require an alignment between the productive and refractive effects of power.

In modernity, control has been the predominant ethos underpinning attempts to create an alignment between power's productive and refractive effects, as modernist humans ascribe to themselves (and their ideas) the ability to control or assimilate nature and subjugated people (Stirling 2014b; Arora 2017). By attempting to control 'unwanted' divergence from planned courses of action, modernists aim to ensure that the productive power of 'sustainable' technologies and 'emancipatory' discourses does not dissipate through refraction, as they are admitted into different practices. However, this 'notional human control' is a fallacy (Stirling 2014b: 7) because it denies the importance of adaptation and adjustment to planned and goal-driven courses of action, as they encounter dynamic socio-ecological realities. These encounters may include resistance posed by other entities. As a result of these encounters, the repressive and productive dimensions of power are refracted. Despite concerted attempts throughout the colonial and postcolonial eras (Arora 2017), modernist humans have failed to control the refraction of productive and repressive power wielded by them on diverse collectives of humans and nonhumans. Moreover, intensifying climate change and widespread unsustainability of modernist practices has put to rest any remaining hope in the 'fallacy of control.

A new strategy is needed to admit 'sustainable' technologies and 'emancipatory' discourses into practices for sustainability transformations. Rather than attempting to align productive and refractive power, using the fallacy of control, an alternative strategy is to care for the achievement of sustainable technologies, routines and discourses in practice. An ethos of care implies that potential harm to or exploitation of any entity is rejected (Wynne 1992; Mayer and Stirling 2002). It implies that the complexity of all entities is respected (Haraway 2009; Davies *et al*. 2016). Above all, it implies that the most marginalised human and nonhuman collectives are afforded the opportunity to nurture their improvisational and adaptive capacities, without any disqualification of their resistance against incursions of new technologies, protocols and discourses deemed superior by power.

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