Agric Hum Values (2015) 32:3–20
DOI 10.1007/s10460-014-9515-5

Cows desiring to be milked? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms

Clemens Driessen · Leonie F. M. Heutinck

Accepted: 20 February 2014 / Published online: 20 June 2014

Abstract Ethical concerns regarding agricultural practices can be found to co-evolve with technological developments. This paper aims to create an understanding of ethics that is helpful in debating technological innovation by studying such a co-evolution process in detail: the development and adoption of the milking robot. Over the last decade an increasing number of milking robots, or automatic milking systems (AMS), has been adopted, especially in the Netherlands and a few other Western European countries. The appraisal of this new technology in ethical terms has appeared to be a complicated matter. Compared to using a conventional milking parlor, the use of an AMS entails in several respects a different practice of dairy farming, the ethical implications and evaluation of which are not self-evident but are themselves part of a dynamic process. It has become clear that with its use, the entire practice of dairy farming has been reorganized around this new device. With a robot, cows must voluntarily present themselves to be milked, whereby an ethical norm of (individual) freedom for cows can be seen to emerge together with this new technology. But adopting a robot also implies changes in what is considered to be a good farmer and an appropriate relation between farmer and cow. Through interviews, attending "farmers' network" meetings in the Netherlands, and studying professional literature and dedicated dairy farming web forums, this paper traces the way that ethical concerns are a dynamic part of this process of rearranging a variety of elements of the practice of dairy farming.

Keywords Milking robots · Dairy farming · Animal welfare · Labor quality · Co-evolution of ethics and technology · Human animal relations · Technology assessment · Automatic milking systems (AMS)

Introduction

Since the 1960s the milking of cows (in the Western world) has mostly been done using a milking machine rather than by hand and bucket, as had been common since the dawn of dairy agriculture (Van Adrichem Boogaert 1970; Bieleman 2000). A milking machine consists of a pump connected via tubes to teat cups, in which a pulsating vacuum simulates a suckling calf or the milking hand of a dairy farmer. The farmer, or an employee, milks eight to twelve cows simultaneously in a milking parlor by attaching the teat cups to the udders of the cows that have been made to walk into designated individual stations.[1] The movement of the cow is restricted for the duration of the milking while she receives a ration of concentrate to ease her behavior. In one early morning and one late afternoon shift,[2] the cows are fetched from the meadow in summer or driven from their housing area to the milking parlor. Each shift for the milker consists of 1–2 h spent in the milking parlor

C. Driessen (✉)
Cultural Geography Group, Wageningen University,
Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands
e-mail: clemens.driessen@wur.nl

L. F. M. Heutinck
Livestock Research, Wageningen University, Edelhertweg 15,
8219 PH Lelystad, Wageningen, The Netherlands

[1] In more large-scale operations this can be up to 30 cows, a situation which is common for instance in parts of the US. This introduction describes the common situation on dairy farms in the Netherlands.

[2] Though for instance in the south of the Netherlands on many farms milking tends to be done according to a later rhythm, something that is sometimes ascribed to the region being Catholic rather than Protestant.

cleaning udders, attaching teat cups, and checking the condition of the cows while watching over the milking process. Some would say it is drudgery, something preferably relegated to an employee. However, for many the discipline of the early rise and the daily routine of "harvesting" is the central and most rewarding part of being a farmer: getting into a state of "flow" with the machinery and the animals, interacting with the cows, and checking on their individual condition in turn, while enjoying the efficiency and the swiftness of the process. This is often carried out with an implicit idea of cooperation between human and animal—notwithstanding the occasional cow that accidentally, or on purpose, kicks off the milking device. It is often said that most important strategic decisions in dairy farming are made "in the pit," where the farmer is concentrating, absorbed in the work, and creating mental space to mull things over. This means that the act of milking becomes an exemplary moment in which the modern dairy farmer, in one of the few such remaining roles in our society, integrates manual labor with strategic management and entrepreneurship (Driessen 2012).

In many cases, though, milking is left to an employee or the task is divided among the family, especially when multiple generations share in the farm work. In very large dairy farms with over a thousand cows, which are common in parts of North America, another division of tasks emerges in which employees work in shifts around the clock to continuously milk batches of cows, often in large carousel systems (e.g., Zellmer 2012). Good (skillful) employees, considered to be necessary in the Netherlands, are increasingly difficult to find, though. And Dutch farmers do not always want to become "personnel managers"—or find that they are incapable of taking on this role—and try to avoid hiring external labor (*vreemde arbeid*) (Booij 2004; Debergh 2007).

As an alternative to the common milking parlor in which, two or three times a day, all cows are milked in groups, a device has been developed that does the milking automatically, without the direct intervention of a farmer. In the Netherlands, as well as in other (developed) countries the world over, the number of automatic milking systems (AMS) replacing conventional milking parlors on dairy farms has been increasing since their commercial introduction in the 1990s. Thousands of farmers operate one or more of these devices (e.g., Huiden 2009), most of them located in Northwestern Europe (Scandinavia, the Netherlands, Germany, France, and the UK), although some can be found in North America, Australia, and New Zealand.[3]

In farms with AMS, individual cows visit the milking robot according to their own inclination, and are mainly motivated by a supply of concentrates offered in the milking box during milking. With the use of sensors, cows are identified by the system and abnormalities in the milk can be detected. Dedicated software stores operational data, milking reports (i.e. daily average per cow, amount of milk, interval between milkings) and milk quality parameters (de Koning and Rodenburg 2004). The management program enables the farmer to control the settings of the system (Meijering et al. 2004). Cows that show abnormalities or have not visited the robot for more than a set period are identified and placed on a so-called *attention list*. These cows are to be checked upon by the farmer, and can (in some setups) be put into an enclosed *waiting area* that they can only leave by visiting the robot.

In this paper we will describe the emergence of this new technology and explore its implications for ethical concerns regarding both farmer and cow welfare. We will argue that these implications are essentially ambiguous and impossible to interpret unequivocally, as the terms in which to evaluate them and the understandings of the experiences of both farmers and cows are found to change as part of the introduction and use of this device. Nevertheless, we believe that continuous debates on interpreting the shifts in practices and discourses are important in order to critically assess and inform technological innovation processes. This is especially important because these changing views on what constitutes a good life for a cow and a farmer, we will claim, are not all merely cases of salesperson rhetoric, but actually also attest to the relevance of normative concerns in technology development. Thus, the moral ideas that changed with the use of a robot can actually be found to feed back into how the robotic system is used and laid out, leading to ongoing techno-moral co-evolution.

Conceptual background

Co-evolution

In various fields that study technological change, it is now commonplace to see the relation between technology and society as one of mutual influence. From the philosophy of technology to innovation studies and various (other) branches of science and technology studies (STS), the core assumption is that change is to be conceived as a process of two-way shaping. The terms used to describe this kind of

[3] As of 2012 in the Netherlands, more than 2,500 farmers operate an AMS, which means over 10 % of the Dutch dairy farms, while over the past few years about a third of new milking installations were robotic (Stichting K.O.M. n.d). The use of AMS in North America is expected to rise as well, for instance, by the manufacturer Lely (Hoard's Dairyman 2012).

process may differ, and accordingly the domains that are thought to interact: the "coproduction of science and social order" (Jasanoff 2013) or the "co-construction of society and nature" (Latour 1992), the "co-shaping of technology and society" and "socio-technical" (Bijker and Law 1992) or "techno-moral change" (Swierstra et al. 2009). Starting from the same basic premise, this paper unsurprisingly corroborates this idea of a two-way influence between technology and society/culture/morality. What may however make it a worthwhile read is that it offers a particular take on how we could understand this mutual shaping process in more detail, and especially how we could think of ethics as part of this process.

Even though the various proposed terms do not diverge much in the way the authors mentioned use them, we find the notion of "co-evolution" to be most appealing, as it implies that what people come to consider to be valuable is not the endpoint of a kind of moral progress, nor the inadvertent "side effect" of technological production, but rather a matter of continuous adaptation to circumstances. The co-evolution metaphor perhaps risks making ethical thought into a rather blind and relativist affair; ethics as merely the outcome of chance variation in whatever happens to be the socio-technical selection environment of particular moral norms, understandings of subjects, etc. The only recommendation or even ideal could then be to foster ethical variety, from a hope that a kind of "moral biodiversity" would contribute to societal resilience. This is perhaps not altogether a wrong idea, especially when both the variation and selection are not fully "blind" after all, but involve intentions and choices by human and even non-human agents. We then can see ourselves actively experimenting with novel ways to live, to relate, and to argue. Evolution increasingly is seen to occur not only by "variation and selection," as a blind and unidirectional affair, but also by horizontal exchange between organisms, through parasitism and symbiosis (Hird 2010). In this version, the obviousness of organism boundaries, especially in processes of change, is severely undercut. While at the same time, perhaps paradoxically, biological processes of co-evolution should not be thought of as lacking meaningful communication and agency (Despret 2013). It goes probably too far to stretch the metaphor into a precise model of the intertwinement of ethics and technology, but it does make for more interesting implications of labeling this as "co-evolution."[4] Thereby the term leads not merely to a view of how technological artifacts and systems "influence" something or some variable we may call "ethics" and vice versa. For our case study, this co-evolutionary understanding would mean the characteristics of cows, farmers, and robots depend on how they relate to each other and to the wider fabric of the world. In our empirical research of the process of ethical appreciation of the milking robot we do not just look at changes in the discourse on dairy farming, but also trace changes in the farmers and cows themselves, and how these feed back into the design and layout of the robot.

From tie-stalls to loose housing

Earlier innovations in dairy farming have also shown processes of coevolving material change and ethical understandings. For example, the switch from the tie-stall to loose housing in cubicle barns that occurred (in the Netherlands) around the 1970s, was motivated by various factors and considerations. Not only was there a development towards increasing the scale of farms and decreasing the amount of labor, also the working conditions of farmers had become a matter of concern, whereby the hard manual labor required by the tie-stall was increasingly thought of as unacceptable (Van Adrichem Boogaert 1970). The change in housing system was accompanied by a shift in what were considered to be desirable and allowable practices with regard to the animals. For example the dehorning of the cows was deemed necessary in loose housing, but had been highly controversial a decade earlier (Bieleman 2000; Van der Ploeg 2003). Reluctant farmers viewed the new loose housing as messy aberrations to good farming practice. While tying up cows to constrain them on a single spot, which was common practice in the old tie-stalls, has nowadays (again, in the Netherlands) generally come to be considered highly undesirable from an animal welfare point of view. In organic farming it is now mostly ruled out, and for calves tying up has been prohibited in the EU. Nevertheless, in a number of European countries the tie-stall still is common, even in countries that have seen extensive debates on animal welfare, such as Nordic and Alp countries.

Ethics in co-evolution?

When the changing character of ethical norms and priorities cannot be taken as a sign of moral progress, does it mean that ethics is merely a matter of alternating fashions? To understand the ethical question in this dichotomous way, we argue, would arise from an expectation that what is ethically right is supposed to have a universal and a-temporal character. Ethical principles and norms, in this view, need to be applied in a local context, but can

[4] Coevolution moreover is a common notion in understandings of agricultural innovation that consider the adoption of new technologies and the development of knowledge as intertwined with alternative ways of organizing agricultural practice. This is seen to include policy, legislation, infrastructure, funding, and market developments, involving competing worldviews and redistribution of costs and benefits (Klerkx et al. 2012).

ultimately be understood as separate from and transcendent of these contexts. By acknowledging or even embracing the dynamic and co-evolutionary character of ethical norms as changing together with material practices, the possibility of making ethical judgments would seem to be precluded. Instead, this paper starts from a pragmatist understanding of ethics which, as Keulartz et al. (2004) have highlighted, is more geared towards accommodating moral change and has closer affinity with the relational and fluid ontologies of sociotechnical coevolution.

One of the central tenets of pragmatism is the disavowal of granting dualisms ontological status. Dichotomies such as mind and body, rationality and emotion, subjective and objective, are not basic and given divisions of our world. In Deweyan pragmatism, ethics emerges in the experience of problematic situations. This type of ethics is dynamic, situated, and centralizes "experience," understood not just as a purely subjective affair that organisms privately undergo, but as both passive and active, as doing and undergoing (Dewey 2005), as bodily and mental, comprising both affective encounters and skillful engagement with the world. This conception of experience makes for an approach to ethics that allows for a self-evident role of both farmers and—so we argue—also animals when considering ethical concerns on the farm. Not as ideal liberal subjects: rational, autonomous, atomistic individuals, but relational characters immersed in practices. The thick description of everyday experiences, and how farmers and animals communicate these, is then an appropriate way to promote ethical reflection and debate (Driessen 2012).

Other approaches to ethics that similarly start from a relational and fluid understanding of humans, animals, and technologies have over the past decades been developed by Whatmore (2002) and Haraway (2008). In exuberant styles, these authors have crafted alternative forms of relating to "companion species" and "intimate assemblages of corporeal becoming." The ethical call in these approaches amounts to learning to be open, to tune in, and to seek to encounter "mindful others." Not by extending humanist models of subjectivity and rights to a select group of higher mammals, but by becoming aware of the various ways in which our language and material practices contain species hierarchies, make us overestimate our human specialness and prevent us from more truly encountering and imaginatively responding to a variety of living beings.

Does this mean ethical concern is to be extended to nonhuman objects too? Extending Latour's "actor network" orthodoxy—in which humans and the entire variety of nonhumans alike are to be considered "actants"—may seem to suggest such a thing (Risan 2005). Is there then no difference between a cow and a robot? In practice there are numerous: a farmer may occasionally talk to a robot, but probably only while swearing when it malfunctions, never kindly, when it operates as expected. The robot is unlikely to ever be caressed; only perhaps kicked. When a robot would be kicked, the farmer may experience embarrassment upon believing someone else saw it, or be worried this might affect the warranty, but when kicking a cow a farmer may experience a sense of shame (Harbers 2002; see also James 2009, p. 41). What counts as communication between farmer and cows can as well be part of the co-evolution process of material arrangement and ethical understandings: The appropriate relation between farmer and cow in a tie stall was found to be one of close personal contact and care. With a robot, the farmer cow relation changes from caring for the animals, towards allowing the animals to take good care of themselves (Heutinck and Driessen 2007).

Thus what a cow is, and how best to relate to her, is the outcome of ongoing processes of socio-technical change. And while especially with the modern high yielding dairy cow it is hard to say where technology stops and the animal begins, this however does not preclude a genuine ethical stance towards them: even stronger, acknowledging the deeply technologically mediated relations of interdependence can also be thought to give rise to the moral challenge of learning to become what Haraway calls "response-able."

This type of ethical theorizing and research does not offer recipes for justifying moral positions and producing logically straightforward moral arguments. Embracing coevolution and disbanding more formal modes of moral theorizing for many involves the risk of losing ethical ground and giving up critical terms such as "natural," "autonomy," "freedom," "exploitation," and "alienation" in a flurry of techno-enthusiasm (see Crist 2004; Weisberg 2009). In this paper we will trace in detail how these terms on the one hand can be found to lack stable meanings in a dynamic technological culture, while on the other hand—through being contested—they still perform vital work in making sense of changing experiences and moral commitments.

Common approaches to farm animal welfare

A pragmatist outlook on ethics focuses on what particular approaches to ethics mean in practice. Each scheme of institutionalizing farm animal ethics entails not just a distribution of moral agency—who decides what a good life is for animals, but also particular ways of defining the central issues. When "animal welfare" (rather than "animal rights") is thought of as the central issue in livestock farming, (intensive) animal production is commonly assumed to be an acceptable or even desirable form of animal use (Holloway et al. 2013). And when animal welfare is thought best decided on by consumers in supermarkets, this means animal welfare will be defined in ways that allow for easy commodification, such as outdoor access (Buller and Roe 2012). The resulting notion of welfare lends itself to marketing and can be made to appeal to the imagination of consumers, or is thought to have implications for food quality and taste. Alternatively, when animal welfare is primarily a matter of state regulation and enforcement, different parameters may become prominent, such as those that can be objectively counted and measured (Veissier et al. 2008; Roe et al. 2011). There has been a drive for "animal based parameters" to define animal welfare more scientifically, e.g., in the EU "Welfare Quality" project. In practice though, also these parameters are defined through on farm measuring, and thus involve negotiation and interpretation (Roe et al. 2011). Apart from implicit decisions on what makes up a good life for a farm animal—one that is natural, stress free, or healthy (Fraser 1995)—animal welfare science tends to bring a particular focus and situatedness, if only for studying animal subjectivity in confined spaces (Johnston 2013). Even in the standardized conditions of laboratories, welfare has been found to be "multiple," not easily defined on the level of species, but dependent on contexts, on qualities and life histories of particular animals, environments, and humans relating to them (Davies 2012). Notwithstanding all these hidden choices and variation, "animal welfare" tends to be used as if it is a (generic and objectifiable) quality of species of animals. Both farmers and animals as active and idiosyncratic beings are absent in most approaches to welfare. Notions of animal welfare that would fit the experience (both affective registers as well as professional skills) of farmers are easily neglected in public debate and policy making (Driessen 2012). And besides farmers, also animals can be thought of as similarly experiential: not just passive "recipients" of welfare, but learning new skills too—something that is salient with the AMS.[5] Meanwhile the "welfare" of farmers is not an issue of public debate or policy making, beyond health and safety regulations and basic rights of farm workers. Though in agricultural technology development this (the character of the resulting work for the farmer) is one of the core values and grounds for marketing, especially in situations where most manual labor is (at least in part) done by the farmer and his/her family, such as on most Dutch (dairy) farms.[6]

[5] This active process learning is also clear in the case of cows that are "dedomesticated" and made to live independently in nature reserves (Lorimer and Driessen 2013).

[6] This means that in the Netherlands the milking robot, unlike other instances of agricultural automation, tends not to be considered as an alternative to migrant labor.

Empirical approach

The research for this paper was conducted between 2007 and 2010 and involved the analysis of discourse on milking robots and practical experiences with these in farmers' magazines, in the promotional material of robot producers, in scientific literature on the impacts of robots, on dedicated dairy farming web forums, and through interviews with three key AMS researchers. To be able to appreciate the different experiences of milking in a conventional milking parlor and with a robot, and to learn about the particular concerns that matter to farmers in this transition, one of the authors has participated in a week-long training course in dairy farming in which both systems were used and taught. The other author has previously studied cow behavior during and after transition to an AMS (Ruis-Heutinck et al. 2001; Heutinck et al. 2004). The practical difficulties and the discussions among farmers were studied by joining several meetings of farmers' networks in which a group of farmers meets at a farm of one of the participants and discusses experiences, problems encountered, and possible solutions to these. The focal country of this research was the Netherlands, where the research and development of the AMS was pioneered by researchers and several companies, and in which a significant number of farmers has adopted and has been widely discussing this technology.

Ambiguous technology assessment

Technological determinism: farm technology innovators on a logical trajectory

With labor costs continuously rising, and considering the ongoing process of dairy farm automation—milking machines with automated uncoupling, automated feeding stations, robotic barn cleaners, and cow brushes—attaching the teat cups to the udders of the cow seemed the obvious next candidate for automation. From the early 1980s onwards, in several countries (notably the Netherlands, Denmark, New Zealand, the UK, and France) farm technologists were actively exploring the possibilities of using a robot to attach the teat cups. As the udders of each cow are positioned and shaped differently, this was found to require the recognition of individual cows, a programmed memory of the position of the particular teats, and how to attach the teat cups.

It became clear to these developers that this seemingly small and logical step in automation would entail larger changes in the setup of the dairy farm. As robotizing the farm worker in the conventional milking parlor would take too many robot arms or robot arms that were too complicated and therefore too expensive, a more efficient setup meant the cows would have to be milked one at a time. And for the robot to be worth the investment, it needed to work to its full capacity. In this way the newly developed device required a thorough change in the organization of the milking process.[7] This involved not only milking one cow at a time instead of the entire herd in batches, but also leaving it up to the cow to decide when to be milked rather than following the rhythm maintained by the farmer. This new requirement in turn led to numerous difficulties and adaptations of farm practices, of the robots, and of the cows. What ensued was not merely a robot, but a larger systemic change in the organization and layout of the dairy farm; hence the name was changed from robotic milking to the more encompassing term automated milking system, or AMS (Meijering et al. 2004).

Besides this inherent dynamic, as part of what might be a general, logical path of increasing automation of manual labor in any Western sector of production, other storylines on the emergence of the AMS resisting this type of technological determinism can be traced as well. First of all, the inevitability of this technological trajectory can be questioned.

Nobody had asked for this "technology push"

For a while the autonomous technology push of the farm technologists was met with skepticism. "Nobody had ever asked for this innovation," the farm ethologist Wiepkema pointed out in his farewell address (Wiepkema 1993, p. 3–4). He claimed, though, not to be opposed to the new device out of principle, but to be protesting against the positive expectations concerning its impact on cow and farmer welfare as claimed by technologists and researchers. He questioned whether farmers would be willing to leave the daily interaction with cows to a machine. And, speaking in 1993, he doubted whether cows, being herd animals, would be willing go to a milking machine voluntarily, as individuals, and questioned what kind of behavior this system would encourage in the cows.

At some points, especially during the nineties, the fate of the AMS seemed uncertain. It was considered by many to be an overly expensive device.[8] In order to create a rationale for investing in it, the benefits needed to be expressed in financial terms somehow. Numerous studies calculated the cost efficiency of this labor-saving device and what its return on investment would be. *Time budgets* of farmers were measured to the minute, to set off the time gained against the costs of the system (Arendzen and Van Scheppingen 2000; Van Zessen 2007; Rodenburg n.d.). It was difficult, however, to put a price on the hours of a farmer, as he or she would need to work elsewhere to actually cash in on the saved time. Eventually, it was found that what the robot offered was not so much time gained, but increased flexibility. The value of this flexibility can be considered in divergent ways, as we will return to below. In the meantime, the cows were experiencing trouble with the robot. Their *somatic cell counts*,[9] an indicator for hygiene and udder health, were measured in real time by the robots, only to reveal that these increased to alarming levels with the introduction of an AMS (Kruip et al. 2002).[10] And the technical feasibility of developing a robust robot seemed difficult as well, because it often malfunctioned and was in need of repair.

Technology assessment in a hybrid, dynamic world

Were the initial problems related to the robots' ability to work reliably merely teething problems? Or were they learning processes of the farmers and cows, which meant that they could then deal adequately with the challenges of the transitional period of moving from conventional to robotic milking? In hindsight it can be (and is often) said that at first the robot was marketed to the wrong farmers (Hoefman 1998): most of the early robots were bought by "technology farmers" that were mainly motivated to do mechanical work and were less interested in spending time with cows.[11] With the milking robot, however, especially in its early days, there was a need for "cow-farmers,"—who are passionate about cow behavior and welfare—as they would be able in an early stage to detect problems with the cows using this new machinery (Van Drie 2005). But at the same time, having the technologically oriented

[7] In terms of Akrich (1992) one could say the robot clearly came with a "script" that required certain behaviors of both human and nonhuman actors. This does not mean that thereby necessarily the robot everywhere produces the same behaviors and even discourses, irrespective of particularities of places and farmers. The potential differences in how AMS may be implemented and itself may be changed as part of regional "niches" of coevolution is an interesting theme for further research.

[8] "Experience teaches however that this type of developments continue and that the results of it will be applied, even if it is not always economically warranted. Therefore also for the milking robot eventually there will be a future. All too high expectations however for its application in the short run do not seem warranted" (Mandersloot and Van Scheppingen 1991, p. 30).

[9] See also Atkins (2010, p. 247) on the broader historical shift in defining milk quality in bacteriological terms.

[10] "I am fond of a robot, but the cell count is a problem on many robot farms. I have seen dozens of them [but] I am not sure what causes it. Not treating [the cows] in time, or too little checking up, or [farmers] believing it will be OK anyway" (Prins 2006).

[11] Several farmers and other commentators (implicitly) use the *farming styles* framework described by Van der Ploeg (2003) to explain the different farmer identities and their relations to milking robot practices.

farmers pioneer these devices was necessary as they were required to constantly repair the still-rickety robots themselves. Stories surfaced of the failure of robots to adequately treat the cows and of detrimental milk quality (Kingmans 1999). Some robots, offered by disappointed farmers, appeared on websites selling second-hand goods—robots that were allegedly bought back by the robot company, which was afraid of bad publicity. In 2001, one Dutch milking robot producer (Prolion) even went bankrupt, in a flurry of financial scandal.

At some points it seemed that the AMS had ended up as a failed project: a promising and futuristic innovation in which a lot of time and money had been invested but that eventually failed to fully materialize as a viable system. It would have been difficult to pinpoint the precise reason for failure, though: Was it too expensive? Was it technically not feasible? Or was there merely a lack of social acceptance and demand?[12] Was it not loved by the cows, or did it not treat the cows right? Or was it that those farmers that loved it did not love cows enough? In this sense the milking robot resembles many pioneering technological systems, such as the automated transport system "Aramis," as described by Bruno Latour (1996). Latour explains this in terms of a relational ontology, in which technological devices are never mere independent objects, but always relational to their core. The functioning or not functioning of a technology is then the outcome of the ways in which it is being embedded in wider "hybrid" socio-technical networks. In this process also what it means for a technology to "function" is not given.

Assessing the impact of the AMS on dairy farming practice

How could and should this technology, and the changes it brings for the relevant stakeholders, be considered normatively? Simply listing the advantages and disadvantages of the new system compared to the conventional system can of course be attempted. The investment costs can be set off against the amount of labor saved. The welfare of the cows can be measured in a variety of ways in the previous and the new situation (e.g., Wiktorsson and Sorensen 2004; Weiss et al. 2004). Impacts on milk quality and production can be traced. During its development over the past decades, some have thus tried to assess the ethical implications of the systems, attempting to categorize the impacts this new device might have on various ethical concerns regarding humans and animals.

In 1994, after the first AMS arrived on the market, a technology assessment was performed, commissioned by the Dutch ministry of agriculture (De Boer et al. 1994). The AMS was considered to constitute a far-reaching change in dairy farming, and to be a technology that was bound to become widespread, though it was expected that some farmers would keep milking in conventional parlors. Although there were a few issues of concern to be addressed, the technology was deemed uncontroversial. The main focus of attention was udder health, which was related to the hygiene of the milking process, as cows' udders might not be cleaned adequately before milking. This was thought to be an issue that would be taken up by the sector itself, and mainly a technological challenge. In hindsight, increased somatic cell counts and udder infections are thought to be reduced by improving the teat cleaning by the robots. If problems persist, these are now blamed on general hygiene, cow health, and herd management, not on the robot per se (Svennersten-Sjaunja and Pettersson 2008, p. 40; Dohmen et al. 2010). This seems to imply that in order for the robot to function adequately, higher hygiene standards have become the norm on robotic dairy farms.

Further concerns were the increased energy use and the problems that operating an AMS would pose to the pasturing of cows in summer. Cows remaining indoors year-round due to robot use were expected to cause concerns regarding animal welfare and the image projected to consumers. It would be overly ironic if the device that is claimed to liberate cows in fact leads to them being locked up in the barn. Other studies into public views on the robots can be considered to reveal their inherently ambivalent character. A study into Dutch citizens' concerns regarding acceptable farm practices found that high-tech solutions such as milking robots were widely valued as positive because they increase the flexibility of farmers and the freedom of cows (Verhue and Verzijden 2003). More recently, however, Boogaard et al. (2011, p. 270) framed the AMS as part of an increasing scale in farming and an absence of farmer-cow relations in an empirical study into the public acceptability of agricultural modernization. They asked survey participants to respond to the statement: "If it is efficient and practical for a dairy farm, then it is acceptable that a dairy farm has 3,000 dairy cows and a few milking robots." The respondents in their study, in significant numbers, dismissed the technology, framed in this way, as being part of an "unacceptable development" (Boogaard et al. 2011, p. 273).

The moral ambiguity of AMS

An unequivocal assessment of the impacts of milking robots appeared to be a difficult task. In general, increasing

[12] In several countries initial attempts to create a working AMS failed, such as in Japan, the US, and Germany (De Koning interview 2008).

the automation of work is considered to induce a process of alienation, especially in the dairy farming sector, which is still seen by many as revolving around human-animal relations (Hansen 2013). Cows in this type of high-tech environment can appear alienated as well, having been turned into industrial machines, and figuring merely as a means of production with closely monitored inputs and outputs rather than as unique living beings (Stuart et al. 2013). And large investment costs of complicated technologies and the associated requirement to gain benefits of scale are mostly considered to be in opposition to the ideal of family farming. But things appear to be more complex here.

Since its early marketing, the AMS has not only been sold to the farming public as the next logical step on the basis that "the future cannot be stopped,"[13] but has also been presented as a good thing that is to be embraced as more natural and something that offers more freedom for both cows and farmers (e.g., Noordhoff 2009).[14] Is this mere *marketing rhetoric*, and does this freedom come at a price (Millar 2000; Holloway 2007), or does the AMS produce genuine improvements in the welfare of humans and animals? We will argue here that a normative evaluation of the AMS can only be understood as part of a wider shift in farming practices and in terms of an intricate coevolution process between material changes (in technological systems and behavioral practices of both farmers and cows) and shifting ethical norms and meanings of central normative concepts. The terms in which to evaluate the practice appear to have changed with the introduction of the new device: new roles are configured, new experiences are generated, and relations change in character. And (perhaps) even the *nature* of the animals—and humans—involved is altered in the process.

Evaluating these new systems as "objects" with qualities and listing the pros and cons of the innovation is, then, a task with at best only temporary results—but one that, nevertheless (if considered as part of a dynamic process), can play a role in ongoing development. Over the course of the last two decades, the AMS has become more embedded in certain farming practices, expectations have shifted, a new generation of farmers has emerged with different desires regarding leisure time and flexibility, and (most) cows in robotic systems have to some extent learned to adapt themselves to the new routine. In the following section this dynamic will be described in detail.

[13] For the often-encountered promotion of technology in this Janus-faced rhetoric of the "future industry," in which new technologies are described as both unavoidable and to be actively embraced, see De Wilde (2000).

[14] "Next to that the cows have a free choice to walk indoors or outdoors. The pinnacle of animal welfare, don't we want to choose freely ourselves" (Grasbaal 2009).

Co-evolution of ethics and AMS technology

Changing discourse on cows

With the emergence of the AMS, we saw the terms in which the system was assessed change. The new system generated lots of new and specific research questions for production-animal scientists, farm technologists, and business economists. There were new focuses and concerns for research projects (Koning et al. 2004). And for the farmers that were involved in pioneering these new devices or discussing their desirability, the AMS was a continual topic of discussion. This shifting discourse concerned both changes in what were central concepts to discuss cows in relation to the robot, most notably freedom and voluntariness, and specific new meanings of concepts, such as naturalness.

Freedom

The opportunity for cows to choose when to be milked spawned a reformulation of animal welfare, partly in terms of individual freedom. One robot producer, Delaval, even thought it important to use an alternative name for the automated milking system: the *Voluntary Milking System.*

Freedom had, over the past decades, become one of the central concepts for defining and debating animal welfare, and is often associated with living in a state of naturalness and non-interference. In farming policies, animal welfare came to be defined in terms of freedoms after the 1965 Brambell report. From this report, animal welfare became commonly defined in terms of basic positive and negative freedoms, including freedom from hunger and thirst, fear and pain as well as freedom to express normal behavior.

Critics of the development of the AMS questioned the liberationist claim and the voluntary nature of cows milking themselves. With the use of the robot, it was revealed that cows did not desire to milk themselves, as was originally expected. The fact that simply offering the opportunity to be milked and to relieve their udders was not enough to make the cows come within the optimal timeframe was argued to be a sign of not delivering on the promise of *cow autonomy* (Wiepkema 1993). A British ethical assessment of the technology was critical of early promises that surrounded the AMS of more freedom for the cows (Millar 2000). Some kind of food reward or forced routing appeared necessary in order to prevent the need for recurrent fetching of cows. Freedom for cows hereby did not meet the standard of *full autonomy*. In particular, the system of iron bars arranged in the barns around the robot to make the cows have a forced route through the robot to get from the resting to the feeding area was thought to undermine the voluntariness that was claimed for the AMS.

Most AMS manufacturers and farmers are now moving away from set ups with forced cow traffic, as research has shown that cows in forced systems may be made to visit the robot more often, but do not produce more milk (Jacobs and Siegford 2012). Holloway (2007) has pointed to the paradoxical nature of the discourse emerging around AMS about the system generating more freedom for the cows and offering a more natural way of milking, in relation to the efforts needed to make the cow go into the robot and the implications for cows that refuse to perform the required behavior. Using Foucault's work on discipline and subjectivity, he argues that the newly gained freedom for the cows comes at the price of being disciplined. Therefore it is freedom of a restricted kind in a system of routings that force the cow to go through the robot to arrive at feeding or resting places. But even in situations of "free cow traffic," the cows gained, or were granted, a new form of subjectivity, but in a Foucauldian sense became also subject to new forms of power and domination. This means that the arrival of the AMS should not be understood as a matter of the simple releasing of an inherent subjectivity which was suppressed in conventional milking systems (Holloway 2007, p. 1050). With this type of critique, however, in which the rhetoric of freedom for cows is unmasked to reveal more subtle forms of domination and control, the critics tend to take over the new norms of freedom, individual choice, voluntariness and even autonomy, as things that are relevant and important for cow welfare. *Cow autonomy* was expanded upon as a criterion of the ethical assessment of dairy systems (Millar 2000), a perhaps unlikely term to evaluate the life of what commonly is viewed as a "herd animal." Thereby the coevolution of specific norms with a technological development is found here to include those critical of that particular development. Alternatively, the finding that being relieved of the milk load is not enough motivation to visit the robot,[15] and the subsequent need for adjustments by the robot developers, can also be taken as indications of the active involvement of the animals in the process of technological design, rather than precluding the possibility of an agential and meaningful form of domesticated bovine subjectivity.

There are other signs that ascribing subjectivity to cows does not necessarily lead to them being fully dominated by farmers. Not only cows, but also, and in close connection to them, farmers acquire their agency, skills, and subjectivity as part of the same process of becoming "robot farmers" with "robot cows." Moreover, in this process, farmers and cows are both actively engaged, learning their new routines and getting habituated to new human-animal relations.

Lazy cows, or incompetent farmers

A recurring theme in farmer's discussions of cows is their purported laziness. With the AMS the active behavior of cows becomes salient and essential to the system. Sometimes cows are suffering from lameness that prevents them from visiting the robot. But there can also be less visible reasons for a lack of self-milking activity. In farming circles there is talk of "lazy cows," who do not move to the robot as required, without them showing any signs of lacking health as an excuse for their behavior (Klop and Bos 2004; Van der Knaap 2008). This term implies that the farmers blame the character of the individual animals, for not behaving in the right way without good reason. It is then a variable that can be taken up in breeding decisions to see whether a hereditary factor is involved (Van der Knaap 2003a). For Holloway et al. (2014) this kind of talk of laziness of cows is an example of farmers ascribing subjectivity to cows that will lead to either disciplining them, e.g., by electrical prods, or culling. Alternatively however, in the farmer's network meeting in which the lead author was present someone raised the possibility of the laziness being a matter of not receiving the appropriate diet. If cows consume too little starch, the fermentation processes in their stomachs may be disrupted. In that case, the issue is redefined from a matter of individual character to one of receiving not the appropriate feed. The cow appears anew. The lack of movement on behalf of the cow was not to be blamed on her deficient motivation, but on the attention and skills of the farmer in providing adequate feed. The farmer subsequently would need to experiment with alternative ways of feeding the cows.

This small example reveals how the behavior of a cow is continuously subject to interpretation within the practice of dairy farming. A situation in which her agency and character are intricately connected to the material and human networks in which she is caught up; and in which the question of whether her behavior is a legitimate expression of discontent with that network or something the farmer thinks can be blamed on her is a matter of continuous interpretation. A process in which the character and skill of the farmer is at stake as well, especially when viewed by his or her peers.

Naturalness

A related, centrally contested concept concerning farm animal welfare is *naturalness* (Segerdahl 2007). The importance and the very meaning of naturalness for dairy cows can be seen to have changed with the introduction of

[15] This could of course have been due to the discomfort caused by early versions of the robot, as was suggested by an anonymous reviewer. Then it would be interesting to explore whether current robots are attractive enough to motivate the cows to milk themselves without food reward.

the new machine. In farmers' magazines, as well as in the public media, automatic milking has been compared to calves drinking from their mother. One farmer with multiple robots has been surprised by the behavior of some of his cows: "It is funny to see that some cows walk from the field straight to the far most robot, apparently these cows have a preference for a particular robot" (Van Raay 2003). The same farmer also has experiences with cows that are moved to a different part of the barn, with a different robot, to "stand moo-ing for a day to the old robot, as a cow who has lost her calf." These kinds of behavioral displays by the animals strengthen these farmers' convictions that a robot comes closest to the natural situation. By relating these anecdotes when interviewed for professional magazines, farmers explicitly interpret the behavior of the cows as recognizing the robot as in some way a *natural* part of their life.

Together with the claim that robots are more natural, a conception of naturalness to which humans are considered not to belong has gained prominence. Farmers, and thereby human-animal relations, are in this view ideally not a salient part of the natural environment of the cow, which implicitly claims that adding a high-tech automated device is. For instance, according to one robot producer: "[F]ast and quiet, yet very robust and gentle. Its repetitive procedures are consistent, just as the cow likes it […] allowing cows to maintain their natural cycle" (DeLaval 2009). Hereby the traditional ways of milking dairy cows, by hand or by hand-operated machine,[16] with this new meaning of naturalness, are rendered *unnatural*. And with this notion of freedom to decide on the desired moment of milking, the conventional mode of milking is newly thought of as *forced*. The calmness of the herd instilled by the robot and the ease with which they learn and manage to operate the device are taken to be indications of increased naturalness. This brings us to the effects of the robots on the cows.

Changing cows

It is not merely the discourse of robot farmers and robot producers that changes with the adoption of the AMS. With the arrival in their barns of a robot, the cows themselves changed in a number of ways too. A finding that fits in with the relational and dynamic understanding of ontology in Actor Network Theory and "more-than-human geography," in which seemingly stable "natural objects" such as dairy cows in fact can be found to continuously co-evolve in relation to their socio-technical environments.

First of all the cows were confronted with new physical requirements. Some cows had irregularities in their udders or in the positions of their teats that the robot was unable to detect or adequately clean and attach the teat cups to.[17] These cows needed to be culled, as did one or two cows that, after the transitional period of a few weeks of learning how to use the system, were not found able to acquire their now obligatory skills or refused to comply with the new regime. There were also instances where a large number of cows were found not suited to robotic milking, which may even mean the cows "win" and the farmer is forced to return to conventional milking technology.[18] Some farmers that installed robots were not able to make the system and enough of the cows work satisfactorily and saw themselves compelled to return to the conventional technology.

Cows (collectively) were not merely passive *end users* in the development of the automated milking system. At several points the behavior of the cows surprised the technologists and pioneering farmers working to develop the robot. The first agro-technologists working on the idea of automated milking had not envisaged the eventual setup (Rossing et al. 1985; De Koning interview 2008). To the surprise of the pioneering companies and researchers, the relief of their milk load was not enough motivation for most cows to present themselves to the robot in time. They needed to be seduced or forced to visit the robot by the offer of some feed in an automated dispenser (Meijering 2004). In this way the robot revealed something about cows and their desires on being used in dairy farming.[19] The cows needed to learn how to operate their part of the robot, which meant presenting themselves in time and standing still when being milked. This is done by a combination of operant conditioning (the feed offered upon visiting the robot) and habituation: "gently forcing" the cows through the robot to get them used to the experience (Davis and Jago 2002).

After earlier setups that emphasized "forced cow traffic" (Ketelaar-De Lauwere et al. 1999), in more recent years it is increasingly acknowledged that leaving the decision to visit the robot more to the cows generates more visits. For example on a dedicated web forum for farmers it is stated that: "Indeed, no fences runs better especially

[16] Indeed, when all quarters of an udder are milked for the same length of time this is not natural. A calf would stop suckling a teat when there was no more milk—just as the AMS can do by detaching one teat at a time.

[17] In 2010 a Dutch veterinarian started performing plastic surgery on cow udders to lift them so that they were connectable to the robot (Hofs 2010). In this way the cows were saved from slaughter, even though the veterinarian was breaking the law while performing invasive treatments on cows for which there is no explicit legal exemption.

[18] For instance Booij (2004) describes a case in which up to 20 % of a herd refused to work the robot, which led to the farmer returning to a conventional milking parlor.

[19] Which can also be taken as a signal that cows are unwilling to participate in the practice of dairy farming, or at least not without being rewarded.

heifers learn it faster without fences and with enough free space around the robot" ("Anton" 2010). One farmer says, "I have learned that one has to let the cow be the boss." Another states: "You have to give the cows a lot of room and not direct them too much" (Hiemstra 2007). Cows are found to develop ways of planning and arranging their visits to the robots; for instance one farmer's experience is that "When the cows go out, they first walk to the end of the field, to then gradually graze towards the barn" (Hiemstra 2007).

With a robot, the cows also come to relate differently to their herd. Especially when cows graze on a pasture and need to walk up to hundreds of meters to use the robot, an AMS requires them to unlearn part of their herd mentality. Instead of being fully individualized by the robot, it appeared that once they learned how to milk themselves and got used to the system, they moved from the pasture to the robot in regular groups of a few fellow cows (Heutinck et al. 2004). Some aspects of their herd mentality were found to be more stable, for example one of the basic requirements of motivating the cows to enter the robot was to be in sight of the rest of the herd (Jacobs and Siegford 2012). Some early attempts to build a robot in what used to be the milking parlor did not work out, as the cows would need to walk individually through narrow corridors out of sight of the herd. This was a clear instance of "not thinking from the perspective of the cow and putting her central," according to one of the AMS research pioneers (De Koning interview 2008).

Other concerns that arose with the first experiences of robotic farming were focused on the new situation's implications for cow behavior. As the TA report had already noted, and as Ketelaar-De Lauwere et al. (1996) had also found, access to the robot becomes an occasion and a site to exert dominance, which means, in an AMS operating to its full capacity, that subordinate cows are only able to get access to the robot at (apparently) less favorable hours such as during the night (Hopster et al. 2002). This means that more freedom of cow traffic around the AMS can increase herd processes in which low-ranking cows are kept from visiting the robot, come to a standstill, and wait for the robot for a prolonged time (Wiktorsson and Sorensen 2004; Hermans et al. 2004). (On the website of robot producer Lely this is explained, however, as: "We see that each cow chooses the milking times that suit her best and that fit with the rank order within the herd.")

This concern over hierarchies and the possibly negative effects of the dynamics within the herd could be said to originate from a view of dairy farming rooted more in individual care systems. However, within the practice of nature management, for instance, dominance exertion in herds is mostly not considered to be morally problematic. This is in part due to a sense of farmer responsibility to each individual cow, but also because dominance in natural herds has a less detrimental effect on cows as there is more opportunity to flee opponents.

While the concern about animals waiting idly for a prolonged time may arise from its negative effects on animal welfare, or for its suboptimal use of the robot, for dairy farmers it also goes against their sense of optimizing the time budget of cows: in order to maintain their high production level, cows should be "doing something useful," such as eating, being milked, or resting (Munksgaard and Søndergaard 2004).

Changing farmers

In response to the new character of the cows and farmers' new relations to the animals, the farmers themselves can be seen to change as well as part of the new system. For them, the transitional period is stressful too, as they need to rearrange their entire farm management to adjust everything to the new system: "The first three weeks were hell, and that's putting it mildly" (Crowell 2012). The robot requires a new look at cow and herd behavior in order to accommodate and use these to *fit* with the AMS (e.g. Heutinck et al. 2004).

According to some marketing outlets, the farmer will become a manager (not of employees, but of animals) rather than a craftsman or a stockperson (Van Drie 2005; Van Leeuwen 2012); "This is a completely different life style, now we primarily need to supervise the cows" (Debergh 2005). The ideal, as presented by the robot-manufacturing companies and taken over by researchers, of what it is to be a farmer is shifted in a particular direction. The professional identity of farming is moved away from manual labor and into the office behind a computer, often in a special "skybox," which is a small, fully windowed office in an elevation in the barn from which the herd can be overlooked.

Several farmers visiting an AMS farm while looking at the robot in action said that they "need to suppress the strong tendency to help out this clumsy looking machine." The process of attaching the teat cups by the robot, which often takes a few tries as its sensors search for the exact location of the teats, does not look efficient at all when compared to the swiftness with which a farmer would be able to attach them in a conventional milking parlor. In this sense, the farmers experience the need for an almost physical restraint to discipline themselves into a new understanding of efficiency: not as swiftly attaching the teat cups, but as being elsewhere to do other things. One farmer that was visited by one of the authors had fully automated his entire farm, after being relocated, with the latest robotic devices, milking robots, feeding robots, and manure robots, etc. According to him, during the first few days on the new farm he "felt like an intern on my own farm, not knowing what to do myself." It took a while to learn his new role, and this involved a new self-understanding, as he made clear in his reference to being an "intern."

There is a tradition in the cultural critique and philosophy of technology that stresses the alienating effects of modern technology on its users. Borgmann (2000), for instance, has described how different technological devices can fulfill the same technical function, but do this in ways that make for very different practices in using and maintaining them, which in turn brings very different ways of gathering and socializing those involved in the process (see also Thompson 2000).[20] The AMS seems to be a clear instance of a loss of both a *focal object*—the milking parlor—and a *focal practice*—the milking. With the milking process *commodified* and the cows turned into users, the farmers are made into managers that supervise their animal workers from a computerized office. Borgmann was a student of Heidegger, and it is tempting to consider the automation of farming in more bleak terms. Then the robot can be seen to actively disclose a fully instrumentalized world in which everything and everyone, from the bodies of the cows to the time of the farmer, emerges as mere resources to be efficiently used (Holloway et al. 2013; see also Driessen and Korthals 2012). But things may be more complicated than this dichotomous story of alienation and the decline of meaningful relations.

Deskilling? Disciplining?

As opposed to the common reproach against industrial automation, many involved continuously stress that the AMS does not function to produce deskilled labor. Whereas in a conventional milking parlor farmers see the cows pass by twice a day during milking, the automated management system produces detailed information on the animals, offering output on parameters such as levels of bacteria in the milk to control and optimize the condition of the cows. Cow health can be monitored to a large extent by means of data generated by the system, in part replacing the human-animal interaction during milking in a conventional system. But as the early experiences with AMS revealed, the skills of farmers in recognizing health problems of the animals are still essential.

Part of the new role of the farmer involves a shift from routine interaction with the cows to a regime of management by exception. A new, specific set of skills is needed to program the robot to create *attention lists* that are adequate, which means having few false negatives or false positives. Apart from milking the cows and registering when each cow made her last visit, the system also detects milk quality deviations, registers the milk volume and body temperature, and tracks instances of disease and fertility (Bieleman 2000). This means the farmer will need to adapt to a different mode of visual control of his cows and to learn to deal with the new management regime (Ouweltjes and de Koning 2004). This new task description can be said to require more discipline of the farmer, to make attention lists and follow up on these, or at least a very different type of discipline than that involved in a twice-a-day milking routine. Previously, the self-discipline of being a dairy farmer consisted of getting up early and getting into a flow of watching the cows pass by, a situation in which small differences stand out and the skill is in paying close attention to these. A good *robot farmer* is defined in a different mutually reinforcing combination of skills and discipline. The character of this robot farmer includes the ability to create adequate *attention lists* that are predictive enough to motivate him or her to follow up on them.[21] In this way, skill and knowledgeability, both in working with the data generated by the robot and in assessing the condition of the cows, as well as creating adequate attention lists, is closely connected with the self-discipline of following up on these lists and actively taking the time to watch the cows.

A farmer interviewed in a professional magazine stresses that to manage a farm with an AMS "one has to be a cow farmer, not a technology farmer" (Van Drie 2005). Robot farmers tend to stress that one should not "try to manage all the cows from behind the computer only." With a robot, one has to be in between the cows a lot and keep a close eye on them (Van Drie 2003). Hereby the early experience of the innovators is repeated, together with the idea of different farming styles and associated personal identities. The farmer continues to describe the actual processes of how high-tech systems and information technology are to be integrated with, rather than be opposed to, the embodied human-animal interaction and skills: "Not just from his office [the farmer] keeps a good overview. When he walks between his cows he at every moment can check on his pocket PC the data of each particular cow" (Van Drie 2005). Other farmers experience a sense of loss, saying, "It is much more hands off. I myself used to try to milk at least once a day. This way it is harder to know your cows more personally. You rely more on computer reports" while the same farmer stated: "It is just a change. You just have to adapt to it" (Youker 2010).

[20] For analogous worries around robotics leading to a diminishing quality of care relations in the sphere of health care, see Wynsberghe (2012).

[21] This is what farmers using an AMS are often called, as for instance can be seen on web forums and in professional media, for instance Van Drie (2005).

Here it seems that co-evolution necessarily means accepting the technological imperative. However, in the process of ongoing adaptation of dairy farming practices, the experiences of meaningful human-animal relations can play a role.

Cow-farmer relations and expectations

The new character of the cow, who no longer associates the farmer with being driven into the milking area, also makes for different human-animal relations. Most cows milked by a robot are said to somehow find out that kicking the robot is not worthwhile, as it is to kick a farmer trying to attach teat cups in a conventional farm: "A cow learns the robot never has bad tempers, and will not respond to any behavior by the cow."[22] One farmer believes that "They'd much rather be milked by a robot than milked by us" (Crowell 2012). Without the farmer coming in twice a day to drive the cows to the milking parlor, the character of the cows is found to change. In the words of one farmer on the public forum of a farming website: "A robot cow is a relaxed, different cow than a traditional one. A robot cow you walk around, you do not push and shove, should mostly treat on the spot and move around as little as possible" (Smink 2006; see also Hopster et al. 2002). A new ideal relation between farmer and cows emerges, in which it becomes a norm to "not disturb the processes in the herd." At the same time, with a robot, cows need, to some extent, to unlearn to behave as a herd and to function as individuals that decide when it is time to be milked. So the farmer leaves more to herd processes, while the robot changes these.

Especially in the transitional phase of milking with a robot, and with cows out on the pasture, the farmer has to learn not to bring in too quickly those cows that have not presented themselves at the robot after some period of time. This will make the cow expect that she will be fetched for milking, instead of learning to go on her own initiative. In this situation the farmer needs to develop a management strategy of collecting cows with long milking intervals that fits him or her best: collecting those cows strictly on time may "save" some milk, but may turn the cows "lazy" because of their habituation to being collected (e.g., Van der Knaap 2003a).[23] On the other hand, giving those cows some extra time may "cost" some milk, but may save the labor of collecting in the long run.

Gaining time or becoming flexible: new meanings of being a family farmer

Is this form of automation part of the ongoing process of increasing scale and reducing the role of humans in farming, eventually doing away with farmers? Or, rather, does it help farmers to improve their labor conditions and lifestyles? Again, these dichotomous positions do not allow for a more subtle assessment of the ensuing implications.

Early on, the robot was promoted as a time-saving device and as a means to allow the farmer to have a social life, doing away with the obligation to milk for several hours a day and to rise early for the morning milking shift. According to one advertisement that depicted men on motorcycles riding against a setting sun, "they have fun even after the cows come home" (Hogeveen and Meijering 2000, p. 318).

But the effect on the "social life of farmers" is not as straightforwardly *liberating* as depicted. Many farmers choose not to switch to automated milking as that would mean losing the rhythm of milking in shifts. And some of the farmers that did switch complain of the new situation in which they need to be on standby for 24 h a day. With the robot connected to their smart phone, when there is a disruption of the robot they receive an instant message that they need to follow up (e.g., Crowell 2012). With the arrival of the robot, for both the farmer and the cows the ideal of temporal regularity was traded in for flexibility and the opportunity to spread activities freely. In order not to make cows get used to being fetched if they have not visited the robot within the required interval, farmers may collect them at irregular hours, some even at night (Hiemstra 2007).

For a while, debates have been ongoing about the economic rationale of investing in the automation of milking. With the acquisition of a robot, costing around €100,000,[24] the cows are no longer the most expensive *capital good* on the farm. To determine its return on investment, a specific perspective on the dairy farm is required. The amount of milk produced is not increased that much by using a robot, therefore most of the justification of the investment is in terms of its labor-saving capacity. So, together with the cows that need to occupy the robot's capacity for the full 24 h, also the farmer is now on a time budget. The robot is

[22] The fact that cows can tell the difference between a robot and a human being can be considered an interesting contribution to the essentialist versus constructivist dilemma sketched by Risan (2005).

[23] For example, according to an anonymous post on a dairy farmers' web forum, an analysis of a farm revealed that: "a robot would generate absolutely no reduction of labor. To the contrary, it generated a stricter planning of activities as with a robot one needs to feed more (to make the cows more active […]) and you need to walk amidst the cows more often to get the lazy cows to the robot" (Anon. 2008).

[24] Which limits the access to this technology, especially in countries where the average dairy herds are far smaller than about 60 lactating cows as is the optimum for robot use.

a device that disciplines both farmers and cows in new ways.

Dairy farmers are commonly known as hardworking people who work long hours. “My weekend lasts from Sunday afternoon one to three o’clock” we heard a conventional dairy farmer claim. When they do the milking in the conventional way, it is clear dairy farmers (without employees) need to work 7 days a week, and from predawn till dusk. Between the milking shifts of early morning and late afternoon, they prefer to “organize their day spontaneously.” With the robot, and (alternatively) with increasing the scale of production due to which farmers can manage larger farms with the help of personnel, the former modes and scale of production however emerge to some as “hidden unemployment.”

In the wake of the introduction of milking robots, studies have been produced accounting for the activities of the farmer for each minute of a day (Munksgaard and Søndergaard 2004). The findings of this research varied; as in the description above, it became clear that with the average of 3 h spent milking, other tasks, such as checking on the cows and on the robot, became important. According to most studies, it was revealed that besides saving some labor time, it was mostly flexibility that was gained. The desire for flexibility can be found to grow as part of the wider process of increasing scale and the related decline in the number of farmers in local communities: “Nowadays [with only a few farmers left in a village community] social events are often held at 4 o’ clock in the afternoon, instead of before when it was common to take the milking schedule into account.” Another take on this is: “The younger generation does not want to work for seven days in a week anymore; they want to have time off.” Also, in the United States, this can be found to be a motive for robotic dairy farming: “We can go to the kids’ functions” and “You can work with the cows around your schedule. The cows don’t control us as much now” (Crowell 2012). This type of remark reveals how being a dairy farmer is not always conceived of in terms of a fully asymmetrical power relation in which solely humans are in charge. Rather, with each material arrangement of human animal relations come different experiences of freedom and being under control, for both farmer and cow. There are other reasons for investing in a robot as well. In any case, it is not necessarily a means to increase the scale of the farm. Rather, it offers an alternative to bringing in labor, as noted earlier. Although hiring an employee to do the milking, even in the Dutch labor market, tends to be cheaper than a robot, a good employee is difficult to find and would require very different management skills, which not all farmers are apt to acquire. Or the robot can be a way of continuing to farm after a certain age at which the manual labor becomes more of a strain, and in the absence of a successor.

It appeared that the desire for flexibility existed especially among younger family farmers. A new situation emerges in which male farmers stay at home and watch over the kids, while their wives can go out to work elsewhere (Van der Knaap 2003b; Mons 2007). In this way, the robot creates a new role within the family for farmers and a new division of domestic tasks. Alternatively, the farmer with a robot can use the time gained to go out and find a part-time job, to take on governing positions in the cooperative organizations which still abound in dairy farming, or to work in education or local politics. Dairy farming with a robot, on the previously normal scale of a herd of 70 cows, is thereby turned into a part-time job.

Conclusion: ethical assessment as part of co-evolutionary dynamics

Assessing the ethical implications of the introduction of the milking robot appeared to be a complicated matter, as both the farmers and the cows go through a process of change following the introduction of a robot. This does not mean that normative concerns—about what makes a good farmer, a good cow, and a good robot—are not part of the innovation process. This process takes place in a dynamic *moral geography* or *moral economy* in which elements of material practices are continuously adjusted to create what can be experienced as internal coherence. Just as specific cow breeds can be described as the product of a particular normative view of good farming and breeding (Theunissen 2008), so too what is deemed a good robot, or whether a robot is deemed to be good at all, is the product—and the site—of moral learning and contestation. The outcome of these processes is likely to be not fully determined by inherent characteristics of the technology, but also by other factors such as regional and cultural variation in farming practices, as well as existing moral commitments.

Does a milking robot deskill the farmer? This question can only be answered by considering the new understanding of the skills of robot farmers, which is newly configured with a particular type of (mediated) self-discipline. Does the robot alienate the farmer? This is likewise dependent on other variables: alienated from what—from the cows? *Robot cows* have to some extent become *individuals* and are to be left to *care for themselves* in social processes within the herd while they change in character in the process of adapting to the robot. Is there alienation from the rhythms of communal life? The villages that farmers live in were changing anyway, making the robot a device to regain the possibility of maintaining communal ties. And the robot can bring new relations to work, to the family, and to the outside world. When viewed in this more dynamic practice perspective, deciding on installing a milking robot means deciding what kind of farmer to be, what behavior of the cows to promote, and what relation between humans and animals to have emerge.

Naturalness is an elusive concept to apply to a dairy farm context (Segerdahl 2007) and thereby also to evaluate AMS with, even though robot marketers tend to claim to have realized a farming practice that reveals the true, natural way of being for a cow (Holloway 2007; (Holloway et al. 2013). In fact, the development of the robot revealed that cows do not desire to be milked (by humans or machines, they do seem to desire to have their calves drink when, in rare occasions, given the opportunity to do so). At least they cannot be lured to the robot in due time without a food reward. In debates on animal welfare, the question "but what do the cows really want?" is only answerable by interacting with them. A cow in a tie stall may very well want different things than a cow in loose housing, as they are made to live a different life style, with very different relations with their herd and with humans. In turn, an AMS embodies a different conception of the *good life* (or perhaps merely acceptable life, or at least a life of reduced suffering) for dairy cows. While *individual freedom* was previously never a grave concern regarding the welfare of herd animals, it has become prominent in discussions concerning *robot farms*. The norm of cow freedom promoted by the robot marketers and inscribed in its design became the focus of academic critique, as early AMS setups especially provided freedom for cows but in the obviously restricted form of *forced cow traffic* that was common at the time. But also farmers themselves experienced this inconsistency of cows being liberated while forced, and increasingly attempts are being made to provide more true freedom of movement and choice for the cows, as long as they also perform in the desired way, of course. Thereby the co-evolution of ethics and technology is not merely a matter of marketing rhetoric accompanying a new device, but is part of a (to some extent) sincere process of reinterpreting and rearranging practices in the light of emerging norms and behaviors.

We may collectively and universally decide on what type of animal agriculture would be acceptable and produce the least amount of suffering, on the basis of previous experience of cow behavior, on what we feel are common sense understandings of appropriate ways of housing cows, and on the basis of scientific studies within a variety of disciplines from physiology to ethology. But leaving it at that could reduce our attentiveness to forms of suffering that would remain and to potential ways of improving systems. What it means to "ask the cow" can be understood as a combination of not only measuring animal science parameters, such as health, heart rate, stress hormones, longevity, and production, but also a prolonged process of human-animal-technology interaction, while experimenting with management and adjusting technological setups. Then the cow and her welfare are considered not as something static that is to be uncovered, but as emergent, together with her new environment. This would mean that an ethical *variable* such as animal welfare cannot be defined only at the species level, say for all cows, so that it can then be fully determined by animal scientists measuring parameters and behaviors of a significant number of representative animals. Instead, the welfare of farmed cows will to some extent depend on the breed characteristics as well as on the abilities, experience, relations, and preferences of individual animals—and the abilities of farmers to adapt to them.

An example of this type of thinking is the "free choice stall" that is experimented with in combination with milking robots by various dairy farmers, in which it is left to the cows themselves to decide whether to go out and graze or remain indoors (e.g., Noordhoff 2009). This is a sign that the norm of "cow freedom" has been taken up by robot farmers, who try to give material shape to it. As can be seen exemplified here, a normative evaluation of something like the AMS can only be understood as part of a wider shift in practices and in terms of an intricate co-evolution process between partly material changes in technological systems and behavioral practices of both farmers and cows in a moral world of shifting ethical norms and changing meanings of normative concepts. The terms in which to evaluate the emerging practice appear to have changed with the new device: new roles are configured, new experiences are generated, and human animal relations change in character. And perhaps even the nature of the animals—and humans—involved is altered in the process.

Evaluating new devices such as a milking robot as *objects* with qualities and listing the pros and cons of the innovation is, then, a task with at best only temporary results. But it is one that, nevertheless, if considered as part of a wider dynamic process, can play a role in the ongoing development of technologies and attending practices. This dynamic conception of ethics does not mean we have to succumb to moral relativism. As ethics then is a process of actively engaging with techno-moral change (Swierstra et al. 2009), in which practitioners and the general public explore their moral commitments in the light of new experiences: new affective relations with cows and learning new skills in responding to them. In this way, the moral character of innovation processes could play a more prominent and explicitly acknowledged role in the design of new technological systems. This is important in the light not just of the advent of the milking robot, but more widely regarding the rather unquestioned embrace of "smart farming" in which arrays of sensors and software are projected to optimize farm practices, seemingly without much reflection on the changing roles and experiences of farmers or cows. Ideally these processes of techno-moral change in which farmers are immersed are explicated in public, instigating newly imaginative ways in dealing also with existing welfare concerns in dairy farming: such as the high incidence of udder inflammation (mastitis) and lameness, digestive problems due to a lack of fibrous feed, increasing absence of access to pasture, the early age of culling, calves being separated from their mothers (Ventura et al. 2013) and veal calves reared and transported under harmful conditions (for instance von Keyserlingk et al. 2013). In this paper, we have seen however that the saliency and meaning of these concerns come out differently when milking with robots than in conventional set-ups. For instance, lameness of cows is more of a problem for the farmer when the cows need to move themselves to a robot. And with a robot allowing for pasturing often becomes a practical challenge, but its importance is acknowledged by many farmers as part of the promise of "freedom for the cows" to decide what to do and where to go, not just when to be milked.

Acknowledgments This paper presents results of the project "Ethical room for manoeuvre in livestock farming" that was funded by The Netherlands Organization for Scientific Research (NWO) project # 253-20-013. The authors in researching and writing this paper owe special thanks to: Michiel Korthals, Volkert Beekman, Marc Bracke, Hans Spoolder, Jan Bloemert, Kees de Koning, Kees van Reenen, Frank Lenssinck, Bert Philipsen, Carolien Ketelaar-de Lauwere, Zwier van der Vegte, members of the Oost-Overijsselse melkrobot netwerk and the Mobiele melkrobot netwerk, de Melkveeacademie; Teachers and farmers at PTC+ Oenskerk, De Boerengroep, Lars Keizerwaard, Douwe Kappers, Maarten Kea, editors Jeffrey Cole and Harvey James and four anonymous reviewers for their critical and encouraging comments.

References

Akrich, M. 1992. The de-scription of technical objects. In *Shaping technology/building society*, ed. W.E. Bijker, and J. Law, 205–224. Cambridge, MA: MIT Press.

Anon. 2008. Robot eruit. *Melkveehouders Prikkebord*. http://melkveehouders.nieuwsgrazer.nl/topic/35889/. Accessed 11 Dec 2010.

"Anton". 2010. Re: Robotmelken: de waarheid, en niks dan de waarheid DEEL 2, 12 January 2010. 13: 04. *Veeteeltforum*. http://www.veeteeltforum.nl/viewtopic.php?f=5&t=3767&start=1320. Accessed 11 Dec 2010.

Arendzen, I., and A.T.J. van Scheppingen. 2000. Economical sensitivity of four main parameters defining the room for investment of automatic milking systems on dairy farms. In *Robotic milking, proceedings of the international symposium held in Lelystad, The Netherlands, 17–19 August 2000*, ed. H. Hogeveen, and A. Meijering, 201–211. Wageningen: Wageningen Pers.

Atkins, P. 2010. *Liquid materialities: A history of milk, science, and the law*. Aldershot: Ashgate.

Bieleman, J. 2000. Landbouw en Voeding. In *Techniek in Nederland in de Twintigste Eeuw*, vol. III, ed. J.W. Schot, 211–233. Zutphen: Walburg Pers.

Bijker, W.E., and J. Law. 1992. *Shaping technology/building society: Studies in socio-technical change*. Cambridge, MA: MIT Press.

Boogaard, B.K., B.B. Bock, S.J. Oosting, J.S.C. Wiskerke, and A.J. Van der Zijpp. 2011. Social acceptance of dairy farming: The ambivalence between the two faces of modernity. *Journal of Agricultural and Environmental Ethics* 24: 259–282.

Booij, A. 2004. Drie robots te koop. *Veeteelt*. 1 April: 42–43.

Borgmann, A. 2000. Reply to my critics. In *Technology and the good life?*, ed. E. Higgs, A. Light, and D. Strong, 341–370. Chicago: University of Chicago Press.

Brambell, F.W.R. 1965. *Report of the technical committee to enquire into the welfare of animals kept under intensive livestock husbandry systems*, 2836. London: HMSO Cmnd.

Buller, H., and E. Roe. 2012. Commodifying animal welfare. *Animal Welfare—The UFAW Journal* 21(1): 131.

Crist, E. 2004. Against the social construction of nature and wilderness. *Environmental Ethics* 26(1): 5–24.

Crowell, S. 2012. Robotic milkers breathe new life into three-generation Pennsylvania dairy. *Farm and Dairy*: 14 June. http://www.farmanddairy.com/top-stories/robotic-milkers-breathe-new-life-into-three-generation-pennsylvania-dairy/38363.html. Accessed 18 Jul 2012.

Davies, G. 2012. Caring for the multiple and the multitude: Assembling animal welfare and enabling ethical critique. *Environment and Planning D: Society and Space* 30(4): 623–638.

Davis, K.L., and J.G. Jago. 2002. How it's done: Cow training at automated milking farmlet. *New Zealand Dairy Exporter*. 54–55.

Debergh, A. 2007. Automatisch Managen. *Veeteelt* 24(10): 26–31.

Debergh, A. 2005. Intensief robotmelken in Canada. *Veeteelt* 22(1/2): 50–51.

De Boer, P.B., J.H.M. Metz, F.L. Pater-Huijsen. 1994. *Volautomatische Melksystemen*. Ministerie van Landbouw, Natuurbeheer en Visserij, Directie Wetenschap en Kennisoverdracht, Stuurgroep Technologisch Aspectenonderzoek, Report no. 4.

DeLaval. 2009. DeLaval VMS voluntary milking system. https://www.youtube.com/watch?v=24zwbJhS9kI. Accessed 11 Mar 2014.

Despret, V. 2013. From secret agents to interagency. *History and Theory* 52(4): 29–44.

Dewey, J. 2005. *Art as experience*. New York: Penguin.

de Koning, C.J.A.M., and J. Rodenburg. 2004. Automatic milking: State of the art in Europe and North America. In *Automatic milking: A better understanding*, ed. A. Meijering, H. Hogeveen, and C.J.A.M. de Koning, 27–37. Wageningen: Wageningen Academic Publishers.

De Wilde, R. 2000. *De Voorspellers: een kritiek op de toekomstindustrie*. Amsterdam: De Balie.

Dohmen, W., F. Neijenhuis, and H. Hogeveen. 2010. Relationship between udder health and hygiene on farms with an automatic milking system. *Journal of Dairy Science* 93: 4019–4033.

Driessen, C. 2012. Farmers engaged in deliberative practices: An ethnographic exploration of the mosaic of concerns in livestock agriculture. *Journal of Agricultural and Environmental Ethics* 25: 163–179.

Driessen, C., and M. Korthals. 2012. Pig towers and in vitro meat: Disclosing moral worlds by design. *Social Studies of Science* 42(6): 797–820.

Fraser, D. 1995. Science, values, and animal welfare: Exploring the "inextricable connection". *Animal Welfare* 4(2): 103–117.

"Grasbaal". 2009. Melkvee Academie—Anton Stokman. *Melkveehouders Prikkebord*. http://melkveehouders.nieuwsgrazer.nl/topic/31947/. Accessed 24 March 2014.

Hansen, P. 2013. Becoming bovine: Mechanics and metamorphosis in Hokkaido's animal-human-machine. *Journal of Rural Studies* 33(1): 119–130.

Haraway, D.J. 2008. *When species meet*. Minneapolis, MN: University of Minnesota Press.

Harbers, H. 2002. Weak ethics, strong feelings. In *Pragmatist ethics for a technological culture*, ed. J. Keulartz, M. Korthals, M. Schermer, and T. Swierstra, 143–149. Deventer: Kluwer Academic Publishers.

Hermans, G.G.N., M. Melin, G. Petterson, and H. Wiktorsson 2004. Behavior of high- and low-ranked dairy cows after redirection in selection gates in an automatic milking system. In *Automatic milking: A better understanding*, ed. Meijering, A., H. Hogeveen, and C.J.A.M. de Koning, 418–419. Wageningen: Wageningen Academic Publishers.

Heutinck, L.F.M., and C. Driessen. 2007. The ethics of automatic milking systems and grazing in dairy cattle. In *Sustainable food production and ethics: Preprints of the 7th Congress of the European Society for Agricultural and Food Ethics; EurSAFE 2007, Vienna, Austria*, 249–254. Wageningen: Wageningen Academic Publishers.

Heutinck, L.F.M., H.J.C. van Dooren, and G. Biewenga. 2004. Automatic milking and grazing in dairy cattle: Effects on behavior. In *Automatic milking: A better understanding*, ed. A. Meijering, H. Hogeveen, and C.J.A.M. de Koning, 407–413. Wageningen: Wageningen Academic Publishers.

Hiemstra, A. 2007. *Laat de koe de baas zijn*. http://www.archief.verantwoordeveehouderij.nl/producten/Koeenwij/Algemeen/Management.pdf. Accessed 20 May 2014.

Hird, Myra J. 2010. Coevolution, symbiosis, and sociology. *Ecological Economics* 69(4): 737–742.

Hoard's Dairyman. 2012. First US milking robot factor opens next week. *Hoard's Dairyman* 21 March. http://www.hoards.com/blog_Lely-robotic-factory. Accessed 30 Jul 2012.

Hoefman, R. 1998. Klanten gezocht die bij de robot passen. *Boerderij/Veehouderij* 84(21): 18–19.

Hofs, Y. 2010. Veearts maakt koeienuier "passend" voor melkrobot. *Volkskrant* 4 January.

Hogeveen, H., and A. Meijering 2000. *Robotic milking. Proceedings of the international symposium held in Lelystad, The Netherlands, 17–19 August 2000*. Wageningen: Wageningen Academic Publishers.

Hopster, H., R.M. Bruckmaier, J.T.N. Van der Werf, S.M. Korte, J. Macuhova, G. Korte-Bouws, and C.G. van Reenen. 2002. Stress responses during milking: Comparing conventional and automatic milking in Primiparous dairy cows. *Journal of Dairy Science* 85: 3206–3216.

Holloway, L. 2007. Subjecting cows to robots: Farming technologies and the making of animal subjects. *Environment and Planning D: Society and Space* 25: 1041–1060.

Holloway, L., C. Bear, and K. Wilkinson. 2013. Re-capturing bovine life: Robot–cow relationships, freedom, and control in dairy farming. *Journal of Rural Studies* 33(1): 131–140.

Holloway, L., C. Bear, and K. Wilkinson. 2014. Robotic milking technologies and renegotiating situated ethical relationships on UK dairy farms. *Agriculture and Human Values* 31(2): 185–199.

Huiden, F. 2009. De melkrobot is volwassen. *Boerderij* 94(24): 21–22.

Jacobs, J.A., and J.M. Siegford. 2012. Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. *Journal of Dairy Science* 95: 2227–2247.

James, S. 2009. Phenomenology and the problem of animal minds. *Environmental Values* 18: 33–49. doi:10.3197/096327109X404735.

Jasanoff, S. 2013. *States of knowledge: The co-production of science and the social order*. London: Routledge.

Johnston, C.L. 2013. Geography, science, and subjectivity: Farm animal welfare in the United States and Europe. *Geography Compass* 7(2): 139–148.

Ketelaar-de Lauwere, C.C., S. Devir, and J.H.M. Metz. 1996. The influence of social hierarchy on the time budget of cows and their visits to an automated milking system. *Applied Animal Behaviour Science* 49: 199–211.

Ketelaar-De Lauwere, C.C., A.H. Ipema, J.H.M. Metz, J.P.T.M. Noordhuizen, and W.G.P. Schouten. 1999. The influence of the accessibility of concentrate on the behavior of cows milked in an automatic milking system. *Netherlands Journal of Agriculture Science* 47: 1–16.

Keulartz, J., M. Schermer, M. Korthals, and T. Swierstra. 2004. Ethics in a technological culture. A programmatic proposal for a pragmatist approach. *Science, Technology and Human Values* 29: 3–29.

Kingmans, R. 1999. Melkrobot is niet voor iedereen weggelegd. *Boerderij/Veehouderij* 84(8): 8–9.

Klerkx, L., B. van Mierlo, and C. Leeuwis. 2012. Evolution of systems approaches to agricultural innovation: Concepts, analysis, and interventions. In *Farming systems research into the 21st century: The new dynamic*, ed. I. Darnhofer, D. Gibbon, and B. Dedieu, 457–483. Dordrecht: Springer.

Klop, A., and C.H. Bos. 2004. Luiekoeienprobleem. *Veeteelt* 21(6): 67.

Kruip, T.A.M., H. Morice, M. Robert, and W. Ouweltjes. 2002. Robotic milking and its effect on fertility and cell counts. *Journal of Dairy Science* 85: 2576–2581.

Latour, B. 1996. *Aramis, or the love of technology*. Cambridge, MA: Harvard University Press.

Latour, B. 1992. Where are the missing masses? The sociology of a few mundane artifacts. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society* (pp. 225–259). Cambridge, MA: The MIT Press.

Lorimer, J., and C. Driessen. 2013. Bovine biopolitics and the promise of monsters in the rewilding of Heck cattle. *Geoforum* 48: 249–259.

Mandersloot, F., and A.T.J. van Scheppingen. 1991. Is er toekomst voor de melkrobot? *Praktijkonderzoek, Waiboerhoeve* 4: 28–30.

Meijering, A., H. Hogeveen, and C.J.A.M. de Koning (eds.). 2004. *Automatic milking: A better understanding*. Wageningen: Wageningen Academic Publishers.

Millar, K. 2000. Respect for animal autonomy in bioethical analysis: The case of automatic milking systems. *Journal of Agricultural and Environmental Ethics* 12: 41–50.

Mons, G., 2007. Hamvraag: wat doet de melkrobotboer met de vrijgekomen tijd? *Agrarisch Dagblad* 23 March: 7.

Munksgaard, L., and M. Søndergaard. 2004. Two case studies on farms combining automatic milking with grazing—time budgets, synchronization of behavior, and visits to the robot. In *Automatic milking: A better understanding*, ed. A. Meijering, H. Hogeveen, and C.J.A.M. de Koning, 286–291. Wageningen: Wageningen Academic Publishers.

Noordhoff, I. 2009. Vrije keuze koeien. *NRC Handelsblad* 24 January.

Ouweltjes, W., and C.J.A.M. de Koning. 2004. Demands and opportunities for operational management support. In *Automatic milking: A better understanding*, ed. A. Meijering, H. Hogeveen, and C.J.A.M. de Koning, 433–443. Wageningen: Wageningen Academic Publishers.

Prins, R. 2006. Melkkwaliteit met melkrobot. *Veeteelt forum.* http://www.veeteeltforum.nl/viewtopic.php?t=286. Accessed 21 Dec 2013.

Risan, L. 2005. The boundary of animality. *Environment and Planning D: Society and Space* 23: 787–793.

Rodenburg, J. n.d. Time for technology: Robotic milking has big labor saving benefits. DairyLogix. http://www.dairylogix.com/14-%20Robotic%20Milking%20has%20big%20labour%20saving%20benefits.pdf. Accessed 14 Jun 2012.

Roe, E., H. Buller, and J. Bull. 2011. The performance of farm animal assessment. *Animal Welfare* 20(1): 69–78.

Rossing, W, A.H. Ipema, and P.F. Veltman, 1985. *The feasibility of milking in a feeding box*. IMAG Research Report 85–2. Wageningen.

Ruis-Heutinck, L.F.M., H.J.C. van Dooren, A.J.H. van Lent, C.J. Jagtenberg, and H. Hogeveen 2001. Automatic milking in combination with grazing on dairy farms in The Netherlands. In *Proceedings of the 35th International Congress of the ISAE*, ed. J.P. Garner, J.A. Mench, and S.P. Heekin, 188. Davis, CA: The Center for Animal Welfare at UC Davis.

Segerdahl, P. 2007. Can natural behavior be cultivated? The farm as a local human/animal culture. *Journal of Agricultural and Environmental Ethics* 20: 167–193.

Smink, E.C. 2006. Onderwerp: melkrobot. *Melkveeacademie forum.* 27 July. http://af-app.melkveeacademie.nl/forum/default.asp. Accessed 7 Apr 2009.

Stichting K.O.M. n.d. Overview of livestock numbers and reports. http://www.stichtingkom.nl/index.php/stichting_kom/category/statistiek. Accessed 1 Feb 2014.

Stuart, D., R.L. Schewe, and R. Gunderson. 2013. Extending social theory to farm animals: Addressing alienation in the dairy sector. *Sociologia Ruralis* 53(2): 201–222.

Svennersten-Sjaunja, K.M., and G. Pettersson. 2008. Pros and cons of automatic milking in Europe. *Journal of Animal Science* 86(13 supplement): 37–46.

Swierstra, T., D. Stemerding, and M. Boenink. 2009. Exploring techno-moral change: The case of the Obesitypill. In *Evaluating new technologies*, 119–138. Dordrecht: Springer.

Theunisssen, B. 2008. Breeding without Mendelism: Theory and practice of dairy cattle breeding in the Netherlands 1900–1950. *Journal of the History of Biology* 41: 637–676.

Thompson, P.B. 2000. Farming as focal practice. In *Technology and the good life?*, ed. E. Higgs, A. Light, and D. Strong, 166–180. Chicago: University of Chicago Press.

Van Adrichem Boogaert, D.H. 1970. *De ontwikkeling van de Nederlandse rundveehouderij in deze eeuw. Een historisch overzicht over de periode tot 1970*. S.l.: Ministerie van Landbouw en Visserij.

Van der Knaap, J. 2003a. Koeien met karakter. *Veeteelt* 20(11): 20–21.

Van der Knaap, J. 2003b. De sociale melkrobot. *Veeteelt* 20(21): 74–75.

Van der Knaap, J. 2008. Voeding beinvloedt robotbezoek. *Veeteelt* 25(11): 80–81.

Van der Ploeg, J.D. 2003. *The virtual farmer: Past, present, and future of the Dutch peasantry*. Assen: Van Gorcum.

Van Drie, I. 2005. Robotboer en koeienmanager. *Veeteelt* 22(3): 64–65.

Van Drie, I. 2003. Op zoek naar juist management. *Veeteelt* 20(6): 16–17.

Van Leeuwen, R. 2012 Nederlandse robot maakt van melkboeren managers. *Sync Businesstrends*. http://sync.nl/nederlandse-robot-maakt-van-melkboeren-managers. Accessed 12 Mar 2014.

Van Raay, C. 2003. Onbeperkt weiden naast melkrobot. *Veeteelt* 20(8): 14–15.

Van Zessen, T. 2007. De prijs van vrije tijd. *Veeteelt* 24(10): 36–37.

Veissier, I., A. Butterworth, B. Bock, and E. Roe. 2008. European approaches to ensure good animal welfare. *Applied Animal Behavior Science* 113(4): 279–297.

Ventura, B.A., M.A.G. von Keyserlingk, C.A. Schuppli, and D.M. Weary. 2013. Views on contentious practices in dairy farming: The case of early cow-calf separation. *Journal of Dairy Science* 96(9): 6105–6116.

Verhue, D., and D. Verzijden. 2003. *Burgeroordelen over de veehouderij. Uitkomsten publieksonderzoek*. Amsterdam: Veldkamp.

Von Keyserlingk, M.A.G., N.P. Martin, E. Kebreab, K.F. Knowlton, R.J. Grant, M. Stephenson, C.J. Sniffen, J.P. Harner, A.D. Wright, and S.I. Smith. 2013. Invited review: Sustainability of the US dairy industry. *Journal of Dairy Science* 96(9): 5405–5425.

Weisberg, Z. 2009. The broken promises of monsters: Haraway, animals, and the humanist legacy. *Journal for Critical Animal Studies* 7(2): 22–62.

Weiss, D., S. Helmreich, E. Moestl, A. Dzidic, and R.M. Bruckmaier. 2004. Coping capacity of dairy cows during the change from conventional to automatic milking. *Journal of Animal Science* 82: 563–570.

Whatmore, S. 2002. *Hybrid geographies: Natures, cultures, spaces*. London: Sage.

Wiepkema, P.R. 1993. *Gedrag, welzijn en duurzaamheid*. Afscheidsrede (Farewell address). Wageningen: Landbouwuniversiteit Wageningen.

Wiktorsson, H., and J.T. Sorensen. 2004. Implication of automatic milking on animal welfare. In *Automatic milking: A better understanding*, ed. A. Meijering, H. Hogeveen, and C.J.A.M. de Koning, 371–381. Wageningen: Wageningen Academic Publishers.

Wynsberghe, A. 2012. Designing robots with care: Creating an ethical framework for the future design and implementation of care robots. PhD dissertation, University of Twente.

Youker, D. 2010. PA dairyman goes high tech with robotic milkers and digesters. *Farm & Dairy*, June 18. http://www.farmanddairy.com/news/pa-dairyman-goes-high-tech-with-robotic-milkers-and-digesters/15153.html. Accessed 18 Jul 2012.

Zellmer, D. 2012. Robotic milking systems growing slowly on Wisconsin dairy farms. Holsteinworld.com. http://www.holsteinworld.com/story.php?id=2491. Accessed 15 Aug 2012.

Clemens Driessen is a philosopher and cultural geographer interested in technology and animals. He has published on the ethics of farmers, on the ways in which new technologies can be found to disclose particular moral worlds, and on ethical and scientific debates in nature conservation. Together with designers of the Utrecht School of the Arts he is attempting to create interspecies video games for farmed pigs to play with their prospective consumers (see http://www.playingwithpigs.nl). Previously a PhD candidate at Wageningen University (Philosophy group) and a postdoctoral researcher at King's College London and Utrecht University, he currently lectures at the Cultural Geography group of Wageningen University, the Netherlands.

Leonie Heutinck is an animal scientist who has done research on the behavior and welfare of dairy cows, beef cattle and veal calves, while working at Livestock Research, Wageningen UR in Lelystad, the Netherlands.