

Antibiotic resistance and the animal based food industry – Antibiotics as a value adding resource in three interdependent industrial settings

Alexandra Waluszewski
Uppsala University¹

*“Research is needed to understand
how Nordic countries have made significant progress.”*
(World Economic Forum Report 2013)

Introduction

World Economic Forum (WEF) identified in 2013 antibiotic resistance as ‘one of the greatest threats to global health’. World Health Assembly (WHO) endorsed in May 2015 a global action plan to tackle antibiotic resistance; ‘the most urgent drug resistance trend’ and was even warning for ‘a post-antibiotic era’, meaning an end to modern medicine as we know it (www.who.int). The message was clear-cut: “If we want to minimize the rate at which antibiotics become obsolete, we should use them as sparingly as possible.” On the bright side, these organisations points to experiences from some European countries showing that it is possible to combat overuse in human medicine; through coordinated policies on prevention and control. A darker pattern is though outlined in relation to animal based food production. Europe is no exception in this case – despite its highly regulated market, high level of education *and* regulation of use of antibiotics in the animal based food industry.

This paper will; besides giving a brief overview of the embedding of antibiotics in the production and use of animal based food, discuss an important system innovation: The new way of use resources, the actors in behind, and the innovative production technologies and methods taking off in the 1980s – and leading up to Swedish pig meat producers unique pioneering role in banning routine use of antibiotics.

The contemporary antibiotic-dependent animal based food production

In fact, the major part of the world consumption of antibiotics takes place in animal based food production; 130 000 tons per year which is about 2/3 of the total consumption (van Boeckel et al 2018). The antibiotics is mainly given as ‘Antibiotic Growth Promoters’ (AGPs) and in routine group treatment of herds – made with or without veterinary prescriptions. From originating in high-income countries, antibiotic intense production systems have been exported to middle- and even low-income countries, embedding antibiotics into every day feeding routines (Kirchelle, 2018; Lhermie et al 2017). If the present trend is not broken, the use of antibiotics in the animal based food production is estimated to increase with more than

¹ Department of Economic History, Uppsala University. Email: alexandra.waluszewski@sts.uu.se

50 percent until year 2030, to reach 200 000 tons of antibiotics per year (van Boeckel et al, 2018). The overuse is, as both WHO and WEF underlines, an issue with consequences reaching far beyond the borders of businesses, regions and nations.

“Many new strains of antibiotic-resistant infections are now common in people after originating in our livestock”. (Boeckel et al, 2018)

Besides World Economic Forum (WEF) and WHO a number of policy reports and pledges to reduce the use of antibiotics in human *and* animal use have presented during since 2010 (Kirchelle, 2018; Waluszewski et al, 2018; Lhermie et al 2017). (Here it is important to note that it is regular group treatment with antibiotics that WHO, WEF and NGO’s are combatting – not individual treatment of sick animals based on veterinary diagnosis and prescription.)

However, behind the awakening awareness seven decades of ignorance of is hiding. In fact, scientific knowledge about the intrinsic characteristics of bacteria mutation, giving rise to resistance, has been articulated both in research publications and general media already since late 1940s (Kirchelle, 2018; Wise, 2007, Waluszewski et al, 2018). Already Sir Alexander Fleming warned against the phenomenon known as *antimicrobial resistance (AMR)* in his Nobel Lecture, December 11 1945.

“The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant.”

Two years later, 1947 a similar concern was presented to the general public through an article in New York Times, where L. P. Garrod argued that the lifesaving antibiotic agents might well ‘breed resistance’ (Wise, 2007). In the 1960s, the European public debate on use of chemicals in food production directed the attention to the use of antibiotics in animal based food production – which at that time had been established as a regular input in both Western countries and on the other side of the iron curtain. In the end of the 1960s public media debate along with resistance reports from professionals in veterinary and human medicine triggered UK Government to initiate the ‘Swann Committee’; to report on antibiotic use in both human and veterinary practice, the resistance issue included. The main conclusion drawn was that antibiotics used for production animals should not be those used in human medicine as this could compromise efficacy in man (Swann et al, 1969; Wise 2007).

However, although the Swann report gave rise to some restrictions in UK and other Western countries; concerning what type of antibiotics allowed to be used in the animal based food industry, it ended in, as Kirchelle (2018) puts it, ‘a patchwork’ of different policy approaches – which did not stop the increasing embedding of antibiotics in businesses engaged in animal based food production as well as aquaculture and plants. In 1980, the British Medical Journal published an editorial text with the title “Why Swann failed”, arguing that the limited regulations that the Swann report gave rise to actually failed to reduce the use of antibiotics in animal based food production (BJM, 1980). Put shortly, the general interpretation; in UK and

other Western economies, was that combatting resistance was an issue of ‘choosing the right kind of antibiotics’ for animal food based production respectively for human health. Instead of decreasing, the routine use of antibiotics increased – and antibiotic dependent production systems was spread globally, to China, Asia, South Africa and South America.

The 1990s saw an intensified engagement in the antibiotic resistance issue by transnational policy bodies; such as the UN and WHO, along with a number of NGO’s (Waluszewski et al, 2018; Kirchelle, 2018; Baraldi et al 2016). These policy bodies did also consider the fact that the main world consumption of antibiotics is taking place in the animal based food industry – with the severe side effect in terms of creating and spreading new types of resistant bacteria to animals and humans. Hence, in perspective of the contemporary ‘animal antibiotic infrastructure’, the seven decades of attempts of creating awareness of resistance and restricted, responsible use must be, as argued by Kirchelle (2018) ‘a history of failure’. But there are some few exceptions.

It is interesting to note that World Economic Forum point directly to the production system developed within the Nordic animal based food industry as a possible solution. While the European use of antibiotics; measured in PCU/kg (Population Correction Unit, amount of antibiotics used for every kg of bodyweight at time of treatment), reaches 453.4 mg/PCU in Cyprus, 362.5 mg/PCU in Spain 294.8 mg/PCU in Italy, 89.2 mg/PCU in Germany, 40.8 mg/PCU in Denmark, the level used in the Swedish animal based food industry is 12 mg,1/PCU. ‘Best in class’ is Iceland with 4,7 mg/PCU and Norway with 2.9 mg/PCU, although the latter figure is affected by including aquaculture. The average for 30 European countries (EU/EEA) is 124.6 mg/PCU (ESVAC 2018). Besides being among the most restricted users of antibiotics in the European animal based food production, the Swedish pig meat producers pioneered internationally in this development path.

A main argument of this paper is that in order to understand the difficulties to reduce the input of antibiotics in animal based food production and use, we have to approach antibiotics as a heterogeneous economic resource, which value is created in direct and indirect interfaces with other resources (Håkansson and Waluszewski, 2002, Waluszewski et al, 2018). This point of departure allows outlining in what way antibiotics affects the value of investments of place in a network involving at least three types of interrelated settings; the using setting of animal based food, the producing setting of animal based food including related suppliers; of antibiotics, equipment, feed etc., and the public and private developing setting related to these. Below we will take a closer look at the research design.

Research design: Problem, Theory and Methodology

To carry out research on the using, producing and developing settings (Håkansson and Waluszewski, 2007) related to animal based food in general and the role of antibiotics in particular implies the need for an approach that allow us to capture the complex connections between established and emerging social and material investments and monetary flows in at least three related settings – and how the antibiotic resistance issue is intervening in these (Waluszewski et al, 2015; 2018). Put shortly, we need an approach facilitating investigations of the embedding of a particular economic resource in different producer and user settings as

a context-dependent phenomenon. In order to shed light over the embedding of antibiotics the production and use of animal based food following *problem area* has to be investigated:

Firstly, the animal based food producing setting, where routine treatment with antibiotics was introduced in the later 1940s and early 1950s, allowing the industrialisation of the traditional labour intensive and small-scale production mode. An important related supplier setting is *the animal pharmaceutical producing setting*, where routine treatment with antibiotics opened the door for important application area, complementary to investments made in antibiotics for humans. However, animal pharma is also engaged in the supply of vaccine – which can compensate for the use of antibiotics in.

Secondly, the animal based food using setting, where routine treatment with antibiotics in the producing setting guaranteed an increasing supply of low price meat and fish products, utilised by the retail industry to attract customer streams. *Thirdly*, the public and private developing setting; that is research related to animal health in a wide sense; including how to prevent and combat infection diseases.

In order to shed light over how the Swedish system innovation allowing the banning of Antibiotic Growth Promotors (AGP) and routine group treatments emerged already in early 1980s, *following overall research question can be outlined:*

- I) What changed resource interfaces, carried out by what actors, triggered by what forces, can be outlined behind the system innovation in terms of the Swedish production system for pig meat, compensating for AGPs and routine group treatments with antibiotics? How were these forces related in the developing, producing and using settings – within and across national borders?

Theoretical point of departure: The IMP Network approach (Håkansson et al 2009) allows investigations of interconnected user-producer interactions in established as well as and emerging business settings. The 4R model is used as guide (Håkansson and Waluszewski 2002) which have been useful in studies of innovation processes in general (Håkansson and Waluszewski, 2002, 2007), and more recently, in studies of innovation challenges related to antibiotic resistance (Waluszewski, Baraldi and Ciabuschi, 2015; 2018; Perna and Waluszewski, 2018). Put shortly, this approach allows investigations of established resource interfaces and how these have been changed, as well as the motivations of the direct and indirect involved actors. Furthermore, it facilitates investigations of distribution of costs, benefits and monetary flows among direct and indirect involved actors (Perna, Baraldi and Waluszewski, 2015, Håkansson and Olsen, 2015).

Methodology: The investigation of the research questions concerning the system innovation emerging to compensate for the Swedish abandoning of AGPs and routine group treatments in the pig meat based food system is made to make an overview over following aspects: a) The changes of resources interfaces, and the actors involved, leading up to new technologies and methods in the *producing setting*; that is pig meat producers as well as direct and indirect suppliers – with animal based pharmaceutical businesses in the forefront – and governmental regulators, media, etc. b) The changes of resources interfaces and the actors involved, leading

up to recognizing pig meat based on restricted use of antibiotics in the *user setting*; that is wholesalers, retailers, consumer groups, media, etc. c) The changes of resources interfaces, and the actors involved, leading up to changes in the *developing setting*; that is public and private research as well as NGO's engaged in research on animal health, antibiotics, resistance and alternative antibacterial methods.

The data collection of this ongoing study is based on a combination of methods. Secondary data, in terms of publications in some different research fields have been utilized to investigate the established producing, using and developing settings related to animal based food in general, and pig meat in particular. Social scientists engaged in research on antimicrobial and antibiotic resistance; that is in history of medicine, history of technology, sociology and more recently, in industrial network studies, have engaged in longitudinal studies of use of antibiotic resistance and how these have been reacted on by public and private actors, including the role of antibiotics in animal based food production. (see e.g. Kirchelle, 2018; Lhermie et al 2017; Wise, 2007; Lie, 2004; Waluszewski et al, 2018). Researchers engaged in antibacterial studies and animal health studies have provided insights into the global animal antibiotic use and into resistance patterns (with van Boeckel et al, 2018, 2015 as some of the most renowned). Furthermore, NGOs, such as ReAct, as well as global policy bodies, such as ESVAC, WHO and FAO are engaged in providing data on global animal antibiotic use and resistance patterns. General as well as industry related media have also been utilised. The data collection has also benefitted from that the project is part of a larger international study; the "Follow the Pig Project", where related investigations are carried out in the Danish, Norwegian and Finnish pig meat production system.²

Primary data have been collected through a *pilot study*, including 12 interviews with respondents representing the producer, user and developing setting. Participating observations been made at a seminar on the banning of AGPs and routine group treatments of animals arranged by the Swedish University of Agricultural Sciences (SLU) and Uppsala Antibiotic Centre (UAC). In the developing setting, two interviews have been made with veterinary researchers; one at the Swedish National Veterinary Institute, SVA and the other at University of Swedish University of Agricultural Sciences. On the producing side, three pig meat farmers and three representatives for slaughterers/food processing firms have been interviewed. On using side, two interviews with representatives for the retail industry and consumer group have been made.

Case study: A system innovation – embedded in a restricted part of the animal based food landscape

If antibacterial drugs when they were first developed was labelled 'magic bullets'; due to their ability to attack specific microbes without harming a body at large, in the perspective of production and use of animal based food products antibiotics could be described as 'magic

² The three other "Follow the Pig" projects are carried out at University of Southern Denmark (lead by Prof. Kristin Munksgaard), Norwegian School of Management BI, (lead by Prof. Debbie Harrison a), and University of Turku, (lead by Prof. Aino Halinen as PI), a cooperation financed by a NOS-HS Workshop grant 2018-2020.

wallets' – increasing the value of a number of related resources without need for heavy investments in hygiene, feed, space and health (Waluszewski et al, 2018).

But in a longer term perspective overuse has a high cost, through its acceleration of the resistance process (which occurs naturally). The cost is partly harming animal based food businesses in themselves – but is above all affecting the global health system and the society at large. Thus, antibiotics are a double-edged sword: although the short-term economic benefits are significant, the long-term side effect of overuse is resistance and a progressive loss of drug efficacy. Below we will make a brief overview of its ability to add value to investments in place in three related settings.

Firstly, in the animal based food production setting, routine treatment of antibiotics; as antibiotic growth promotors, AGPs, (banned in Sweden since 1986, in EU since 2006 and in the US 2015) and in term of routine group treatment (increasingly applied in the wake of the banning of AGPs, with or without veterinary prescriptions) is adding value to a number of resources – at least if considered in a narrow perspective assuming away the consequences of resistance. Regular treatment with antibiotics; given to animals in feed and/or drinking water – especially of pigs which are among those which are given the highest input of antibiotics – is adding value to a number of investments in place. Lack of investments contributing to animal health; such as investments in space, in hygiene and precautionary infection control, in vaccine and in high quality feed, can be compensated with routine group treatments of groups of animals with antibiotics. Furthermore, antibiotics increases the growth of the animals and shorten the production cycle from birth to slaughter, and reduces the need for personnel – as well as education of personnel. (Kirchelle, 2018; van Boeckel et al 2018; Lhermie et al 2017; Finlay 2004).

Secondly, in the animal based food using setting, routine treatment with antibiotics in the producing setting is a prerequisite for the supply of large volumes of low price products. Cheap meat and fish products are utilized by the wholesale and retail industry to attract consumer streams (Kirchelle, 2018; Finlay, 2004; Cantillon and Håkansson, 2009).

Thirdly, in the animal pharmaceutical producing setting routine treatment with antibiotics represents an important application area. When antibiotics for production animals was launched in the late 1940s, it was soon revealed that the new drug did not only curbed diseases – but also affected the growth of the animals. Furthermore, antibiotic residues could be utilized as an insert in animal feed production. Low doses of antibiotics, supplied by pharmaceutical companies in terms of Antibiotic Growth Promotors (AGP) were also argued to protect against bacterial diseases – implying that the fact that it is low dosing that breed resistance was ignored (Finlay, 2004; Kirchelle, 2018).

Despite that antibiotics for animals are sold for a far smaller amounts of money compared to human drugs, they represent a significant revenues source for pharmaceutical companies

engaged in veterinary products.³ The US and European producing setting is dominated by five larger so called *market-authorization holders* (MAH's); companies holding the right to sell a drug in a given country: 1) Zoetis (former subsidiary of Pfizer; 2) Boehringer Ingelheim Animal Health (BI) including Merck Animal Health and Merial, 3) Ely Lilly including Elanco and Novartis Animal Health, 4) Bayer HealthCare Animal Health, 5) Virbac Group.⁴ To that can be added some 50 smaller US and European market-authorization holders. Furthermore, there are some hundred Asian companies engaged in different activities related to the production and marketing antibiotics for animals.⁵ Related to the MAH's there is an intricate supplier structure in terms of following activities: a) *Active Pharmaceutical Ingredients (API)*, manufactured from raw materials through both chemical and biochemical processes. In the wake of large pharmaceutical companies' outsourcing and off-shoring of manufacturing activities, the main API production activities is located to Asia, mainly to India and China.⁶ b) the API's are transformed to drugs for humans/animals by *drug manufacturers*, and c) which products are marketed by the MAH's and d) distributed by wholesalers/retailers for human/animal applications in open clinics or in hospitals – and for the animal side; embedded into feed by feed suppliers and/or added to feed and/or drinking water by farmers – with or without veterinary prescriptions. The latter phenomenon is appearing both in terms of physical over the counter sales and over the internet.

The animal pharma industry has a double role in relation to production systems of animal based food. On one hand they are engaged in the development and production of vaccines – allowing decreasing use of antibiotics for animals (Postma et al, 2015). On the other hand, antibiotics for production animals still represents a significant part of the revenue.⁷ Both through lobbying groups and through individual statements, the MAH's for animals has taken standpoint for the contemporary user levels. Or as stated by Bayer, one of the largest producers:

*“Antibiotics are essential in preserving the well-being and health of pets and farm animals. Given their importance, antibiotics should always be used responsibly in order to protect their effectiveness for future generations. This does not simply mean using less. It means using the right antibiotic upon diagnosis of a bacterial infection, in the necessary dose, for the appropriate duration, and always with veterinary oversight.”*⁸

³ <https://www.theguardian.com/environment/2018/jun/19/how-much-does-big-pharma-make-from-animal-antibiotics>

⁴ <https://animalpharm.agribusinessintelligence.informa.com/> 2019-05-14

⁵ <http://www.mdtvalliance.org/active-pharmaceutical-ingredients-explained/> 2019-05-14

⁶ <http://www.mdtvalliance.org/active-pharmaceutical-ingredients-explained/> 2019-05-14

⁷ <https://animalpharm.agribusinessintelligence.informa.com/>

⁸ <https://animalhealth.bayer.com/our-business/antibiotics>

As pointed out in the introduction, WHO, FAO, World Economic Forum, and a number of NGO's with ReAct in the forefront, stress the urgent need to combat the overuse of antibiotics in animal based food production. This implies an appeal for innovative production systems including investments in health, hygiene, feed and vaccine solutions – that can compensate for a reduced input of antibiotics on regular base. Put shortly, there is an urgent need for animal based food businesses that can provide wholesalers, retailers, end-consumers and society at large with products based on low use of antibiotic. Interestingly enough, the Swedish production system, developed in the wake of the banning of AGP's and the requirement of heavy restrictions on routine group treatments was initiated by some individual farmers and their organizations – and not by politicians and policy. Below we will take a closer look at this important system innovation – which embedding is still mainly restricted to the Nordic countries.

Banning of AGP's and routine group treatments as standard – a Swedish system innovation

In May 2014, just before the EU election, a Swedish ICA Kvantum retailer declared that Danish pig meat would be excluded from the assortment. The reasons were several, with lack of animal welfare as a main argument, including that the animals were given antibiotics as a precautionary measure, promoting antibiotic resistance.⁹ Instead, this hypermarket would only allow pig meat produced in a system where antibiotics were used to treat specific, sick animals; that is without routine use of antibiotics. The ICA Kvantum hypermarket had no difficulties to find Swedish suppliers able to fulfil this requirement. The action caused a lot of attention in media, and was soon followed up by the three largest Swedish wholesalers; ICA, Axfood and Coop.

ICA declared that all suppliers; not only suppliers to own brand products, had to fulfil following requirements: “Supported by Swedish law the lowest level of animal welfare demand for meat, milk and eggs in the central assortment is as follows.” [...] “Antibiotics may not be routinely used as a precautionary measure, but only after veterinary prescription. Antibiotics and hormones may not be used as growth promoters.” A similar policy was presented by Coop: “Antibiotics should only be used to treat sick animals on individual level. Suppliers that cannot fulfil a responsible use are deselected.”¹⁰ Axfood also declared that use of antibiotics in the animal based meat food production contributes to increasing antibiotic resistance: “A significant part of the overuse is due to that big amounts of antibiotics is used as a precautionary measure, instead of treating sick animals individually”.¹¹ Axfood's policy was however more general: “We have purchasing requirements implying that we can choose suppliers that actively is working with decreasing the use of antibiotics.”¹²

⁹ <https://www.expressen.se/gt/ica-handlaren-vagr-ar-salja-danskt-flaskkott/>

¹⁰ <https://www.coop.se/vart-ansvar/hallbarhetsarbete/kott/djurvalfard/> 2019-05-16

¹¹ <https://www.axfood.se/kontakt/fragor-och-svar/antibiotika/> 2019-05-16

¹² <https://www.axfood.se/kontakt/fragor-och-svar/antibiotika/> 2019-05-16

In 2017, the Swedish Wholesaler Association *Svensk Dagligvaruhandel*, including Axfood, Bergendahls, Coop, ICA, Lidl och Livsmedelshandlarna, made a joint statement, declaring that use of antibiotics in the animal based food industry is contributing to increased resistance and is a future threat to public health. By defining specific demands for the purchasing of imported meat used for own brands, the ambition was to contribute to change. The wholesaler association presented following purchasing criteria for meat – however only for own brand products: “Antibiotics may not be used as growth promotor and should only be used after veterinary prescription”.¹³

When the Swedish wholesalers engaged in promoting animal based food production free from antibiotics as growth promoters and routine group treatment of animals, Swedish pig meat producers and their business cooperatives had already been engaged in this issue for more than three decades. The farmers and their organisations plead for a tougher antibiotics regulation eventually resulted in the passing of a new law in Sweden in 1986, banning growth antibiotics (SFS 1985:295¹⁴). Hence, the engagement started long before it became a global policy issue, and a decade before the Swedish actions for decreased use of antibiotics for humans became organised through the establishment through STRAMA in 1995 (Gröndal, 2018).

A number of related forces can be outlined behind the Swedish ban of growth antibiotics and the antibiotic routine treatments of groups of animals. One main driving force was the concern of animal welfare. Already in 1971 a book in this issue, named the ‘Animal Factory’¹⁵, (Soller, 1971), caused attention in media. An even more intense media debate took off in the early 1980s, where the use of chemicals and antibiotics in animal based food production was approached mainly from an animal welfare perspective. One of Sweden’s largest newspapers published a series of articles on this theme, and the journalist in behind also published a book on the same theme, with the title “Mass food”¹⁶ (Michelsen, 1981), causing attention also in other media.

Some farmers were seriously worried about the use of antibiotics as a problem of treating animals with chemicals and as an environmental problem. This anxiousness triggered a few of them to start to experiments with excluding routine treatments with antibiotics through feeding. Furthermore, to address this issue the Swine Farming Association and the related Swedish Farmers Association. As one of the pioneering farmers expressed his worries: “What happens when the antibiotics through the manure leaks out in the soil?”¹⁷ The farmers that engaged in excluding AGP and routine treatments firstly had to engage in this on a ‘trial-and-error’ like basis, although some support could be gained from researchers at the Swedish University for Agricultural Sciences. Furthermore, in order to get feed with antibiotics they had to pay a higher price to the main supplier owned by the Swedish Farmers Association –

¹³ <https://www.svenskdagligvaruhandel.se/dagligvaruhandel-n-tar-stallning-minskad-antibiotikaanvandning/> 2019-05-16

¹⁴ https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-1985295-om-foder_sfs-1985-295 2019-05-17

¹⁵ Swedish title: ‘Djurfabriken’

¹⁶ Swedish title: ‘Massmaten’

¹⁷ Interview, farmer, Sweden, 2019-04-25

until the Swedish ban of antibiotic as growth promotor in 1986 drugs such as Bionox and similar substances were regular ingredients in pig and poultry feed.

There were some individual veterinaries and researchers engaged in animal health supporting the ‘trial-and-error’ like efforts to exclude antibiotics. Furthermore, there were also some leading managers at the Farmers Association that engaged in this issue. The latter’s initial motivation was; in the wake of the intense media debate on animal welfare and overuse of chemicals including antibiotics, the worry to lose consumers’ trust in animal based food. But there was also resistance, expressed by hesitating veterinaries, feed suppliers and individual farmers, arguing for the positive consequences of routine use of antibiotics, for animal growth and health. And there were the suppliers of antibiotics for production animals; that is representatives for the pharmaceutical companies, frankly expressing a negative attitude directly to the engaged managers at the Swedish Farmers Association.

After having the issue on the agenda since 1981, in 1984 the Swedish Farmers Association agreed to approach the Swedish Government with a suggestion for a new law, banning antibiotics growth promotor; that is forbidding routine treatment of groups of animals through feed or drinking water. The actions from the Swedish Farmers Association did, together with the engagement from politicians representing the Center Party (with close connections to the Swedish Farmers Association) presenting some Parliament bills. The engagement resulted in a new law, banning the use of AGP’s; that is routine treatment of antibiotics in feed and water without veterinary prescription, from 1986 (SFS 1985:295)¹⁸.

The new regime revealed *what* the routine treatment of antibiotics had covered for. After the ban, several farmers got problem with diseases and the veterinary prescription of antibiotics increased the first years after the ban. This became the take off for a more systematic development of a new pig meat production regime, with prevention of disease as a key ingredient. Basically all activities from insemination to slaughter were scrutinized, and a new production system was worked out, including new stable design based on specific sections for each stage of the breeding process, intense hygiene efforts, new types of feed, vaccine, etc. A significant numbers of actors contributed to develop this ‘system innovation’, compensating compensate for AGP and routine treatment with antibiotics; farmers, veterinaries, researchers engaged in different aspects of animal health, slaughters, transporters, equipment suppliers, feed suppliers, suppliers of vaccine, etc.

As discussed above, in contrast to the Swedish development path, the antibiotic dependent animal based food production system and its negative consequences for animal welfare, environment and antibiotic resistance became largely ignored in the animal based food production in the main part of US, Europe and Asia. Although resistance was a recognised phenomenon already in the late 1940s and early 1950s; not only in the academic research setting but also in the animal based food producing setting and among producers of antibiotics, the common interpretation was that the resistance issue could be balanced with the right choice of antibiotics. Something that also appeared feasible during this era, when the number of pharmaceutical companies engaged in development of new antibiotics constantly increased; from end of World Ware 2 until the 1990s (Waluszewski et al, 2018). Hence, the

¹⁸ https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-1985295-om-foder_sfs-1985-295 2019-05-17

Swedish case appear as a challenging exception, where it was actors in the producing setting started to discuss how to get rid of routine treatment with antibiotics already in the early 1980s.

“The great attention to the overuse of antibiotics in the animal based food industry makes me really happy – but we should have seen this 30 years ago” (Manager at a farm engaged in excluding antibiotics from the early 1980s and onwards, interview April 2019)

For decades the innovating Swedish pig meat producing setting faced a rather uninterested user setting – and difficulties to achieve return of investments. The situation escalated when Sweden became an EU member in 1995 – and the borders were opened for an inflow of cheap pig meat based food products, produced in systems relying in significant higher use of antibiotics. Many small producers had to face bankruptcy, and the Swedish pig meat production fell from about 4 million to 2.5 million animals per year.

It was not until around 2013-2014; in relation to the EU election, that the overuse of antibiotics in the EU pig meat based food production – and especially the Danish situation; affected by some severe outbreaks of MRSA, that the Swedish production system became recognized by retailers and end-consumers. From 2014 an onwards Swedish wholesalers and retailers started to brand Swedish meat as being production without routine treatment of antibiotics. However, the purchasing of animal based food in the public setting still have to follow EU procurement rules – and cannot prioritize suppliers due to their antibiotic policy.

“The public awareness of antibiotic resistance is the best thing happening for Swedish meat production. Suddenly farmers are getting payed for all the efforts made. But still Swedish hospitals and schools serves cheap imported food based on antibiotic intense production systems.” (Manager, Swedish pig farm, interview October 2018)

The design of this system innovation; the triggering events and the expected and realized outcome, are interesting in its own case. However, considered in terms of the need for similar changes in the global animal based food industry, there are significant reasons for future research on the key conditions behind this change.

Concluding discussion

The antibiotic resistance issue in general, and its appearance in the animal based food industry in particular – and the need for radical global changes and innovative solutions that it calls for – raises questions related policy’s understanding of how this issue should be solved. The view of innovation and industrial renewal that has been adopted by global policy engaged in this issue; with WHO and World Economic Forum as some of the most renowned, is highly inspired by the contemporary policy mode, with National Innovation System (NIS) as role model (Eklund 2013; Eklund and Waluszewski, 2015). In this perspective, a main challenge is to make scientific knowledge advances available to market actors, which are assumed to transform these into new processes, services and products – given an existing business or

societal need (Eklund and Waluszewski, 2015). What's been added in policy advices related to the antibiotic resistance challenge is the need for 'market entry rewards' for pharmaceutical companies engaging in R&D and market investments in new antibiotics (Baraldi et al, 2016; Drive-AB 2018)

Empirical research on resistance (Kirchelle, 2018; van Boeckel et al 2018; Waluszewski et al, 2018; Lie, 2004; Finlay 2004) as well as the empirical indications of this pilot project challenges this view of innovation. If we just consider Europe, or Scandinavia, the producer and user reactions on scientific and media reports on resistance reveals rather different patterns. Scientific knowledge concerning different types of risk caused by overuse and resistance have been available since the late 1940s; through scientific publications and media reports – but the reactions in terms of changes in the producing and using settings have mainly been restricted to Sweden and its Scandinavian neighbors Norway, Finland – and more recently, Denmark. (Kirchelle, 2018; van Boeckel et al 2018).

In Sweden, it was farmers and their cooperative associations and businesses related to pig meat based food that long before governmental and policy bodies – as well as NGO's – took reports on overuse of antibiotics and animal health seriously. Individual farmers and managers representing and their organisations exerted pressure on the government to ban the use of growth antibiotics, and continued to argue for this in EU when Sweden became member in 1995. Similar patterns; where businesses able to provide innovative solutions with societal benefits put pressure on governments, have been observed in previous empirical studies (Håkansson and Waluszewski, 2002). Hence, the paper provides empirical insight into the importance of mobilizing and organizing through interconnected relationships in order to create changes of established resources interfaces – and how this can lead up to both new regulations and; through a number of related, stepwise changes carried out by numbers of related actors, new system innovations.

World Economic Forum (2013, p. 33) conclude the discussion of overuse of antibiotics in the animal based food industry with underlining that "research is needed" which can contribute to our understanding of the forces behind "significant progress" made in the Nordic animal based food production. The ambition with this ongoing project is to contribute to this understanding, through revealing the actors, driving forces and contextual features behind the fact that the Swedish pig meat based food system was able to provide wholesalers, retailers and end-consumer with end-products based on 'low levels of antibiotics' – since three decades before it became an issue recognized by global policy.

REFERENCES

Baraldi, E., Ciabuschi, F., Leach, R., Morel, C.M., Waluszewski, A. (2016). Exploring the Obstacles to Implementing Economic Mechanisms to Stimulate Antibiotic Research and Development: A Multi-Actor and System-Level Analysis. *American journal of law & medicine* 42(2-3):451-486.

Cars, O., A. Hedin, and A. Heddini, 2011. The Global Need for Effective Antibiotics-Moving towards Concerted Action. *Drug Resist Updat*, 14(2), pp. 68-69.

Cassini, A., Diaz Högberg, L., Plachouras, D., Quattrocchi,., Hoxha, A., Skov Simonsen, G., Colomb-Cotinat, M., Kretzschmar, M.E., Devleeschauwer, B., Cecchini, M., Ait Ouakrim, D., Cravo Oliveira, T., Struelens, M.J., Suetens, S., Monnet, D.L., and the Burden of AMR Collaborative Group 2018. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015: a population-level modelling analysis. *Lancet Infect Dis*. Published Online November 5, 2018 [http://dx.doi.org/10.1016/S1473-3099\(18\)30605-4](http://dx.doi.org/10.1016/S1473-3099(18)30605-4)

Curry, Helen Anne. *Evolution made to order: Plant breeding and technological innovation in twentieth-century America*. Chicago: The University of Chicago Press, 2016.

Editorial, (1980) Why has Swann failed? *British Medical Journal*, 17 May 1980.

ESVAC 2018. European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption, 2018. Eighth ESVAC report, 15 October 2018. Brussels: European Medicines Agency.

Eklund, M., 2013. "Science Policy in a Socially Embedded Economy." In Rider, S, Hasselberg, Y., Waluszewski, A, eds. 2013. "Transformations in Research, Higher Education and the Academic Market. *The Breakdown of Scientific Thought*." Dordrecht: Springer Science & Business Media.

Eklund, M., Waluszewski, A. (2015). *The diversity of systemic thinking: The underpinnings of NIS and IMP and the different assessment of an industry. The IMP Journal*, Bingley: Emerald Group Publishing Limited. Vol. 9. Iss. 1: 26-45

Håkansson, H., Ford, D., Gadde, L-G, Snehota, I., Waluszewski, A., 2009. *Business in Networks*. Wiley, Chichester.

Håkansson, H., Waluszewski, A., 2002. *Managing Technological Development. IKEA, the environment and technology*. Routledge, London, New York.

Håkansson, H., Waluszewski, A, (eds) 2007. *Knowledge and Innovation in Business and Industry*. London: Routledge.

Håkansson, H., Olsen, O. 2015. The roles of money and business deals in network structures *Industrial Marketing Management*, Vol 48, pp 207-217.

Hoffman, J., Outterson, K. 2105. What Will It Take to Address the Global Threat of Antibiotic Resistance? *The Journal of Law, Medicine and Ethics*. Special Supplement to Vol. 43:2, Symposium Articles Antimicrobial Resistance, pp. 6-11.

Lhermie, G.,Gröhn, Y.T. Raboisson, D, 2017. Addressing Antimicrobial Resistance: An Overview of Priority Actions to Prevent Suboptimal Antimicrobial Use in Food-Animal Production. *Frontiers in Microbiology*, Volume 7, Article 2114.

Michelsen, T., 1981. *Massmaten: svenskt jordbruk i kemiåldern*. Stockholm: Rabén & Sjögren.

Perna, A., Baraldi, E., Waluszewski, A. (2015). Is the value created necessarily associated with money? On the connections between an innovation process and its monetary dimension: The case of Solibro's thin-film solar cells. *Journal of Industrial Marketing Management*, Vol. 46, pp. 108-121.

Perna, A., Waluszewski, A. 2018. The Interplay Between Innovation and Accounting: The Border-Crossing Q-Linea Project and Its Within-Border Accounting. In *Accounting, Innovation and Inter-Organisational Relationships*, Martin Carlsson-Wall, Håkan Håkansson, Kalle Kraus, Johnny Lind and Torkel Strömsten (Eds), pp. 12-28. Routledge: New York.

Postma, M., Stärk, K., Sjölund, M., Backhans, A., GrosseBeilage, E., Lösken, S., Belloc, C., Collineau, Iten, D., Visschers, V., Nielsen, E.O., Dewulf, J., 2015. Alternatives to the use of antimicrobial agents in pig production: A multi-country expert ranking of perceived effectiveness, feasibility and return on investment. *Preventive Veterinary Medicine*, Vol. 118, pp. 457-466.

SFS (1985:295) Lag om foder. Svensk författningssamling. Stockholm

Waluszewski, A., Håkansson, H., Snehota, I., 2017. Researching the Interactive Business World; Interplay of Research Object, Methodology and Theory. In *No Business is an Island: Making Sense of the Interactive Business World*, Håkansson, H and Snehota, I, (Eds), pp. 195-212. Emerald Publishing: Bingley

Waluszewski, A., Baraldi, C., Ciabusch, F., 2018. Increase development and decrease use! Innovation controversies caused by antimicrobial resistance. In *Controversies in Healthcare Innovation Service, Technology and Organization*, Hoholm, Thomas, La Rocca, Antonella, Aanestad, Margunn (Eds.), pp. 309-340, Palgrave Macmillan: Basinstoke.

World Economic Forum Report 2013. *Global Risks. An Initiative of the Risk Response Network*. Geneva: WEF

Swann, M. M. et al (1969) Report of the Joint Committee on the Use of Antibiotics in Animal Husbandry and Veterinary Medicine. London: Her Majesty's Stationery Office.

Van Boeckel, et al 2018. Reducing antimicrobial use in food animals. *Science* 357 (6358) pp. 1350-1352.

Wise, R., (2007) *Journal of Antimicrobial Chemotherapy* (2007) Vol. 60, Suppl. 1, pp 5–7