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Needs for innovation in network:

Problematizing the role of policy, producer, and user addressing AMR issue.

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Abstract

Antibiotics have been and nowadays are yet essential medicines for human diseases treatment. Antibiotics are vital for treating traditional infections as well as rare diseases. However, since the antibiotic was discovered, was known the related Antibiotic-Resistant issue, commonly called Antimicrobial Resistance (AMR). Antimicrobial Resistance is a phenomenon that occurs when bacteria become able to survive in presence of an antimicrobial, e.g. an antibiotic.

The problem is of global relevance on the health side since currently, the AMR produces 1 million deaths per year, as well as on the economic side:

100 trillion dollars per year are the estimated costs in terms of the public health system, loss of productivity and so on.

The cause that mainly affects the phenomenon is the misuse and the abuse of antibiotics. 70% of antibiotics sold globally were used on animal-meat food production. The introduction of antibiotics on animal-meat food production has its roots in the industrialisation and mass production era of the second post-war period. The use of antibiotics in the animal-meat food industry was embedded initially, to enhance animal health. Nevertheless, right from the very early stages, it was revealed as an economic resource, that seems endemically embedded in several animal-meat production regimes, so far.

The Italian meat industry considered the best in class worldwide for the variety and quality of its products, is however among the most affected by the phenomenon of AMR. Other nations, Sweden at the forefront, have been pioneering in this regard, but not exempt from the great sacrifices associated with change, which they have had to face to innovate their production system. The innovation policies in place to combat AMR globally aim to reduce the use of antibiotics in the food industry. However, such policies would seem to want to impose the economic weight and risks associated with innovation, exclusively on the producers of the food industry, while the benefits would fall to the actors of the network and to the entire society in the long term.

The goal of this study, based on empirical research, is to understand and analyse the key components of the network, their interactions and their influences to better understand, what are the key factors that act as drivers or, on the contrary, they slow down or hinder the change needed to deal with AMR issue, or as was recently defined as the Silent Pandemic.

Keywords: antimicrobial resistance, business networks, innovation.

Abstract (Italian version)

Gli antibiotici sono stati e sono tuttora medicinali essenziali per il trattamento delle malattie umane. Sono fondamentali per curare le infezioni tradizionali e le malattie rare. Tuttavia, fin dalla loro scoperta era già noto il problema dell'antibiotico resistenza. L'Antimicrobial Resistance (AMR) è quel fenomeno che avviene quando un battere riesce a sopravvivere in presenza di un antimicrobico, come ad esempio un antibiotico. Il problema è di rilevanza mondiale sia dal lato sanitario, attualmente, infatti l'AMR produce attualmente 1 milione di morti annui, sia dal lato economico, 50 trilioni di dollari annui (spese sanitarie).

La causa che maggiormente influenza il fenomeno dell'AMR è l'uso improprio e l'abuso di antibiotico. Quasi il 70% degli antibiotici venduti a livello globale viene utilizzato nel settore della produzione di carne animale. L'introduzione dell'antibiotico nella produzione di carne animale ha radici risalenti all'industrializzazione del secondo dopoguerra. Il suo utilizzo, da essere inizialmente pensato per andare a migliorare la salute degli animali si è presto rilevato essere una risorsa economica, che sembra oramai in molte realtà industriali, endemicamente incorporato. L'Industria della carne italiana, considerata la best in class a livello mondiale per la varietà e la qualità dei suoi prodotti, risulta però essere tra le più colpite dal fenomeno

dell'AMR. Altre nazioni, la Svezia in prima linea, sono state pionieristicamente innovative in tal senso, ma non esenti dei grandi sacrifici connessi al cambiamento, che hanno dovuto affrontare per innovare il loro sistema produttivo.

Le politiche d'innovazione in atto per contrastare l'AMR a livello globale hanno l'obiettivo di ridurre l'utilizzo degli antibiotici nell'industria alimentare. Tuttavia, tali politiche sembrerebbero voler di imporre il peso economico e i rischi connessi che comporta l'innovazione, esclusivamente a carico dei produttori dell'industria alimentare, mentre i benefici ricadrebbero agli attori del network e alla società intera a lungo termine.

L'obiettivo di questo lavoro, basato su una ricerca di carattere empirico, è quello di comprendere e analizzare le componenti chiave del network, le loro interazioni e le loro influenze per comprendere, quali siano i fattori chiave che fungono da driver o, viceversa, rallentino o ostacolino il cambiamento necessario per affrontare il problema *dell'Antimicrobial Resistance*, o come recentemente, è stata definita, della *Pandemia Silenziosa*.

Keywords: antimicrobial resistance, business networks, innovation.

Acknowledge

As I write these words, I realize that I have reached an important milestone, a challenge I undertook with myself three and a half years ago. I could have done better, definitely, yes. I could have done it sooner, maybe. However, what I consider most important is that I have done so, and if I have done so, it is thanks to a number of people, whom I have had the honour and good fortune to meet and whom I would like to thank from the bottom of my heart.

First of all, I have to thank the person who made me know and fall in love with research in the field of economics and management, my supervisor, Prof. Andrea Perna, thanks to whom I found the strength, the inspiration, the courage to take this new path, that has transformed all my feelings and that I hope it can continue with as many exciting challenges as it has been so far. He helped to train me as a person and as a researcher, with his invaluable advice and suggestions. Thanks.

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Table of contents

1. Framing the research

1.1. The overall objectives and research design

The overall objective of this study is to problematize the policy ambition to promote innovation to address the problem of antimicrobial resistance (AMR).

Hence, the research investigates on how the main actors, engaged in the antibiotic network are trying to address the misuse and abuse of antibiotics that represent most of the cause of antimicrobial resistance. Thus, the study aims to increase understanding of the different roles involved in the challenge of innovating to change the use of that resource, i.e. antibiotics, which in different user settings seems to be endemically embedded.

Antimicrobial resistance (AMR) - the ability of bacteria to resist antimicrobial treatments, in particular antibiotics - has a direct impact on human and animal health and carries a heavy economic burden mainly due to higher costs in term of public and private health care and a decrease of private and public business productivity caused by most slowly capability to heal, and so more days of diseases and absences from work. The AMR is responsible for around 700,000 death per years, of whom 33,000 deaths per year in the EU. Antibiotic resistance is mainly caused by the abuse and misuse of antibiotics and 70% of antibiotic consumption occurs in the food industry and specifically in the food-meat production chain (Van Boeckel, 2017). This study is based on an empirical case study, conducted on the pig-meat industry, as that is commonly recognized to use the highest input of antibiotics (Kirchhelle, 2018).

To change the use of antibiotics is paramount for the ability to curb antibiotic resistance (van Boeckel et al. 2015, 2017; Kirchelle, 2018; Kahn 2016). The problem of overuse, misuse, and underuse, speeding up the natural bacterial mutation process, cannot be solved by developing new antibiotics. There has been a dearth of truly innovative antibiotics since the 1980s, due to both scientific challenges and lack of financial incentives for drug developers, and even if some new products might be launched within a few years, the future use of these have to restricted in order to protect their efficacy (Baraldi et al, 2020; Waluszewski et al, 2016).

Despite decades of national and global regulations and policy advice in order to change the use of antibiotics for animals, the global trend is that the use of antibiotics for food animals is increasing (van Boeckel et al, 2015; 2017). Within EU the use of antibiotics for animals has been regulated since 1998, culminating with the 2006 EU Feed Additives Regulation, banning all marketing and use of antibiotics as growth promoters in feed. Notwithstanding, the EU use patterns are still high and varied. While Sweden represents the most restricted use, Italy is something of an opposite, representing one of Europe’s most extensive use of antibiotics in animal-based food production (ESVAC/EMA, 2020).

The focus on the phenomenon of antimicrobial resistance at the policy level is growing globally, incrementally (World Economic Forum 2013, WHO, FAO, UN General Assembly 2016, etc.) and multisectoral, giving rise to what the UN, has defined as One-Health approach, that is a multidisciplinary approach of the problem from the point of views of veterinary, human and environmental.

In the European Union, this model has been adopted and integrated into the Commission’s sustainable policy agenda. To address the issue of antimicrobial resistance, EU Member States' policy makers are required to implement Objective 9 of the Common Agricultural Policy (CAP 9), which is included in the EU farm-to-fork strategy, part of the European Green Deal (Moschitz et al.2021; Duncan et al. 2020).

This has led to issue several regulations, which, however, seem to have been interpreted in a very different way by the individual Member States.

These policies have the ambition that the governments of the single countries should implement and should encourage policies to innovate the production systems of the meat industry, in order to drastically reduce the misuse and abuse of antibiotics in the food industry. In the European Union, despite having the same legislation on the use of antibiotics, there are very wide differences about their use between state and state (ESVAC, report 2021).

Overall, there is a scarcity of studies investigating the extent to which antibiotics have replaced or reshaped material infrastructure, an important aspect to consider in attempts to "eradicate" the dependence on antibiotics in different parts of contemporary society (Chandler, 2016).

The research is based on an empirical study on innovation policy in the field of Antimicrobial Resistance and on the role of Italian and Swedish animal food production systems.

The policy efforts to connect scientific knowledge with business development can be characterized by their strong focus on the supply and intermediary side […] However, a question that is less often considered, if even reflected upon at all, is how the user structure, i.e. new and established businesses and organizations, can embed this knowledge into a business world full of already activated and interdependent solutions (Håkansson & Waluszewski, 2007: p10). The empirical study is analysed from a resources interaction perspective (Håkansson & Waluszewski, 2007).

1.2. Innovation: theoretical models and empirical world

The vision of innovation as a driving force for technological development and economic growth has also made policy maker a frequent user of the concept, emphasising mainly the potential benefits of engaging in innovation for actors such as business and universities (see e.g. Eklund, 2007; Widmalm, 2008). Moreover, in the last decades, innovation policy is also called to treats sustainable challenges, as societal, environmental and health related, issues.

The main-stream policy advisory tends to incentive the public-private cooperation, to foster a kind of innovation, based on the neoclassical conception of market (Snehota, 2004). The technology models, which inspire the mainstream of innovation policy, seem to promote a type of collaboration based on competition between companies, which encourages the production of inventions rather than innovations. When applied in a policy context such a vision results in misleading recipes of how to promote innovation. (Bygballe & Ingemansson 2011). Innovation policies, particularly put forth by innovation institutions within the OECD and the EU, have for the last decades been based on ideas about inter-organizational relations and so-called 'triple helix' relationships as the perhaps most important means for enhancing innovation. In particular, the notions of clusters and of innovation systems have had a huge impact on European (and other) innovation policies, emphasizing local geographical co-location and interaction as the key to enhancing and expanding innovation. However, when examining closer these policies, they often seem to lack a deeper understanding of the substantial aspects of local networks; what they consist of, and how they are shaped and maintained. They are recently also criticized for not understanding the importance of international network relationships as explanation for successful innovation (Fitjar& Rodriguez-Pose, 2011). Moreover, most industries today are globalizing related to competition, how they are organized, how knowledge and information flow, etc. Hence, many policies and policy instruments aiming for the creation and fostering of innovation networks (or clusters or innovation systems) seem to rest on relatively naïve conceptions of networks.

To address systemic economic challenges, such as rising public health care costs, both the OECD and the WEF direct their expectations towards increasing public-private cooperation. In the case of healthcare, expectations are directed at the ability of private companies to deliver cost-effective health innovations and its ability to organise activities efficiently. (Hakansson, Waluszewski, 2020).

Actually, these types of economic models are based on the concept of the linearity of innovation[1] in a market. From this point of view, innovation is not a process of mutual development between producers and users, but rather a linear procedure of new solutions "pushed out" by technology providers or "pulled out" by potential users.

At contrary, to become an innovation, that is, a widely used solution, the new solution must not only be transferred from one context to another but have to actually adapt to these different contexts, and it often takes place in established producer-user relationships (Harrison & Waluszewski, 2008; Håkansson et al., 2009). Furthermore, when the exchange of knowledge come from outside the established relationships and interaction pattern, the change could result more difficult.

The prestigious policy advisor, WEF (2018, p. 13), underlines that "governments, businesses and civil society organisations" must find "new ways of tackling the systemic risks that affect us all", such as AMR issue.

These policies didn't consider the patterns of interactions between users, producers that are crucial in order to rise up an innovation (Waluszewski,

[1] For example, Freeman (1995: p9) comments: "A linear model of science and technology 'push' was often dominant in the new science councils that advised governments. It seemed so obvious that the Atom Bomb was the outcome of a chain reaction: basic physics => large-scale development in big labs => applications and innovations (whether military or civil)."

2007). Furthermore, this study aims shed light on a lack of knowledge pinpointed in the literature as well as on the empirical world means concerning on how policy innovation have to consider the needs of innovation related on the several actors involved within the network.

1.3. A bibliometric analysis

In order to validate the framework of our research on the topic of AMR in innovation studies on industrial and policy perspectives, we decided to conduct a systematic bibliometric analysis, which is a rigorous method for exploring and analysing large volumes of scientific data (Donthu et al., 2021). Hence, a bibliometric approach consists of applying statistical methods to determine qualitative and quantitative changes in a given scientific topic (De Bakker et al., 2005). Data mining was conducted on February 2022 using Scopus, a premier worldwide scientific database of papers, whilst the data analysis was carried out using Bibliometrix (Aria & Cuccullullo, 2017), an R-tool for comprehensive science mapping analysis, version 3.0 (released on July 17, 2020). In order to find the studies on the aforementioned topic, we used the following query: TITLE-ABS-KEY (innovation AND policy AND antibiotic). The search's results led to 131 documents, with a reference period from 1985 to 2021. From this standpoint, we have identified the adequate keywords analysing papers available in the literature, and then we checked the selected. After that we tried other queries to test that the first one was the most inclusive and complete one (i.e. we tried with: “TITLE-ABS-KEY ("innovation policy") AND ("antibiotic resistance" OR "antimicrobial resistance")” or “TITLE-ABS-KEY ("innovation policy") AND (AMR) OR ("antibiotic resistance" OR "antimicrobial resistance")”, anyway the first one resulted to better fit with our research, providing the most large result, without the need to filter the dataset. The main contribution of the bibliometric analysis is that it acts as a guide to the status of research (Rey-Martí et al., 2016) providing useful information and emerging trends for the selected topics in a particular field (Alsharif et al., 2020). In this research we used the following bibliometric indicators: year of publication, research area, country of publication, most frequently cited journals, top all keywords, all keywords, and keywords-clusters.

Table 1 - Main information about data - AMR innovation policy

Description	Results
MAIN INFORMATION ABOUT DATA	

Timespan	1985:2021
Sources (Journals, Books, etc)	104
Documents	131
Average years from publication	7.3
Average citations per documents	18.36
Average citations per year per doc	2.495
References	6347
DOCUMENT TYPES	
Article	79
book chapter	3
conference paper	1
Editorial	7
Letter	2
Note	6
Review	30
short survey	3
DOCUMENT CONTENTS	
Keywords Plus (ID)	1828
Author's Keywords (DE)	394
AUTHORS	

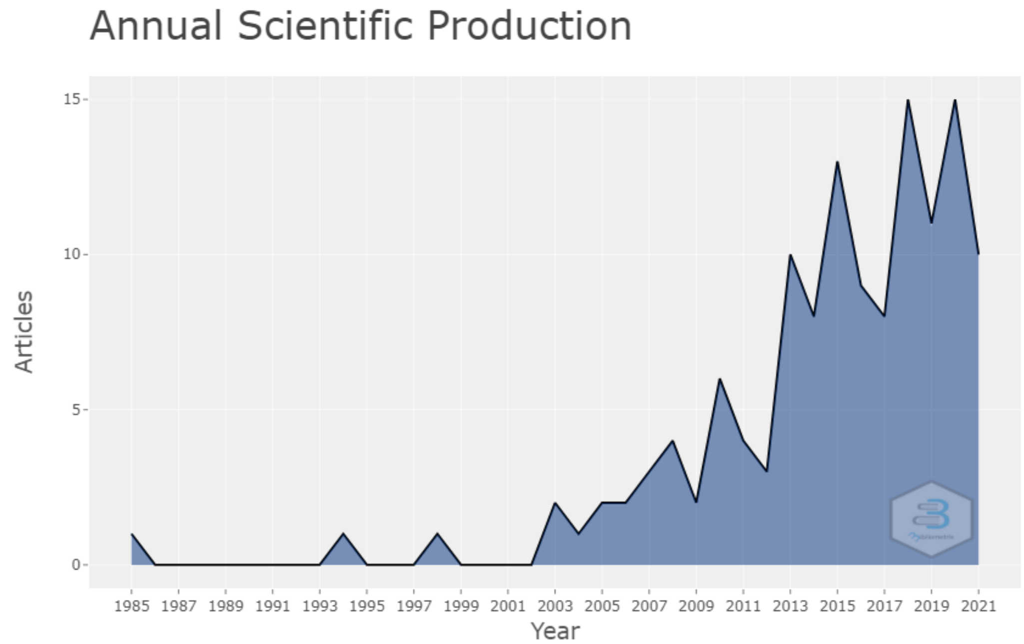
Authors	585
Author Appearances	639
Authors of single-authored documents	33
Authors of multi-authored documents	552
AUTHORS COLLABORATION	
Single-authored documents	33
Documents per Author	0.224
Authors per Document	4.47
Co-Authors per Documents	4.88
Collaboration Index	5.63

Source: author's elaboration on Scopus, February 2022

Year of publication

Firstly, as shown in fig.1 (Below), we used the "year of publication" as a unit of analysis. This indicator revealed that the topic is growing year by year, starting from far 1985 and it has had the first increase from 2002. After that, it has had an exponential growth especially in the last decades. Hence, findings show that the interest in this area of knowledge has far roots, increased year by year, and assume high relevance in the last decades.

Figure 1 – Year of publication



Source: author's elaboration by Bibliometrix R-Studio and Scopus, February 2022.

Research area

In order to reach useful information about the AMR and innovation policy topics, table 1 reports the number of articles published in different knowledge fields. As it can be noted, and in line with our known, despite innovation and innovation policy are topic traditionally positioned in the Business and Management studies, there are scarse attention on the topic of AMR in the "Business, management and accounting" area, represented by only 6 articles.

Table 2 - Research Area

Medicine	96
Pharmacology, Toxicology and Pharmaceutics	18
Biochemistry, Genetics and Molecular Biology	15
Social Sciences	12
Nursing	11
Immunology and Microbiology	9
Arts and Humanities	6
Business, Management and Accounting	6
Agricultural and Biological Sciences	5
Environmental Science	5
Chemical Engineering	4
Engineering	4
Economics, Econometrics and Finance	3
Chemistry	2
Health Professions	2
Neuroscience	2
Computer Science	1
Decision Sciences	1
Earth and Planetary Sciences	1
Energy	1
Materials Science	1
Multidisciplinary	1

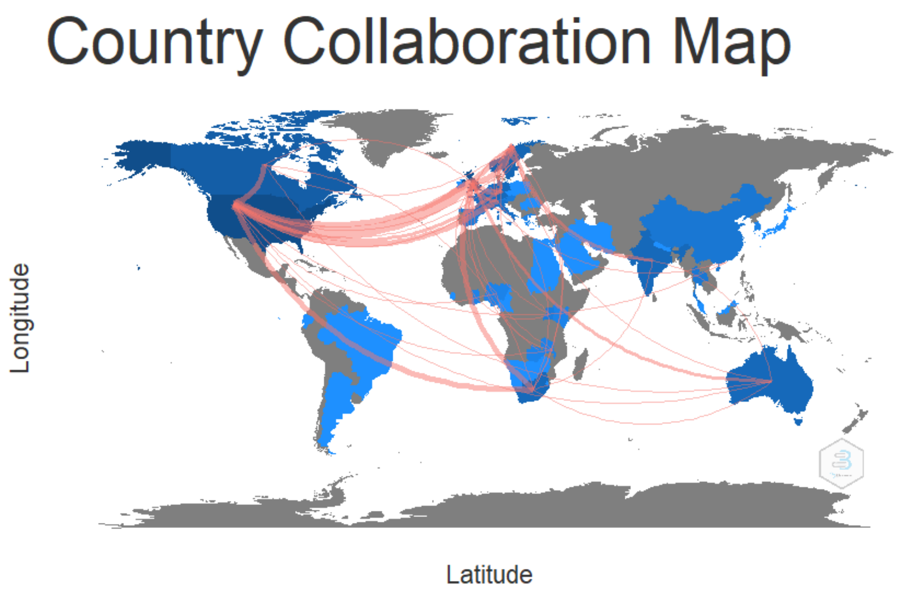
Source: authors' elaboration on Scopus, Feb. 2022

Thus, findings reveal that despite the alarm denouncing by policy advisory, with world Word Economic Forum in forefront (2018), an important difference between the number of studies published in "Business, management and accounting" and the number in other research areas. This evidence demonstrates that these topics are relevant in the field of business and management, but the related literature have to be developed.

Country of publication

Another interesting aspect concerns the geographic division of the published documents. From this standpoint, United States is in the first position with 39 publications, followed by the United Kingdom with a total of 36 published papers, South Africa (27 papers) and the Australia (25 papers). By contrast, Italy is in 5th place with a number of 21 published articles.

Figure 2 - Countries in and overlay visualisation



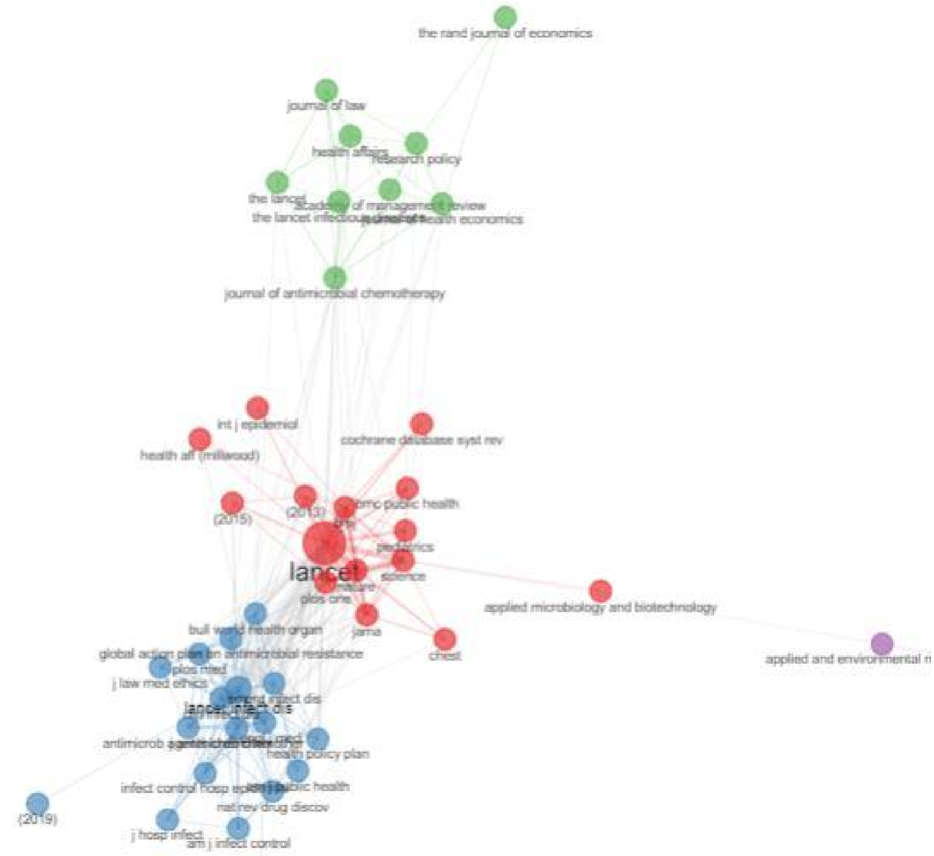
Source: authors' elaboration on Scopus, Feb. 2022

Most relevant sources

This study shows the most frequently cited journals for the analysed topic. This unit of analysis allows understanding the most influential publications in a specific research field (Donthu et al., 2021). In order to reach the aim, fig. 3 shows that confirm that the medicine journal is at the top of the ranking (red colour), however the new trend is represented by economic and policy journal (green colour), where the central journal is "Research Policy".

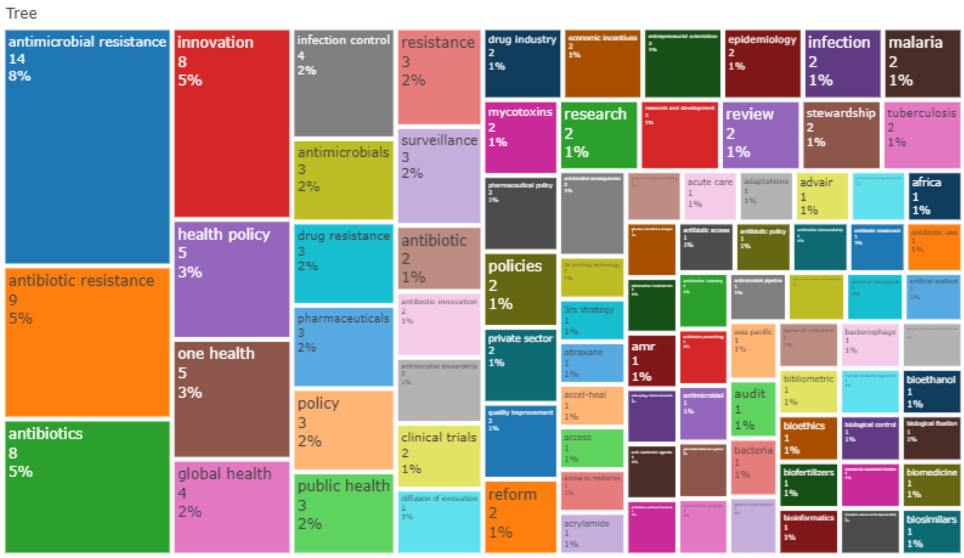
This indicator is essential in the bibliometric analysis because, nonetheless, there are various methods to establish the relevance of publications in a research area, the most objective and forthright measure of its impact are its citations (Pieters & Baumgartner, 2002; Stremersch et al., 2007).

Figure 3 - Most relevant sources



Source: authors' elaboration on Scopus, Feb. 2022

Figure 4 - The most relevant keywords.



Source: authors' elaboration on Scopus, Feb. 2022

Figure 5 - Main author's keywords.

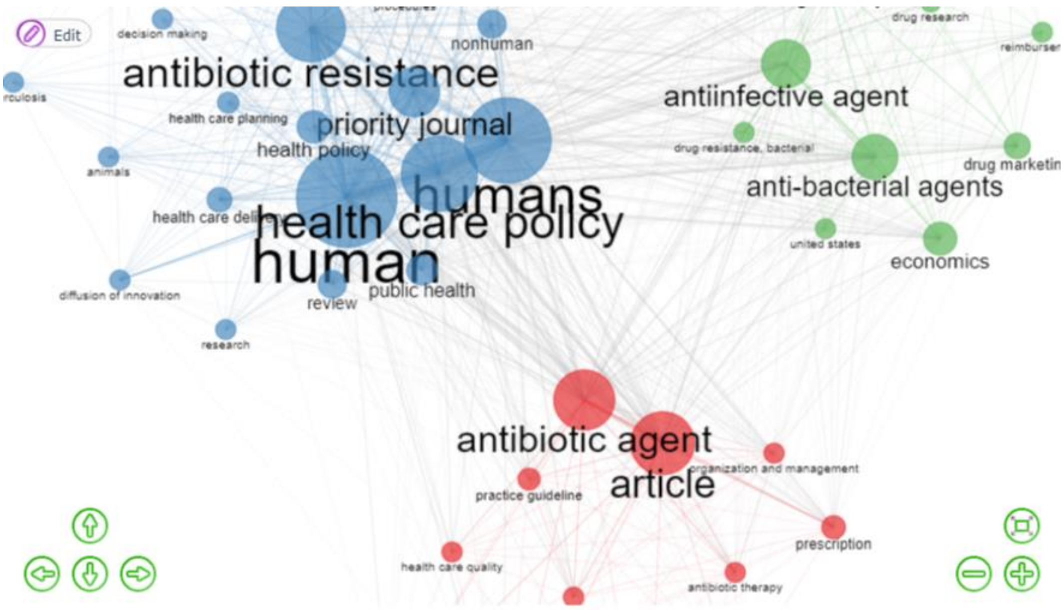
Source: authors' elaboration on Scopus, Feb. 2022

Clustering

In order to highlight the connections between different topics, clustering is a crucial unit of analysis for bibliometrics, whose primary purpose is to develop thematic or social clusters. As noted in fig. 5, our analysis reveals three main clusters. The blue one is focused on "health care policy" in humans, and it is the most linked with all the other clusters.

The green one regards economics field, and the main keywords are "antimicrobial resistance costs" or "public health efficiency". The red one concerns business and organizational studies, and it is linked with innovation and new drugs development.

Figure 6 - Three main clusters.



Source: authors' elaboration on Scopus, Feb. 2022

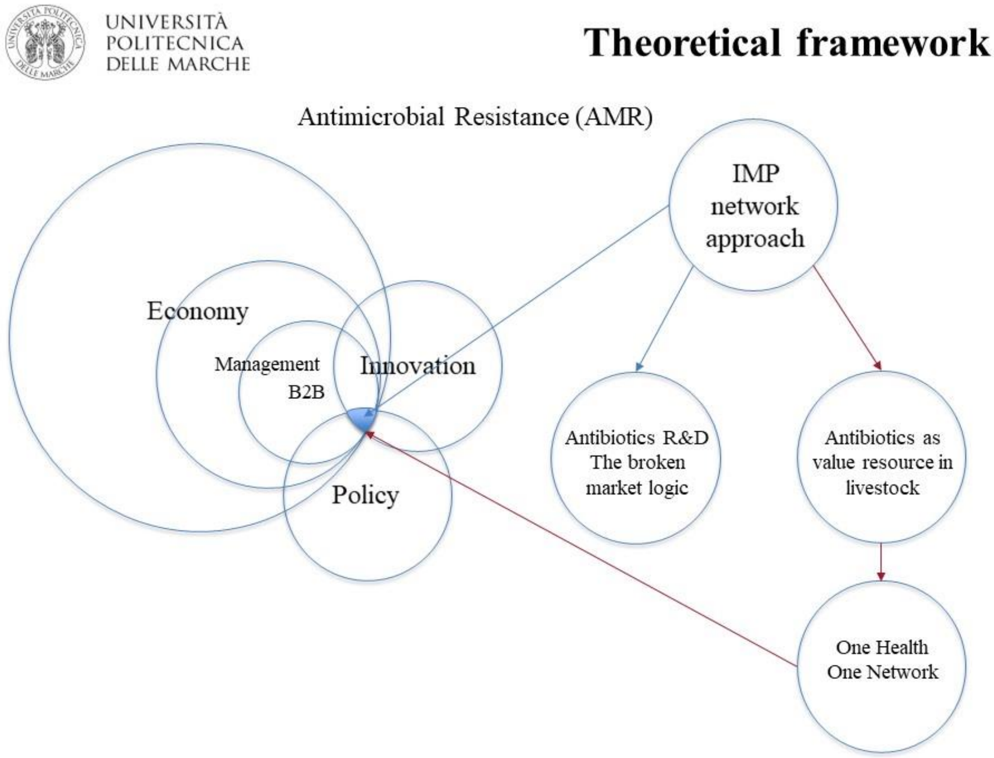
Examining the red one cluster (business and organizational studies), emerging 11 articles with two research streams:

1. Management and performance in human care
2. Innovation policy
    a. The broken market of Research and Development for new antibiotics

b. The innovation in animal-food industry to reduce the antibiotic dependence

The common denominator of the last stream is the IMP network approach, that result in line with our research interest, and allow us to better analyse the complexity and multifaceted of the network of AMR issue, as illustrated in the next section.

Figure 7 - the research theoretical framework



Source: authors' elaboration on Scopus, Jan. 2022

1.4. Innovation through the IMP network approach lenses

The theoretical point of departure is process-oriented innovation studies, acknowledging path dependencies in terms of connectivity of social and material resources in place (Van de Ven et al., 1999; Håkansson et al., 2009; Håkansson and Waluszewski, 2002). More precisely, the study uses the conceptualisation of Industrial Network research setting (Håkansson et al., 2009), based on the notion that economic exchange has a qualitative content, that the resources exchanged are heterogeneous, that is dynamic, and that the value is created in directly and indirectly-related resource interfaces, in cross-organisational interdependencies. Hence, it is an approach that has a close kinship with notions on interdependency made in the heterodox economics research field (see e.g. Lawson, 2005; Marglin, 2008; Mirowski, 2011; Fourcade, et al., 2015).

We use the notion of the different resource interaction patterns in using, producing and developing settings (Håkansson and Waluszewski, 2007, pp. 152-156; Perna and Waluszewski, 2018) to capture the role of antibiotics in the two focal systems. Briefly put, in the using setting the value of a resource depends on its contribution to established systems of products and services, in the producing setting on its contribution to investments in place in facility systems, and in the developing setting on how it is related to knowledge production patterns in public research and private R&D (Håkansson and Waluszewski, 2007, pp. 153-155). Hence, we adopt the assumption that the use of any economic resource is taking place in different user settings, where its features are combined with other resources in different ways, affecting any force mounting for change of it (Håkansson and Waluszewski, 2007; 2009; Latour, 1984; Woolgar, 1991). This understanding of the complexity of use is resting on the recognition of resource interdependency across organisational and legal borders, made in Science & Technology Studies (STS) (Bijker et al, 1997; 2012; Jasanoff et al, 1995), in Heterodox Economy Studies (Fourcade et al., 2015; Marglin, 2008; Lawson, 2005), and in this projects' main source of inspiration, Industrial Network Studies (Håkansson and Waluszewski, 2002; Håkansson et al., 2009; Håkansson and Snehota, 2017). The latter research fields interest in and extensive empirical studies of how resources are used, produced and developed in our society have underlined their heterogeneous characteristics, interconnectedness and different contributions to different actors in the user settings they are embedded into (Håkansson and Waluszewski, 2007; Waluszewski et al, 2017; Håkansson and Snehota, 2017).

These research experiences point to the importance of capturing the different main user settings a focal resource is embedded into; where its features are combined with other resources in different ways, affecting any force mounting for change of it (Håkansson and Waluszewski, 2007; 2009; Latour, 1984; Woolgar, 1991). As soon as a resource; in this case antibiotics, is considered from the different user settings it is embedded into, its different technological, scientific, and economic contributions are outlined. A basic notion is that it is not the resource in itself, but its effects on direct and indirect related resources in the different user context that defines its value (Håkansson and Waluszewski, 2009, p. 5). Moreover, the use of a specific resource can take place in direct and indirect combinations with physical and social resources, by commercial, governmental and non-governmental actors, being more or less fundamental in these different user systems (Håkansson and Waluszewski, 2007; 2009).

Hence, any change in the use of a specific resource will have consequences for direct and indirect related resources. The presented study relies on the notion of three main aspects affecting attempts to achieve change in the use of a specific resource embedded into several user settings (Håkansson and Waluszewski, 2007, p.147-150): a) the relatedness of user settings, b) the distributed consequences of change in user interfaces, and, c) the need for knowledge development across user interfaces. What these aspects have in common is that they point to the insufficiency of relying on individual behaviour or individual decision making in order to achieve change. (Håkansson and Waluszewski, 2007, p.147-150).

1.5. Interdependencies in the network

A cornerstone in the IMP approach is the study of interaction. As it is described by Håkansson and Snehota (1989) no is an island, instead they interact with suppliers, customers, competitors, authorities and non-governmental organizations in order to create value. Thus, interaction is a key process in the business landscape which shapes the features of companies, their activities and resources.

What has been outlined is a business landscape where companies interact with other companies and organizations in order to create value. This process is characterized by the formation of business relationships which emerge through extended interaction over time. The relationships create and direct interdependencies between people and other immaterial and material things across company and organizational borders. Furthermore, through these relationships, exchange and processes become standardized; activities and resources are organized in network-like structures leading to higher efficiency. Thus, any company's internal organizing of material and immaterial resources is related to the organizing that takes place within and between other companies (Håkansson & Snehota, 1995; Håkansson & Waluszewski, 2002; Ford et al., 2003).

However, it should also be acknowledged that relationships do not only relate to positive contributions such as higher efficiency and innovativeness. There is another side of relationships that is characterized by conflicts.

These processes do not necessarily mean that the outcome will be negative; friction can also be a source of advancement. On another note, established relationships can make it more difficult for other solutions (outside of the relationships) to contribute to innovativeness and efficiency (Gadde & Håkansson, 2001; Håkansson & Waluszewski, 2002).

Hence business relationships can be said to be characterized by both positive and negative effects. On the one hand, they decrease independence for companies and related counterparts, but on the other hand they increase efficiency. The important point here though, does not really relate to whether they are good or not but just that they are an integral part of the business landscape. Or as it is stated by Ford et al. (2003: p37):

It is not a matter of choice for a company whether or not it should have relationships. All companies have relationships now and all companies have always had them. We would go as far as to claim that a company cannot exist without relationships. But those relationships can vary in content, strength and duration.

In our thesis the interactions between resources are focal to understand how the antibiotics became an embedded resource and with which resource combination was compensate in one case, and furthermore which interdependencies hinderance the dis-embedding process in another case.

1.6. The complexity of innovating within the network

The idea that there needs to be some form of compatibility with already existing structures to embed something new is supported by scholars of the IMP network approach. As Håkansson and Waluszewski (2007) conclude, the less change the new will impose on the old structure, the easier it will be to embed the new. In this context, if a new solution is significantly different from the current resource structure, the resistance to finding a use will be stronger. Also, when resources have a use, they must not only fit with material and tangible artefacts (Håkansson & Waluszewski, 2002; Waluszewski et al., 2009), they also need a fit with immaterial and intangible social structures (Latour, 1984; Bijker, 1987; Bijker & Pinch, 1997; Håkansson & Waluszewski, 2002). Thus, when something new is introduced, the effects are not fully possible to predict because it occurs in relation to a large number of different resources owned and managed by various actors.

2. Objectives and research questions

Previous estimation of deaths associated with antibiotic resistance were to restrained. The latest figures, presented in Lancet study in January 2022, estimates that 1.27 million deaths per year are direct attributable to antibiotic resistance, while 4.95 million deaths are associated with resistant bacteria. The study shows that low- and middle-income regions are hardest hit by this ‘silent pandemic’, but also that resistant bacterial infections are extensive in central and southern Europe, while the Nordic region is an exception.

To change the use of antibiotics is paramount for the ability to curb antibiotic resistance (van Boeckel et al. 2015, 2017; Kirchelle, 2018; Kahn 2016). The problem of overuse, misuse and underuse, speeding up the natural bacterial mutation process, cannot be solved by developing new antibiotics. There has been a dearth of truly innovative antibiotics since the 1980s, due to both scientific challenges and lack of financial incentives for drug developers, and even if some new products might be launched within a few years, the future use of these have to restricted in order to protect their efficacy (Baraldi et al, 2020; Waluszewski et al, 2016). The growing awareness about the ‘discovery void’ or ‘dry pipeline’; characterising the antibiotic development period from the late 1980s up to today, along with growing bacterial treatment failures, increasing health care costs and increasing mortality, have put antibiotic resistance or AMR on the global policy agenda (Chandler, 2019; Baraldi et al, 2016). Since the first decades of the 20th century, to restrain overuse of antibiotics has stabilised as a common policy goal (Chandler, 2019).

Perhaps overuse and misuse are most widespread in the animal-based food setting. About two-thirds of the world's use of antibiotics is estimated to take place in animal husbandry, to a large extend to combat production-related diseases and to stimulate animal growth (Van Boeckel et al., 2015; 2017; Kirchhelle, 2018; Kahn, 2016). In spite of decades of national and global regulations and policy advices, with the UN General Assembly first ever 'High-level Meeting' on Antimicrobial/Antibiotic Resistance in September 2016 as the most prestigious, the global trend is that the use of antibiotics for food animals is increasing (van Boeckel et al, 2015; 2017). The antibiotic dependent animal-based food that contemporary global policy aims to combat; allowing intense farming and high density of animals, are exported from high-income regions to middle- and even low-income regions, with Brazil, Russia, India, China, and South Africa as the most expansive (van Boeckel et al, 2015; 2017 Kirchhelle, 2018).

Even within EU; were the use of antibiotics for food animals has been regulated since 1998; culminating with the 2006 EU Feed Additives Regulation, banning all marketing and use of antibiotics as growth promoters in feed, the use patterns are still high and varied (ESVAC/EMA 2020; Nunan/EPHA, 2022). If the new EU regulation (2019/6) that came into force on January 2022 will be more successful is still an open question. The updated rules are again banning routine use of antibiotics and is also restricting the preventative use; that is usage as a compensation to investments in precautionary health, hygiene and animal welfare. One of the main goals is to “ensuring prudent and responsible use of antimicrobials in animals, including reserving certain antimicrobials for the treatment of infections in people”.

However, already before taken into practice the updated EU regulation has been meat by doubt. While welcoming the rules, the European Public Health Alliance (EPHA) stress that a radical reduced use of antibiotics requires significant investments in more health-oriented animal farming systems (EPHA/Nunan, 2022). So far there are few signs of any significant systemic change in this direction, or as EPHA puts it: […] “there is little indication that Europe actually is moving away from highly intensive livestock farming systems, where excessive routine use of antibiotics covers up for inadequate animal husbandry and high levels of disease.”

There is however an EU member state that already has achieved what’s suggested in the new regulation. The usage ‘minimised’ usage level in Sweden, along with the Nordic neighbours Iceland and Norway (outside EU but in the European Economic Area, EEA) reveals that there are measures within reach that allows radically reduced usage levels. Already the ‘average’ users within EU; that is among others France and Germany, have usage levels about 10 times higher than the Swedish. (EPHA/Nunan, 2022; EMA/ESVAC 2020)

The famous food EU member state Italy is along with Poland and Spain using about 20 times as much antibiotics for animals compared to Sweden (EPHA/Nunan 2022; EMA/ESVAC 2020). Furthermore, while the Swedish use to 90% consist of treatment of individual animals, the ‘average and ‘large’ user consists of routine treatments of groups of animals, indicating it is driven by lack of investments in precautionary health, animal welfare and biosecurity (EPHA/Nunan, 2022; Kirchhelle, 2018).

How come that two EU member states, Sweden and Italy, that for decades have had to cope with the same EU regulations use of antibiotics for animals, have so radically different usage patterns? This is the overall interest of the paper, which focus on the use of antibiotics in Italian and Swedish pig meat-based food; an area that along with poultry traditionally represents the highest use levels.

The aim is to shed light over the challenge of reducing the use of a particular resource, in this case antibiotics, over time embedded into several user settings, creating economic benefits to direct and indirect related businesses, organisations and to consumers, while it at the same time has severe negative long-term consequences, for the efficacy of antibiotics, for human and animal health, environment, and society at large. Before presenting the research design more, some basic characteristics of the focal Italian and Swedish settings will be considered.

About two thirds of the world's consumption of antibiotics goes to animals, the majority to food animals, most often given as a precautionary measure to combat production related diseases, and to stimulate animal growth (Van Boeckel et al., 2015; 2017). Antibiotic-resistant bacteria of animal origin, as Van Boeckel et al., (2015) summarise, can be transmitted to humans through the environment, food products and farm workers:

> *"This widespread use of antimicrobials in livestock contributes – by means of natural selection – to the emergence of antimicrobial-resistant bacteria (ARBs) and has significant public health implications." Van Boeckel et al., 2015, p. 5649)*

If no radical changes are made both the consumption levels and deaths caused by AMR are estimated to continue to increase (Van Boeckel et al., 2015; 2017). In this paper, we focus on the production systems practiced in two European countries, representing one of the lowest and one of the highest consumption of antibiotics in animals, and the driving forces behind them. More precisely, we focus on pig meat based food production, which conventionally, along with poultry, represents the highest consumption of antibiotics (Kirchhelle, 2018).

"The ban is the final step in the phasing out of antibiotics used for non-medicinal purposes. It is part of the commission's overall strategy to tackle the emergence of bacteria and other microbes resistant to antibiotics, due to their overexploitation or misuse." (EU, 2005, IP/05/1687)

Two decades before the EU ban, Sweden legally banned growth-promoter antibiotics (AGPs) and routine group treatments with antibiotics through feed and water in 1986. Two years before the ban the consumption level was estimated to be 46 mg/PCU. Hence, the point of departure for the Swedish engagement in a production regime compensating for routine input of antibiotics was below what Van Boeckel et al. (2017) suggest as a maximum global goal to combat overuse of antibiotics/antimicrobials in animal-based food production:

> *"A global regulation putting a cap of 50 mg of antimicrobials per PCU per year, the current global average amount, could reduce total consumption by 64%."*
> *(Van Boeckel et al, 2017, p. 1351).*

The choice of the production systems practised in Italy and Sweden are made to shed light on an aspect stressed by Cassini et al. (2019); the fact that not only antibiotic consumption patterns, but also the burden of antibiotic resistant bacteria 'varies greatly' between countries even within the highly regulated EU. In Italy more than 10,000 deaths per annum are attributed to antibiotic resistant infections (Cassini et al., 2019). Although Italy has a large population of elderly, Cassini et al. (2019, p. 64), underline that "it is notable that about a third of the deaths due to infections with antibiotic-resistant bacteria in the EU and EEA were in Italy". The lowest death rate was reported in Iceland (in EEA but not EU), followed by Estonia, Netherlands and the Nordic countries, including Sweden. The restricted consumption of antibiotics in Sweden in general is ascribed its almost century long history of use control of drugs, based on public health need (Kirchhelle, 2018; Hobaek and Kveim Lie, 2019).

Furthermore, the choice of Sweden was made to highlight the fact that there actually exist production systems that have abandoned the conventional antibiotic dependency for decades, despite that modern animal production practices have become associated with "regular use of antimicrobials, potentially increasing selection pressure on bacteria to become resistant" (Van Boeckel et al., 2015, p. 5649). While the Italian production regime confirms this picture, the Swedish case reveals that it is not mandatory (Postma et al., 2015; Sjölund et a.l, 2015).

The aim is to pinpoint the role of antibiotics in the different systems and the driving forces behind them, and to discuss the requirements for a radical reduction of antibiotics to not only be the odd, but the regular case. Hence, the ambition is not to make a strict comparison, but rather to pinpoint the different types of driving forces that are behind the different systems and approaches to antibiotics.

How can the introduction of antibiotics into animal-based food production be restricted when, as Chandler (2019) argues, the role of antibiotics is not bounded and separable, in different arenas for economy, politics, humans and nature? What forces and key features can be outlined behind the Swedish production system, that actually compensate for routine group treatment with antibiotics? And what aspects are behind the different antibiotic consumption pattern in the Italian setting? These are the key questions of this paper. We also consider the difficult distribution of costs and benefits, when the cost of change mainly appears in the producing setting, and the benefits to a large extent in health care, in environment and society at large.

Behind the contemporary resistance awareness at least seven decades of ignorance of it was hiding. Scientific knowledge about the intrinsic characteristics of bacteria mutation, giving rise to resistance, was articulated in parallel with the launch of antibiotics for humans and animals since the late 1940s, in both research publications and general media (Kirchhelle, 2018; Wise, 2007). However, the main conclusion drawn, by for example the UK Swann committee in the late 1960s, was that the resistance challenge could be dealt with as a matter of choice: antibiotics for production animals should not be those used in human medicine as this could compromise efficacy in man (Swann et al., 1969; Wise, 2007; Kirchhelle, 2018). Hence, although politicians in several countries noticed and acted upon knowledge about the resistance phenomenon, it ended up in, as Kirchhelle (2018) puts it, in 'a patchwork' of different policy approaches that did not hinder an increasing consumption of antibiotics in animal-based food production.

Hence, if antibiotics were labelled 'magic bullets' when they were first launched due to their assumed ability to attack specific microbes without harming a body at large, in perspective of production and use of animal-based food products they gained the role of 'magic wallets' – a fast track to increased value of a number of related resources in the producing and using settings. The distribution of cost and benefits related to routine group treatment of antibiotics, though, is complex. The acceleration of the resistance process and the progressive loss of drug efficacy partly harm the animal-based food businesses and the personnel, but above all it affects the health system and society at large. At the same time, there are a number of economic actors in both the producing setting, including suppliers of animal pharma, and in the wholesale/retail using setting that at least from a short-term economic perspective benefits from the regular antibiotic group treatment. ‘Precautionary’ routine group treatment allows an increased ‘density’ of animals at production sites, a shortening of the production cycle from birth to slaughter, and a reduced cost of staff. Hence, it compensates for investments contributing to animal health, that is in hygiene and precautionary infection control, in space as well as in education of personnel (Kirchhelle, 2018; Van Boeckel, et al., 2017; Lhermie et al., 2017; Finlay, 2004). Furthermore, it allows the supply of large volumes of low price products to wholesalers and retailers, used to attract consumer streams (Cantillon and Håkansson, 2009; Finlay, 2004; Kirchhelle, 2018).

In the following section we take a closer look at the different role of antibiotics in Swedish and Italian pig meat based food. Table 1 below gives an overview of the production structure of each setting, and show that there are large differences also in other aspects; in terms of sows/per farm and slaughtered pigs/farm. However, despite the large differences in antibiotic consumption patterns, productivity in terms of slaughtered pigs/sow is about the same.

2.1. Methodological consideration

We adopted a qualitative case study approach, as the explorative nature of the study (Voss et al., 2002), to investigate on a phenomenon that already in evolution and with uncertain boundaries. According with Jensen and Sandström (2016, p. 9):

> *"The case, in a case study, can, in our opinion, be a number of different phenomena: it can be a movement, a process, an object, a human, an organisation, a group, an element, an activity, a thought or picture, a decision, liquids, animals, bodies, systems, a history, a myth, a ritual, a ceremony. The list can be made longer, but the point is clear."*

Actually, we intend the case as the phenomenon of AMR, and the study concerned several cases where this phenomenon was address in different way (Fornstedt, 2021). Not with the intention to make a comparison, but rather to observe the different pathway emerging in different settings, far in time and space, but both under the same regulation.

Furthermore, our case study followed an abductive logic (Dubois & Gadde, 2002; Baraldi et al., 2012):

“whereby theory and data collection were continuously matched during our research process. Specifically, we moved between theoretical models and empirical data several times as a result of conducting a continuous analysis of the material, which re-directed our data collection, theoretical focus, and research questions”

The methodology applied was influenced by the specific systemic features of the use of antibiotics (Baraldi et al, 2016; Waluszewski et al, 2018; Perna and Waluszewski, 2018; Waluszewski et al, 2021); by social scientists engaged in studies in AMR captured in terms of ‘antibiotic infrastructure’ in order to illustrate physical and cultural interdependencies (Chandler, 2019; Kirchhelle, 2020). The data collection concerning the role of antibiotics in different user settings related to animal based and attempts to achieve change is based on a combination of methods. In order to capture the use of antibiotics in different settings direct and indirect related to pig meat-based food we have.

The data collection related to both cases is based on a combination of methods. Published studies in antibacterial studies and animal health studies were used to gain insights into the global animal antimicrobial/antibiotic resistance challenge (e.g. van Boeckel et al, 2018, 2015 and Postma et al, 2016; Stein, 2011; Smart and Marstrand, 1972). Furthermore, global policy bodies, such as ESVAC, WHO and FAO, and NGOs, was used to gain data on global animal antibiotic use and resistance patterns. Studies in history of medicine, history of technology, sociology and industrial network studies provided insight into the emergence of an antibiotic dependent animal based food production and use settings (e.g. Kirchelle, 2018; Podolsky and Kveim Lie 2016; Lhermie et al 2017; Elzen et al, 2011; Wise, 2007; Waluszewski et al, 2018).

The data collections in the Italian and Swedish setting focused the role of antibiotics in pig meat-based food in each setting; to understand the producing and using regimes and actor composition of the network – at public/private. Thereafter, and still ongoing, we focus the attention on the analysis of actions and changes made in in relation to attention to AMR.

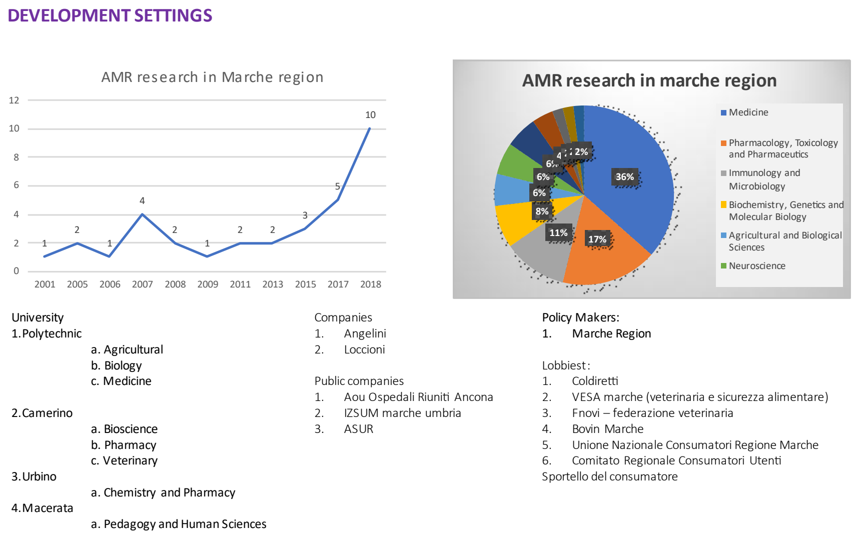
In both the Swedish and Italian case interviews have been made with researchers focused on the topic of AMR in the animal based-food industry; interviews have been made with scientists engaged in this topic in veterinary, microbiology, biology and medical researcher.

In the producing setting interviews have been made with pig meat farmers, farmers organisations, representatives for slaughterers/food processing firms.

In the using setting has been representatives for retail industry and consumer organisation. All interviews, which lasted from about 45 minutes to half day site visits, was made with semi-structured guides, focusing on the role of antibiotics and AMR in the different settings in general and for the specific respondents. That is, specific themes (Kvale, 1997) were prepared and provided guidance during the interview, leaving space for discussions and encouraging the informants to add further information (Johnsen and Ford, 2007). The themes have been followed to varying degrees, but they were useful as a structure and for support during the interviews. The preparations and introductions functioned as a way of setting the scene for conducting fruitful interviews. In total, 60 personal interviews, including site visits, were carried out, focusing on the role of antibiotics and AMR in the different empirical settings in general and for the specific respondents. We use the notion of the different resource interaction patterns in using, producing and developing settings (Håkansson and Waluszewski, 2007, pp. 152-156; Perna and Waluszewski, 2018) to capture the role of antibiotics in the two focal systems. Briefly put, in the using setting the value of a resource depends on its contribution to established systems of products and services, in the producing setting on its contribution to investments in place in facility systems, and in the developing setting on how it is related to knowledge production patterns in public research and private R&D (Håkansson and Waluszewski, 2007, pp. 153-155).

The starting point of mapping the sample of actors engaged was on one hand the reports published by IZS (Experimental Zoo-prophylactic Institutes), which showed us that the Marche Region is one of the most important Regions in terms of antibiotics consumption data in the pig-meat production context. Then we proceed using Scopus and R-studio to understand the actors engaged in the developing settings by region and by research centres. Moreover, a website content analysis is provided to catch policymakers (developing setting too) engaged in antimicrobial resistance stewardships and pig-meat industry website (producing settings) and GDO website (using settings).

Figure 8 – Sampling by Scopus AMR research in the Marche Region

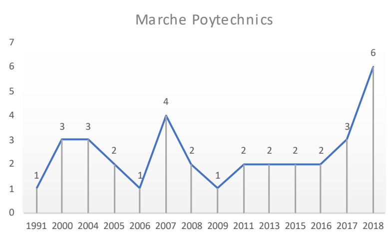


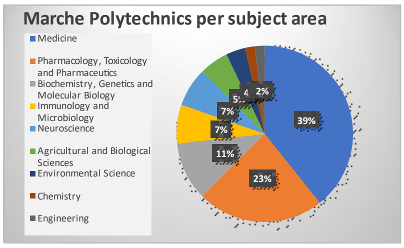
Source: author's elaboration by Scopus, June 2019

Figure 9 – Sampling by Scopus AMR research in the Università Politecnica delle Marche

DEVELOPMENT SETTINGS

Your query : (KEY(antimicrobial resistance) AND (LIMIT-TO (AFFILCOUNTRY,"Italy")) AND (LIMIT-TO (AF-ID,"Università Politecnica delle Marche" 60031624)))





Your query : (KEY (antimicrobial AND resistance AND pig OR swine OR pork) AND (LIMIT-TO (AF-ID,"Università Politecnica delle Marche" 60031624)))
YEAR 2004
n. of results 1
journal (2004) International Journal of Food Microbiology, 97 (1), pp. 17-22. Cited 42 times.
authors Busani, L., Del Grosso, M., Paladini, C., Graziani, C., Pantosti, A., Biavasco, F., Caprioli, A.

Source: author's elaboration by Bibliometrix R-Studio and Scopus, June 2019

Figure 10 – Sampling by Website Content Analysis

DEVELOPMENT SETTINGS **Policymakers AMR stewardship Marche Region**

Gruppo Tecnico Regionale per l'applicazione a livello regionale del Piano Nazionale di Contrasto all'Antimicrobico Resistenza

NOMINATIVO	ENTE
Dr.	Referente Regionale per il contrasto dell' AMR
Pro	Referente Regionale per le sorveglianze dedicate all' AMR
Dr.	Riferimento tecnico regionale (microbiologo) per la rete di sorveglianza dell' antibiotico resistenza AR-ISS
Dr.	Referente regionale per la sorveglianza dell' AMR nel settore veterinario
Dr.	Referente regionale per la sorveglianza delle infezioni correlate all' assistenza (ICA)
Do	Referente Regionale per il consumo degli antibiotici nel settore umano
Do	Referente Regionale per il consumo degli antibiotici nel settore veterinario
Do	Referente Regionale per la sorveglianza dei residui degli antibiotici negli alimenti di origine animale.
Do Not allow to share personal sensitive data	Referente Regionale per le misure per la prevenzione delle malattie infettive in ambito veterinario e delle zoonosi
Do	Referente Regionale per l'uso corretto degli antibiotici in ambito umano
Do	Referente Regionale per la comunicazione e informazione per il contrasto all' AMR
Do	PF Prevenzione e promozione della salute nei luoghi di vita e di lavoro
Do	Referente Regionale per la formazione per il contrasto all' AMR
Do	Scuola di Bioscienze e medicina veterinaria università degli studi di Camerino
Do	Dirigente P.F. Assistenza Ospedaliera emergenza-urgenza e ricerca
Do	P.F. Prevenzione veterinaria e sicurezza degli alimenti
Do	Medico legale esperta in Rischio Clinico (P.F. Territorio e integrazione ospedale territorio)
Si	Segreteria P.F. Territorio e integrazione ospedale territorio

Source: author's elaboration, June 2019

Figure 11 – Sampling by Website Content Analysis

PRODUCTION SETTINGS

Pharma & Chem industry	revenue
Not allow to share personal sensitive data	533.369
	104.095
	37.326
	30.983
	22.735
	17.745
	17.080
	12.375
	10.220
	10.057
	922.387
Totale imprese	16

Source: author's elaboration, June 2019

Then we started to conduct a pilot study going to interview the first actor caught through the aforementioned process. Then at the end of each interview, we ask about the relationships, connections and references of each interviewee. So, we spread our sample and mapped the network following the relationships and references of our interviewees and combine the Scopus and R-studio dataset and websites content analysis.

The same process has been spread to reach the whole sample, and we concluded as the last interviewees didn't contribute to adding new information as the previous interviewees (Atkinson et al. 2004).

The interviews were conducted to the key informants (Regional Councillors, CEOs, R&D, Vets, Microbiologist, Pharmacists, Buyers), within 18 different organizations, arranged as follow:

Developing setting

n. 2 Regional Governments

n. 4 research centres

n. 1 Regional AMR stewardship

n. 1 Vet Pharma Industry

n. 1 Pharma Industry

Producing setting

n.2 Large-scale meat producers

n. 1 Large-Scale organic meat producers

n. 2 Small-scale pig-meat producers

n. 3 Farmers

Using setting

n. 2 slaughterhouse and salami factories

n. 1 large-scale distribution

To gain data on global and country-specific animal antibiotic consumption and resistance patterns, reports by ESVAC, WHO and FAO were used. Published antibacterial studies and animal health studies were used to gain insight into the global animal antimicrobial/antibiotic resistance challenge, and social science and humanities scholars provided insight into the emergence of an antibiotic-dependent animal-based food production and use settings. Furthermore, participating observations were made during a workshop titled ‘Antibiotics and Resistance – Pig Meat Production and Consumption’ arranged by one of the authors at Uppsala University in May 2019, with the ambition to gather researchers’ and experts’ views on Swedish producing and using systems and their emergence.

Besides, participating observations was made at a workshop titled ‘Antibiotics & Resistance – Pig Meat Production & Consumption’ was arranged by the one of the authors, at Uppsala University/Uppsala Antibiotic Centre (UAC) in May 2019. Seven invited key notes presented different angles on this topic and was discussed by some 40 participants mainly representing academic research.

2.1.1. Research questions

So, the research questions related to this project are as follows:

RQ1

How has antibiotic consumption and awareness of antibiotic resistance affected the relationship between pig meat producers and export-oriented domestic wholesale and retail?

Is the adoption of a system of innovation inextricably linked to monetary dimensions and economic logics?

RQ2

How can the introduction of antibiotics in food production of animal origin be limited when, as Chandler (2019) argues, the role of antibiotics is not delimited and separable, in different and separable areas, in different areas for the economy, politics, man and nature?

RQ3

Can we expect consumers of antibiotics for animal food to engage in systemic change when it is not very clear whether others will ever be willing to share in the cost of change?

3. AMR case study

Antibiotic – from a 'magic bullet' to a 'magic wallet'

The first decades of the 21st century became something of a breakthrough for global policy attention to antibiotic resistance, captured in terms of, 'misuse' and 'overuse' of antibiotics for humans as well as animals, addressing also the need for access to antibiotics in low-income regions. For example, in May 2015 the World Health Assembly (WHO) endorsed a global action plan to tackle antibiotic resistance, appointed 'the most urgent drug resistance trend'. Similar messages were addressed by the tripartite alliance of the World Health Organization (WHO), the Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE) and the UN General Assembly.

Behind the contemporary resistance awareness at least seven decades of ignorance of it was hiding. Scientific knowledge about the intrinsic characteristics of bacteria mutation, giving rise to resistance, was articulated in parallel with the launch of antibiotics for humans and animals since the late 1940s, in both research publications and general media (Kirchhelle, 2018; Wise, 2007). However, the main conclusion drawn, by for example the UK Swann committee in the late 1960s, was that the resistance challenge could be dealt with as a matter of choice: antibiotics for production animals should not be those used in human medicine as this could compromise efficacy in man (Swann et al., 1969; Wise, 2007; Kirchhelle, 2018). Hence, although politicians in several countries noticed and acted upon knowledge about the resistance phenomenon, it ended up in, as Kirchhelle (2018) puts it, in 'a patchwork' of different policy approaches that did not hinder an increasing consumption of antibiotics in animal-based food production.

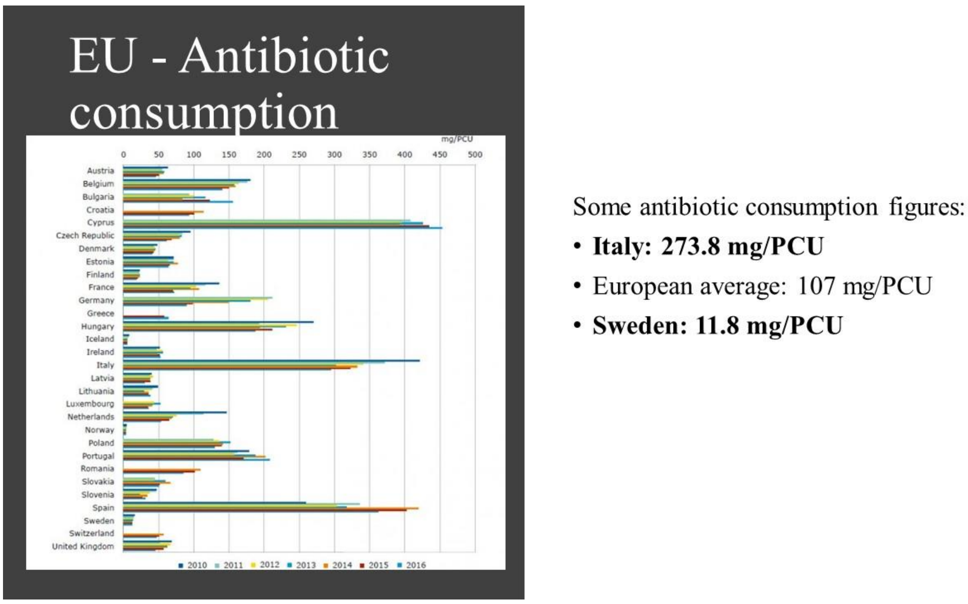
Hence, if antibiotics were labelled 'magic bullets' when they were first launched due to their assumed ability to attack specific microbes without harming a body at large, in perspective of production and use of animal-based food products they gained the role of 'magic wallets' – a fast track to increased value of a number of related resources in the producing and using settings. The distribution of cost and benefits related to routine group treatment of antibiotics, though, is complex. The acceleration of the resistance process and the progressive loss of drug efficacy partly harm the animal-based food businesses and the personnel, but above all it affects the health system and society at large. At the same time, there are a number of economic actors in both the producing setting, including suppliers of animal pharma, and in the wholesale/retail using setting that at least from a short-term economic perspective benefit from the regular antibiotic group treatment. ‘Precautionary’ routine group treatment allows an increased ‘density’ of animals at production sites, a shortening of the production cycle from birth to slaughter, and a reduced cost of staff. Hence, it compensates for investments contributing to animal health, that is in hygiene and precautionary infection control, in space as well as in education of personnel (Kirchhelle, 2018; Van Boeckel, et al., 2017; Lhermie et al., 2017; Finlay, 2004). Furthermore, it allows the supply of large volumes of low-price products to wholesalers and retailers, used to attract consumer streams (Cantillon and Håkansson, 2009; Finlay, 2004; Kirchhelle, 2018).

In the following section we take a closer look at the different role of antibiotics in Swedish and Italian pig meat-based food. Table 1 below gives an overview of the production structure of each setting and show that there are large differences also in other aspects; in terms of sows/per farm and slaughtered pigs/farm. However, despite the large differences in antibiotic consumption patterns, productivity in terms of slaughtered pigs/sow is about the same.

3.1. The Italian paradox: Made in Italy and AMR as usual

Italy is recognized as a global excellence in many sectors, among others for quality, tradition, culture and knowledge in food, however at the same time it is one of the worst countries to combat AMR. Italy is the country with the highest mortality rate (10,000 deaths/year) for antibiotic resistance (EFSA, 2018). The data on antibiotic consumption presented by ESVAC show that the intake of antibiotics in food production of Italian animal origin is about 20 times higher than in the Nordic European countries, despite the common EU regulation on the subject since 2006.

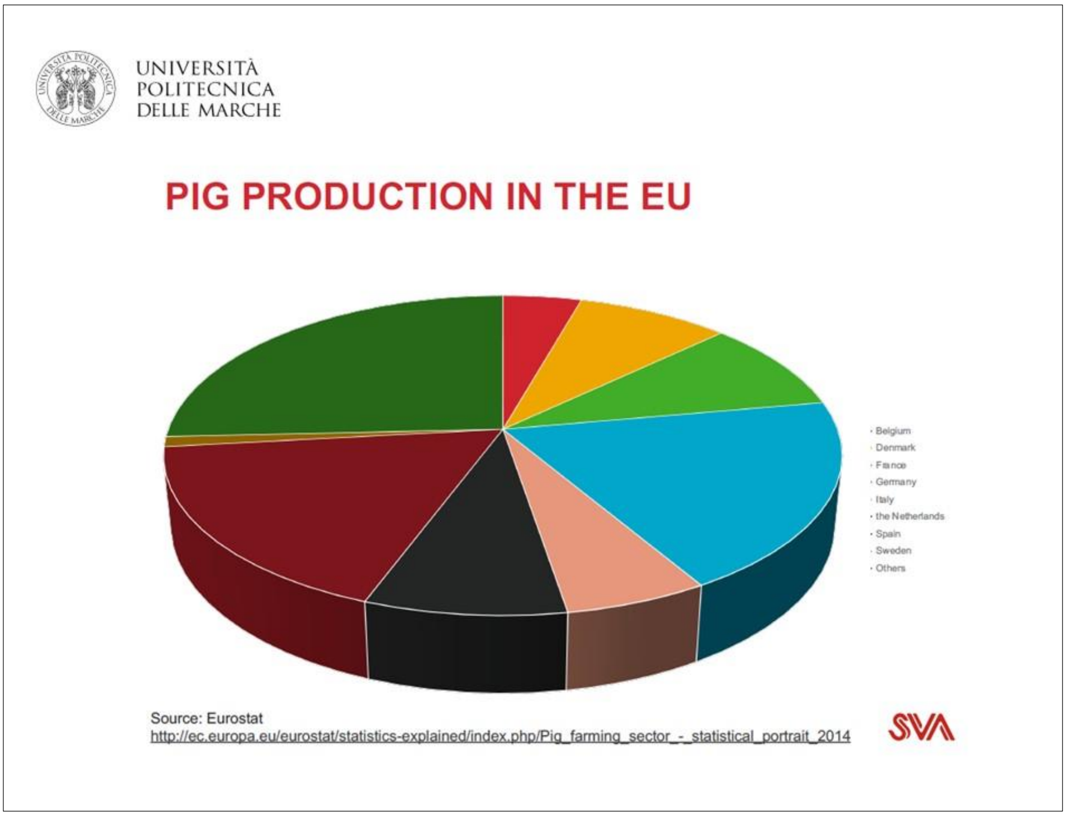
Figure 12 - ESVAC Report on EU Antibiotic Consumption



Source: author's elaboration based on ESVAC report 2019

'Italian food' benefits from being associated with such unique qualities that the origin in itself function as a kind of quality guarantee, in relation to both domestic and global customers (Ricci et al, 2018; Temperini et al, 2016). To protect specific original food products, and above all the 'Italian food' logo, is of greatest importance for business related to animal-based food production (Ricci et al, 2018; Temperini et al, 2016). Significant efforts are also undertaken, also by governmental bodies, to protect Italian original food products, with Parma ham as one of the most renowned. At national level, products with specific regional characteristics can be protected under logos such as "Qualità Alto Adige" (Ricci et al, 2018). On EU level food productions can be rewarded with the logos 'Protected Designation of Origin' (PDO) and 'Protected Geographical Indication' (PGI). The brand protecting efforts makes any attempt to change the use of antibiotics to a delicate issue; how will admitting that the contemporary use patterns have detrimental consequences for the efficacy of antibiotics, for human health and for the environment influence the brand?

Figure 13 - Pig Production in EU



Source: author's elaboration based on Eurostat – accessed Feb. 2022

Although the Italian production regime is much more heterogeneous than the Swedish, including a wide variety of size and modernity of farms, 'precautionary' routine group treatment with antibiotics is a common ingredient. The high consumption of antibiotics is accompanied with a high level of resistant bacteria in pig livestock. For example, about 34.9% of the Italian pig livestock are infected by LA-MRSA , while the Swedish Public

Health agency reports only a few cases of this antibiotic-resistant bacteria among Swedish production pigs.

However, also in the Italian setting there are forces mounting for decreased consumption of antibiotics in animals. First, the media have recently began directing attention to the phenomenon of antibiotic resistance, both in relation to humans and animals. For example, in the spring of 2019, the RAI television company's investigative journalism series 'Presadiretta' devoted a program to the Italian pig meat production system, to the high routine group treatment of animals with antibiotics, and how this is related to AMR. The program included a report from a Swedish pig farm, focusing on what measures are behind the restricted antibiotic consumption. More recently, the ongoing Covid-19 pandemic increased the media attention to AMR.

Second, pressure is coming from the EU, among others based on data presented in the ESVAC and EFSA reports, denouncing the challenging Italian AMR situation. The political sphere is also faced with the economic burden of AMR on the health system, pointing to the overuse of antibiotics in the animal-based food production system. Some response has also been achieved. However, it took until 2017, more than a decade after the EU ban on antibiotic as a growth promoter, before specific domestic regulations on antibiotics for animals were enacted. A ‘National Plan to Fight Antimicrobial Resistance’ (PNCAR 17-20) was issued, to be followed by a mandatory requirement on veterinary electronic prescriptions of antibiotics in 2018. Furthermore, on February 11, 2020, four parliamentary motions were approved unanimously, brought to the court by the Social Affairs and Health Committee. These guidelines like approvals aim to increase investments in public research, in public health and in food control, and in monitoring the use of antibiotics in animal-based food production. Still, none of these regulations include an imperative legislation hindering the use of antibiotics as ‘prophylaxis therapy’.

AMR as usual: an antibiotic-based production system

Opposite of Swedish production, the Italian one is characterised by intense trading and transporting of live animals. Most Italian pig farms practice so-called ‘open cycle’, where pigs from birth until they’re ready to be slaughtered (160kg) are bred in a system where different farms specialise in different stages of the production cycle; that is on different ages of the piglets.

Table 1. Swedish and Italian Consumption of antibiotics for animals’ production figures related to pork based food (2017).

	SWEDEN	**ITALY**
Antibiotic consumption mg/PCU	*11.8*	*273.8*
Pig production, slaughtered pigs	2.5 million/year	11.4 million/year
Pig production farms	1.272	26.582
Import of pig meat	Import 27% 116.000 tons	Import 37,3% 1.059.840 tons
Export of pig meat based food	-	413.440 tons
Sows	120.000	561.640
Sows/farm	173	53
Slaughter pigs/farm	823	407
Slaughtered pigs	116.000 tons	1.484.515 tons
Pigs/sow/year	26.7	18.4
Pigs/sow/litter	14.3	13.9
Slaughtered pigs/sow/year[2]	*26*	*26.43*

[2] Interpig 2018

The production of piglets in general takes place on specialised farms. It's a common practice to put the sow within narrow cages before and after farrowing, on average 123 days per years. The piglets remain with the sow until the end of the weaning phase, that is until they reach the weight of about 30/40 kg. This implies that after 3 weeks, the piglets can be moved away from the sow, transported and mixed with other piglets at another type of farm, specialising in the subsequent phase of skinning and fattening. Moving piglets at such an early stage includes at least two types of health consequences.

First, when the weaned piglets are mixed with others they have not been in contact with at the farm where they are born, they react with stress and aggressive behaviours. They get scratches on their bodies, increasing the risk of infection. They bite others' tails, which is the reason for systematic tail docking, and often also sanding of the teeth. This is a painful experience that increases stress and weakens the immune system of the animals.

Second, the transporting and mixing of piglets from farm to farm increases the spread of infections. Although some farms have adopted the all-in all-out system and practice a total disinfection of the stable whenever a batch of pigs is moved, the transportation and mixing increases the risk of infection. To reduce the risks of diseases, so-called antibiotic prophylaxis is most often applied.

Despite European legislation, it is common that pigs and piglets do not have access to straw or similar material. The same legislation also provides that animals should have a place to lie down and one to defecate. However, it is common that boxes have no such separate places. The health conditions of the pigs are further affected by the following conditions: during hot seasons stables often reach high levels of humidity (up to 80%) and temperature (30°-35°), (levels far higher than those indicated by the ministry's guideline), increasing pigs' levels of aggression and weakening their immune system, affecting the animals' adipose organ.

Although all treatments with antibiotics or other drugs have to be made on veterinary electronic prescriptions and each animal has to be tracked into a sort of medical journal, routine group treatments are accepted as a prophylactic health measure. The large pig meat producers usually employ the veterinarian, while smaller producers use private veterinarian services. Large pig meat producers (>500 sows) are obliged to carry out self-monitoring concerning purchasing of antibiotics. The data is monitored by local health offices, so in case of anomalies they carry out targeted inspections and report to the Ministry of Health. However, publicly organised inspections at production sites are restricted, and also the consequences of disrespecting animal health regulations. The acceptance of prophylactic use of antibiotics is still high.

Restricted user reactions

Over recent years, the wholesale and retail settings have started to pay attention to the way antibiotics are used in animal-based food production. In the spring of 2017, Coop-Italia became the first actor in the retail setting to declare support for animal welfare in food production, including the reduction of antibiotics. The campaign included demands on a progressive reduction of antibiotics on farms in order to combat resistance. Coop-Italia's initiative created a ripple-effect and several other wholesale and retail companies adopted similar policies. However, a common denominator of those initiatives was their 'marketing experiment- like' character, resting on the understanding that the general social awareness of AMR is poor and widely underestimated. This implies that, so far wholesalers and retailers have not expressed any mandatory requirements on the pig meat food producers.

The basic requirements on antibiotics for animals in the Italian respectively Swedish system respectively the basic characteristics of the producing systems are summarised in two tables below.

3.1.1. The Swedish case: lessons learnt by pioneers

Although the Swedish minimised use of antibiotics is lifted forward as a successful case in policy circles and by researchers (EPHA/Nunan, 2022;

WEF, 2013; Kirchelle, 2018; Begemann et al, 2018) it also has a dark side; at least for those who initiated and invested most in the change (Waluszewski et al, 2021). It was some pioneering pig-meat farmers' and the farmers' association engaged in getting rid of routine use of antibiotics already in the early 1980s. Eventually, they could not only experience a successful systemic change able to compensate for group treatment of animals with antibiotics, but also that there is no guarantee that those who carries the main cost of change also will be economically rewarded (Waluszewski et al, 2021). When Sweden entered EU in 1995, the state protected agriculture was replaced by opened borders, followed by an influx of cheap pig meat-based products from antibiotic dependent production systems. Almost half of the domestic pig meat-based production volume was lost, and basically all small and medium size producers were forced to close down (Waluszewski, 2022). With these experiences at hand, it is easy to understand those users of antibiotics for animals that are aware of the need to change but claims that they are scared of the burden the Swedish farmers had to face. Or as asked by Kirchhelle, (2018), 'why should farmers accept being put at a disadvantage', which will be the case if the cost of change cannot be shared by others.

When the engagement against routine use of antibiotics took off in the early 1980s, Sweden was not yet part of the EU, agriculture was protected and the farmers' cooperation dominated owners of a number of companies related to the industry; that is of feed suppliers, slaughters and processing firms, and equipment suppliers. Behind the engagement in working out a production system that could compensate for routine group treatment of animals with antibiotics, at least three types of forces can be outlined:

First, there was an intense media debate on welfare for production animals and the role of chemicals within agriculture. The author Barbro Soller had already published a book in 1971 whose title can be translated to The Animal Factory and can be considered as a Swedish contribution to the international debate following Ruth Harrison's bestseller Animal Machines, published in 1964. In 1981 one of the largest Swedish newspapers, Dagens Nyheter, through a series by journalist Thomas Michelsen, drew attention to the role of chemicals in animal-based food production in general, antibiotics included. Michelsen also published a book on the same theme, with the translated title, Mass food, Swedish agriculture in the age of chemicals . Although the main media attention was directed to the role of chemicals in animal feed and to the lack of animal welfare, the fact that about 30 tons of antibiotics per year was given to food animals was debated.

Second, the role of chemicals in general and antibiotics was also considered by individual farmers engaged in pig meat production.

Antibiotics were a regular ingredient in purchased feed, and several farmers worried about the long-term consequences. Some started experimenting with excluding routine treatments with antibiotics – and had to pay a higher price for antibiotic-free feed. Through contacts on individual levels, researchers at the Swedish National Veterinary Institute contributed their advice. The engagement was mainly driven by environmental concerns. As one of the pioneers in the engagement of excluding routine group treatment expressed his worries: "What happens with the soil in the long run, when manure from pigs fed with antibiotics is spread out on it?" The same farmer brought up the issue to debate in the Swine Farming Association. In 1984 a bill was presented to the Swedish Farmers' Association, suggesting the organisation mount a ban of AGP.

Third, the routine input of antibiotics was also questioned by some managers within the Swedish Farmers' Association, mainly motivated by a serious worry of losing consumers' trust in animal-based food, as a result of the intense media debate on animal welfare and use of chemicals and drugs. After having the issue on the agenda since 1981, and after being approached with the suggestion of a ban in 1984, the Swedish Farmers' Association decided to approach the Swedish Government. A suggestion for a new law was presented, banning antibiotics growth promoter, that is forbidding routine treatment of groups of animals through feed or drinking water. There also was a close connection between the Swedish Farmers' Association and the Centre Party, formerly the Farmers' Party, which supported the bill. The bill also received support from the Social Democrats.

However, the ban suggestion also met resistance. The strongest argument against it was presented by representatives of the pharmaceutical industry, addressed directly to pioneering farmers, representatives of the Farmers' Association and the Centre Party. There were also individual farmers and individual veterinarians who were negative fearing both problems with infections and increasing production costs. On the political side, the Right-Wing party argued that the law was not necessary since the output, the food products, did not include any antibiotic residuals.

Eventually, the engagement by individual farmers and by the Farmers' Association, spurred by the media debate, resulted in the Parliament passing the bill. As the first country in the world, Sweden, in 1986 gained a new law banning the use of AGPs, that is routine treatment with antibiotics in feed and water without veterinary prescription (SFS 1985:295). From then onwards antibiotics were only allowed by veterinary prescription for treatment of medical diseases. The Centre Party also suggested that the same ban should be applied to import meat – a requirement that was turned down by the Parliament.

The ban did reveal what the routine treatment of antibiotics had covered up. During the first decade after the ban, pig meat producers and their veterinarians had to cope with diseases and a higher mortality among piglets, both in the suckling and weaning period. However, the total consumption of antibiotics did decrease, from 46 mg/pcu two years before the ban of growth promoters, to 31 mg/pcu in 1990, although group treatment increased. From 1995 forward group treatment has been constantly decreasing, today representing about 10% of the total consumption of antibiotics.

A new production system

Behind this development a systematic development process can be outlined, with disease prevention and biosecurity as key ingredients. Basically, all activities from insemination to slaughter were scrutinised, and a new batch-based production system was introduced, including a new stable design based on specific sections for each stage of the breeding process. New hygiene routines were established, new types of feed were developed along with vaccines and other precautionary measures. Although no farm is exactly like another, some common denominators can be outlined:

Sows are free ranged in groups until about a week before litter. Then the sow is moved to her own box, where she can still move freely and pursue her building instinct. After littering, the sow and the piglets stay in the box 4-6 weeks. For the piglets, the weaning period is the most critical in terms of health, and the earlier the weaning, the higher the risk for infections such as diarrhoea, and for the need for treatment with antibiotics. Weaning is not allowed to take place until 90% of the piglets are more than 26 days old. After the weaning period, first the sow is moved out of the box while the piglets stay for some weeks more, in order to not be exposed to a new environment during this sensitive period. Then the piglets are moved to larger boxes at the same farm, for growing and fattening periods. When they are 6-7 months and weigh about 100 kilos they are slaughtered. Tail docking is not practiced, and tail biting is rarely observed (EU legislation forbids tail docking, but due to generous exceptions it is practiced in many production regimes). After each movement of animals, boxes are totally cleaned, and in between the boxes are mucked regularly, which is labour intensive since they are covered with straw. Before any new animal is brought into the herd it must spend some weeks in quarantine. No visitors are allowed to enter the stable without permission and then only with protective clothes and shoes. The transporters, moving animals from stable to slaughter, are no longer allowed entrance into the stable.

All treatment with antibiotics or other drugs requires veterinary prescriptions, and each animal must have its own medical journal. The

Swedish Board of Agriculture is the owner and organiser of the ‘District Veterinaries.’ This implies that the veterinaries are state employed. The District Veterinaries guarantee access to veterinaries over the whole country around the clock and are also a state operative resource in case of outbreaks of infectious diseases. Besides the District Veterinaries, the consultancy company ‘Farm and Animal Health’ (Gårds och Djurhälsan), owned by the Swedish Meat Producers’ Association, Swedish Pig Farmers’ Association, Swedish Beef Producers’ Association, and Swedish Sheep Breeders’ Association provide advice and knowledge dissemination on animal health and production economy.

A significant number of actors contributed to develop this ‘system innovation’, compensating for antibiotic as growth promoters and routine treatment with antibiotics; farmers, farmers’ cooperative organisations, veterinaries, researchers engaged in different aspects of animal health, slaughters, transporters, equipment suppliers, feed suppliers, suppliers of vaccine, etc.

After three decades – supporting user reactions

The expectation expressed by the pioneers, that the new production regime should represent a ‘market advantage’, however, proved to be a rough overestimation. The expected positive reaction from the user side, that is the wholesale and retail industry, as well as private and public consumers, disappeared. The situation escalated when Sweden became an EU member in 1995. The borders opened up for an influx of pig meat-based food products produced in systems relying on significant higher consumption of antibiotics, lower production costs and 20-30 % lower consumer prices. The Swedish production fell from about 4 million pigs before the EU entrance – to stabilize on about 2.6 million animals per year since then. Behind these figures a dramatic restructuring of pig farms is hiding; basically, all small and medium size producers closed down their activities, and the remaining larger producers increased the herd size and production volume.

It was not until around 2013-2014; in relation to the EU election, when media paid attention to the high consumption of antibiotics in the EU pig meatbased food production in general, and especially to the Danish situation; affected by some severe outbreaks of MRSA, that a general attention was directed to what actually had been achieved in the Swedish producing setting. In May 2014, just before the EU election, a Swedish ICA Hypermarket declared that Danish pig meat would be excluded from the assortment. The main argument was lack of animal welfare, and that the animals were given antibiotics as a precautionary measure, promoting antibiotic resistance. Instead, this hypermarket would only market pig meat produced in a system where antibiotics were used to treat sick animals by veterinary prescription; that is, without routine group treatment.

The action from the individual ICA Hypermarket created a lot of media attention and was soon followed up with new policies on animal welfare and antibiotics, by the three largest Swedish wholesalers: the private ICA and Axfood and the cooperative Coop. ICA declared that all suppliers, not only suppliers of its own brand products, had to fulfil the following requirements: “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.” Similar policies were presented by Coop , Axfood and the Swedish Wholesaler Association .

The most significant change was the branding ‘Swedish meat’, including consumer information about the restricted Swedish consumption of antibiotics used only as medical treatment due to veterinary prescription. Despite that the consumer price for Swedish pig meat was about 0.2-0.3 Euro higher per kilo compared to the EU average, the consumption pattern changed. As one pig meat producer expresses it:

“The growing antibiotic resistance awareness is the best thing that happened to us. At last we are compensated for all the work we have done to get rid of antibiotics.”

Table 2: Basic antibiotic requirements and resistance levels

	SWEDEN	ITALY
AGP	Forbidden since 1986	Forbidden (EU reg.) since 2006
Individual treatment	90%	10%
Main antibiotic classes sold	Penicillin	Tetracycline (32%), Penicillin (24%),
LA-MRSA in slaughter pig herds	LA-MRSA free[3]	34.9%
ESBL in slaughter pig herds	Occasionally, a few cases reported	17.6%
Salmonella	Salmonella Free	9.64% source EFSA (sample 716 units tested)[4] 5.3% source OFFICIAL NATIONAL CONTROLS (sample 5.641 pig carcasses) 1.6% SELF-MONITORING (sample 14.368 pig carcasses)

[3] 'The latest screening of pigs in Sweden was in a nucleus and multiplying pig herds in 2014. MRSA was not detected, indicating a favourable situation.' (Swedres-Swarm, 2018, p. 96)

[4]'The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2017' (EFSA & ECDC, 2018). This data has been elaborated from the tables in appendix, related to that report. However, it has emerged that the related sample is very small, just 716 units tested.

Table 3: Basic requirements

REQUIREMENTS	SWEDEN	ITALY
'All in, all out' /batch prod	Batch production, breeding and fattening (close cycle) most common.	High heterogeneity: Two types of systems: 1) Most common: Open system. Breeding and fattening at specialised farms. Often batch wise. 2) Breeding and fattening (close cycle), less adapted to batch production.
Space, m2/sow with piglets	6 m2	4.6 m2
Lactation period	28 days	21 days in opens systems. 28 days in closed systems.
Tail docking	Forbidden	Common practice (up to 90%)[5]

[5] https://www.theguardian.com/environment/2019/jan/19/curse-tail-docking-painful-truth-italy-pigs

		Allowed if there are substantiated and proven needs.
Fixation of sow	Forbidden	About 123 days/year, common practice. EU allows sow fixation 150-170 days/year.
Slatted floor	Forbidden	Allowed, with specific features for materials and width of slots.
Bedding material, e.g. straw	Required	Required a place suitable to rest, dry and cleaned. Required bedding material only for piglets.

However, for the pig meat producers the engagement in the development of a production regime compensating for antibiotics did not become the commercial success that was expected. Before the EU entrance, both pig meat producers and Farmers Association had expected that the very restricted input of antibiotics should be a strong quality parameter. On the user side, low production costs, providing low prices, was a main target. After the EU entrance pig meat-based products from antibiotic-based production system was flowing in – and the wholesale and retail industry did not do any special activities to explain why the consumers had to pay about 0.2-0.3 Euro per kilo more compared to the average price of pig meat imported from Europe. The Swedish pig meat production fell radically, from about 4 to 2.6 million pigs per year. Basically, all small and medium size production units had to close down.

It took around 30 years, until the high level of input of antibiotics, the high level of MRSA in the Danish pig herds, and animal welfare, including cutting of tails practiced in Denmark, got attention in general media, that the 'Swedish way' got attention on the user side. An individual retailer excluded Danish pig meat and did instead start to inform the consumers about the restricted use of antibiotics in the Swedish producing setting. The retailer's engagement was reported in media, something that forced the three dominating wholesale companies to react. Privately owned ICA and Axfood and Coop did all develop new guidelines for its own animal-based brands. The common requirement was that antibiotics should be used only to treat sick animals – not to compensate for lack of biosecurity and space. Following 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.”

The Swedish production regime was made visible through a new label ‘Swedish meat’, including information about the role of antibiotics in the production.

“The public awareness of antibiotic resistance is the best thing that happened for Swedish pig farmers. Suddenly those of us that still are in business are getting payed for the efforts made. (Swedish pig farmer, October 2018)

“The situation in Sweden regarding antibiotic resistance in bacteria in humans and animals is still favourable from

an international perspective. This confirms that our strategies to promote the rational use of antibiotics and to limit the spread of antibiotic resistance are effective."

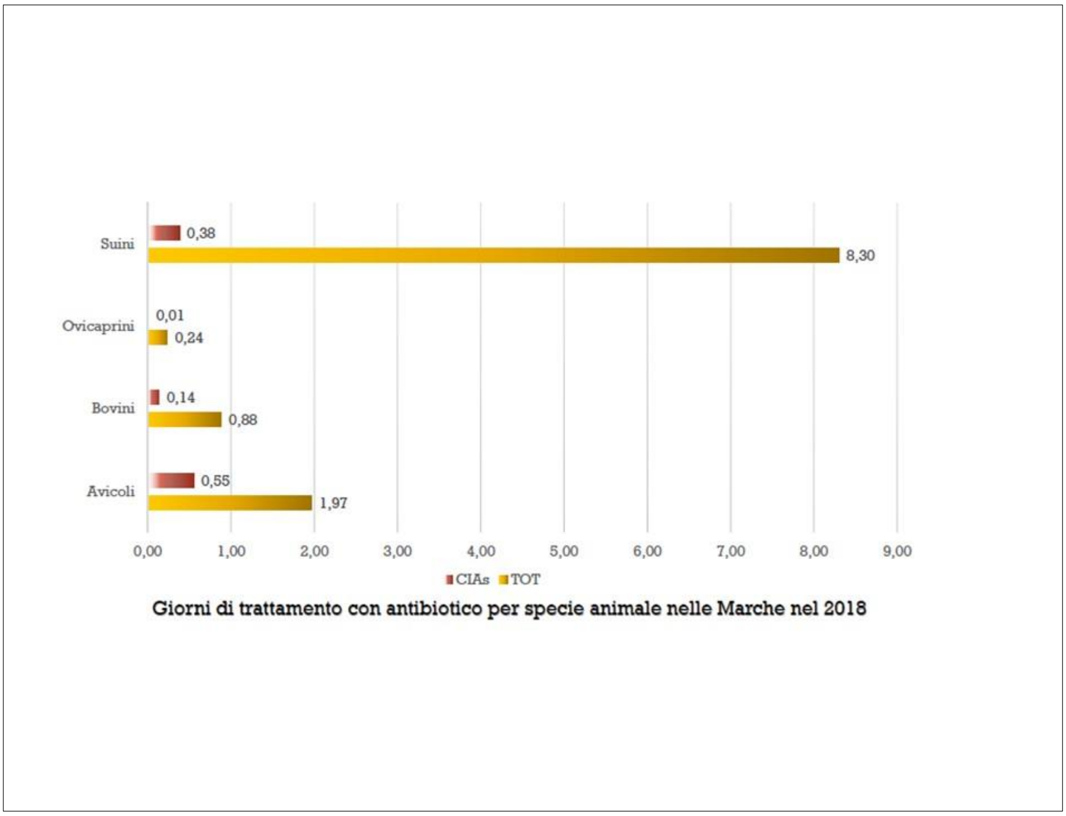
(Swedres-Swarn 2018)

3.1.2. Focus on the Marche Region: starting from the middle

After the presentation of the Italian and Swedish cases studies we would now focus on the starting point of our research with the Italian Marche Region case.

The relevance and particular configuration of this case, representing the starting point of our research, actually, came out, after had finished and scrutinized the entire work.

Figure 14 - Day of Antibiotics treatments in animal-food industry of Marche Region



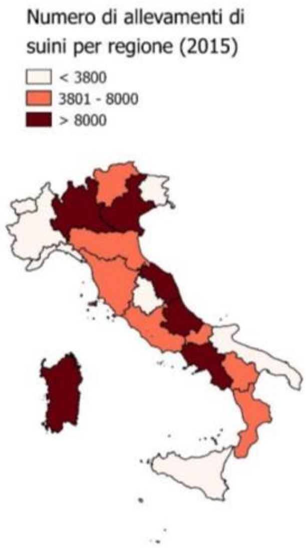
Source: author's elaboration based on IZSUM report – accessed Jan. 2020.

In the Italian Marche Region, the antibiotic as value resource in animal-based food was introduced at the end of 1940s and early 1950s, as it provided an ability to treat infection diseases with devastating economic and animal health consequences.

Tuberculosis and anthrax were no more infection diseases that threatened the whole farms. The consequences of antibiotics were however not only that bacterial infections were stopped, but also the growth of the animals increased significantly, affecting directly the animal intestinal bacterial flora. Antibiotics became a part of the production routine, both in Western and Eastern economies. For pigs it also meant a shortened production cycle: the weening period could be shortened, and the sow could faster get into production again.

Figure 15 - Consistency of livestocks of italian regions

ALLEVAMENTI SUINI PER REGIONI			
Regioni	2013	2014	2015
Piemonte	2.915	2.952	2.983
Valle d'Aosta	52	54	58
Lombardia	8.646	8.820	8.810
Trentino-Alto Adige	5.183	5.488	5.666
Veneto	9.249	9.150	9.201
Friuli Venezia Giulia	1.925	2.042	2.134
Liguria	528	578	600
Emilia Romagna	4.900	4.757	4.224
Toscana	7.300	7.312	7.158
Umbria	3.267	3.464	3.612
Marche	**14.794**	**14.449**	**14.529**
Lazio	4.940	5.131	5.281
Abruzzo	14.335	14.847	15.394
Molise	5.149	5.359	5.527
Campania	26.503	25.026	20.098
Puglia	947	983	1.002
Basilicata	6.873	7.248	7.411
Calabria	7.151	7.326	7.150
Sicilia	1.656	1.669	1.701
Sardegna	17.721	17.556	17.646
Totale	144.034	144.211	140.185



Source: author's elaboration based on Istat – accessed Feb. 2020

The drawback was the routine use drove antibiotic resistant bacteria – spreading also to humans. Below we will take a closer look at how the role of antibiotics and AMR has been dealt with in two different settings; the Italian where the main resistant bacteria as MRSA and ESBL is present in a majority of the pig livestock. In Sweden the pig livestock is reported MRSA free, while only a few cases of ESBL have been reported. However, there are also other difference among these two contexts, while Sweden is mainly producing for domestic use, the Italian production is export oriented.

2017	ITALY	SWEDEN
Antibiotics Mg/PCU	273.8	11.8
LA-MRSA in slaughter pig herds	34,9%	LA-MRSA free[6]
ESBL in slaughter pig herds	17,6%	Only a few cases reported.
Pig farms	26 582	1 272
Sows	561 640	120 000
Sows/farm	53	173

[6] 'The latest screening of pigs in Sweden was in nucleus and multiplying pig herds in 2014. MRSA was not detected, indicating a favourable situation.' (Swedres-Swarm, 2018, p. 96)

Slaughter pigs/farm	407	823
Slaughtered pigs	11.4 million	2.5 million
Meat production	1 460 000 ton	241 000 ton
Import/Export	Import 37,3% 1 059 840 ton	Import 27% 116 000 tons

Table 1. Basic figures of the Italian and Swedish producing setting

First stages: between 50s and 70s

The first main change about the use of antibiotics concerned the producing setting and came out from the early 50s. During this stage, it was introduced a new breed import from England, the famous “large white” breed. The motivations that drove this trend, started in the North of Italy and then spread in the Marche Region too, were exclusively an economic issue. The large white breed is more prolific and fertile and develops capability adaptation to live in tight space. However, it tends to get sick easier and to suffer cold temperature. In the same years, the antibiotics treatments in the animal food industry became a normal trend, due initially to respond to the needs of the new breed and then to the value-added that it gave to the industry. Antibiotics allowed to cure and take care of the animals without the need for heavy investments in hygiene, feed, space and health. Furthermore, antibiotics increased the growth of the animals and shortened the production cycle from birth to slaughter. Next to this, the chemical-pharmaceutical industry initiated the commercialization of both antibiotics and fertilizers. In this period no limitation regarding the use of antibiotics was introduced. In 1969 was established the Free University of Ancona (Capital City of Marche Region), with the creation of the Faculty of Engineering and the Faculty of Medicine and Surgery and the merge with the already existing Faculty of Economics (1959). As consequence of the growing economic development, agriculture as well as livestock farming in Marche region boomed, with about 69.760 farms, herding on average 5,2 pigs per farm, in 1970, following about the general Italy's growth trend (924.819 farms, herding on average 3,6 pigs per farm).

From 70s to early 2000s

Since the beginning of 70s the industrialization of the whole agri-food sector begun together with the presence of a more intensive production system: the result was a higher concentration of the number of pigs per farm with a reduction of the number of the total farms (see Appendix, Figure 1-Livestock Evolution in the Marche Region). Meantime, in the same years the first wholesale and retail industries were established.

The small family livestock was excluded from this kind of distribution channel, that required high volumes of product, high standardization, and low contributing margin to the suppliers, constrained them to produce in large scale to decrease the productions' costs. Marche followed an international trend, where routine treatment with antibiotics was established as prerequisite for the supply of large volumes of low-price products. Cheap meat products were targeted as major business by the wholesale and retail industry to attract consumer streams (Kircheelle, 2018; Finlay, 2004).

At national level, in 1970 were established the Experimental Zoo-prophylactic Institutes that represented an operational tool linked to the National Health Service with tasks of epidemiological surveillance, experimental research, staff training, laboratory support and diagnostics in the context of official food control. It was then organized in subsidiaries at macroregional level. In the Marche Region was established one subsidiary, named Experimental Zoo-prophylactic Institute of the Umbria and Marche Regions (IZSUM), since the early 2000s. Beside that during the academic year 1988-89 the Faculty of Agriculture was founded (degree in Agricultural

Sciences), as well as the Faculty of Mathematics, Physics and Natural Sciences with a degree course in general biology.

Third stage 2000-2020

The last two decades have been characterized by higher attention to the phenomenon of AMR. The first signals of change have been found in the developing setting: for instance, some public research centre started to receive more recognitions on their studies based on the phenomenon of the antimicrobial resistance. An important boost came from the internationalisation of the research carried out at the University of Ancona (Faculty of Applied Sciences), and it was fundamental the connection between that Faculty with the Department of Microbiology and Virology of the Norwegian University of Tromsø. Those studies gained several interesting results, presented in scientific publications in international journals. Moreover, in the same period, new collaborations between the University of Ancona (whose denomination changed to Università Politecnica delle Marche – UNIVPM – in 2003) and other organizations such as the Experimental Zoo-prophylactic Institute of the Umbria and Marche Regions (IZSUM) were established.

Meantime the Faculty of Agricultural studies reached important results in respect with the launch of applied research in collaboration on AMR with big local animal-based food companies. An informal structure and a natural and collaborative division of tasks have therefore been created: IZSUM institute and the Faculty of Applied Science specialized to sampling and data analysis, begun to collaborate with the Faculty of Agricultural studies, specialized to qualitative and quantitative research on the field in collaboration with local companies.

The central government of the Marche Region started to promote research projects focused on the antimicrobial resistance and animal welfare with the goal to make bridges between academic research and local companies. Nevertheless, the actions of the regional government on AMR have been increasing exponentially since the last 4 years. The attention of the Marche Region on AMR issue has been an incremental and top-down path; from the international level down to the national level and finally, it reached the regional level in 2016. Then it continued to develop in tow, under the pressure and stimuli received at national level on one side and under the push from the public research centres on the other side. These types of projects were also reinforced when the European Parliament – in 2006 – established the ban toward the use of antibiotics.

Hence, in 2015 the Health National Service commissioned the Experimental Zoo-prophylactic Institutes to monitor the antimicrobial resistance at the regional level. So, in the same year, IZSUM institute, (directly control by the national government), began to control the consumption of antibiotics and antimicrobial resistance in the Marche Region animal-based food industry.

Meantime, the Marche Region administration implemented the first action to reduce and control the consumption of antibiotics in the animal field starting with an experimental stage of the use of veterinary electronic prescription in 2016, (this was then turned in a specific regulation in 2019).

In 2017, the Italian government issued the National Plan to Contrast the Antimicrobial Resistance (PNCAR, 2017-2020) received and implemented by the Marche Region in 2018 when the AMR stewardship of the Marche Region was created. The AMR stewardship represents a multidisciplinary team, composed by doctors, veterinaries and managers, appointed to contrast the misuse and overuse of antibiotic with the One-Health approach, either in animal or human field. Lastly, the Italian Parliament too showed a higher interest on AMR when – in February 2020 – a Professor of Pharmacology from the University "Federico II" of Naples gave a speech on this topic at the Chamber of Italian Deputies: this fact triggered the attention of the Italian media attention and right after a documentary on the abuse of antibiotics in livestock called “Malati di farmaci” (“Sick by drugs”) was broadcasted.

Figure 16 - Mapping the Antibiotic Network in the Marche Region

Source: author’s elaboration

SUMMING UP: CHANGES IN THE ITALIAN/MARCHE DEVELOPING SETTING – BUT INCREASING CONSUMPTION OF ANTIBIOTICS IN THE PRODUCING SETTING

There is an ongoing debate in Marche Region concerning the trend in the consumption of antibiotics. According to the Veterinary manager in charge of AMR stewardship of the Marche Region the consumption is decreasing whereas the IZSUM shows that between 2015 and 2018 the total consumption of antibiotics increased by a certain rate. One reason of this controversial result is that assessing the consumption in terms of DDD and analysing it by the category of animals emerge that the requirement for pig is increased while the consumptions of other animal species is decreasing.

> *"The problem of a so high data of consumptions is due to pig micro-enterprises. They don't have the power to distribute their products, they have high costs of productions and low contribution margin, and they haven't financial resources to innovate their production system" (Veterinary Manager, Italian pig farm, interview March 2020).*

In the producing setting, the small livestock reduction went on till nowadays. Total farms with pigs now are 14.529 farms, organized in 2.134 companies, with a notable increase of pigs per farm (112,5 pigs per farm). To hindering the haemorrhage of small livestock in 2001 is born a consortium of pig-meat producers (it is built on about 400 farms) that commercialise products with own unified brand. In 2019 this organization started to collaborate with UNIVPM in three different projects: 1. Swine Antibiotic Free (SAF) 2. Regeneration of an ancient local swine's breed (RE.SU.MA.). The projects are funded in cooperation by European Regional Development Fund, the Marche Region and UNIVPM. The network of collaborations was extended across the regional border, to a private Animal Production Research Centre (C.R.P.A.), from Emilia Romagna Region. The aims of the projects are:

a) the setup of the "Guideline for the preparation of a technical specification for the certification of conformity of an antibiotic-free product";

b) the collection of breeding data;

c) collecting qualitative index at the slaughterhouse;

d) sensory quality of meat (panel test);

e) consumer acceptability indication (consumer test);

f) publication of research results.

On the other hand, the other main player of animal-based food production in the Marche Region, in 2002, decided to turn the production into organic-farm, to achieve a market niche and increase the market share. To achieve this objective, the company made a vertical integration, to control all the supply chain downstream, from the feed to the semi-finished product. However, only in the last few years (2017), the company addressed the issue of antimicrobial resistance, and in two years they reduced about 50% of consumptions of antibiotics. This transition required huge efforts in particular for innovating the machinery.

From the retailer business perspective, in Marche Region some collaborations have been developed since 2010 mostly together with the regional Universities. For instance, through the creation of dedicated University spin-off named Alpha-lab – which is the result of a tight collaboration between UNIVPM and Alpha – scientific initiatives such as research pilot projects aimed to understand how to increase the welfare of animals have been launched. Alpha – which represents the biggest retail company of the region – has confirmed the interest in the field of the antimicrobial resistance. According to the company's purchasing manager one big issue is represented by the lack of willingness of pig producers to modify their production systems:

> *"The resistance to change, it's more a cultural issue than an economics issue. Because we'd be willing to recognize a premium price to have better products, antibiotic-free." (March 2020).*

The Marche Region case discussion

We just acknowledge the first difficult of the case study was to contain the case within the regional border, when the network of several actors, especially on the producing setting overcoming the border. However, after that we enlarge our study, and then we come back to the beginning, because of two findings:

1. The Marche Region is the broadest organic food producer in Europe (Girolomoni, Expò 2020, Dubai[7]) and that is positive affecting the reductions of AMR. The changing seems to be drive by one of the

[7] Girolomoni, Expò 2020, Dubai, https://www.ansa.it/marche/notizie/2022/02/21/expo-dubai-distretto-bio-marche-si-presenta-come-modello-unico_c8d151ad-477d-4790-a2b6-7f7dca225ef2.html, last retrived Feb. 2022

private companies interviewed, pioneer in Italy in the organic food sector.

2. However, the Marche Region starting point about AMR, are very high compared to the volume of the production, due to several reason:
   A constellation of micro-firms, often linked with Big Producers (by agistment contract), is difficult to control by authorities, has lack of competences and resources to innovate.

So, we could provide some line of discussion in relation to our research questions. That is, 1) reflections on how the consumption of antibiotics, and more recently, the awareness of resistance, have affected the relation between pig meat producers in the Italian Marche region and domestic and export-oriented wholesale and the retailing industry, and 2) due to the experiences made in the Swedish regions, what changes have to be made in order to reach a significant decrease in the input of antibiotics?

1) First and foremost, in the Italian Marche case, the awareness of the effects of AMR comes out as a reaction of the regulations imposed by the institutions, from EU down to the local regional governments. It is a sort of top-down mechanism. However, although the top-down spread has made impact in the developing setting and attracted research attention and

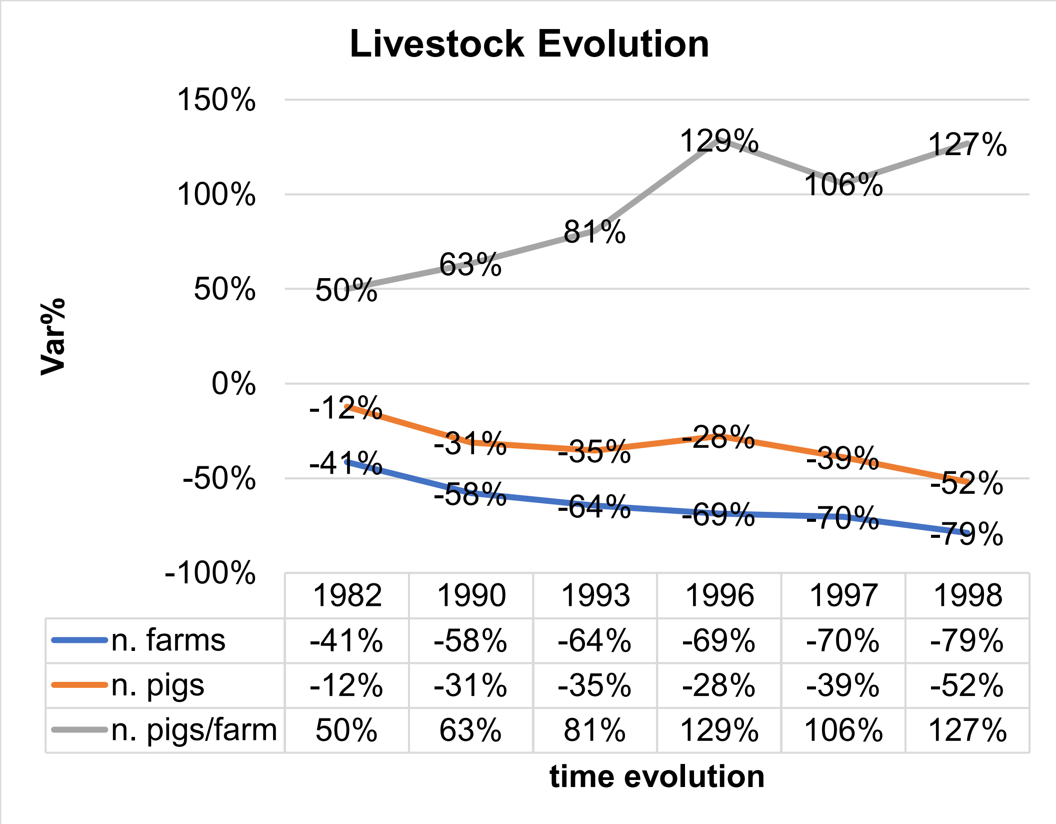
triggered research projects, it seems not have trickled down to the producing setting. The 2006 EU regulation have not made any visible imprints in terms of decreasing input of antibiotics in the Italian/Marche production regimes.

The Swedish history reveals a totally different pattern. The ambition to reduce the input of antibiotics came from individual farmers, that managed to mobilize Farmers Association and eventually politicians. The Swedish engagement did also have a significant impact in the establishment of the 2006 EU ban.

3) So far, the attention to antibiotic resistance is an issue among researchers. It the Italian/Marche producing regime is going the be transformed to a system using antibiotic only as a veterinary medical resource; that is to treat individual sick animals due to veterinary prescription, a systematic development of the production regime has to be undertaken. The challenge is not lack of knowledge among researchers and veterinary expertise, but a motivation in the producing and using setting. To decrease the input of antibiotics the production regime has to be systematically reviewed, and each step

in the production cycle has to be reconsidered. The density on production sites probably has to be decreased, and the investments in biosecurity has to increase – something that will increase production costs. For a change in the Italian production regime to occur, not only the main actors in the producing setting have to be mobilized, but also in the using setting – if the costs are not only going to affect the producers.

Figure 17 - Livestock Evolution in the Marche Region



	1982	1990	1993	1996	1997	1998
n. farms	-41%	-58%	-64%	-69%	-70%	-79%
n. pigs	-12%	-31%	-35%	-28%	-39%	-52%
n. pigs/farm	50%	63%	81%	129%	106%	127%

Source: own elaboration based on V° general agricultural census ISTAT.

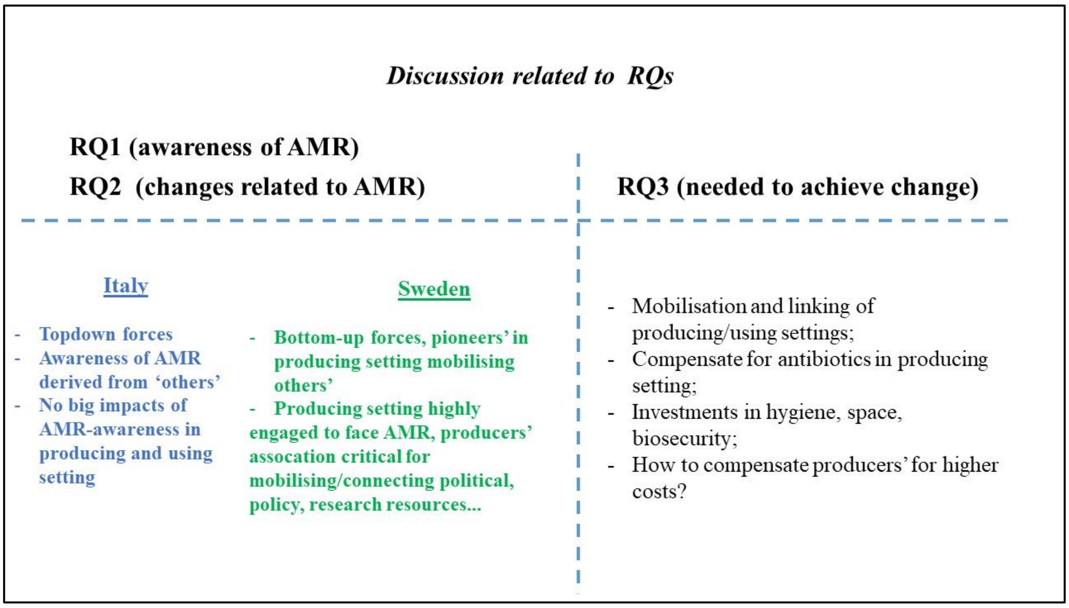
4. Conclusions

If combatting antibiotic resistance through development of new drugs, new diagnostics and new vaccines are dependent on future research advances and heavy investments in their industrialisation, a radically reduced consumption of antibiotics in animal-based food is a contemporary solution, with a rather long history, at least in some modern production regimes.

This is not to say that the search for new drugs represents ‘rocket science’, and reducing consumption represents simple ‘implementation.’ Rather, as the paper has illustrated, a production system able to compensate for routine group treatment of animals with antibiotics is the outcome of an extensive, long-term interaction process, where both those directly involved, and a number of related actors need to be engaged.

Previous studies on systemic changes based on normative concerns have pinpointed ‘outsiders’ as the main driving actors; that is activists and interest groups (Van de Poel, 2000; Elzen et al., 2011). However, as the Swedish case has illustrated, ‘insiders,’ that is those representing investments in place in the producing setting, are paramount for the ability to achieve change (Håkansson and Waluszewski, 2002). In the Swedish setting, ideas brought forward by engaged scientists, journalists and activists were not only accepted, but also fought for by resourceful actors in the producing setting, prepared to make significant changes in the material structure and engaged in mobilising others in coordinated actions across organisational borders.

Fig. 8 – Discussion related to RQs



Source: author's elaboration

This engagement rested on an awareness that the cost of change would mainly appear at production level but was motivated by a trust in the user setting's willingness to share them. The EU entrance and opened borders crushed this expectation. However, after three decades, the user side eventually recognised the connection between antibiotic resistance and the way animal-based food is produced and accepted a somewhat higher consumer price. The limited general awareness about antibiotic resistance in the Italian context, as well as of the health of food animals, implies that an important prerequisite for motivating investments in the producing setting is missing. Although there are engaged researchers, politicians and journalists who struggle to increase awareness about AMR and the importance of reducing the consumption, these ideas have not yet trickled down to the 'insiders,' that is into the producing setting.

This points to the importance of getting support from those who will be

directly affected by a legal ban. In the Swedish case, it was leading actors in the producing setting that chased the legislators – not vice versa – as in the Italian setting. In the first case, the 1986 ban was received as the outcome of a joint engagement and as a guarantee for 'fair play,' forcing all producers to follow the same route. In the second case, the 2006 EU ban was received as just another obstacle that put animal-based food producers in this region at a

disadvantage to those who still have unbounded access to antibiotics. As Kirchhelle (2018) asks, why should farmers accept being put at a disadvantage, which will be the case if not all are following the same rules. Hence, a ban in itself does not make change; those who are obliged to follow it must first share the ideas it is resting on, and second, be prepared to change the material structure in relation to it. Third, they must at least expect a ‘fair’ distribution of costs and benefits among producers and users, and, to survive in the long run, be provided with an economic context where all players are forced to follow the same route.

Although the Swedish pig meat producers had high expectations that the EU ban would force all European producers phase out antibiotic-based production systems, this has not yet been realised.

Hence, the perseverance of antibiotic-based production systems is not due to lack of scientific knowledge, practical experiences, or unsatisfactory outcome of systems able to compensate for antibiotics through precautionary health and biosecurity – but rather of lack of ability to

disseminate knowledge to a general public, and of acting on this in existing producing and using settings. The latter require enduring interaction among actors that despite different roles, different economic strength and often clashing interests, are prepared to act on knowledge about antibiotic resistance, and to make the investments necessary to combat this; in producing systems, in using systems, in research, and in legislation. To achieve this is nothing but social rocket science.

4.1. Policy and managerial implications

The need to innovate and the needs of actors involved in the network

What emerges from this study is that the needs that are behind each setting are very different from each other, although setting are each other's strongly interdependent within the same network.

One Health in One Network

Policy advisory, therefore, should first of all formulate proposals that take into account rather the networks that have been established spontaneously over time and those born with the intention of creating a social impact (see Baraldi, 2022), rather than suggesting policies based on regional borders, which do not coincide with the borders of the networks. Secondly, it should formulate hypotheses of incentive for innovation by distributing costs and risks in the network, without demanding it only from a part of it. Finally, it should introduce expert figures in network management and innovation management in the governance of the implementation of these policies.

4.2. Further research and limitations

The empirical materials for chapter (3) were originally scheduled to be totally collected through in presence face-to-face interviews. However, due to the pandemic emergency, part of these were gathered by recorded video-call interviews. Yet, it is possible that more aspects of AMR would have been better investigate in presence, as that could had enriched the interviews with other context information.

However, the study is not without its limitations. First of all, we presented a bibliometric analysis of literature. The choice was dictated by the fact that once we identified, through the abductive method, the positioning of our research, we immediately identified a real scarcity of literature. As theoretical framework turned out to be very narrow, the bibliometric analysis, seemed to us the most suitable for our study. However, it is suggested for future research to adopt a systematic review of the literature, which could in fact provide more depth to the study. Secondly, we defined the sample of interviews, with the method of the snow-ball sample, then the representativeness of the sample is not guaranteed. However, since the research is based on the case study method (Yin, 2014), the author did not intend to consider the results to be statistically generalizable, but analytically generalizable. Moreover, as already mentioned, we did not want to make a comparison between case studies, but we considered the AMR phenomenon as a single case study, reporting the phenomenon seen spatially and temporally in different business landscape, that allowed us to detect different ways of dealing with the AMR issue, and highlighting its advantages and disadvantages.

Future trajectories of research, however, could go to detect individual case studies in a "classic" way, to understand how a single organization manifests its needs related to innovation, when this is driven and pushed by external actors such as policy makers or on the user side or even on the competition side.

It would also be interesting and relevant for future research to build multidisciplinary research teams, including scholars of innovation policy and network and business and management, as well as veterinarians, doctors, biologists, in order to be able to see the problem with the widest possible visual angle, and capture new solutions to contrast such enormous issues as Antimicrobial Resistance is.

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List of figures

List of tables