# Directionality
## and systemic governance

### Lessons from Brazilian pig system transformations from the 1960s to date

Jean Carlos Porto Vilas Boas Souza

# Propositions

1) Since directionality is hard to be managed as a concept, it provides narrow directionality to investigate socio-technical transformative processes in reality.
   (this thesis)

2) Unravelling directionality matters in agri-food systems, however its interaction with systemic governance matters even more for who is interested in driving change.
   (this thesis)

3) Addressing the future's steerability also relies on finding out where society should place its scientific efforts in the present.

4) Innovation that improves daily life ignoring diversity, distribution, and democracy does not fit into a more sustainable world.

5) A Ph.D. journey is a blind adventure that brings to the fore gradually our previous blindness.

6) Living abroad makes it easier to realize that borders and differences dwell in our pre-conceptions.

Propositions belonging to the thesis, entitled

'Directionality and systemic governance: lessons from Brazilian pig system transformations from the 1960s to date'.

Jean Carlos Porto Vilas Boas Souza

Wageningen, 16 November 2020.

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# Directionality and systemic governance

Lessons from Brazilian pig system transformations from the 1960s to date

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One of my thesis' propositions argues that 'a Ph.D. journey is a blind adventure that brings to the fore gradually our previous blindness.' I would like to add that this self-knowledge process also shows you how different people, in somewhat distinct manners, are vital to amend our blindness along the way.

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## Summary

Different actors, for different reasons, have increasingly questioned how current development models affect distribution, diversity, directionality, and democracy issues within socio-technical systems where the contemporary world meets its basic needs, such as food, energy, and transport. Scholars focused on analyzing agri-food systems' evolution have paid close attention to how directionality interacts with systemic governance to promote specific goals – e.g., to make systems more organized, efficient, or profitable; to make them more environmentally friendly, inclusive, or resilient. Despite valuable critiques and theoretical reflections provided by previous literature regarding directionality and systemic governance, there is a call for 1) sharpening how directionality influences transformative processes; and 2) shedding light on the role of systemic governance in the steerability of directionality. This thesis aims to contribute to these debates by analyzing case studies related to the evolvement of Brazilian pig production from the 1960s to date.

This thesis is structured around six chapters. Chapter 1 is the general introduction, which sets the scene of the study justifying the research choices, research questions, and the methodology used to answer the research questions. Drawing upon gaps pointed out by previous literature, this thesis presents two objectives: 1) to deepen the understanding of how agri-food systems' directionality unfolds, and 2) to unravel further how systemic governance elements contribute to steering agri-food systems' directionality.

As an entry point for the thesis, Chapter 2 provides an exploratory study to improve the understanding of directionality. The chapter looks at the evolvement of Brazilian pig production through an analytical model structured to unravel the dynamics and consolidation process behind innovation directions and their influence over socio-technical systems' directionality. The findings identify that innovation takes some direction and leaves others aside according to a sort of 'filtering processes.' They also show that discontinuities trigger cycles of articulation and institutionalization of new sets of influencing practices, technologies, and rules. Additionally, the study reveals that innovation direction requires a constant interaction between micro, meso, and macro analysis levels. Mostly, Chapter 2 adds to previous literature, based on how innovation directions emerge and become consolidated, that the steering of directionality is related to a multifaceted guiding force.

Chapter 3 is the first study focused on the interaction between directionality and systemic governance. It investigates how boundary infrastructures (collection of boundary objects, boundary organizations, or boundary spanners) developed in Brazilian pig production from the 1960s up to date. The chapter elucidates how boundary infrastructure elements reinforce each other and how their interactions play a role in long-term agricultural transformative processes. The study adds to previous work in a twofold way: 1) it shows that different boundary work elements (objects, organizations, and spanners) are highly intertwined and complementary in boundary infrastructures, and 2) it demonstrates that some parts of boundary infrastructures are temporary, while others consolidate and become definite. Beyond that, by providing interfaces to bring together science, policy, and practice, boundary infrastructures perform as a pivotal systemic governance element, influencing socio-technical systems' directionality.

Chapter 4 looks at how ecologies of intermediaries play a role in directionality issues. The study unravels the implementation of the European animal welfare standards in Brazilian pig production. It connects the standards implementation and intermediation literature to deepen the understanding of how ecologies of intermediaries steer transformative processes to a certain degree. The study enriches debates on how contextualized strategies bridged by collective intermediation efforts affect how innovation unfolds

in an agri-food sector. The findings provide evidence that collective intermediation efforts are pivotal in addressing demands (such as translation, adaptation, regulation) that emerge from the complex situation of change provoked by the implementation of international animal welfare standards in local contexts. Another contribution is to infer that temporary coalitions are also crucial for interactions between systemic governance and directionality.

Chapter 5 contributes to understanding the dynamics behind the embedding of imported innovations in long-term transformative processes, and the translation roles public research and technology institutions may play. By focusing empirically on how Embrapa (a governmental research company) contributed to embedding the so-called pyramid concept and hybrid pigs technology, this chapter reveals interesting findings linked to agri-food systems' directionality. It adds to theory on agricultural technology development and innovation by 1) showing how multiple, parallel, and reciprocally influential unpacking and repacking efforts unfold over time and take part in embedding imported innovations in receiver contexts, 2) refining translation roles played by public research and technology institutions (RTI) from positions they assume in ecosystems related to the embedding of imported innovations in receiver contexts, and 3) demonstrating that public RTIs can assume stable and temporary translation roles over time.

Finally, Chapter 6 looks back on the research questions, brings the main findings together, and gives them an in-depth interpretation. Here the main conclusions are presented together with implications for policy and practice and suggestions for further research. The thesis proposes, as one of its key findings, the 'streams of directionality' concept. In doing so, it offers a more fine-grained comprehension of how directionality unfolds in agri-food systems by 1) arguing that the guidance directionality exerts on agri-food systems is multifaceted, and 2) implying that its multifaceted guidance unfolds through different levels and domains. Chapter 6 also sharpens how systemic governance elements contribute to steering agri-food systems' directionality. Drawing upon the streams of directionality concept, this thesis offers a double understanding of synchronization in the steering of change. Moreover, chapter 6 presents cross-cutting issues (directionality and sustainability issues, concrete directionality, reflexivity and monitoring, and conceptual refinements) and implications for policy and practice (e.g., there is a need to pay explicit public policy attention to build systemic governance elements to promote the synchronization or desynchronization of the guiding forces linked to directionality).

# Samenvatting

Verschillende actoren, om verschillende redenen, hebben zich steeds meer afgevraagd hoe de huidige ontwikkelingsmodellen de distributie, diversiteit, directionaliteit en democratieproblemen beïnvloeden binnen sociaal-technische systemen waarin de hedendaagse wereld voorziet in zijn basisbehoeften, zoals voedsel, energie en transport. Wetenschappers die zich richten op het analyseren van de evolutie van agrovoedingssystemen hebben veel aandacht besteed aan de wisselwerking tussen directionaliteit en systemisch bestuur om specifieke doelen te bevorderen - bijvoorbeeld om systemen meer georganiseerd, efficiënter of winstgevender te maken; om ze milieuvriendelijker, inclusief of veerkrachtiger te maken. Ondanks waardevolle kritieken en theoretische reflecties uit eerdere literatuur over directionaliteit en systemisch bestuur, is er een roep om 1) aanscherping hoe directionaliteit transformatieve processen beïnvloedt; en 2) licht werpen op de rol van systemisch bestuur bij de stuurbaarheid van directionaliteit. Dit proefschrift beoogt een bijdrage te leveren aan deze debatten door casestudy's te analyseren die verband houden met de ontwikkeling van de Braziliaanse varkensproductie van de jaren zestig tot nu.

Dit proefschrift is opgebouwd rond zes hoofdstukken. Hoofdstuk 1 is de algemene inleiding, die de scène schetst van het onderzoek en de onderzoekskeuzes, onderzoeksvragen en de methodologie die gebruikt wordt om de onderzoeksvragen te beantwoorden rechtvaardigt. Voortbouwend op hiaten die in eerdere literatuur zijn aangegeven, presenteert dit proefschrift twee doelstellingen: 1) het begrip verdiepen van hoe de directionaliteit van agrovoedingssystemen zich ontvouwt, en 2) verder ontrafelen hoe systemische bestuurselementen bijdragen aan het sturen van de directionaliteit van landbouw- en voedselsystemen.

Als startpunt voor het proefschrift biedt Hoofdstuk 2 een verkennend onderzoek om het begrip van directionaliteit te verbeteren. Het hoofdstuk behandelt de ontwikkeling van de Braziliaanse varkensproductie door middel van een analytisch model dat is gestructureerd om de dynamiek en het consolidatieproces achter innovatierichtingen en hun invloed op de directionaliteit van sociaal-technische systemen te ontrafelen. De bevindingen laten zien dat innovatie een bepaalde richting inslaat en andere buiten beschouwing laat volgens een soort 'filterprocessen'. Ze laten ook zien dat discontinuïteiten cycli van articulatie en institutionalisering van nieuwe sets van beïnvloedende praktijken, technologieën en regels in gang zetten. Bovendien laat de studie zien dat innovatierichting een constante interactie vereist tussen micro-, meso- en macroanalyses. Meestal voegt Hoofdstuk 2 toe aan eerdere literatuur, gebaseerd op hoe innovatierichtingen ontstaan en geconsolideerd worden, dat het sturen van directionaliteit gerelateerd is aan een veelzijdige leidende kracht.

Hoofdstuk 3 is de eerste studie die zich richt op de interactie tussen directionaliteit en systemisch bestuur. Het onderzoekt hoe grensinfrastructuren (verzameling grensobjecten, grensorganisaties of boundary spanners) zich ontwikkelden in de Braziliaanse varkensproductie vanaf de jaren zestig tot nu toe. Het hoofdstuk maakt duidelijk hoe grensinfrastructuurelementen elkaar versterken en hoe hun interacties een rol spelen in langetermijn landbouwtransformatieprocessen. De studie voegt op een tweevoudige manier toe aan eerder werk: 1) het toont aan dat verschillende grenswerkelementen (objecten, organisaties en steeksleutels) sterk met elkaar verweven en complementair zijn in grensinfrastructuren, en 2) het toont aan dat sommige delen van grensinfrastructuren tijdelijk zijn , terwijl andere consolideren en definitief worden. Afgezien daarvan, door interfaces te bieden om wetenschap, beleid en praktijk samen te brengen, fungeren grensinfrastructuren als een cruciaal systemisch bestuurselement en beïnvloeden ze de directionaliteit van sociaal-technische systemen.

Hoofdstuk 4 bekijkt hoe ecologieën van intermediairs een rol spelen bij directionaliteitsvraagstukken. De studie ontrafelt de implementatie van de Europese dierenwelzijnsnormen in de Braziliaanse varkensproductie. Het verbindt de literatuur over de implementatie van normen en de bemiddelingsliteratuur om het begrip te verdiepen van hoe ecologieën van tussenpersonen tot op zekere hoogte transformatieve processen sturen. De studie verrijkt debatten over hoe gecontextualiseerde strategieën die worden overbrugd door collectieve bemiddelingsinspanningen, invloed hebben op hoe innovatie zich ontvouwt in een agrovoedingssector. De bevindingen tonen aan dat collectieve bemiddelingsinspanningen cruciaal zijn bij het beantwoorden van eisen (zoals vertaling, aanpassing, regulering) die voortvloeien uit de complexe situatie van verandering die wordt veroorzaakt door de implementatie van internationale dierenwelzijnsnormen in lokale contexten. Een andere bijdrage is om te concluderen dat tijdelijke coalities ook cruciaal zijn voor interacties tussen systemisch bestuur en directionaliteit.

Hoofdstuk 5 draagt bij aan het begrijpen van de dynamiek achter de inbedding van geïmporteerde innovaties in transformatieprocessen op de lange termijn, en de vertaalrollen die publieke onderzoeks- en technologie-instellingen kunnen spelen. Door empirisch te focussen op hoe Embrapa (een onderzoeksbedrijf van de overheid) heeft bijgedragen aan de verankering van het zogenaamde piramideconcept en hybride varkenstechnologie, onthult dit hoofdstuk interessante bevindingen die verband houden met de directionaliteit van landbouw- en voedselsystemen. Het draagt bij aan de theorie over de ontwikkeling en innovatie van landbouwtechnologie door 1) te laten zien hoe meervoudige, parallelle en wederzijds invloedrijke inspanningen voor het uitpakken en opnieuw inpakken zich in de loop van de tijd ontvouwen en deelnemen aan het verankeren van geïmporteerde innovaties in ontvangende contexten, 2) het verfijnen van de vertaalrollen die worden gespeeld door publiek onderzoek en technologie-instellingen (RTI) vanuit posities die ze innemen in ecosystemen met betrekking tot de inbedding van geïmporteerde innovaties in ontvangende contexten, en 3) aantonen dat openbare RTI's in de loop van de tijd stabiele en tijdelijke vertaalrollen kunnen aannemen.

Hoofdstuk 6 tenslotte blikt terug op de onderzoeksvragen, brengt de belangrijkste bevindingen samen en geeft ze een diepgaande interpretatie. Hier worden de belangrijkste conclusies gepresenteerd samen met implicaties voor beleid en praktijk en suggesties voor verder onderzoek. Het proefschrift stelt, als een van de belangrijkste bevindingen, het concept 'streams of directionaliteit' voor. Door dit te doen, biedt het een meer fijnmazig begrip van hoe directionaliteit zich ontvouwt in agrovoedingssystemen door 1) te beargumenteren dat de richtinggevoeligheid van agrovoedingssystemen veelzijdig is, en 2) door te impliceren dat de veelzijdige begeleiding zich ontvouwt op verschillende niveaus en domeinen. Hoofdstuk 6 geeft ook aan hoe systemische governance-elementen bijdragen aan het sturen van de directionaliteit van landbouw- en voedselsystemen. Voortbouwend op het concept van directionaliteit, biedt dit proefschrift een dubbel begrip van synchronisatie bij het sturen van verandering. Bovendien presenteert hoofdstuk 6 transversale kwesties (directionaliteit en duurzaamheidskwesties, concrete directionaliteit, reflexiviteit en monitoring, en conceptuele verfijningen) en implicaties voor beleid en praktijk (er is bijvoorbeeld een noodzaak om expliciete aandacht te besteden aan het overheidsbeleid om systemische governance-elementen op te bouwen. om de synchronisatie of desynchronisatie van de leidende krachten verbonden met directionaliteit te bevorderen).

# CHAPTER 1

General Introduction

# 1. General introduction

## 1.1. Introduction

This thesis contributes to debates on directionality by explaining how it unfolds in reality and how systemic governance elements contribute to its steerability in agri-food systems. It focuses on investigating the role of particular structures, networks, and key actors in steering complex changes and their outcomes, using case studies from the Brazilian pig sector as its empirical scenario. Earlier work has provided useful critiques and theoretical reflections on directionality issues related to agri-food systems (Stirling, 2009; Ladu et al., 2020; Schot and Kanger, 2018; Scordato, Bugge, and Fevolden, 2019). However, there is a call for further analysis of how directionality takes place and how it is governed in agri-food systems (Pigford, 2018; Lamine, Darnhofer, and Marsden, 2019; Schot and Kanger, 2018).

This first chapter affords a general introduction and background to the thesis. It elaborates on the societal problem and research gaps and introduces the main conceptual issues that underpin the thesis. These inform the empirical chapters, which are embedded in specific scientific debates. After that, the general research objectives and questions are presented, followed by the research approach, and finally, the thesis outline.

## 1.2. Setting the scene: The ubiquitous debate on directionality

The hegemonic way in which the contemporary world has evolved (generally based upon industrial mass production and individualized mass consumption) became growingly criticized, provoking the emergence of an ubiquitous debate on development in recent decades (Geels and Penna, 2015; Gupta, 2015; Hess, 2014; Perez, 2010; Sachs et al., 2019). Different actors (e.g., NGOs, public organs, policymakers, consumers) for different reasons (e.g., economic, environmental, social, ethical) started raising questions (e.g., who gains and who loses?; what are the real costs involved?; who make the choices?) related to the dominant vision for progress (Arond, 2011; Schot and Kanger, 2018; Stirling, 2009). Such questioning has defied concepts as modernization and industrialization (Grin et al., 2010; Iizuka, 2015; Sovacool et al., 2020). Beyond that, it has particularly stimulated further reflections on how current development models affect distribution, diversity, directionality, and democracy issues within socio-technical systems where the contemporary world meets its basic needs, such as food, energy, and transport (Leach et al., 2020; Leach et al., 2012; STEPS Centre, 2010).

Notably, the debates on the dominant vision for progress have paid close attention to why changes based on multiple social, organizational, and technical innovations choose some directions, while leaving aside other transformation options in any given socio-technical system (Devaux et al., 2016; Leach et al., 2020; Stirling, 2011). These debates underline that such comprehension is pivotal to unravel further socio-technical systems' directionality - i.e., the dominant pathway that drives the direction of change in socio-technical settings and has to do with benefits, costs, and risks associate with transformative processes underpinned by innovation (STEPS Centre, 2010). Particularly, directionality has been a steady interest of scholars focused on food production systems (Leach et al., 2020). They have studied from varied points of view how to influence agri-food systems' directionality proactively to promote specific goals – e.g., to make systems more organized, efficient, or profitable; to make them more environmentally friendly, inclusive, or resilient (Eastwood et al., 2019; El Bilali, 2019; Läpple et al., 2016; Maye and Duncan, 2017).

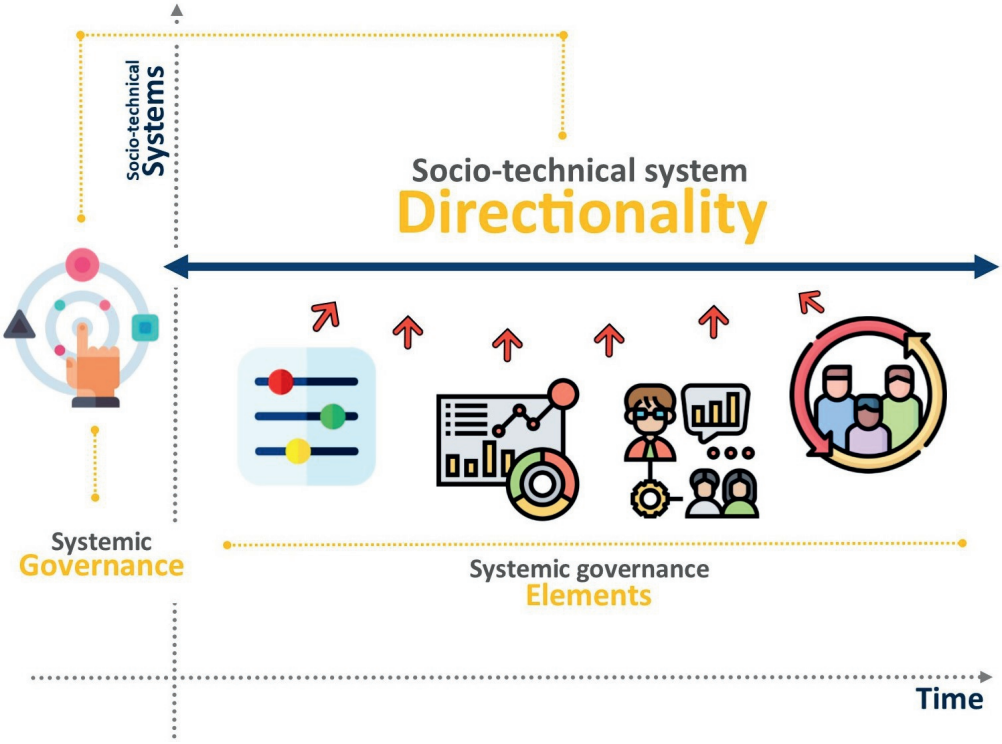
Directionality is a central concern in perspectives such as agricultural knowledge and information systems and agricultural innovation systems (Kilelu et al., 2011; Klerkx, van Mierlo, and Leeuwis, 2012). Both focus mainly on investigating how to mobilize varied organizations, enterprises, and individuals to pursue shared transformative ambitions – e.g., to make food production more professional, technological, commercial, and integrated. Directionality is also pivotal for scholars who engaged in analyzing food production evolving through transitions research repertoire (El Bilali and Probst, 2017; Ingram, 2018). Such extant literature has approached directionality mostly by 1) analyzing how to cultivate radical agricultural innovations in shielded spaces (Blesh and Wolf, 2014); 2) investigating how to accelerate sustainable innovation journeys based on agroecological models (Lamine, Darnhofer, and Marsden, 2019); and 3) enlightening how to implement strategies of discontinuation and 'exnovation' in locked-in agri-food systems (Eksvärd, 2018).

The debates on directionality have likewise implications for recent trends such as mission-oriented innovation policy and inclusive development strands of literature applied to food production. The former has drawn increasing attention to how public policy can give direction to economic growth and innovation in order to tackle societal and technological challenges related to agri-food systems, such as climate change, inequality, environmental degradation, and more sustainable and healthier food consumption patterns (Mazzucato, 2018; Mazzucato and Penna, 2016; Wright, 2012; Ziegler, 2020). The latter has analyzed how policy interventions may work for the benefit of lower-income groups since growth processes in agri-food systems have not often distributed their outcomes equitably (Fressoli, Dias, and Thomas, 2014; Paunov, 2013). Directionality linked to inclusive development studies applied to food production refers mostly to how innovation can be proactively mobilized to improve the living conditions of marginalized groups or individuals in agri-food systems (FAO, 2018; Petersen and Kruss, 2019).

Despite their different and sometimes even opposed perspectives in terms of a vision for progress, these strands of literature emphasize that systemic governance has a straight connection with agri-food systems' directionality (Garrido and Moreira, 2017; Klerkx et al., 2012; Mazzucato and Penna, 2016; Weber and Rohracher, 2012). They understand systemic governance mostly as the synchronization of actors and structures regarding 1) shared visions and expectations about desirable developments; 2) collective construction of formal and informal rules to make concrete shared visions and expectations; 3) organized spaces for experimentation and learning; and 4) coordinated actions to enable practical transformation (Kemp, Schot, and Hoogma, 1998; Loorbach and Huffenreuter, 2013) – see Figure 1.1. Admittedly, previous literature has provided valuable critiques and theoretical reflections on how to cultivate systemic governance to mobilize different actors and structures in pursuing the desired directionality for a specific agri-food system (Arond et al., 2011; Dentoni, Waddell, and Waddock, 2017; El Bilali, 2018; Elzen et al., 2011; Lamine et al., 2012).

However, increasingly scholars have recommended additional studies to further understand its interactions with systemic governance (Magrini et al., 2016; Pigford et al., 2018). They argue that firstly it is needed to better explain how directionality unfolds in reality (Schot and Kanger, 2018). Indeed, extant work often presents a rather intangible picture of directionality, what bounds the comprehension of its steerability by systemic governance actions (Lamine et al., 2019). In sum, scholars consider timely 1) sharpening how directionality influences transformative processes; and 2) to shed light on the role of systemic governance in the steerability of directionality. This is where this thesis will focus on, as further explained in the next section, which will explore how previous literature has approached the interaction between directionality and systemic governance.

**Figure 1.1.** Pivotal thesis' concepts and their interactions.




## 1.3. Building agri-food systems' directionality: potential systemic governance elements

Extant literature in science and technology studies (STS), business management, innovation studies, and knowledge management have looked at which sort of elements operationalize systemic governance and influence socio-technical systems' directionality, although they often have not been seen explicitly as such (i.e., as directionality elements). Three strands of interrelated, yet with different conceptual origins, strands of thinking can be discerned.

The first is systemic boundary work, which functions as a support structure of dominant development pathways (Star, 2002; Star and Ruhleder, 1996). Specifically, scholars focused on science and technology studies (STS) have increasingly mentioned the importance of boundary infrastructures in the steering of socio-technical systems (Clark et al., 2016; Star and Bowker, 2006). They described boundary infrastructures as boundary elements (e.g., innovation platforms, public or private organizations focused on the development of a particular sector, national or sectoral development policies) that engage in some degree of collaboration, and on which actors from science, policy, and practice (e.g., research institutions, policymakers, industries, NGOs) connect to achieve shared goals (Dagiral and Peerbaye, 2016; Steger et al., 2018). In reality, when boundary infrastructures facilitate particular interactions between science, policy,

and practice actors – and consequently leave aside potentially alternative interactions somehow, they contribute to making possible intended innovation streams, thus materializing themselves as a directionality element.

Secondly, there are also interesting insights on practical instruments linked to systemic governance that come from business management and innovation studies, specifically focusing on how ecologies of intermediaries contribute to building development pathways – e.g., see (Kivimaa et al., 2017; Stewart and Hyysalo, 2008). Multiple intermediaries sometimes function somewhat connectedly and complementarily within a sort of landscape of intermediation (Steyaert et al., 2016). Thus, they thrive the capacity of mobilizing a multitude of actors (e.g., research or innovation agencies, funding agencies, private consultancy companies, independent technological consultants, knowledge advisors, NGOs, industries, producers) around challenging societal or sectoral chores, which would be rather demanding for a single intermediary organization or individual (Kivimaa et al., 2019; Manders, Wieczorek, and Verbong, 2020). In practice, such different people and organizations when assembled as an ecology of intermediaries articulate expectations, demands, and visions; provide knowledge exchange and back learning processes; foster capacity building; and provide institutional support, such as advocacy or lobbying initiatives (Stewart and Hyysalo, 2008; Van Lente et al., 2003). In a nutshell, they perform as a pivotal element to give directionality for socio-technical systems.

Thirdly, STS, innovation studies, and knowledge management have looked at how the 'translational work' performed by particular actors to embed locally the growingly global flows of knowledge and traveling of innovation plays a role as a directionality element (Jansen, 2004; Binz and Truffer, 2017; Glover et al., 2019). Previous literature underlines that private and public organizations or individuals who are focused on interpreting what comes from abroad exert an essential role in terms of innovation steering in local contexts (Barnard and Chaminade, 2017). They do it by unpacking and repacking imported innovation, which has been a directionality element in settings as those seen in emerging countries (Maat and Glover, 2012., 2012). In reality, unpacking often implies to build up local skills related to imported innovation through actions such as the establishment of international research agreements, applied experimentation partnerships, and capacity building strategies (Stone and Glover, 2016). In turn, repacking comprehends to adjust imported innovations as far as necessary to local contexts, and it also implies adapting the local context to what comes from abroad (Berger and Hofer, 2011). Therefore, 'translational work' influences systemic governance directionality in a twofold way: 1) when what will be translated is chosen; and 2) when the 'translation' shapes imported innovation and local contexts to fit one into another.

Admittedly, one can find other insights from different strands of literature that could be understood as potential elements related to the steering of directionality. However, boundary infrastructures, the ecology of intermediaries, and 'translational work' concepts described here were chosen as conceptual lenses to investigate systemic governance elements that link to the directionality presented or intended by agri-food systems. Therefore, this thesis seeks to deepen the understanding of agri-food systems' directionality by looking at how boundary infrastructures, the ecology of intermediaries, and 'translational work' have taken part in building Brazilian pig production directionality from the 1960s to date.

## 1.4. Study context: Directionality and systemic governance elements in Brazilian pig production

Two transitions can be seen in the Brazilian pig sector from the 1960s to date. The first, a past one, relates to the industralization of pig production. The second, an ongoing one, materializes as a transition in the making, in which sustainability elements are considered more strongly. Brazilian pig production evolved from a semi-professional setting (headed by small independent producers and regional and national industries up to the 1980s) to an industrial intensive production basis (dominated by industries focused on the international market, highly professionalized producers, and a complex chain of suppliers) (Sebrae, 2016; Souza et al., 2011). Despite undeniable economic and social benefits provided by the pig sector in Brazil, regions where pig meat production and industrialization are a leading activity have struggled with unwelcome outcomes. For instance, they presented in the last decades growing inequalities – pig production has become increasingly concentrated in fewer industries and producers (Spies, 2003); increasing environmental threats – pig production is one of the most environmentally unfriendly agri-food sectors in Brazil (Miranda, Bonez, and Palhares, 2011); and persistent animal welfare issues – pig sector has been challenged by international buyers to eliminate the use of cages for pregnant sows for instance (Dias et al., 2018).

As a result, chiefly from the 2000s, Brazilian pig production directionality became increasingly contested (Brooks, 2017; Guimarães et al., 2017; Spies, 2003). From one side, local NGOs, consumers, and public organs started defying industries, producers, and suppliers to adopt technologies and procedures that reduced societal and environmental impacts linked to pig production (ABCS, 2014; Souza et al., 2011). On the other side, international buyers growingly demanded of the Brazilian pig industries commitment with global directives in terms of animal health, animal welfare, and fair trade, what also pressured the introduction of several technological and organizational novelties in recent years (Maciel, Mol, and Bock, 2015; von Keyserlingk and Hötzel, 2015). Similarly what has taken place worldwide, such claims for practical actions established hotly scientific and policy debates on how to induce the emergence of more sustainable development pathways through incremental or radical innovation in Brazilian pig production (Guimarães et al., 2017; Schmidt, 2017).

Thus, the discussion on systemic governance elements involved in sttering agri-food systems' directionality is also timely in the Brazilian pig production context. Besides, the systemic governance elements identified in this study (boundary infrastructures, ecologies of intermediaries, and 'translational work') have exerted influence over how the pig sector evolved. For instance, systemic interfaces between science, policy, and practice were fundamental to implement the vertical coordination production model, which reshaped the Brazilian pig production development pathway from the late 1980s onwards (Guimarães et al., 2017; Sebrae, 2016). Moreover, the collaboration between varied intermediaries has been pivotal to deploy animal welfare international standards in Brazilian pig production (Dias et al., 2018; Hötzel et al., 2018). Hence, the pig sector in Brazil also offers an attractive setting to investigate the role of ecologies of intermediaries in the establishment of alternative development pathways in agri-food systems.

Additionally, the embedding of imported innovation constituted the most significant technological and organizational evolvement applied in Brazilian pig production (Souza et al., 2011; Spies, 2003). It means that 'translational work' has functioned likewise as a systemic governance element. Finally, investigating systemic governance elements linked to the directionality of past transitions, can also better inform how to design systemic governance for transitions in the making in agri-food systems.

## 1.5. Research questions and objectives

In light of the developments outlined above, this thesis looks at the following overarching research question:

- How has directionality unfolded in agri-food systems and how has systemic governance taken part in its steerability?

Concerning this overarching research question, the thesis addresses several sub-questions focusing on:

- Analyzing agri-food systems' directionality.

What is directionality in agri-food systems?; how does it drive the direction of change in reality?

- Examining how systemic governance relates to directionality in agri-food systems.

How does systemic governance take part in establishing directionality in agri-food systems?; how does it enable its steerability?

- Investigating systemic governance elements linked to directionality in Brazilian pig production.
- How did the environmental crisis in the 2000s foster innovation and influence Brazilian pig production directionality?; which were boundary infrastructures' contributions to the transition from the spot market to the vertical coordination in the pig sector in Brazil?; how have ecologies of intermediaries carried out intermediation efforts for the implementation of European animal welfare standards in pig production in Brazil?; what is the influence of the 'translational work' played by a public research and technology institution (Embrapa) in the transformation of the Brazilian pig genetics improvement model from the 1980s onwards?

Through answering these research questions, this thesis explores a twofold objective:

- To deepen the understanding of how agri-food systems' directionality unfolds;
- To unravel further how systemic governance elements contribute to steering agri-food systems' directionality.

## 1.6. Research design, case study selection, and methods

This section describes the overall research design of the thesis, providing general information on data collection and analysis. Each of the chapters presents specific detail on the research methods relevant to it. A case study research design was singled out to investigate how systemic governance elements contribute to steering directionality in Brazilian pig production. This thesis took the case study method as it is better suited to affording in-depth insights into complex social phenomena or social processes, allowing an integrated seizing of the experiences of those involved and making possible a broad characterization of targeted processes (Flyvbjerg, 2006; Hyett, Kenny, and Dickson-Swift, 2014; Yin, 2009). Thus, it provides enough evidence to describe systemic governance elements and their interactions with socio-technical systems' directionality.

The study went through two steps. The first step was guided by the first research objective and applied a multiple case study approach to map different elements identified as undertaking actions related to how different innovation streams relate to Brazilian pig production directionality. This step followed an inductive strategy, as suggested by Thomas (Thomas, 2006). A priori, the study began with the

conceptualization of the concepts linked to socio-technical systems' directionality and systemic governance from literature. This previous in-depth understanding allowed this thesis to picture elements that could have taken part in steering directionality in Brazilian pig production. From the exploratory study, the second step focused on single case studies, providing a detailed analysis of episodes in the Brazilian pig production trajectory where boundary infrastructures, ecologies of intermediaries, and 'translational work' were deemed influential for contributing to directionality. Furthermore, the thesis followed an inductive reasoning to some extent, based on grounded theory reasoning (Bitsch, 2005; Strauss and Corbin, 1994). Some of the concepts applied in the thesis (e.g., the coundary infrastructures concept) were not present at the outset. They came up from a back and forth between theory and empirical understanding, which allows a deepening from theory (Age, 2011).

### 1.6.1. Case studies selection

The selection of case studies also unfolded as a two-step process. The first step took place with an initial exploratory study based on the previous knowledge of the researcher (who has worked in the Brazilian pig sector and headed socio-technical development projects since 2000) and sources as books, reports, scientific papers, newspaper articles, and internet databases. Multiple events characterized as remarkable changes in directionality were mapped, picturing a historical perspective on which circumstances and elements have affected the Brazilian pig production development over time. The mapping allowed the study to find single cases where boundary infrastructures, ecologies of intermediaries, and 'translation work' functioned as systemic governance elements, thus playing a concrete directionality role.

In the second step, four case studies were then purposively chosen: 1) the Brazilian pig production environmental crisis in the 2000s and its consequences for innovation and directionality; 2) boundary infrastructures' contributions to the transition from the spot market to the vertical coordination in the pig sector in Brazil; 3) intermediation efforts for the implementation of European animal welfare standards in pig production in Brazil; and 4) the influence of the 'translational work' played by a public research and technology institution (Embrapa) in the transformation of the Brazilian pig genetics improvement model from the 1980s onwards. All the case studies were deemed to play concrete systemic governance and influence the steering of directionality in the pig sector. Therefore, they can be considered potentially illustrative (Eisenhardt and Graebner, 2007; Flyvbjerg, 2006; Yin, 2009).

### 1.6.2. Data collection approaches and data analysis

Dates were collected in the fieldwork periods July to December 2017 and March to April 2019. The primary data sources were 53 in-depth interviews with key actors involved with Brazilian pig production. They are representatives from varied interests, such as industries, producers, pig genetics companies, institutions, NGOs, science institutions, and advisory services. The study reached an initial list of interviewees and relied on the researcher's previous knowledge about Brazilian pig production and additional information from publications and websites of industries, associations, public organs, NGOs, and science institutions. The study also applied the snowballing method (Kumar, 2011), and from the initial round of interviews, extra influential interviewees were added (nine in the first fieldwork period and four in the second one). The interviews lasted between half an hour and two hours and were recorded and transcribed verbatim. They followed an interview guide based on our literature review. Core and additional secondary data were also

collected. The core secondary data consisted of books, scientific papers, policy briefs, magazine and newspaper articles, and databases available on the internet. Interviews' content was analyzed through coding guided by sensitizing concepts derived from the theoretical frameworks underlying the different studies. The details of the analyses are provided in the individual chapters.

## 1.7. Thesis outline

In this section, there is a brief introduction to the specific thesis chapters' scope - Figure 1.2. provides an overview. Chapter 2 is an exploratory study that deepens the understanding of directionality by looking at how innovation streams were established in Brazilian pig production. It builds an analytical model to unravel the dynamics and consolidation process behind innovation directions and their influence over socio-technical systems' directionality. The model is tested empirically in the pig sector in Brazil. The results identify that innovation takes some direction and leaves others aside according to a sort of 'filtering processes', in which discontinuities trigger cycles of articulation and institutionalization of new sets of influencing practices, technologies, and rules. Additionally, the study reveals that innovation direction requires a constant interaction between micro, meso, and macro analysis levels, as well as deepens policy debates around the development of systemic conditions for building intended directionality.

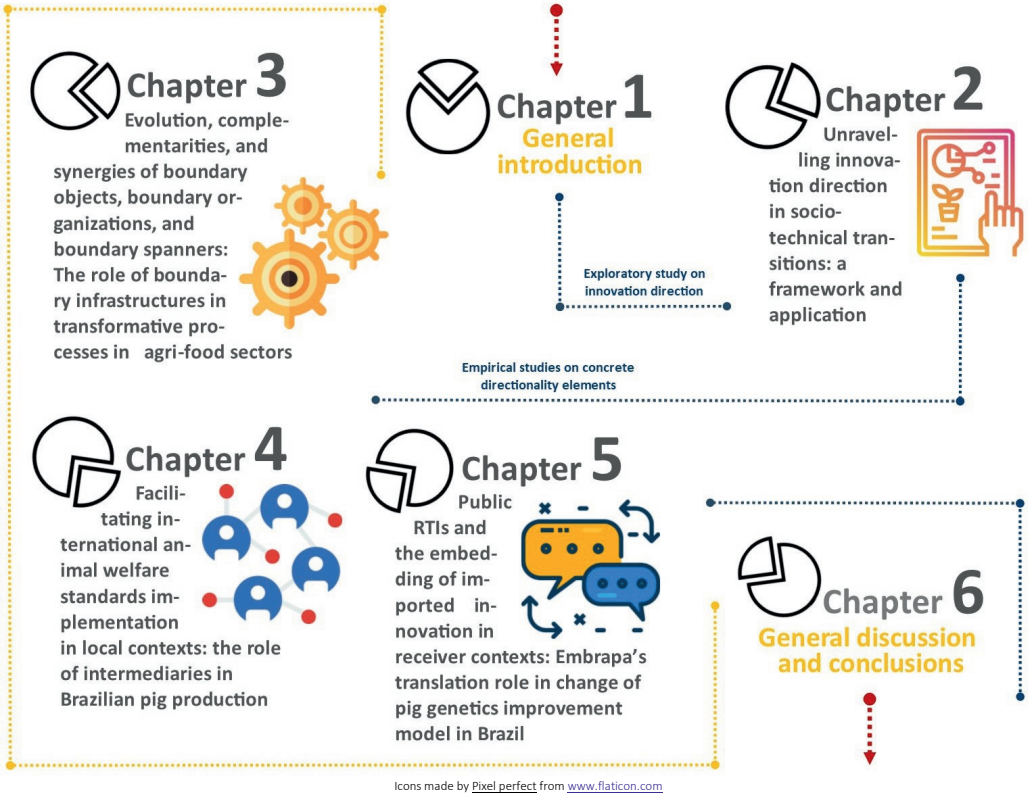
The upcoming chapters (3, 4, and 5) focus on how different systemic governance elements got involved in building Brazilian pig production directionality from the 1960s to date. Chapter 3 investigates how boundary infrastructures (collection of boundary objects, boundary organizations, or boundary spanners) developed in Brazilian pig production from the 1960s up to date. The chapter emphasizes how boundary infrastructure elements reinforce each other and how interactions between them play a role in long-term agricultural transformative processes. The study adds to previous work by showing that different boundary work elements (objects, organizations, and spanners) are highly intertwined and complementary in boundary infrastructures. Thus, they cannot be analyzed disconnectedly. Chapter 3 also shows that some parts of boundary infrastructures are temporary, while others consolidate and become definite.

Chapter 4 unravels the implementation of the European animal welfare standards in Brazilian pig production, a transformative process that has influenced directionality. Specifically, it aims to connect the standards implementation and intermediation literature to deepen the understanding of how an ecology of intermediaries facilitates the implementation process of international animal welfare standards. The study enriches debates on how one can develop contextualized strategies that translate recognized international regulations into practical local animal welfare improvements, thus affecting in a certain degree how innovation unfolds in the pig sector. The findings provide evidence that collective intermediation efforts are pivotal in addressing demands (such as translation, adaptation, regulation) that emerge from the complex situation of change provoked by the implementation of international animal welfare standards in local contexts.

Chapter 5 zooms in on the dynamics behind the embedding of imported innovations in long-term transformative processes, and the translation roles public research and technology institutions may play. By focusing empirically on how Embrapa (a governmental research company) contributed to embedding the so-called pyramid concept and hybrid pigs technology, this chapter reveals interesting insights linked to agri-food systems' directionality. Moreover, it adds to theory on agricultural technology development and innovation in a threefold way: 1) showing how multiple, parallel, and reciprocally influential unpacking and

repacking efforts unfold over time and take part in embedding imported innovations in receiver contexts; 2) refining translation roles played by public research and technology institutions (RTI) from positions they assume in ecosystems related to the embedding of imported innovations in receiver contexts; and 3) demonstrating that public RTIs can assume stable and temporary translation roles over time. Lastly, Chapter 6 provides a synthesis of the findings and a reflection on the study's implications for theory, policy, and practice.

**Figure 1.2.** Overview of the thesis.

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# CHAPTER 2

Unravelling innovation direction in socio-technical transitions: a framework and application

# 2. Unravelling innovation direction in socio-technical transitions: a framework and application



**Abstract:** Sustainability transitions studies attach growing importance to directions that innovation may take to achieve more sustainable practices. However, aspects of innovation direction require further elaboration. Adopting a multi-level perspective, the concept of demand articulation, institutional theory, and the theory of modal aspects, this study elucidates the nature of innovation direction and builds an analytical model to unravel its dynamics and consolidation process. The model is tested empirically in the pig production system in Brazil. The results identify important issues linked to sustainability transitions, such as trajectories in terms of event-chains and rounds of moves and countermoves; the dominant designs emergence process; and directionality failure in policy interventions. This study also reveals that innovation direction requires a constant interaction between micro, meso, and macro analysis levels. The analysis also helps to widen policy debates around the development of systemic conditions for building desired sustainable innovation directions.

## 2.1. Introduction

The contemporary world meets its basic needs, such as food, energy, and transport, through complex socio-technical systems, which are generally based upon industrial mass production and individualized mass consumption (Geels and Penna, 2015; Hess, 2014; Perez, 2010). In the last decades, this prevailing model has provided improvements in terms of life expectancy, material well-being, and technological development. However, it has not been able to cope with persistent problems such as unequal social distribution of system benefits and increasing environmental degradation (Foster and Heeks, 2013; Gupta et al., 2015). Sustainability transition studies[1] have focused on analysing how the world may move from its current status to more sustainable practices (Markard et al., 2012). In this endeavour, special attention has been paid to the directions[2] potentially taken in socio-technical innovation[3] to guide and promote development of sustainable technologies, processes, beliefs, behaviours, and so on (Bouma et al., 2011; de Haan and Rotmans, 2011; Levidow et al., 2014; Opitz et al., 2016). Direction furthermore matters because it determines how benefits, costs, and risks from innovation are shared in socio-technical systems (Stirling, 2009). Framing direction is therefore a crucial issue on debates about innovation and socio-technical systems governance for transitions (Shove and Walker, 2010; Smith and Stirling, 2010; Smith et al., 2005).

With a view to analysing the role of innovation direction in socio-technical systems, transition scholars have sought to depict how and why, over time, some directions of change are chosen instead of others (Elzen et al., 2011; Geels, 2002, 2004; Grin and Schot, 2010). Scholars have often approached innovation direction from micro, meso, and macro perspectives or levels of analysis, often with intersections. The socio-technical transitions typology may be seen as a macro level analysis of innovation direction. Geels and Schot (2007) proposed the first typology for socio-technical transitions, encompassing two dimensions: the timing and the nature of multi-level interactions. This option led them to distinguish four transition pathways: technological substitution, transformation, reconfiguration, and de-alignment and re-alignment. Later, Geels et al. (2016) reformulated and differentiated pathways through the lens of trajectories in terms of event-chains and rounds of moves and countermoves enacted by actors. They also suggested that transitions may shift between pathways, depending on struggles over technology deployment and institutions. This literature strand indicates that socio-technical transitions follow some patterns that later tend to be replicated in similar conditions (Fuenfschilling and Truffer, 2014; Geels, 2011).

Dominant designs and lock-in concepts also play a role in the macro level of analysis. The dominant designs concept has been influential in studies focused on explaining directions taken by technological change in the last decades (e.g. Abernathy and Utterback, 1978; Anderson and Tushman,

[1] The field of sustainability transition studies is a recent focus within the transition studies literature. In this study, Fuenfschilling and Truffer's (2014) conceptualization is adopted. They regard the field as mostly composed of four research strands: strategic niche management, transition management, multi-level perspective, and technological innovation systems. For this study, it is important to underline that the field of sustainability transition studies embraces the transition management strand, which has given special attention to innovation direction issues from the outset, e.g. see Grin et al., 2010a; Loorbach, 2007; Rotmans et al., 2007.

[2] The terms direction and directionality are often used interchangeably in transition innovation studies, but they appear to mean the same thing. Here, we chose the term direction to mean prevailing routes taken by innovation in a socio-technical system.

[3] This study follows recent views about innovation that go beyond the classical Schumpeterian interpretation of technological change and therefore stress the complex character of innovation (Rosenberg, 1994). Drawing upon innovation systems theories and transitions theories, the socio-technical innovation approach acknowledges that novelties are qa socially constructed (Torresa, 2017; Schaile et al., 2017). For simplicity, in this article the word innovation is applied to refer to the concept of socio-technical innovation.

1990; Cecere et al., 2015; Chen et al., 2017; Koski and Kretschmer, 2007). Most literature on dominant designs unravels how a single architecture establishes dominance in a product category following four phases: technological discontinuity, era of ferment, dominant design, and incremental technical progress (Anderson and Tushman, 1990). The lock-in concept focuses on how mechanisms help to maintain consistency and internal dynamics in socio-technical systems. However, lock-in also hinders systems' adaptive capacity in that it keeps them fixed in a dominant direction (Foxon, 2002; Kuokkanen et al., 2017; Perkins, 2003).

From a meso perspective, scholars have studied how direction shapes transitions and its place in approaches such as strategic niche management (Boon et al., 2014b; Kemp et al., 1998; van Eijck and Romijn, 2008), transition management (Loorbach and van Raak, 2006; Rotmans et al., 2001; Rotmans et al., 2007), and reflexive interactive design (Elzen and Bos, 2016) and its place in (technological) innovation systems. Some studies have looked at expectations and guiding visions, or the lack of them (Berkhout, 2006; Borup et al., 2006; van Lente, 2012). Expectations and visions can influence the decision of individuals and organizations to engage in certain technological paradigms and trajectories (Dosi, 1982) that can drive an effective coalition for transformative change (Budde et al., 2012). Innovation direction has been also approached from the system failures perspective, which posits that a socio-technical system can be steered if its imperfections are grasped and fixed (Metcalfe, 2005; Rotmans et al., 2001; Weber and Rohracher, 2012). Moreover, scholars argue that mending system failures fosters reflexivity as a response to increasing complexity in innovation (Lindner et al., 2016).

At the micro level, Geels and Schot (2010), when analysing how the multi-level perspective (MLP) approach can cope with conflict and power struggles, articulated the link between agency and field level trajectories. The latter highlights actors' actions in the development of key event cycles within a system and can be seen as an implicit way to describe directions. This strand of work has recently received much attention in transition studies, with a focus on institutional entrepreneurship and other concepts to grasp agency (de Haan and Rotmans, 2018; Farla et al., 2012; Wittmayer et al., 2017).

In spite of these contributions, there are still gaps in our understanding of innovation direction from transition studies point of view. First, the current literature does not explain in detail how innovation direction is shaped over time, as previous analyses have not unravelled its dynamics completely, or have not even zoomed in on its role in socio-technical changes (this correlates with Svensson and Nikoleris's, 2018, recent critique that transition analysis does not fully understand the interplay between multiple factors in transformative change). Third, studies on innovation direction do not specify how it is consolidated (Fuenfschilling and Truffer, 2014). Previous literature makes it seem that these changes in system directions are a given, as if they take place randomly. Thus, there is room to deepen how interactions among actors have built these changes.

This chapter aims therefore to achieve a more fine-grained understanding of innovation direction. Beyond contributing to scientific debates, this undertaking better posits this thesis in view of recent policy debates linked to normative dimensions of innovation in science, technology, and policy, such as responsible research and innovation (RRI) (Garrido and Moreira, 2017; Owen et al., 2012), mission-oriented innovation policy (Markard et al., 2016; Mazzucato, 2018; Schot and Kanger, 2018), and policies for transformative changes (Weber and Rohracher, 2012). All of these approaches argue that it is feasible to steer research and innovation towards wider social and policy aims as well as economic goals (Lindner et al., 2016; Wittmayer et al., 2017) via structured innovation policy interventions, in order to foster sustainable development pathways (Patterson et al., 2017).

In this chapter we will concentrate on the following research questions: What are the dynamics behind innovation direction? To answer this question, we built and empirically applied an analytical model. The MLP was adopted as a broader lens, thereby using empirical data to grasp the broad context and the starting point of an innovation direction. The model itself was constructed by matching the concept of demand articulation with institutional theory (IT) and the theory of modal aspects (TMA). In blending these theories, an innovation direction filter was assembled, which consists of two connected and interdependent layers: the articulation layer and the institutionalization layer. This model was applied in an empirical setting relating to historical transitions in the Brazilian pig production socio-technical system.

The remainder of the chapter is structured in five sections. The building of the analytical model is explained in section 2. Section 3 presents the methodology for applying the model in the Brazilian pig production case. Section 4 presents the analysis and the empirical results of the case study, zooming in on the environmental crisis in Brazilian pork production. Section 5 presents a discussion and lessons learned from applying the model, and conclusions are drawn in section 6.

## 2.2. Deeping the conceptual understanding of innovation direction

Previous literature offers four useful clues about what innovation direction comprises. First, it is built by actors' (individuals and organizations) interactions (Geels et al., 2016) (Wittmayer et al., 2017). Second, it is complex, in that serendipitous events, feedback effects, uncertainties, and non-linearity may shape directions (Schlaile et al., 2017). Third, it is dynamically stable (Geels, 2004; Holtz et al., 2008; Papachristos, 2011). This means that a configuration of actors and elements that underpins a direction is not static but constantly changing. Fourth, it is influenced highly by institutional dynamics. Lawrence et al. (2002) articulated a concept of institution linked to innovation when analysing the role of collaboration in institutional innovation. They proposed that institutions may be understood as relatively widely diffused practices, technologies, or rules that have become entrenched in the sense that it is costly for actors in an institutional field to choose other practices, technologies, or rules. Institutions exert institutional control over actors, thereby impacting their visions, expectations, and actions. At the same time, they are shaped by institutional agency – the work of actors to transform, build, maintain, or break off institutions (Lawrence, 2008). Given these insights, we propose to see in this study innovation direction as a set of influencing practices, technologies, and rules that together denote an institutionalized direction for innovative initiatives developed by actors in an institutional field.

### 2.2.1. Innovation direction filter

In order to operationalize innovation direction analysis, we have built an analytical model based on the MLP, matching it with the concept of demand articulation, IT, and the TMA. Together, these theories construct what we have named an innovation direction filter, split into two connected and interdependent layers (Figure 2.1 presents the analytical structure developed to investigate how innovation directions are articulated and institutionalized). The analogy of a filter, which separates and purifies certain elements according to its purpose, seeks to reinforce the idea that innovation direction goes through a refinement process in order to turn a diffuse set of potential answers to an instability in

an institutional field into an institution. The following describes how each layer unfolds in the proposed innovation direction filter.



### 2.2.2. First layer: discontinuities, demands, and sets

Transitions studies largely take transitions as non-linear processes that emerge from the interplay at three analytical levels: niches (seen as a micro level: places where radical innovations meet proper conditions to be fostered), regimes (seen as a meso level: a semi-coherent set of rules that steers and coordinates how system actors fulfil a societal function), and landscape (seen as a macro level: the broad exogenous context that exerts pressure over a system and is beyond the direct influence of regime and niche actors) (Elzen et al., 2004; Geels, 2011; Genus and Coles, 2008).

The interplay between landscape, regime, and niche is also useful for grasping how innovation directions originate. Socio-technical systems evolve over time, coping with a continuous flow of discontinuities attached to its systemic societal function (e.g. a single country's food system is disturbed from time to time by unexpected events such as droughts, forefront technologies such as biotechnology, political issues such as international standards, or economic changes such as a free trade agreement). Some of these discontinuities are massive and push actors to search for alternative rules of the game, opening a window for establishing a new sets of practices, technologies, and rules (Smith and Raven, 2012; Farla et al., 2012). In the case of innovation direction, massive discontinuities are the starting point of the innovation direction filtering process. This study defines massive discontinuity as discontinuity in relation to the dominant design concept. Anderson and Tushman (1990) emphasized that, at irregular intervals, unexpected events or chronic problems make a dominant design unfeasible, affecting not only its profits and outputs, but even its foundations and existence. Similarly, in this study, massive discontinuity is defined as an event that threatens the way in which a socio-technical system continuity is structured. This event can be a natural accident, a political crisis, a new technological paradigm, or a combination of internal and external instabilities that can lead to a system disruption. In short, a massive discontinuity can make the performance of the system's societal function unfeasible. Consequently, actors are mobilized to search for a new configuration that allows the system to keep its social function.

From the moment a massive discontinuity begins to affect a socio-technical system, an existing institutional field is affected, or a new one emerges, possibly comprising all or parts of a socio-technical system, depending on the nature of the discontinuity. Institutional field in this study is understood as a social arena in which actors (e.g. producers, companies, suppliers, governmental organs, non-governmental organizations, and consumers) share a common meaning system and interact more frequently with one another than with actors outside the field (Scott, 1994). It is in this institutional field linked to the discontinuity that actors enact an articulation process to build a set of practices, technologies, and rules with the view to recovering system stability.

Demand articulation literature in the context of innovation studies has focused on learning processes about needs for emerging technologies (Klerkx et al., 2006; Van den Belt and Rip, 1987). The demand articulation concept is useful for analysing innovation directions because it emphasizes how interactions between actors build pathways for technological changes. Building upon Boon et al.'s (2008, 2011) model – which analyses demand articulation process in intermediary organizations – in this study, demand articulation is defined within the innovation direction filter as iterative and creative dynamics in which actors attempt to unravel how to address answers to emerging matters in the institutional field

generated by a discontinuity. This model helps to frame how actors articulate new sets of influencing practices, technologies, and rules.

The first step in the articulation layer comprises the agenda, which indicates to actors the most urgent matters to approach. The initial agenda is strongly linked to immediate consequences that a discontinuity causes to the institutional field. Afterwards, the agenda becomes guided by feedback linked to the new set of practices, technologies, and rules. It can also be influenced by unforeseen internal or external events.

Once actors are aware of the agenda, the second step in the articulation layer concerns socio-cognitive positions (te Kulve et al., 2018). Depending on their interests, visions, beliefs, values, and strategies, actors position themselves in the institutional field linked to a massive discontinuity. Actors often adopt reactive positions at first while analysing how their counterparts intend to tackle discontinuity consequences. Later, positions become clearer, and actors develop an accurate view of what to expect from one another.

Negotiation forms a third step. In the case of innovation direction, negotiation can be understood as a convergence exercise in which actors make moves and countermoves through a process of joint construction (Boon et al., 2014a).

When actors achieve a satisfactory level of common meanings, alliances, and strategies about what has to be done to tackle the discontinuity, they become able to define focused demands, the fourth step. Actors can approach focused demands in a shared or individual manner.

The set of influencing practices, technologies, and rules linked to focused demands is the last step in the first layer. It results from the interplay between actors in the previous steps and seeks to answer in practice challenges established in the agenda. In doing so, it sends actors signals about trends, technological routes, desired values, and so on, impacting their visions, expectations, and actions linked to innovation. It is also the target when actors build, maintain, or transform an innovation direction. The set of influencing practices, technologies, and rules is also the starting point of the model's second layer.

### 2.2.3. Second layer: aspects and increasing structuration

The second layer of the innovation direction filter focuses on how to describe the evolution from loosely structured elements towards a dynamically stable configuration of influencing practices, technologies, and rules linked to an innovation direction. Here, we employ IT, which is currently an important approach in organizational science that pays careful attention to socio-technical processes that influence the legitimacy and survival of institutions (Scott, 2013). IT has also been applied in transition studies (Fuenfschilling and Truffer, 2014). In the innovation direction filter, it helps to frame how a set of influencing practices, technologies, and rules developed by actors establishes itself over a certain period of time. This adaptation is similar to that made by Fuenfschilling and Truffer (2014) in order to improve the operationalization of the socio-technical regime concept.

Tolbert and Zucker (1996) state that the innovation institutionalization process has three distinct phases: habitualization, objectification, and sedimentation. Analytical heuristics like these phases are useful, despite the model proposed in the current study not applying them fully because of the dynamically stable characteristic of innovation direction. Inspired by Tolbert and Zucker, we contend that

the set of influencing practices, technologies, and rules that underpins an innovation direction starts from an initial effort addressed through a demand articulation process connected to an agenda. Uncertainty about the usefulness of the set is still significant, in spite of early results (habitualization). Later on, the set enlarges its competence to mobilize resources, make alliances, and foster a collective rationality (objectification). Finally, the set achieves a recognized level of acceptance regarding how to approach questions posed in the agenda of an institutional field (sedimentation).

IT has already been applied to transitions to refine what constitutes socio-technical systems (Fuenfschilling and Truffer, 2013; Holtz et al., 2008), but following Svensson and Nikoleris (2018) we refine this further by using the TMA. Proposed by the Dutch philosopher Herman Dooyeweerd to provide a ratio of aspects of experienced reality, the TMA sheds light on dimensions that help to analyse complex socio-technical dynamics (Basden, 2008; Basden and Burke, 2004). Following the examples of Wigbouldus et al. (2016) and Muilerman et al. (2018), in this study the original suite of 15 aspects (Numeric, Spatial, Kinematic, Physical, Biotic, Sensitive, Analytic, Formative, Lingual, Social, Economic, Aesthetic, Juridical, Ethical, and Certitudinal) are condensed into six aspects linked to the institutional field in which innovation direction is institutionalized (see Table 2.1.). The function of aspects in the innovation direction filter is to show the dimensions of the institutional field linked to the massive discontinuity that are being addressed by the set of influencing practices, technologies, and rules. We posit that, insofar as a set that underpins an innovation direction fulfils aspects of the institutional field, it increases its institutionalization and leverage.

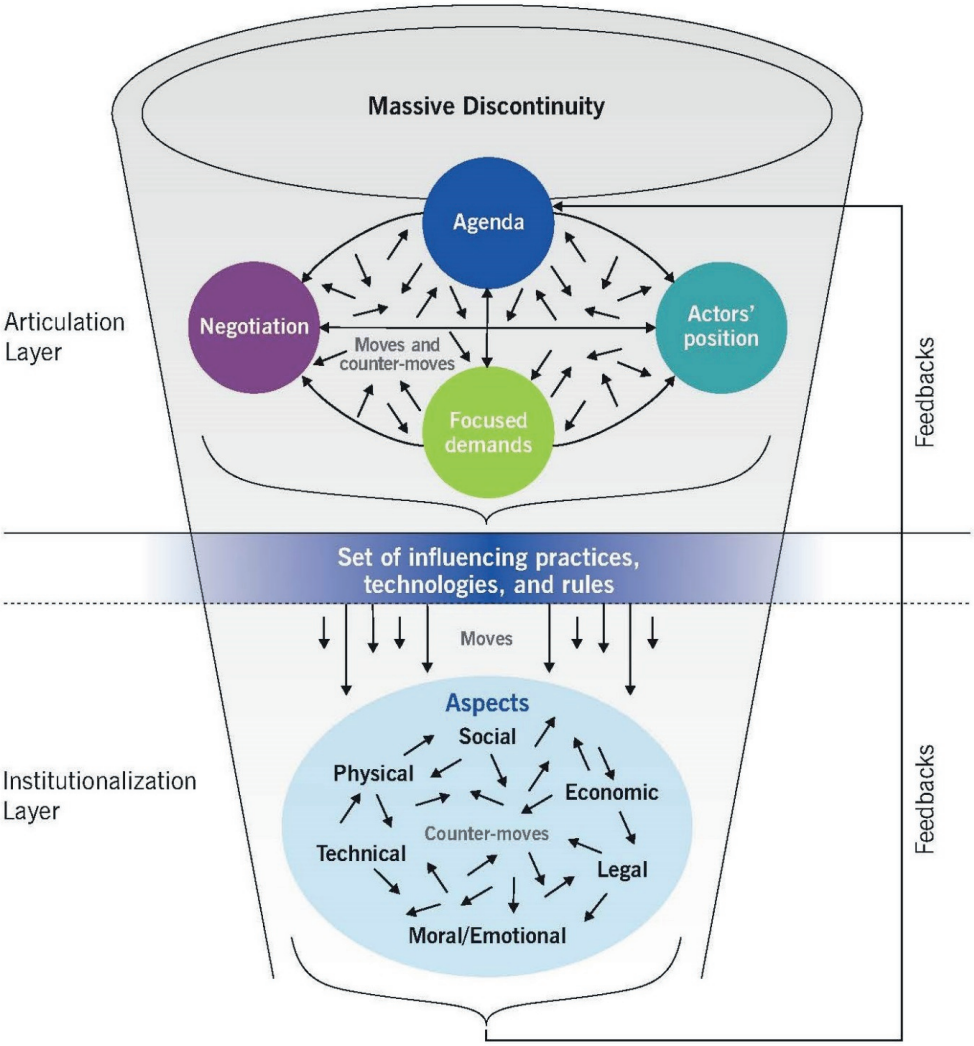
**Table 2.1.** Aspects in relation to innovation direction filtering (Wigboldus et al., 2017).

| Aspects linked to innovation direction entrenchment | The aspects in the original TMA set to which they relate | How does each aspect put into practice its filtering feature in regard to practices, technologies, and rules proposed towards the system discontinuity approached? |
|---|---|---|
| **Physical** | Numeric, Spatial, Kinematic, Physical, Biotic | Quantities required, spatial and geographical needs, right pace of change, energy and matter issues, topics linked to life (human, animal, or vegetal) |
| **Social** | Social, Lingual, Formative | Social development, social organization, culture, communication, education, symbolic representation |
| **Technical** | Analytical | Technologies, methodologies, standards |
| **Economic** | Economic | Costs, profits, market, investments |
| **Legal** | Juridical | What is due? |
| **Moral/Emotional** | Ethical, Sensitive, Certitudinal, Aesthetic | What is it right to do? faith, vision, emotional, supportive, feeling |

We assume that the fulfilment of the six aspects follows a similar rationale as the three stages of the institutionalization process (habitualization, objectification, and sedimentation). According to Tolbert and Zucker (1996), they represent the degree to which an institution is experienced by actors as part of an objective, external reality and as a coercive fact. The six aspects are not seen as stages of institutionalization in the innovation direction filter; however, the more aspects a set of innovation direction fulfils, the more institutionalized it will be. Although the fulfilment of the six aspects cannot be split up into stages like the institutionalization process, it is assumed to take place in cycles, once the initial agenda – and consequently the first set of influencing practices, technologies, and rules – of an innovation direction tends to be unable to address at once all dimensions of the institutional field linked to a massive discontinuity. For example, if climate changes threaten to increase droughts in a crop production region and actors in the institutional field linked to this massive discontinuity define the search for adapted seeds as an initial agenda, the first set of influencing practices, technologies, and rules built will tend to focus firstly on physical and technical aspects.

The fulfilment of the six aspects also plays a role in feeding back to the agenda and starting a new cycle of articulation and institutionalization. When a set of influencing practices, technologies, and rules goes through an institutional field, it leaves a track about how it approached each aspect. This interplay between sets and aspects provides feedback for the institutional field agenda regarding which aspect has been fulfilled (or partially fulfilled) and which has not. Who determines whether the aspects are being met and what feedback should be sent to the agenda constitutes the interplay between moves and countermoves in the institutional layer. Here, we follow Geels et al.'s (2016) understanding about moves and countermoves linked to socio-technical transitions in order to grasp this interplay. Moves and countermoves constitute an articulated dynamic interaction in which different actors or social groups react to one another's actions to reproduce or modify elements of a socio-technical system. In the institutional layer, the articulated dynamic interaction takes place between the set of influencing practices, technologies, and rules and actors. The set acts as a move and can provoke countermoves from actors who feel harmed by its side effects, excluded from its positive effects, or worried about its environmental externalities. We posit that every countermove directed at the set of influencing practices, technologies, and rules concerns one of the six aspects of the institutional field and that it somehow can turn into a feedback to the agenda. Besides feedback from the interplay between moves and countermoves in the institutional layer, new cycles of articulation and institutionalization may be led by serendipitous events, such as natural disasters, political crises, or spontaneous social mobilizations.

**Figure 2.1.** The innovation direction filter proposes an analytical structure to investigate how innovation directions emerge and consolidate.




## 2.3. Methodology

### 2.3.1. Case selection

To test the model empirically, the Brazilian pork production sector (BPPS) was selected as a case. This case is suitable to unravel the complexity of innovation direction dynamics because it has been susceptible to novelties and pressures from all around the world (Brooks, 2017; Iizuka and Gebreeyesus, 2016; Spiertz and Kropff, 2011) and because Brazilian pig production has evolved, in 50 years, from an artisanal and fragmented activity to an agri-industrial system that is the fourth largest world producer and exporter (ABPA, 2017). Taking the period from the 1970s to date, this study focuses empirically on

the state of Santa Catarina to analyse the overall BPPS, as Santa Catarina is the biggest pork meat producer and exporter in Brazil. Furthermore, the state pioneered the introduction and development of modern Brazilian pig production and has reliable databases about the evolvement of the pig production system in the last 50 years (Talamini et al., 2014).

### 2.3.2. Data collection and analysis

The primary sources of data for this work were a series of 41 in-depth interviews conducted with influential actors in the BPPS, such as representatives from industries, producers, governmental institutions, NGOs, science institutions, and advisory services (see Appendix). A scoping study mapping important players linked to innovation resulted in 32 interviewees; nine further interviewees were added by the snowballing method (Kumar, 2011). The interviews, conducted between July and December of 2017, followed an interview guide focused on how socio-technical changes took place in the BPPS from the 1970s to date.

Core and additional secondary data were also collected. The core secondary data consisted of books, scientific papers, policy briefs, official public reports (such as Brazilian Agricultural Census), media articles published in newspapers and magazines, and private and public archives of institutions linked to the BPPS. Additional secondary data were obtained from pig industries' official internet sites and annual reports published by associations of industries and producers.

All the interviews were recorded and transcribed verbatim. Interview content was triangulated with secondary data. As suggested by Yin (2009), analysis of the transcripts and secondary data started during data collection. The developing analysis helped to sharpen later interviews and to focus on crucial events linked to Brazilian pig production development.

The two layers in the model built from the literature, each with its specific elements, were then applied to analyse and interpretatively construct the innovation direction dynamics in the Brazilian case. The process went through the following two analytical steps: description of the massive discontinuities linked to the BPPS's societal function; application of the innovation direction filter to one of the BPPS's innovation directions.

## 2.4. Results

### 2.4.1. The BPPS trajectory in the last decades

Brazilian agriculture experienced a radical transformation in the 1970s, making Brazil an acknowledged success case of agricultural development in a developing country (Ioris, 2017). The BPPS participated in this agricultural revolution and reached remarkable social and technical results specially from the 1980s onwards. In 2015, the value of Brazilian pig meat gross domestic production reached 20.22 billion dollars, and the sector employed 126,000 workers directly and 923,000 workers indirectly (Sebrae and ABCS, 2016).

The rise of the BPPS was linked to landscape pressures in the 1960s that led to the destabilization of the previous pork meat production socio-technical regime in Brazil and the strengthening of niche initiatives established in the state of Santa Catarina. In the early 1960s, Brazil faced an accelerated urbanization process (Brito, 2006). At the same time, the increase in electric power supply – through the construction of several hydroelectric dams from 1964 onwards (Kilvington, 1983) – and improvements in the food industry caused deep changes in the Brazilian consumer market (Chaddad, 2016).

Two changes in Brazilian society were especially relevant for the pig production system at the time. The first was the popularization of domestic refrigerators; this met the demand arising from the new Brazilian urban family profile, as in 1960 16.5% of Brazilian women were employed outside the home (Brabo et al., 2015). The second was the introduction of vegetable oils (Chaddad, 2016). These two changes deeply damaged the market for pork lard, the main product extracted from pig production in Brazil at the time. The refrigerator gradually replaced lard as a tool for meat conservation, and vegetable oils substituted pork lard in Brazilian kitchens even more quickly, as local and national media echoed the vegetable oil industry's argument that its product was healthier than animal lard (Spies, 2003).

The responses to these pressures came from a niche established in the western region of Santa Catarina. Colonized by second generation Italian and German immigrants in the early 20th century, Western Santa Catarina was structured socially and economically around small farms producing grain, poultry, pigs, and milk (Spies, 2003). Influenced by their European heritage, the owners of those small properties produced artisanal pork meat products, such as sausages. Between the 1940s and 1950s, some entrepreneurs started small industries, which besides pork lard and salted pork meat offered some types of Italian sausages (Bosísio et al., 2003). When pork lard lost its value, those small entrepreneurs already had the knowledge to focus on the production of industrialized products from pig meat.

Some of the small industries in Western Santa Catarina became leading national companies in the pig sector in less than 20 years. They established a new configuration in the BPPS, taking advantage of the windows of opportunity that opened in the 1960s. This new socio-technical regime is still based on industrialized products. Seventy-five percent of pig meat produced in Brazil is converted into sausages, ham, salami, and so on (ABPA, 2017). Production is concentrated in three large industries, all originating in Santa Catarina and inserted in the international pig market. These industries have developed a highly capable supplier structure, which invests in imported technologies and solutions (especially from the United States and Europe) as a pillar of their uninterrupted development (Santos Filho, 2012). Industries and suppliers also avail of support from their own private and public science structures to facilitate technology adoption and adaptation processes (Talamini et al., 2014).

Since the mid-2000s, when the BPPS started to focus on expanding exports as a way to overcome consumption stagnation in the domestic market (Roppa, 2009), the interplay between landscape, regime, and niche in the BPPS led to a new configuration. Landscape pressures such as international standards of sanitary control and traceability required significant changes in several stages of the pig production process in Brazil (Talamini and Santos Filho, 2017). At regime level, instabilities arising from shortcomings such as the high negative impact on the environment, deficiencies in grain production in regions with concentrated pig production, and cyclical economic crises provoked a reduction in both producers and industries (Lundström, 2011). In terms of recent niches, most initiatives are linked to the development of alternative technologies or production organizations aligned to the dominant model. An example is the emergence of the cooperative model of pig production. It innovated in regard to managing the business

and how industry and producers relate. However, it follows the same production logics as private industry (Spies, 2003).

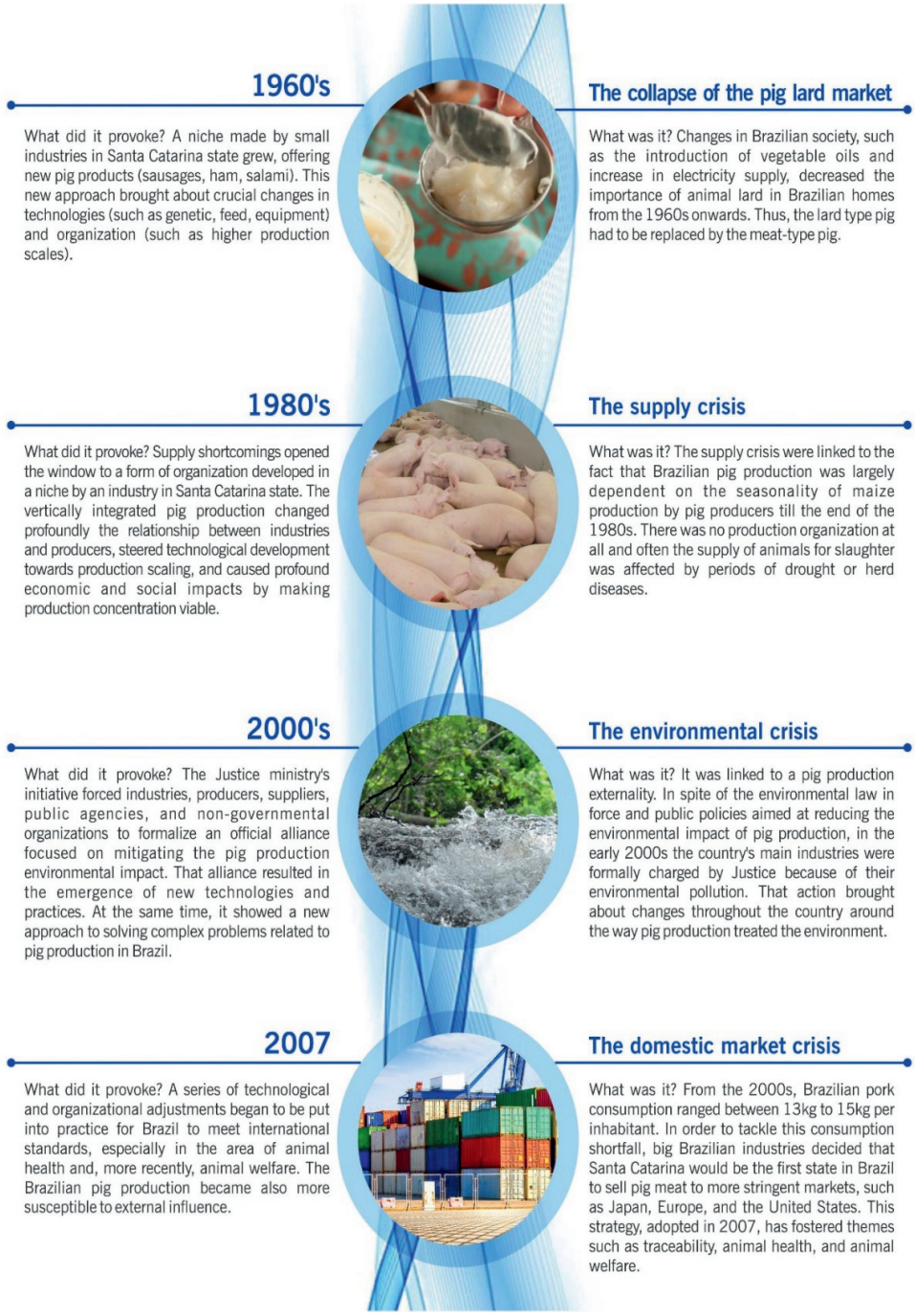
### 2.4.2. Discontinuities and windows for new directions

From interviews and secondary data collected in the field, this study was able to identify four massive discontinuities in the BPPS in the last five decades: the collapse of the pig lard market, the supply crisis, the environmental crisis, and the domestic market crisis (see Figure 2.2.). All of them led to new sets of formal and informal practices, technologies, and rules that together have influenced innovation direction to date. All of these developments were concentrated in Santa Catarina, geographically and politically speaking, but later on influenced the industry countrywide.

As stated in section 4, the collapse of the pork lard market can be seen as the starting point of the current BPPS. It was the most disruptive discontinuity and replaced the previous model, pushing the industrialization of Brazilian pig production. The other three massive discontinuities are more incremental, despite the significant transformations that they provoked. The supply crisis was linked to Brazilian pork production being largely dependent on the seasonality of maize production till the end of the 1980s. In practice, maize seasonality meant that there was a 'pig harvest' once a year when producers finished fattening their animals and sold them on the free market for the best price. There was no production organization at all and often the supply of animals for slaughter was affected by periods of drought or herd diseases. That situation lasted until the late 1980s, when new practices, technologies, and rules came into play in Santa Catarina to tackle that system discontinuity.

The environmental crisis is linked to a pig production externality, and Santa Catarina, the largest Brazilian producer, was the first to feel it. In spite of the environmental law in force and public policies aimed at reducing the environmental impact of pig production, in the early 2000s the country's main industries were formally charged by the Justice ministry with causing environmental pollution in Santa Catarina. That action brought about changes throughout the country around the way pig production approached environmental issues. A new set of practices, technologies, and rules also arose when big Brazilian industries decided in 2007 that Santa Catarina would be the first state in Brazil to sell pig meat to more stringent markets, such as Japan, Europe, and the United States. This internationalization strategy was an answer to persistent difficulties about improving internal consumption, the domestic market crisis. Ever since, it has fostered themes such as traceability, animal health, and animal welfare.

**Figure 2.2.** Massive discontinuities in Brazilian pig production and their consequences.



### 2.4.3. The environmental crisis and the rise of an innovation direction in Brazilian pig production

Having described the massive discontinuities in pig production in Santa Catarina over time, this study now focuses on the environmental crisis to analyse how innovation direction unfolds in socio-technical systems. This event was chosen because several interviewees detailed how and why this massive discontinuity struck pig production in Santa Catarina and the whole country afterwards. Furthermore, the environmental crisis has been studied by many researchers in the last decade, offering valuable secondary data.

Brazilian society started to pay attention to pig production environmental externalities in the 1990s. With the expansion of the vertically integrated industrial model of pig production,[4] pig production increased in scale and became concentrated in fewer properties, industries, and regions. Consequently, soil, water, and air came under pressure where pig production became a focus (ICEPA, 1999). Western Santa Catarina was the site most affected by pig production environmental externalities. In 2003, this region of approximately 25,000 square kilometres (26% of the total Santa Catarina area) accounted for more than 80% of the 5.4 million pigs produced in Santa Catarina, equivalent to 32.81% of Brazilian production at the time (ABPA, 2003). The daily volume of waste produced reached 30,000 cubic metres and was almost fully released into the environment without adequate treatment (Miranda et al., 2012), resulting in overwhelming negative consequences for nature and people. For instance, the Santa Catarina Company for Agricultural Research and Rural Extension (Epagri) conducted research on water quality in Western Santa Catarina between 1999 and 2001. Epagri found out that 85.5% of the surface water sources used by farmers and urban populations reached faecal coliform levels above the recommended level in that period. The same study pointed out that pig production was the main source of water pollution (Baldissera, 2002).

The environmental impact of pig production might be regarded as a discontinuity in itself, and it impacted innovation somewhat in the 1990s. However, it was not enough to foster the emergence of a fully new set of practices, technologies, and rules that could be labelled as a new innovation direction. What was missing was a massive discontinuity linked to this environmental issue that would mobilize actors around an alternative innovation outlook. The massive discontinuity only came about when one of the system actors made an unexpected move. In October 2001, the Public Prosecution Service of the State of Santa Catarina proposed a deal to the pig production sector as a response to huge numbers of environmental pollution cases caused by the – accidental or not – discharging of pig manure into surface water sources in the previous 10 years. In addition, only 8.35% of the rural properties where pigs were produced at the time had the mandatory environmental licence (Miranda et al., 2012). According to the Public Prosecution Service, producers, industries, suppliers, and local and state governments should officially make a commitment to comply with all requirements of the environmental law within a period of time that would be agreed upon. If they did not accept the deal, the environmental law would be applied in its totality immediately, which would certainly render pig production impracticable in most cases.

[4] According to Spies (2003), this model is characterized by a contractual relationship between an integrator (an industry usually, but in some cases a cooperative or a big producer) and pig producers. The former is obliged to supply pigs for rearing, feed, medicines, advisory services, and all the support needed to achieve the best production results possible. The latter have to provide housing and manpower to execute the animal husbandry patterns specified by the integrator. Producers' income is linked to the achievement of productivity goals specified by the integrators.

### 2.4.4. First layer: articulation and set of practices, technologies, and rules

The Public Prosecution Service position triggered immediately the rise of an institutional field linked to the environmental crisis in Brazilian pig production. In this social arena focused on elucidating how to cope with the Public Prosecution Service's demands, actors began to interact actively to build common meanings, alliances, and strategies. The initial agenda that arose in the environmental issue institutional field was composed of two questions: 1) How would all pig producers introduce the needed improvements in their properties to achieve the mandatory environmental licence? 2) What technological improvements would decrease the environmental impact of pig production waste? Both topics stimulated actors to position themselves regarding how to tackle the Public Prosecution Service's demands. Depending on their interests, visions, beliefs, values, and strategies, actors took conservative and defensive positions linked to the initial agenda. None of them publicly opposed the deal proposed by the Public Prosecution Service, but neither did they take responsibility for the problem. For example, industries wanted to keep pig production as it was, without taking on environmental costs or significant structural changes. Producers claimed that they were being induced by industry to adopt an environmentally unsustainable production model, and they would not agree to pay for adjustments themselves. In turn, local and state governments regarded the pig production environmental crisis as basically a private matter, in which they could not play a central role.

Actors' positions implicated that it would take a long time and a lot of effort to link focused demands construction to the initial agenda. The negotiation phase began indeed when actors recognized that they did not have enough data to address the problem; this in practice meant that neither party could convince the other that it was right. The output was the setting up of a working group in the institutional field with representatives of industries, producers, governments, 16 municipalities of Western Santa Catarina, universities, public advisory services, and public research institutions. The non-governmental organization, Lambari Consortium, led the working group and had a strategic role as intermediary. In 2002, the Lambari Consortium carried out a diagnosis and found that 91.75% of 4,000 pig farms encompassed in the 16 municipalities researched did not have the mandatory environmental licence. Moreover, 78% did not fulfil the environmental law on two or more items, and 71% produced more manure than they could treat and store (Miranda and Miele, 2009).

The diagnosis shed light on the real extent of the environmental impact of pig production in the institutional field and triggered a new stalemate. The Public Prosecution Service wanted the agreement to solve the environmental crisis to be individualized. That is, each pig producer would have to make an adjustment to his property to meet the environmental legislation and make a commitment about a deadline. The producers feared having to bear intervention costs on their own and they hesitated to act. After more than a year of discussions, an agreement was reached in June 2004 on how to fund the interventions needed in pig production properties. Industries agreed to finance producers with whom they had raw material supply contracts. The 10% who did not have fixed contracts with industries were partially aided by the Santa Catarina government. Those commitments in the institutional field ended the negotiation phase linked to the initial agenda and established two focused demands: deploy the agreement demanded by the Public Prosecution Service and decrease the environmental impact of pig production in Western Santa Catarina. These demands guided the first set of influencing practices, technologies, and rules in the institutional field linked to the environmental crisis in Santa Catarina. Table 2.2. presents a comparison between practices, technologies, and rules before and after the first set.

**Table 2.2.** The set of influencing practices, technologies, and rules and the institutional field.

**Overall view of innovation direction in the institutional field linked to the environmental crisis in Santa Catarina state**

| | Practices | Technologies | Rules |
|---|---|---|---|
| **Before the environmental crisis** | Pig production did not take into account the environmental limits of the properties in which animals were produced.<br><br>Advisory services provided by industries to producers focused only on increasing animal production. | Focused only on the liquid route of pig manure treatment, such as tanks to separate liquids from solids and produce organic fertilizer after 120 days of storage.<br><br>The environmental technology used to be rather less developed compared to other Brazilian pig production dimensions, such as genetics, food, and animal health. | The environmental law linked to pig production was not taken into account by the vast majority of producers and industries.<br><br>Industries did not have internal rules linking production to the environmental limits of the rural properties where pigs were raised. |
| **After the first set linked to the environmental crisis** | The environmental limits of the properties in which animals were produced became a parameter to define production size.<br><br>Private system of funding investments in environmental adequacy was enacted in pig production. | Focused on both the liquid route and the solid route of pig manure treatment.<br><br>Actors searched for and improved or new technologies linked to water distribution at pig farm facilities and pig production waste management, such as biogas generation, composting of pig manure, cisterns for rainwater storage, and more efficient water distribution equipment. | Individualized agreements entered into by producers and industries as instruments of environmental intervention in pig production. |

### 2.4.5. Second layer: aspects and feedback

From the moment that the first set of influencing practices, technologies, and rules linked to the environmental crisis was put into practice in the institutional field, it started to go through a process of evaluation and legitimization, which in the model proposed in this study is understood as the second layer, the institutionalization process. In this layer, the set acts as a move addressed to aspects of the institutional field. The first set linked to the environmental crisis clearly was capable of meeting four aspects of the institutional field: legal, economic, technical, and social.

The set could fulfil immediately two out of four aspects. The first was the legal aspect. As soon as the producers signed the agreement with the Public Prosecution Service, they got temporary environmental licences and about three years to outline and deploy environmental projects for their properties. In other words, the Public Prosecution Service made law enforcement malleable for a while, and the 91.75% of producers who would not comply with environmental rules committed to investing in individual environmental improvement projects. With regard to the legal aspect, the new rule 'Individualized agreements as instruments of environmental intervention in pig production' proved to be highly effective and has become an example followed later by other pig production regions (Miranda et al., 2013). The economic aspect also was fulfilled swiftly. On the one hand, the new practice 'Private system of funding investments in environmental adequacy' achieved an unprecedented way of financing environmental interventions in Brazil. On the other hand, it prevented a significant part of Santa Catarina's pig production from becoming unfeasible, which would certainly provoke overwhelming economic losses for all actors embedded in the pig production system in Santa Catarina.

The technical and social aspects were just partially fulfilled. From June 2004 to the end of 2005, researchers and advisory service professionals designed intervention plans for each property that did not comply with the environmental legislation. All intervention projects included more efficient water distribution equipment. Depending on the volume of waste and the area of land available, technologies such as biogas generation, composting of pig manure, and cisterns for rainwater storage were also incorporated. However, issues such as cheaper and easy handling treatment methods for pig manure, reuse of water used in facility clean-ups, and reduction in nutrient load in feeding provided to animals remained unaddressed. Regarding the social aspect, the initial set of influencing practices, technologies, and rules avoided a social collapse as it ensured the economic structure of an important agricultural region in Santa Catarina. Another contribution was to build formal spheres to debate environmental issues; this would play a decisive role later in the development of environmental education programmes.

The first set also addressed the physical and moral/emotional aspects, but without major changes in either of them initially. This becomes clear when we see how actors reacted to the first set, heading countermoves to it. In 2005 and 2006, annual seminars were held to evaluate the first phase of the agreement with the Public Prosecution Service. Meetings were also held only with pig producers in order to ascertain their perception of the agreement. These formal evaluations and the daily positive and negative results experienced by actors provided feedback to refresh the agenda linked to the environmental crisis. In short, countermoves/feedback linked to the initial set of influencing practices, technologies, and rules addressed the following points in the institutional field agenda: 1) They fixed an emergency situation, but not the high environmental impact of pig production in Santa Catarina, and this kept non-governmental organizations and the Public Prosecution Service focused on pig production in regard to environmental issues; 2) Pig production waste treatment technologies needed to be further developed to deal with the environmental challenges of Brazilian pig production; 3) Producers and industries should adopt new practices regarding water usage in pig production countrywide; 4) Parallel to the legal and technological intervention on farms, it would be necessary to develop environmental education programmes aimed at all pig production system actors in Santa Catarina (Miranda et al., 2006).

From 2006 to date, the set of influential practices, technologies, and rules made new moves that were responded to by actors' countermoves, which fed in turn new cycles of articulation and institutionalization in the institutional field. For instance, in order to address the social and the moral/emotional aspects, actors requested educational practices to support legal and technological interventions aimed at reducing pig production environmental impact. From 2008, the set embodied

practices such as the deployment of networks to monitor river water quality; the development of initiatives linked to fostering pig producers' social organization; and the development of a special project to popularize pig producers' updated water consumption parameters. Table 2.3. presents the current overall view of innovation direction in the institutional field linked to the environmental crisis in Santa Catarina.

**Table 2.3.** The current set of influencing practices, technologies, and rules and the institutional field.

**Current view of innovation direction in the institutional field linked to the environmental crisis in Santa Catarina state**

| | **Practices** | **Technologies** | **Rules** |
|---|---|---|---|
| **Set linked to the environmental crisis** | Private system of funding investments in environmental adequacy in rural properties **– Economic aspect**<br><br>New water management practices in pig farm facilities based on updated water consumption parameters per animal **– Technical and Physical aspects**<br><br>Deployment of environmental indicators in the advisory services model provided by industries to pig producers **– Technical aspect**<br><br>Development of an organic fertilizer market based on pig manure **– Economic and Social aspects**<br><br>Development of actions linked to environmental education and producers' organization – **Moral/Emotional and Social aspects** | Focused on both the liquid route and the solid route of pig manure treatment – **Technical aspect**<br><br>Development of machines for pig manure compost automation – **Technical aspect**<br><br>Optimized biogas production systems – **Technical aspect**<br><br>Optimized systems for the withdrawal of nutrients from pig manure – **Technical aspect**<br><br>Optimization of feed nutrient balancing – **Technical aspect**<br><br>Improved drinking fountains, distribution pipes, water meters, automatic water supply systems, and methods of storing rainwater and water from surface sources – **Technical aspect** | New set of procedures and documentation for pig production environmental licensing issued in 2014 – **Legal aspect**<br><br>Informal rule adopted by industries that started to link the number of pigs that a producer could keep on his property to the availability of water, land, and waste treatment technology – **Physical and Social aspects** |

The current set of influencing practices, technologies, and rules in the institutional field linked to the environmental crisis can be considered highly institutionalized as it fulfils all the aspects. This finding does not mean that the environmental question is solved in practice in Brazilian pig production, nor that the set has reached a point where actors' countermoves are no longer directed at it. In short, after many rounds of moves and countermoves that went through processes of articulation and institutionalization, this set has had an effective influence on actors developing innovative alternatives linked to environmental issues in pig production in Santa Catarina. However, as Santa Catarina is the biggest and more influential pig producer in Brazil, it is taken for granted that directions built in it have effects on innovation in the overall Brazilian pig production system.

## 2.5. Discussion

The construction and the application of the analytical model contribute to sustainability transitions studies by offering an explanation of innovation direction dynamics and consolidation process. Unravelling innovation direction in socio-technical systems adds to previous literature specifically in (1) refining the understanding of trajectories in terms of event-chains and rounds of moves and countermoves in socio-technical transitions; (2) elucidating the dominant designs emergence process; (3) nuancing approaching innovation direction as a constant interaction between micro, meso, and macro levels of analysis; and (4) contributing to a fine-grained understanding of directionality failure in policy interventions. We also discuss the model's limitations and avenues for further research.

### 2.5.1. Refining the understanding of trajectories in terms of event-chains and rounds of moves and countermoves in socio-technical transitions

The reformulated typology proposed by Geels et al. (2016) developed the 'local logic' of the transition pathways typology, which relies less on external landscape pressure and more on shifting actor coalitions, struggles, and adjustments in formal rules and institutions. They chose to analyse transitions through lenses of different granularity and underpinned their refreshed typology with explanations of trajectories in terms of event-chains and rounds of moves and countermoves – the first typology focused on aggregate explanations in terms of alignments of trajectories within and between niche, regime, and landscape levels (Geels and Schot, 2010). The model constructed and applied in this study refines the understanding of trajectories in terms of event-chains and rounds of moves and countermoves in socio-technical transitions in a twofold way.

Firstly, the model elucidates how a sequence of events, or an event-chain, that justifies a trajectory can be understood and described at field level. The reformulated typology of socio-technical transitions means that each event in a trajectory can be analysed in terms of more specific morphogenetic cycles. The model constructed in this study reveals a clearer picture of how these cycles of endogenous enactment begin and how they unfold. The first cycle of articulation and institutionalization of an innovation direction is triggered by an event that harms the dynamically stable features of a socio-technical system – this initial event is called a massive discontinuity in this chapter, e.g. a natural accident, a political crisis, a new technological paradigm, or a combination of internal and external instabilities that can lead to a system disruption. In the case analysed here, an action by the Public Prosecution Service functioned as a massive discontinuity and guided the initial agenda after destabilizing the pig production

system in Santa Catarina. Actors build a set of influencing practices, technologies, and rules in response to the discontinuity that destabilizes the system. This set acts on the system and receives feedback to the extent that it answers system aspects destabilized by the discontinuity. Feedback triggers a new process of articulation and institutionalization, which adds new changes to the set of practices, technologies, and rules, and so on. In the Brazilian case, the initial event-chain was the Public Prosecution Service action, which was followed by new event-chains such as the deployment of individualized agreements entered into by producers and industries as instruments of environmental intervention; the development of a new paradigm of pig waste management (the automatized solid manure route); the enactment of a new environmental law for pig production in Santa Catarina; and so forth. The model also considers that unexpected events, external or internal, can play a role in each cycle of articulation and institutionalization – despite unexpected events not playing a relevant role in the case analysed here. Thus, it contemplates exogenous and endogenous events that underpin an innovation direction trajectory.

Secondly, the model offers a fine-grained understanding of the progressive interweaving of moves and countermoves within the sequence of events that builds a trajectory. Studies that propose transition pathways (Geels, 2007; Geels et al., 2016) contend that in each event of an event-chain actors react to one another's moves. This action/reaction game has often been associated in these studies with practical implications, such as making investment decisions about R&D directions, introducing new technologies, developing new regulations, proposing new practices, mobilizing forces against an unsustainable production model. The model constructed and applied in this study reveals that moves and countermoves also underpin an articulation process before having practical implications. Discontinuities foster agendas, which provoke negotiations between actors and the delineation of demands. Moves and countermoves are enacted in this articulation process within an exercise of convergence, in which actors may reshape interests, visions, beliefs, values, and strategies in light of shared understandings. In our case, the Public Prosecution Service move provoked several countermoves from other actors in the pig production system in Santa Catarina. The main debate regarding this first move was about who would be charged with the environmental intervention costs in pig producers' properties. Eventually, after two years of negotiation, actors switched their initial strategies, converged their interests, and were able to build an unprecedented practice linked to funding environmental intervention. The model also emphasizes that the set of influencing practices, technologies, and rules built in response to a discontinuity are influenced by the articulation process based on actors moves and countermoves; and the relation between the set and the institutional field aspects can be understood as another level of moves and countermoves. The set of influencing practices, technologies, and rules is a move regarding the institutional field. The feedback aspect addressed to the set is a countermove, which fosters a new cycle of articulation.

### 2.5.2. Elucidating the dominant designs emergence process

In spite of the technological focus of the dominant designs concept, some scholars have underlined that the emergence of a dominant design is also driven by non-technological factors, such as the interaction between actors, organizational and socio-political processes, and historical events (Munir and Jones, 2004; Seidel et al., 2016; Tushman and Rosenkopf, 1992). For example, Lee et al. (1995) proposed a framework to unravel the emergence process of a dominant design. They stressed that, to grasp why sometimes a dominant design is not necessarily the technologically superior one, it is essential to understand the driving forces (technological and non-technological).

The model constructed in this study offers fine-grained guidance about the interaction between technological and non-technological driving forces involved in the emergence of a dominant design. The articulation phase of the model, for instance, may unravel how actors connect agendas and demands to technological choices in the era of ferment, thereby helping to grasp the reasons behind a dominant design. The Brazilian case shows that an action of the Public Prosecution Service triggered a quest for technological improvements linked to a decrease in the environmental impact caused by pig production 3waste. Diverse and complementary factors – economic (what type of waste management technology could producers adopt without threatening their viability and without increasing pig meat prices for consumers?), social (what kind of waste management technology could demand less physical efforts of pig producers?), legal (what type of waste management technology could help pig producers to achieve the mandatory environmental licence?), and environmental (what kind of waste management technology could decrease the impact of pig production on water quality?) – interacted in order to suggest general requirements for suppliers interested in developing solutions recently adapted to Brazilian pig production. In practice, those non-technological forces defied the hegemonic liquid manure route of pig waste management and may lead the change that may convert the automatized solid manure route of pig waste management into a dominant design in Brazilian pig production.

Additionally, the innovation direction model refines dominant designs in the sense of a dominant architectural solution, as applied sometimes by the organizational ecology literature to demarcate a determined period. Argyres et al. (2015) argue that the ecology literature hints that legitimation processes drive the selection of a dominant solution, so that such a solution is not necessarily the most efficient or effective from a technical standpoint. The set of influencing practices, technologies, and rules in the innovation direction model can be seen as a dominant architectural solution, which is continuously articulated by actors and legitimated through institutional field aspects. This corroborates the organizational ecology literature approach, in which a dominant solution is driven by a process and not just by the most efficient or effective technology. Furthermore, the model underlines that the dominance of a dominant set of practices, technologies, is not an end point, thereby confirming the cyclical nature of dominant architectural solutions or dominant designs in the most recognized sense (Anderson and Tushman, 1990; Seidel et al., 2016; Wade, 1995).

### 2.5.3. Nuancing approaching innovation direction as a constant interaction between micro, meso, and macro levels of analysis

In order to understand innovation direction within the broader complexity of transitions, this study described how previous literature has approached it from different levels of analysis – micro, meso, and macro (e.g. Geels et al., 2016; de Haan and Rotmans, 2018; van Lente, 2012). Unlike previous literature, which often focuses on more specific dynamics, the analytical model constructed and applied in this study makes it feasible to grasp innovation direction as a process of multiple interwoven levels, meaning that it is intrinsically linked. The articulation phase of the innovation direction filter allows the micro level of analysis to be unravelled, showing how actors' agency turns agendas provoked by a system discontinuity into influencing practices, technologies, and rules. In turn, the set of influencing practices, technologies, and rules represents the meso perspective of analysis, in that it can play a role in shaping expectations and opportunities for actors for example; or it can uncover why a system copes with specific failures. The macro level of analysis refers to the institutionalization phase of the innovation direction model. This stage addresses how an institutional field, which may be a whole socio-technical system,

absorbs the set of influencing practices, technologies, and rules (a macro move) and what sort of feedback this absorption provokes (a macro countermove). The model demonstrates that the interaction of these three levels of analysis is fundamental to describing how a sequence of events justifies and enables an innovation direction. Table 2.4. presents how levels of analysis are interwoven in the Brazilian case.

**Table 2.4.** Levels of analysis in the innovation direction model applied in the Brazilian case.

| **Levels of analysis in the innovation direction filter** | To what level of analysis does it pertain? | How does it explain the construction of an innovation direction in the Brazilian case? | How is it interwoven with other levels of analysis in the Brazilian case? |
|---|---|---|---|
| **Articulation phase** | Micro | It shows how actors' reactions (moves and countermoves) to a system discontinuity linked to the environmental issue fostered the emergence of influencing practices, technologies, and rules that underpin innovation direction in Brazilian pig production. | Agendas and demands linked to the environmental issue articulated by actors helped to elucidate the set of influencing practices, technologies, and rules that started to steer innovation. At the same time, institutional field feedback to the set guided new agendas for actors relating to the environmental issue. |
| **Set of influencing practices, technologies, and rules** | Meso | The set of influencing practices, technologies, and rules explains how the discontinuity linked to the environmental issue was answered by actors. It also helps to grasp how reactions to it influence actors' visions and expectations and system failure assessment regarding the environmental issue. | The set of influencing practices, technologies, and rules linked to the environmental issue prevents pig production from interfering in institutional field aspects, such as the legal aspect. It also helps to analyse actors' agency outcomes regarding the environmental issue. |
| **Institutionalization phase** | Macro | The institutionalization phase shows how Brazilian pig production has been addressed by the set of influencing practices, technologies, and rules linked to the environmental issue; and how institutional field feedback influences new cycles of articulation and institutionalization. | The institutionalization phase shows why the set of influencing practices, technologies, and rules linked to the environmental issue supports an innovation direction in Brazilian pig production. It also influences continuous interactions between actors to improve the set. |

### 2.5.4. Contributing to a fine-grained understanding of directionality failure in policy interventions

Recent debates linked to normative dimensions of innovation in science, technology, and policy have considered how structured innovation policy interventions may foster sustainable directions to achieve deep societal changes (e.g. Markard et al., 2016; Garrido and Moreira, 2017; Mazzucato, 2018). A crucial issue in those debates is to grasp and describe how public policies, including those directed at innovation, technology, and science, have been framed over time, because framing can be understood as a powerful directionality tool. Schot and Steinmuller (2018) delineate three framings related to innovation, technology, and science policy: innovation for growth (linked to mass production and consumption); national innovation system (linked to consequences for individual nation states of their experience with modern economic growth); and transformative change (linked to how to use science, technology, and policy to achieve sustainable and inclusive societies). The third one is in the making, and Schot and Steinmuller underline that the transformative change framing should take into account analysis about structural failures in public policies based on previous framings to justify its policy intervention rationale.

Drawing upon the framework developed by Weber and Rohracher (2012), we suggest that policies for transformative change begin with the recognition of four types of failure: directionality, policy coordination, demand articulation, and reflexivity. In our view, the innovation direction model is useful for acquiring a fine-grained understanding of directionality failure in public policies. Schot and Steinmuller (2018) see directionality failure as the lack of means for making social choices about alternative development pathways. According to the model constructed and applied in this study, a public policy aimed at fostering a desired innovation direction would firstly have to be able to cause a discontinuity in the system that mobilized actors. Then it would have to influence the articulation phase in order for the set of practices, technologies, and rules linked to the system discontinuity to take into account desired alternative development pathways. Thus, the model shows that a failure in directionality is linked to the lack of means for building, more than making, collective choices.

The Brazilian case described here offers clues about how a public policy could foster means for building collective choices towards alternative development pathways. In the early 2000s, Santa Catarina's Public Prosecution Service proposed an agreement to bring pig production waste management into line with the environmental law. The Public Prosecution Service's action was a move that provoked a system discontinuity. However, in practice it could also be seen as a public policy that aimed to foster an alternative development pathway, in which environmental issues become crucial for innovation. As a public policy, the agreement proposed by the Public Prosecution Service gave direction, established a discontinuity to mobilize actors, and fostered means to build collective choices such as the private system of funding investments in environmental adequacy, the development of an organic fertilizer market based on pig manure, the new set of procedures and documentation for pig production environmental licensing, the development of technologies such as composting pig manure, and so on. Overall, what has taken place in Brazilian pig production is a practical example of how to develop what Weber and Rohracher (2012, 1042) call 'certain corridors of acceptable development pathways' – i.e. a mix of soft instruments of coordination and information, hard interventions like regulations and standards, and funding, for instance for research, in order to guide forces of innovation, production, and consumption.

Additionally, the innovation direction model reinforces the correlation between discontinuity and direction, similar to findings described by Kivimaa and Kern (2016) when proposing that ideally policy

mixes for transitions should include elements of creative destruction. This correlation is significant, because it suggests a potential starting point for public policies that aim to drive research and innovation towards broader social, political, and economic objectives, such as mission-oriented innovation policy (Binz and Truffer, 2017; Mazzucato, 2015). Rather than fostering technologies or setting incentives for particular sectors, public policies with wider aims to carry out complex missions might provoke a controlled discontinuity in order to create the required conditions to establish an intended innovation direction in a socio-technical system.

### 2.5.5. Model limitations and further research

In spite of the potential offered by the model constructed and applied in this study to elucidate innovation direction and how it relates to sustainability transitions themes, some limitations hinder further interpretations. Firstly, the study describes only one of the directions that steer innovation in Brazilian pig production; this means that a broader analysis would be needed to grasp past or in-the-making transitions from an innovation direction perspective. Even if the new direction analysed shows that the environmental issue has become an innovation direction, it cannot be said for instance that, on the basis of its mere emergence, a transition towards sustainability is taking place in Brazilian pig production.

Secondly, the model proposed may not embed the complexity behind an innovation direction completely. For example, the model suggests that the set of influencing practices, technologies, and rules are set up following a sequence of steps that take place one after another over time. The reality, however, is sometimes messier. Actors may negotiate something that was not initially on the agenda; or a technology or practice generated in another context may be added to the set unexpectedly; or a natural event may change the agenda or focused demands. Deepening the understanding on how unexpected behaviours, events, and outcomes affect articulation and institutionalization phases of the model demands further development.

Thirdly, in order to improve the analysis of the interplay between sets and aspects, further efforts may be undertaken towards how to measure fulfilment aspects. Improved metrics will lead to a better understanding of what each aspect means in the context of the innovation direction analysed. Moreover, they can qualify explanations around feedback from aspects directed towards the agenda in the first phase of the model.

The construction and application of the model also raised new questions. One of them concerns how innovation directions relate to one another in a socio-technical system. As directions come from discontinuities that affect systems from time to time, it is presumed that innovation directions settled in a system have some kind of interconnection and interplay. Moreover, it is likely that this link between directions has some effect on the composition of the set of influencing practices, technologies, and rules underpinning each of them. Another open question relates to how a direction stops being relevant to an institutional field. This study explores how a direction emerges and how it consolidates itself; but the process of its disappearance, or replacement, has not yet been analysed. Focusing on this analysis would also contribute to the debate on how to promote guided socio-technical transitions, as it would help to clarify how to replace an undesired direction.

## 2.6. Conclusions

The aim of this study was to present a more fine-grained conceptualization of innovation direction. We aimed (1) to explain in a clearer way the nature of innovation direction, (2) to unravel how innovation direction is shaped over time, and (3) to describe how innovation direction is consolidated. Drawing on different literature strands, this study builds and empirically applies an analytical model (the innovation direction filter) to bridge the gaps identified in the literature. In doing so, we showed that the innovation direction filter provides important insights into issues linked to sustainability transitions, such as refined understandings of (1) trajectories in terms of event-chains and rounds of moves and countermoves in socio-technical transitions, (2) the dominant designs emergence process, and (3) directionality failure in policy interventions. We also revealed that (4) innovation direction may be approached as a constant interaction between micro, meso, and macro analysis levels.

We specifically built on the MLP to grasp the broad context and the starting point of an innovation direction. In order to describe how an innovation direction is established in a socio-technical system, we matched the MLP to the concept of demand articulation with IT and the TMA. By initiating a deeper discussion on innovation direction, we wish to foster further analysis linked to designing policy instruments with capacity to build the conditions for actors to put into practice more sustainable technologies, processes, rules, behaviours, and so on.

We argue that the conceptual model and the analysis presented in this study are a refined step towards understanding the interplay between innovation direction and sustainability transitions. Conceptually, we proposed a definition of the nature of direction in the innovation realm, because innovation direction is often defined in a vague way or is implicit in previous literature (e.g. Stirling, 2009; Lindner et al., 2016; te Kulve et al., 2018). Furthermore, we presented an analytical structure composed of two connected and interdependent layers (the articulation layer and the institutionalization layer) to describe and understand the dynamics behind an innovation direction and applied it to one case study that stressed the need for further conceptual and methodological refinements. Empirically, the study provided an overview of one of the directions that have driven innovation in Brazilian pig production recently. It showed that environmental issues became part of the Brazilian pig production innovation agenda in the early 2000s. However, important gaps remain to be bridged as some crucial environmental issues remain unresolved, such as the deployment of improved pig manure management systems and the reduced funding for educational programmes.

The analytical model presented here is a very proxy way of analysing innovation direction, and it is necessarily subject to improvement. One shortcoming of the kind of analysis undertaken is that, although we can describe and understand the sequence of events that builds an innovation direction in a particular socio-technical system, we can grasp only in a general way how to steer innovation direction in practice from the innovation direction model. Alternatively, a more detailed analysis could combine insights from the innovation direction filter with approaches such as reflexive interactive design, which employs design and design activity as an intermediate intervention, simultaneously working on agency in experiments and on structural changes in the system as a whole (Bos et al., 2009; Klerkx et al., 2012). Thus, the model would help to elucidate the sets of influencing technologies, practices, and rules that underpin innovation directions in an institutional field, whereas the reflexive interactive design approach could build bridges between desired directions and influencing technologies, practices, and rules included in the sets.

We argue that the type of analysis conducted in this study is useful for policymakers, in that it contributes to deepening the understanding of why innovation takes some directions instead of others in a socio-technical system. This comprehension is crucial for policymakers to grasp the roots of unsustainable innovation and the sorts of articulation and institutionalization processes behind them – following Schot and Steinmuller's (2018) call for structural failures analysis in public policies as a starting point for policies affected by transformative changes. Applying the broader innovation direction conceptualization in the context of public policy will hopefully help to widen innovation policy debates around the development of systemic conditions needed to build desired sustainable innovation directions.

# CHAPTER 3

Evolution, complementarities, and synergies of boundary objects, boundary organizations, and boundary spanners: The role of boundary infrastructures in transformative processes in agri-food sectors

# 3. Evolution, complementarities, and synergies of boundary objects, boundary organizations, and boundary spanners: The role of boundary infrastructures in transformative processes in agri-food sectors



**Abstract:** Scholars have often applied the concept of boundary work and its conceptual progeny to explain how people and institutions collaborate in transformative processes within agri-food sectors. However, previous studies focus mostly on boundary objects, boundary organizations, or boundary spanners, and often investigate concrete innovation projects instead of broad transformative change processes. This study aims to combine the different boundary work concepts by adopting a more fine-grained understanding through using the boundary infrastructure concept. The principal research question is how boundary infrastructures (collection of boundary objects, boundary organizations, boundary spanners) support transformative change and evolve with these processes. Empirically, this study shows how this sort of structure evolved in Brazilian pig production from 1960 to date. In doing so, we describe how boundary infrastructure elements reinforce one another and how interactions between them play a role in long-term agricultural transformative processes. Furthermore, by applying the boundary infrastructure concept, this study further unravels how a boundary work perspective sheds light on long-lasting changes in an agri-food sector. The study adds to previous work by showing that the different boundary work elements (objects, organizations, and spanners) are highly intertwined and complementary and cannot be seen as disconnected, and they support sector evolution but also develop as a result of it. Some parts of this boundary infrastructure are temporary, whereas others consolidate and become definite socio-technical system structures. Boundary infrastructure elements may display structural flexibility, meaning that what some see as a boundary object other see as a boundary organization. Using boundary infrastructure as an analytical concept may help to unravel better the political dynamics and inclusion and exclusion processes in food system transformation.

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## 3.1. Introduction

Agri-food sectors undergo continuous transformative processes. Throughout these journeys, they transition from a specific socio-technical setting[5] to a new one, often structured around more complex and broader configurations (Ingram, 2018; Šūmane et al., 2018). These changes take place in response to varied phenomena, such as economic and market developments, technological breakthroughs, environmental impacts, population growth, dietary changes, and societal demands (Darnhofer, 2015; FAO, 2019; Grin, 2010). Regardless of their nature, long-term transformative processes in agri-food sectors become increasingly structured as actors replace existing elements from, and add new elements to, the socio-technical setting in which they are embedded – e.g., new visions, discourses, projects, policies, standardized practices (Ingram, 2015; Levidow, 2015; Pigford, Hickey, & Klerkx, 2018; Schot & Kanger, 2018).

When such new elements are developed, some of them assume specific supportive roles in furthering the transformative process (Clark et al., 2016). It has been noted that the most influential ones are those that can mobilize actors from diverse contexts, thus enabling collaboration around specific aims (Dagiral & Peerbaye, 2016). Scholars have often applied the boundary work concept and its conceptual progeny as a theoretical and analytical lens to understand elements that bind people and institutions with different interests (Franks, 2010; Turnhout, 2009; Betzold, Carew, Lewis, & Lovell, 2018; Bos, 2009; Favilli, Rossi, & Brunori, 2015; Tisenkopfs et al., 2015; Sarkki et al., 2019). Proposed initially to comprise efforts to delimit science from non-science (Gieryn, 1983), the idea of boundary work has since been used to describe the activities of those seeking to mediate between science, policy, and practice (Clark et al., 2016) but increasingly also as a way to connect multiple actors in innovation and transformation processes (Klerkx et al., 2012; Smink, Negro, Niesten, & Hekkert, 2015).

In the realm of transformative processes in agri-food sectors, earlier studies have often looked at one concept within boundary work (e.g., single boundary objects, specific boundary organizations, specific boundary spanners) or have looked at smaller innovation processes (in terms of scope and timescale) within broad transformative processes (Champenois & Etzkowitz, 2018; Eden, 2011; Fong, Valerdi, & Srinivasan, 2007; Hassink, Grin, & Hulsink, 2015). Earlier work includes, for example, the role of design process outputs (scale models, visualizations, written specifications) as boundary objects in a radical innovation process (Klerkx et al., 2012); how Dutch cooperatives have performed as boundary organizations in sustainable land management issues (Franks, 2010); and how international agricultural researchers have played a role as boundary spanners in projects for sustainable development in Africa and Asia (Kristjanson et al., 2009). Some studies have looked at both boundary objects and boundary spanners (Kimble, Grenier, & Goglio-Primard, 2010; Klerkx, Aarts, & Leeuwis, 2010; Tisenkopfs et al., 2015) or at the formative processes of boundary work (Betzold et al., 2018) but have not analysed in detail how different elements of boundary work connect and contribute to building new socio-technical settings in long-term agricultural transformative processes. Hence, there is a gap in agri-food transformation studies on how different elements within boundary work – boundary objects, specific boundary organizations, specific boundary spanners – interact over time in transformative processes.

[5] Drawing upon approaches from a socio-technical systems perspective, this study understands a socio-technical setting as interdependent material and social frameworks, such as policies, culture, technologies, or markets, which over time evolve into a dynamic stable configuration that enables the fulfilment of a societal function – e.g., see Fuenfschilling and Truffer (2014) and Geels and Schot (2010).

With the purpose of understanding such types of interactions, Star and Ruhleder (1996) and Bowker and Star (2000) introduced the concept of boundary infrastructure to enhance and strengthen boundary work analysis and to provide an analytical tool fitted to large-scale infrastructures. They describe boundary infrastructures as connected boundary objects on which actors rely while collaborating to achieve shared goals (Bowker & Star, 2000; Star & Ruhleder, 1996). The concept has been applied mainly empirically on digital knowledge platforms. Those studies looked at how actors who shared the same infrastructure influenced, and were influenced by, digital platforms linked to themes such as climate change, healthcare, and rare diseases (Dagiral & Peerbaye, 2016; Park, 2010; Tempini, 2015). Bowker and Star's (2000) boundary infrastructure description pictured this kind of structure composed by boundary objects solely. However, boundary work literature relating to organizational changes (Clark et al., 2010; Holzer, Wolf, & Kocher, 2011; Kirchhoff, Esselman, & Brown, 2015; Lee, 2007; Mollinga, 2010) makes explicit that actors and organizations, e.g., boundary spanners and boundary organizations, also play a decisive role in boundary infrastructures.

Following this line of thought, this study extends the concept of boundary infrastructures and views them as comprised of three types of boundary infrastructure elements: boundary objects, boundary organizations, and boundary spanners. Thus, also following earlier work in the agri-food sector that already linked different boundary concepts to explain socio-technical changes (albeit without an integrative concept like boundary infrastructures) (Betzold et al., 2018; Kimble et al., 2010; Tisenkopfs et al., 2015), this study employs our broader interpretation of the boundary infrastructure concept and aims to describe how a boundary infrastructure evolves and its role in long-term transformative processes. Empirically, this study looks at the Brazilian agricultural sector, which has undergone major transformative processes in recent decades. We analyse the transition from the spot market[6] to vertical coordination[7] in Brazilian pig production (BPP) from the 1960s to date. The question that guides this study is: How has boundary infrastructure evolvement, and the interaction between boundary infrastructure elements, played a role in the transition from the spot market to vertical coordination in BPP? This question connects to recent efforts to further unravel how interactions between science, policy, and practice promote coordination, close down contingency, and impact long-term changes in agri-food sectors (Chabbi et al., 2017; Nel et al., 2016; Sarkar, Poon, Lepage, Bilecki, & Girard, 2018; Zougmoré et al., 2019). Moreover, this kind of deeper understanding of boundary infrastructures is critical for debates on transformation towards sustainable food systems (e.g., Lamine, 2011; El Bilali, 2018; Ingram, 2015; Gaitán-Cremaschi et al., 2019), as it gives insights into transition dynamics.

The remainder of the chapter is structured in five more sections. The conceptual approach is explained in section 2. Section 3 presents the methodology for applying the conceptual approach in the

[6] The spot market is a kind of production governance in agriculture described by the literature on transaction cost economics theory (TCE) (Cavaliere, Peri, & Banterle, 2016; Martinez, 2002). It is the traditional form of market organization in which a commodity is sold for the highest price available and delivered immediately or within a short period. There is no written or oral contract between the firm and the farmer for either buying or selling. Farmers buy inputs from a supplier of their choice and sell their products to whomever they want (Rehber, 1998). This study applies a broader understanding of the spot market concept and sees it as a general organizational setting with social, legal, technological, and economic dimensions.

[7] Vertical coordination in agri-food sectors generally refers to the synchronization of successive stages of production and marketing, concerning the quantity, quality, and timing of product flows (Martinez, 2002). Vertical coordination unfolds in practice through contract farming schemes, in which farmers remain legally autonomous but are heavily dependent on a contractor, who provides all critical resources (such as piglets, feed, medicines, and advisory services) (FAO, 2013; Schulze, Spiller, & Theuvsen, 2007). This study applies a broader understanding of the vertical coordination concept and sees it as a general organizational setting with social, legal, technological, and economic dimensions.

BPP case. Section 4 presents the analysis and the empirical results of the case study. Section 5 presents a discussion and lessons learned from the Brazilian case, and conclusions are drawn in section 6.

## 3.2. Operationalizing boundary infrastructures: boundary infrastructure elements and interpretative flexibility

As indicated above, this study argues that elucidating how a boundary infrastructure evolves is an interesting way to unravel how links are made between elements that influence long-term transformations in agri-food sectors. Before describing the conceptual framework applied in this study, it is necessary to enter a caveat. Boundary infrastructures make up sectors' socio-technical setting. They co-evolve with socio-technical setting dynamics, exerting mutual influence (Fremont, Eklinder Frick, Åge, & Osarenkhoe, 2019; Orsini, Louafi, & Morin, 2017; Steger et al., 2018). However, to facilitate the understanding and analytical application of the boundary infrastructure concept, we look at them as if they were detached from the socio-technical setting.

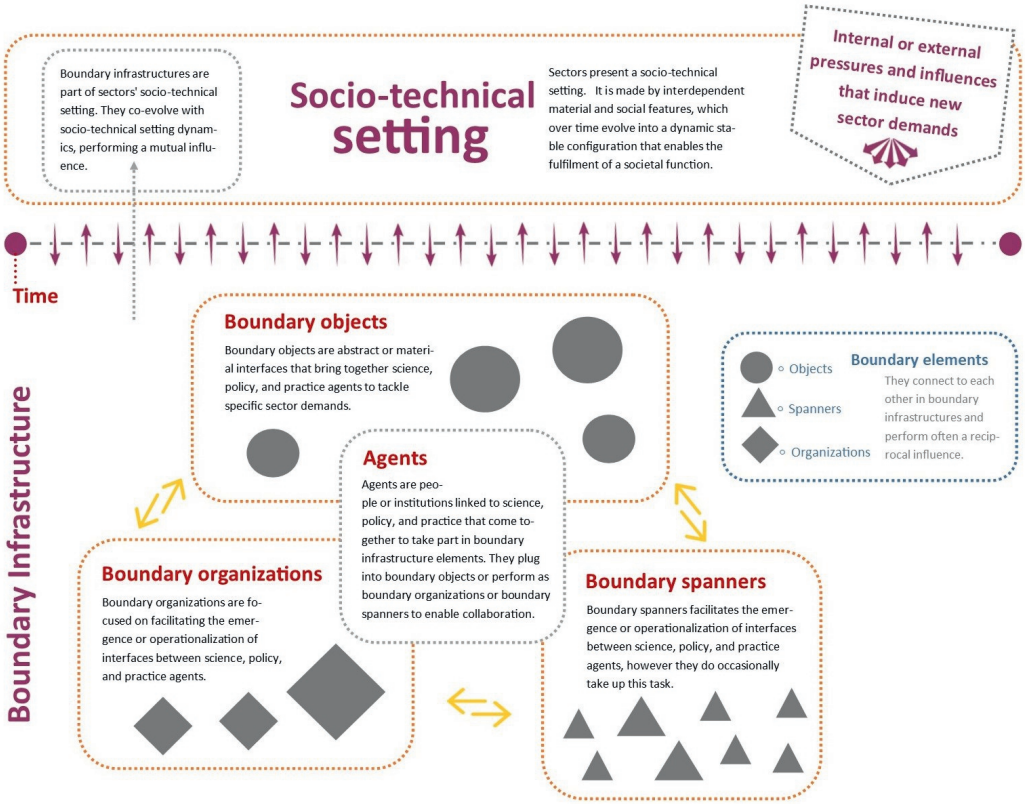
Following Star and Ruhleder (1996), Bowker and Star (2000), and Clark et al. (2016), this study employs a broader interpretation of boundary infrastructures and sees them as a collection of connected and complementary boundary infrastructure elements that enables collaboration between actors from science, policy, and practice. This study understands actors from the transformative agency perspective (Emirbayer & Mische, 1998; Engeström, 2006; Virkkunen, 2013). Transformative agency differs from conventional notions of agency as it focuses on how individuals engage in collective change efforts (Haapasaari, Engeström, & Kerosuo, 2016). Therefore, transformative agency actors are individuals (people or institutions) with the capacity to perform specific roles connected to collective actions to accomplish intended sectoral changes (Heinz, 2009). In boundary infrastructures, actors are people or institutions linked to science, policy, and practice that come together to participate in boundary infrastructure elements. Actors can also play a role as boundary infrastructure elements (boundary organizations and boundary spanners) in specific actions. Boundary infrastructure elements (boundary objects, boundary organizations, and boundary spanners) are presented in Figure 3.1.

Boundary objects in boundary infrastructures are abstract or material interfaces (such as discourses, innovation platforms, projects, public policies) that can mobilize and enable collaboration between science, policy, and practice actors (Dagiral & Peerbaye, 2016; Star & Bowker, 2006). Boundary objects, as pieces of boundary infrastructures, are able to bring together people and institutions with different interests to tackle sector demands (Steger et al., 2018) – e.g., an innovation platform that brings together researchers, consultants, governmental organs, private actors, and NGOs to nurture sustainable initiatives in a sector disturbed by environmental issues.

Boundary organizations and boundary spanners in boundary infrastructures relate to roles played by both institutions and people that produce credible, relevant, and legitimate infrastructural boundary objects (Orsini et al., 2017). Boundary organizations in boundary infrastructures are organizations focused on mediating between actors from science, policy, and practice to build or operate infrastructural boundary objects in a specific sector (Champenois & Etzkowitz, 2018; Kirchhoff et al., 2015). Moreover, they are acknowledged and mostly accepted by science, policy, and practice as a boundary organization. An NGO specifically assigned to set up and run an innovation platform is thus seen as a boundary organization.

In turn, boundary spanners are people or organizations that participate in or facilitate the emergence or operationalization of interfaces between science, policy, and practice actors (Bednarek et al., 2018). They perform in a similar way as boundary organizations in boundary infrastructures. However, it is not the primary function of boundary spanners to foster or participate in infrastructural boundary objects (Lundberg, 2013). They occasionally become involved in bridging initiatives that end up adding new pieces to a boundary infrastructure (Gertzell, 2015) – e.g., an academic researcher involved by giving research-based advice on the setting up and running of an interface is seen as a boundary spanner.

**Figure 3.1.** Socio-technical setting and boundary infrastructure conceptualization.




Previous literature on boundary work also emphasizes the central role of interpretive flexibility in clearing up how actors cooperate beyond their own boundaries and in understanding the interaction between heterogeneous worlds (Star, 2010). Interpretive flexibility was initially proposed to address the functionality of boundary objects, to elucidate how abstract and concrete devices operating between boundaries keep their coherence in general or more specific usages (Bowker & Star, 2000; Star & Griesemer, 1989). Beyond that, interpretive flexibility can elucidate how boundary work more generally harmonizes different interpretations and views to enable cooperative work in the absence of consensus, as boundary organizations and boundary spanners facilitate the understanding between actors by helping actors to be flexible in their interpretation of situations, problems, and solutions and to be sensitive to

other interpretations (Betzold et al., 2018; Klerkx & Leeuwis, 2008; Smink et al., 2015). Drawing upon these previous insights, we infer that boundary infrastructures as a whole also present an interpretative flexibility. This represents their capacity to allow actors to develop equally valid different interpretations, views, and uses of their elements, according to contextual factors. Thus, interpretive flexibility enables actors to share uses and meanings of boundary infrastructure elements (common usage), while also allowing actors to apply them to their own specific situation and give them a particular use and meaning (tailored usage). We now explain the research methods, and then, we examine how boundary infrastructures have evolved in BPP.

## 3.3. Research methods

This study took a qualitative approach based on an exploratory case study design to unravel how boundary infrastructures evolve and how they play a role in transformative processes, following others who have taken a similar approach to study this topic (Geels & Penna, 2015; Royer, Bijman, & Abebe, 2017; Spiertz & Kropff, 2011; Trifković, 2014). Case studies are suitable to approach phenomena that are not well known, have many facets, and require an in-depth perspective (Eisenhardt & Graebner, 2007; Gray, 2004). Furthermore, a useful strength of the case study research methodology is that it affords a rich context for answering 'how' and 'why' questions (Yin, 2009).

The empirical case analysed in this study comes from the agricultural context in Brazil, a developing country where agri-food sectors have undergone remarkable transformative processes in recent decades (Boddey, Xavier, Alves, & Urquiaga, 2003; Brooks, 2017; Chaddad, 2016). We focus on how boundary infrastructure development influenced the transition from the spot market to vertical coordination in BPP – Brazil is now the fourth largest world producer and exporter of pork products (ABPA, 2019) – from the 1960s to date. Four reasons underpin this choice. First, BPP has been one of the most transformative agri-food sectors in Brazil in the last six decades (Chaddad, 2016), evolving from an artisanal and fragmented activity to a well-structured agri-food sector (Talamini, Pinheiro, & Santos Filho, 2014). Second, interfaces between science, policy, and practice played an essential role in its development, especially after vertical coordination emerged (Guimarães et al., 2017; Sebrae & ABCS, 2016). Third, many people who had critical roles in BPP development are still available to describe how this sector has evolved. Furthermore, BPP has reliable databases about its growth in the last 60 years.

The primary data sources for this work were 41 in-depth interviews conducted with influential actors in BPP, such as representatives from industries, producers, governmental institutions, NGOs, science institutions, and advisory services (see Appendix 1). After mapping crucial players linked to pig production governance (based on previous knowledge about BPP and additional information collected on websites made available by industries, associations, public organs, NGOs, and science institutions), this study established a list of 32 interviewees. Nine further interviewees were added via the snowballing method (Kumar, 2011). The interviews, conducted between July and December of 2017, lasted between half an hour and two hours and were tape-recorded and transcribed verbatim. They followed an interview guide based on our literature review of transformative processes in agri-food sectors and the boundary infrastructure concept. The interview guide focused on: 1) basic information on the BPP trajectory, 2) the sort of interfaces between science, policy, and practice that influenced BPP development, 3) and BPP general performance and societal impacts over time. Core and additional secondary data were also collected. The core secondary data consisted of books, scientific papers, policy briefs, official public reports,

and media articles published in newspapers and magazines. Additional secondary data came from pig industries' official websites and annual reports published by industry and producer associations (see Appendix 2 for core and additional secondary data sources).

Furthermore, we triangulated the interview content with secondary data. As suggested by Yin (2009), analysis of the transcripts and secondary data started during data collection. Thus, we could sharpen later interviews and focus on significant events linked to the BPP trajectory. The triangulation between interview content and secondary data was interpreted using the theoretical framework as an analytical lens. In terms of possible biases, as regards internal validity, the findings rely on actor representatives in high positions (usually CEOs or senior consultants) who were able to provide a broad view of BPP evolvement and functioning. In terms of external validity, the findings linked to interviews, secondary data, and the interpretation underpinned by the theoretical framework were reviewed by two researchers specialized in BPP development. They validated the boundary infrastructure evolvement described in the results section.

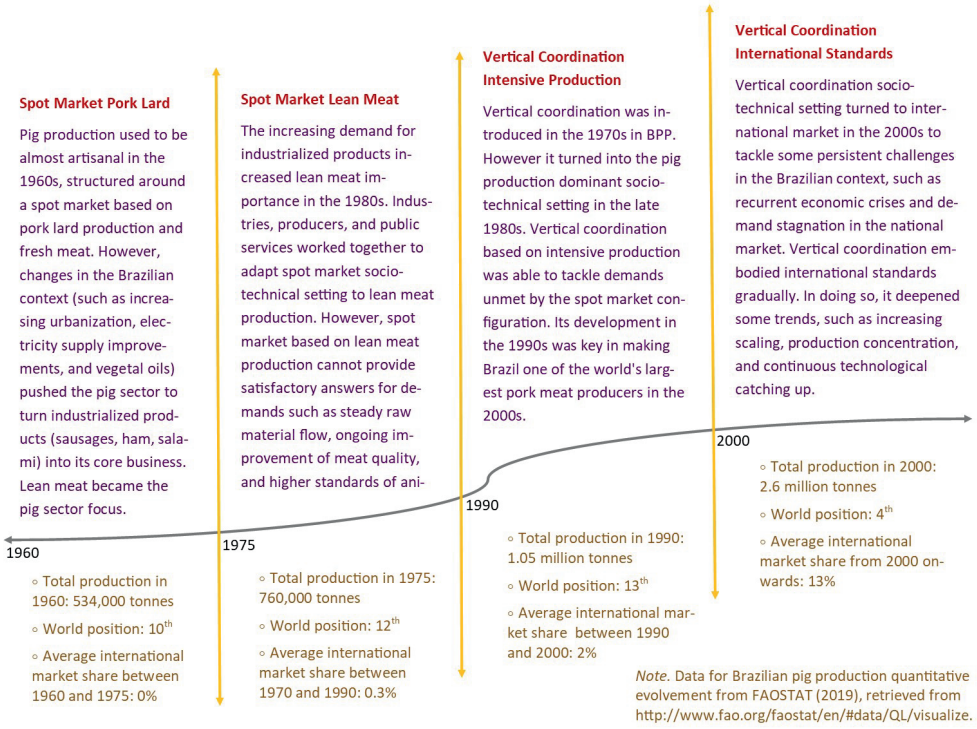


## 3.4. Results

### 3.4.1. Spot market: from pork lard to lean meat

Brazilian agriculture went through a massive transformation in the 1970s, making Brazil an acknowledged success case of agricultural development in a developing country (Ioris, 2017). BPP participated in this transformation and achieved remarkable social, economic, and technological results mainly from the 1980s onwards (Talamini et al., 2014) – see also Figure 3.2. for a brief overview of the BPP socio-technical trajectory. In 2015, the value of Brazilian pig meat gross domestic product reached 20.22 billion dollars, and it accounted for 1% of overall Brazilian gross domestic product. Moreover, the sector employed 126,000 workers directly and 923,000 workers indirectly (Sebrae & ABCS, 2016).

**Figure 3.2.** Brief overview of BPP evolvement from the early 1960s to date.



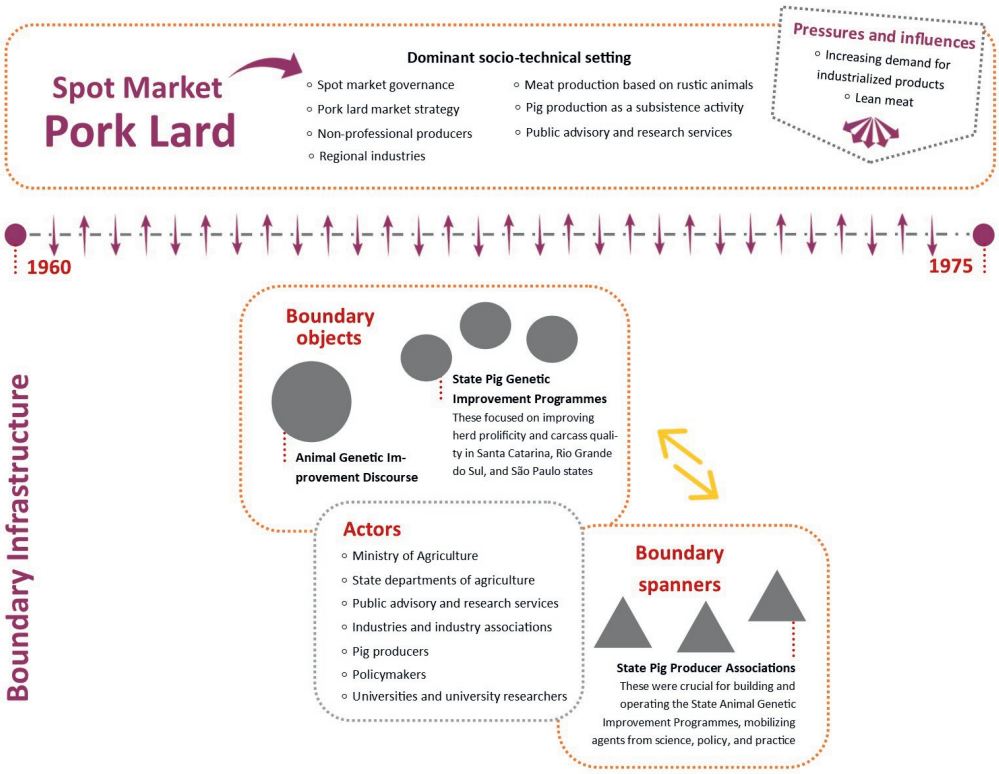

The narratives from the interviews with BPP representatives indicated that the spot market, which focused on pork lard in the 1960s, relied on subsistence pig producers. At the time, producers had pigs for their own consumption and used to sell their production surplus to small regional abattoirs once or twice a year. This socio-technical setting proved suitable for raising rustic animals that were suitable for lard production and did not demand specific skills from producers. However, changes in the Brazilian economy and society (Brito, 2006; Chaddad, 2016) pushed pig production to focus on products such as sausages and ham (see Figure 3.2.). Thus, the setting where rustic animals rich in fat were raised, industrialized, and commercialized became outdated. Gradually, the BPP socio-technical configuration turned its focus to lean meat, an essential raw material for processed pork products.

The pig production boundary infrastructure was composed of a few boundary infrastructure elements in the period between 1960 and 1975 when the pork lard production model was hegemonic (see Figure 3.3.). Mostly, the animal genetic improvement discourse and state pig genetic improvement programmes played a role as boundary objects in the spot market pork lard boundary infrastructure. They mobilized science, policy, and practice actors to improve herd prolificity and carcass quality in Santa Catarina, Rio Grande do Sul, and São Paulo states, where BPP was concentrated at the time. Pig producer associations in those states performed as boundary spanners in the spot market pork lard boundary infrastructure. They were crucial mainly in building and operating state pig genetic improvement programmes. For instance, pig producer associations coordinated collaboration between researchers, policymakers, industries, pig producers, state departments of agriculture, and research and public advisory

services to make feasible the importation of improved genetic material, the Brazilian pig genealogical record service, and the application of zootechnical tests and feeding experiments. Although comprised of a few elements, the spot market pork lard boundary infrastructure was coherent with a socio-technical setting dominated by regional industries, subsistence producers, a pork lard focus, rustic animals, and roughly processed pork products.



**Figure 3.3.** Socio-technical setting and boundary infrastructure evolvement linked to the spot market pork lard.




Changes in the Brazilian social and structural context throughout the 1960s (see Figure 3.2.) influenced BPP to transition its focus from pork lard to lean meat in the mid-1970s (Bosísio, Lody, & Souza, 2003; Brito, 2006). In its new dominant socio-technical setting, BPP became led by industries with a national scope. The pig sector also started pushing producers' professionalization, animal health improvements, further herd genetic improvement, and processed pork products aimed at urban fast-food consumption (Souza, Talamini, Scheuermann, & Schimidt, 2011). BPP representatives interviewed in our fieldwork research emphasized that new boundary infrastructure elements emerged at the time to support a socio-technical setting structured around lean meat (see Figure 3.4.). One of these elements was the intensive production discourse. As an infrastructural boundary object, this discourse convinced actors to develop

more efficient interfaces between science, policy, and practice focused on sector demands, such as increasing lean pig meat availability.

The National Pig Research Centre emerged attached to that setting, bound to intensive production and lean meat. After joint action by actors such as producer associations, industry associations, and policymakers, in 1975, in Santa Catarina state, the Ministry of Agriculture deployed a branch office of the Brazilian Agricultural Research Company (Embrapa) dedicated to pig production research and technology transfer (Souza et al., 2011). Embrapa's new office, named the National Pig Research Centre, became the first boundary organization in the BPP boundary infrastructure. From 1975 to the mid-1990s, the National Centre led efforts to build and operate interfaces where science, policy, and practice actors could collaborate to develop means to tackle sector demands – e.g., disease eradication actions, animal health capacity programmes, experimental technological stations, and pig genetic improvement programmes.

It was mainly the National Centre that headed the implementation and running of the National Pig Research Programme between 1978 and 1992. At that point, this programme functioned as a crucial boundary object in the spot market lean meat boundary infrastructure. The main role of the National Programme was as an innovation platform, and it mobilized the Ministry of Agriculture, state departments of agriculture, public advisory and research services, universities, industries, and producers to establish – or adapt to the Brazilian context – pig genetic standards, animal health protocols, technological packages, and animal feeding recommendations. Furthermore, the programme backed state pig producer associations (which kept their role as boundary spanners) in the enhancement of the state pig genetic improvement programmes.

Notably, boundary infrastructure elements connected to one another in a more complementary way in the spot market lean meat boundary infrastructure, in comparison with the previous BPP configuration – e.g., boundary spanners (producer associations) were backed by a boundary object (the National Pig Research Programme) and boosted other interfaces between science, policy, and practice (state pig genetic improvement programmes). Not only did connections between boundary infrastructure elements evolve in the spot market lean meat setting, but also boundary infrastructure interpretive flexibility changed and enabled actors to make a more tailored usage of boundary infrastructural elements. For instance, the National Pig Research Programme (boundary object) provided new funding sources for university researchers (science actors), who sought to shape their research interests with the agenda addressed by the National Programme. In turn, industries (practice actors) used the National Programme as a learning source. They took advantage of interactions fostered by it to further develop crucial internal processes, such as their own research and advisory capacities.

The tailored usage of boundary infrastructure elements was also behind the emergence of an alternative boundary object in the early 1980s. Inspired by the intensive production discourse and influenced by the increasing interactions between science, policy, and practice actors, one of the biggest Brazilian pig industries at the time[8] started experiencing an organizational innovation. Sadia realized that it could take over the whole production process to minimize recurrent supply crises regarding raw materials.

[8] Sadia, Perdigão, Ceval Seara, Aurora, and Frigorífico Chapecó were the largest Brazilian pork industries in the 1980s (Nicolau, Vargas, & Balzon, 2001). In 1985, they accounted for more than 30% of Brazilian production (Spies, 2003). All of them started in the state of Santa Catarina, but, from the beginning of the 1980s, they led the first round of a concentration process of pork meat industrialization in Brazil. In the mid-1980s, the most prominent industries began to buy local or regional pig industries countrywide (ABCS, 2014).

Initially, Sadia[9] developed a specific project (named Project B), which can be seen as the embryonic motion towards the integration system,[10] an infrastructural boundary object that would have a crucial role from the 1990s to date. The following quote illustrates Project B evolvement:

> *Then, we launched the beginnings of a vertical coordination model, which we called 'integration system' later on [...]. Our goal was to convince producers and also the company about the need for a new production organization. We did not talk to the company at first because Sadia already had poultry integration. They believed that the feed volume needed to vertically coordinate pig production meant spending a huge working capital [...]. Anyway, we selected a skilled group of producers, signed a contract, and we started providing them with an advisory service, genetically improved animals, and some inputs to upgrade herd feeding [...]. This project was successful, and then it became the vertically coordinated system we have today. (A former Sadia executive).*

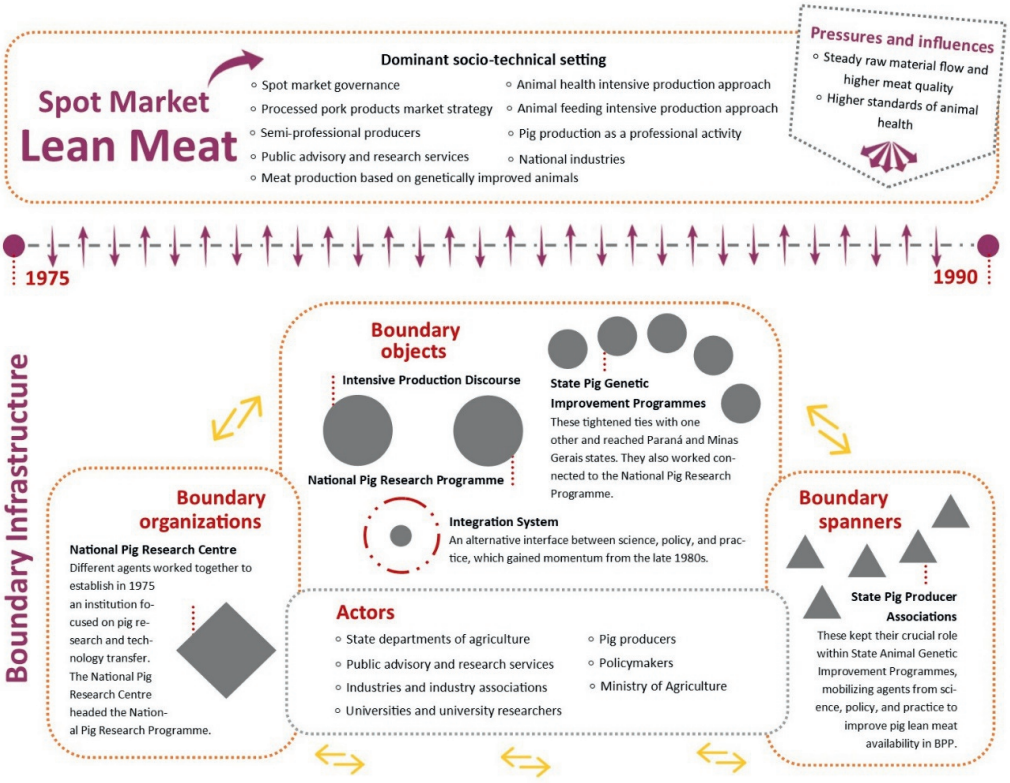
Despite its acknowledged improvements, the spot market lean meat setting failed to cope with some internal pressures and external influences, mostly related to organizational issues and meat quality. The focus on industrialized products provoked the modernization of slaughtering production lines in the 1980s, which were experiencing difficulties in operating appropriately with uneven carcasses in terms of length and thickness of bacon produced. Furthermore, the spot market lean meat setting could not guarantee a steady raw material flow (see Figure 3.2.). The following quote of a former industry executive emphasizes those weaknesses:

> *There had to be a standard. Besides, in the 1980s, pig production based on the spot market did not achieve the development we needed in terms of animal health, animal feeding, and management. Brazil was beginning to export carcasses to Europe, and we could not get raw material in the spot market to sell to importers [...]. There was no way to keep up things that way. (A former industry executive).*

[9] Sadia (Sociedade Anônima Concórdia) was established in 1944 in Concórdia, a small town located in the west region of Santa Catarina state (Dalla Costa & de Souza-Santos, 2009). In the 1950s, it was the first to link pork meat industrialized products (such as ham and sausages) to the most significant urban markets (such as São Paulo and Rio de Janeiro) in Brazil. Sadia also adapted to Brazil the vertical coordination model in broiler and pig production, introduced turkey meat in the Brazilian market, and led the Brazilian efforts to start selling meat to Asia in the 1970s. In 2009, Sadia and its major competitor in Brazil (Perdigão) announced a merger and became one the most important world food industries, named BRF Brasil Foods S.A. (from 2013 onwards, the company was named BRF S.A. only) (Dalla Costa & de Souza-Santos, 2009). BRF has more than 100,000 employees worldwide and 30 different brands in its portfolio, and its gross revenues in 2018 reached US$ 9.49 billion (BRF, 2019).

[10] Integration system is the generic name given in Brazil to pig production governed by a contract between pig processing industries and pig producers. In that model, the contractor, commonly an industry, coordinates production operations vertically. Generally, the producer makes available facilities where pigs are raised and whose features must meet the integrator's standards, besides providing his own or contracted labour. In turn, industries provide pigs, animal feeding and advisory services, and the transportation of inputs to rural properties and pigs to slaughterhouses. Each integration system adapts itself to the context in which the industry and its associated producers embed, but in general all have the following items: contracts between producers and industries, their own advisory service, and strict technological packages (Miele, Santos Filho, Martins, & Sandi, 2011; Sebrae & ABCS, 2016; Spies, 2003).

**Figure 3.4.** Socio-technical setting and boundary infrastructure evolvement linked to the spot market lean meat.




### 3.4.2. Vertical coordination: a radical change

Because of the spot market lean meat shortcomings, another configuration established itself gradually (see Figure 3.2.). Vertical coordination intensive production focused on regulating raw material flow at the beginning and evolved into a complex set of industries, producers, suppliers, and correlate entities pursuing connected objectives over time. As already mentioned, Sadia deployed Project B experimentally in the early 1980s and migrated to the integration system swiftly. In a few years, according to fieldwork interviews, more than 60% of raw material processed by Sadia came from producers attached to the company via contract farming.[11] In the late 1980s, Sadia was followed by other relevant Brazilian pig industries. Vertically coordinated intensive production became the BPP dominant socio-technical setting in the early 1990s and quickly improved raw material quantity and quality. In 1990, Brazil was the thirteenth biggest world pig producer (1.050 million tonnes). Ten years later, it achieved the fourth position (2.6 million tonnes) (FAOSTAT, 2019). Moreover, Brazil moved from a miniscule position in world exports in the 1970s and 1980s (0.3%) to an average market share of 2% in the 1990s and 13% in the 2000s (Souza

[11] At the time, Sadia applied a basic contract farming in which pig producers promised to deliver all their production to the company in exchange for advisory services, some animal feeding inputs, and genetically improved animals.

et al., 2011). Pig production underpinned by a vertical coordination model went from less than 15% of overall production in 1990 (Souza et al., 2011) to 33% in 1994 (Nicolau et al., 2001), 42% in 1997 (Martinelli, 2009), 50.5% in 2000 (ABPA, 2000), and 83% in 2017 (Martins, Trienekens, and Omta, 2017).



The narratives from the interviews with BPP representatives stressed that the vertical coordination intensive production setting introduced significant changes in BPP (see descriptions of socio-technical settings in Figures 3.4. and 3.5.). For instance, pig producers became professional producers associated mostly with an industry. Moreover, industries deployed private advisory and research services, animal feeding turned into a parallel business, and the pig sector established a carcass typification policy. As expected, those changes also deeply impacted BPP boundary infrastructure at the time (see Figure 3.4. in comparison to Figure 3.5.). Remarkably, the integration system became the most effective boundary infrastructure element in the vertical coordination intensive production boundary infrastructure. As a boundary object, the integration system functioned as a concept in common usage, giving BPP an improved framework to deepen the production intensification that had started in the spot market lean meat. In practice, each of the biggest pig industries in Brazil developed its own integration system. This meant that the integration system boundary object also allowed a tailored usage. Thus, industries mobilized science, policy, and practice actors to shape particular integration systems according to their associated producers' features, target markets, and the general context in which they were embedded.

The emergence and establishment of the integration system boundary object affected other boundary infrastructure elements. For instance, input suppliers such as geneticists, medical suppliers, and animal feed companies, thrived as boundary spanners. They gradually played a role as builders of interfaces where mainly science and practice actors collaborate to develop solutions linked to sector demands – e.g., genetically improved animals, disease control actions, or protocols and products to improve feed absorption. Input suppliers' ascendance as boundary spanners also impacted the role of the National Pig Research Centre as a boundary organization. It retained its importance as an institution focused on pig research and technology transfer, but its field of action narrowed down after the completion of the National Pig Research Programme in the early 1990s. State pig genetic improvement programme boundary objects also lost significance when interactions between suppliers and the integration system became dominant in terms of pig genetic development. They were replaced by the public pig genetic programme boundary object, which enabled collaboration between science (National Pig Research Centre), policy (state departments of agriculture), and practice (independent pig producers, producer associations, and cooperatives) actors to develop alternative hybrid pigs adapted to the Brazilian environmental features.

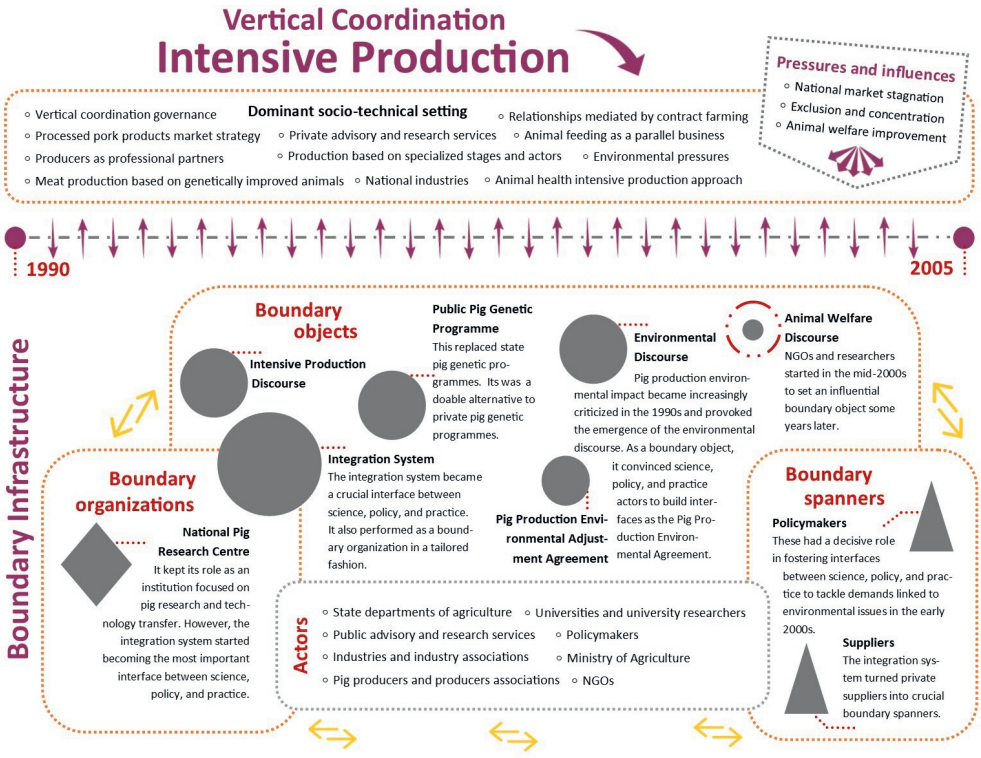
The vertical coordination intensive production boundary infrastructure also reshaped the prevailing manner of interaction between science, policy, and practice in BPP. In previous settings, boundary infrastructure elements had close ties with public initiatives. Thus, public actors linked to science (such as the National Pig Research Centre) and policy (such as state departments of agriculture) often played decisive roles in boundary infrastructure elements such as the National Pig Research Programme and state pig genetic improvement programmes. Conversely, private initiatives gained momentum in the vertical coordination intensive production boundary infrastructure and began to concentrate productive collaborations between science, policy, and practice actors. This meant that practice actors (such as industries and suppliers), for the first time, headed the establishment of crucial boundary infrastructure elements in the BPP boundary infrastructure – e.g., the integration system boundary object.

Nonetheless, public initiatives did not disappear entirely. They regained their leadership in mobilizing science, policy, and practice actors when social issues provoked instabilities in the BPP setting. For instance, a substantial social claim relating to a pig production environmental impact in the early 2000s influenced the BPP socio-technical setting and fostered the emergence of the environmental discourse as a boundary infrastructure element. It positioned itself as a boundary object that convinced science and policy actors to tackle the environmental crisis. As a result, policymakers (such as public prosecution services and state environmental protection departments) performed as boundary spanners, mediating the development of interfaces where science, policy, and practice could work together to soften the pig production environmental impact.

The most acknowledged public initiative at the time was the Pig Production Environmental Adjustment Agreement, deployed in Santa Catarina state, where pig production environmental issues used to be massive. The agreement was an official deal between public prosecution services, producers, industries, suppliers, and government that resulted in fine-grained technologies, updated residue management practices, and unprecedented protocols to prevent water waste in every stage of pig production. As an infrastructural boundary object, the agreement developed a standard about how to foster collaboration between science, policy, and practice to tackle environmental issues; and this guided similar interventions countrywide. Public initiatives also contributed to the emergence of an alternative boundary object in the vertical coordination intensive production boundary infrastructure. The animal welfare discourse arose in the mid-2000s, fostered by public (the National Pig Research Centre and federal universities) and practice (NGOs) actors. At the time, it mobilized science, policy, and practice only around topics linked to economic impacts, such as pre-slaughter management.

Boundary infrastructure interpretive flexibility stretched notably at the time. Not only was the tailored usage of boundary infrastructure elements enhanced, but the elements also started performing different complementary roles, as in the case of the integration system. This accomplished a twofold role in the vertical coordination intensive production boundary infrastructure. In common usage, the integration system performed as a boundary object, binding and organizing actors to tackle sector demands. Conversely, in tailored usage, it functioned primarily as a boundary organization. In other words, each industry developed an integration system focused on fostering collaboration between science, policy, and practice actors to tackle its demands – e.g., some integration systems deployed their own pig genetic improvement programmes, mobilizing private genetic companies, universities, and producers according to their interests. In practice, the role of a single boundary organization (the National Pig Research Centre), working for the whole sector, was gradually replaced in the BPP boundary infrastructure by tailored local boundary organizations (industry integration systems).

**Figure 3.5.** Socio-technical setting and boundary infrastructure evolvement linked to vertical coordination intensive production.




### 3.4.3. International standards strategy

In spite of its achievements in terms of pig meat production increase, quality control, and a steady raw material flow, the vertical coordination intensive production socio-technical setting could not properly tackle some issues such as demand stagnation in the national market (see Figure 3.2.). Such instabilities provoked further changes in BPP, although they were less radical than the transition from spot market lean meat to vertical coordination intensive production. In 2007, the World Organization for Animal Health (OIE) recognized Santa Catarina state as a foot-and-mouth disease-free area without vaccination. Thus, Brazil reached one of the main animal health requirements to sell pig meat to more stringent markets, such as Japan, Europe, and the United States (ABCS, 2014). This accomplishment deepened the international standards strategy in BPP, started in the early 2000s. This is illustrated by the following quote of a former industry executive:

> *I got tired of going to Europe and hearing this in the 1990s: 'If you want to sell meat to us, you have to follow international rules linked to animal products trade.' Markets that pay better are pretty strict [...]. That is why Brazilian pig industries have come together to enhance our animal health protocols to international levels [...]. When we started selling our meat to those stricter markets, we entered a stage where we could no longer go back and that international approach would have to be extended to other production processes. (A former industry executive)*

The vertical coordination international standards socio-technical setting introduced one change mainly. BPP governance, previously linked only to vertical coordination, became firmly attached to international standards. In practice, this meant that patterns imposed by international buyers gradually became important drivers in the BPP socio-technical setting (e.g., in the late 2000s, Brazilian industries started pursuing international protocols linked to subjects such as animal health, animal feeding, animal welfare, environment, traceability, and pig meat processing processes). The international standards strategy also led BPP towards a commoditization approach - in the agri-food sector, a commodity is an agricultural product produced on a world scale, focused on foreign trade, with similar physical characteristics and with profits more linked to large-scale trade than to unitary prices (Belke, Bordon, & Volz, 2013). In doing so, it split pig producers into two different specialized types (piglet producers and fattening producers) and continuously increased production scales (pig production became more concentrated in bigger pig producers and in fewer industries but with international scope) (Sebrae, 2016).

According to the narratives from the interviews with BPP representatives, the integration system deepened its relevance as a boundary infrastructure element when the vertical coordination international standards setting became prevalent (see Figure 3.6.). Adapting BPP to international requirements in areas such as animal health, animal welfare, antibiotics, and environmental practices required closer ties between science, policy, and practice actors, and the integration system performed as the most efficient element to increase those interactions. An example of the integration system's crucial role as a boundary infrastructure element concerns changes in animal welfare. In the early 2010s, the integration system reacted to pressures coming from the socio-technical setting (national and international claims for fairer intensive animal production practices) and boundary spanners (NGOs and the National Pig Research Centre) regarding animal welfare issues. In doing so, it mobilized science, policy, and practice actors to debate how BPP could align voluntarily with European animal welfare standards in terms of rules, technologies, equipment, practices, and assurance schemes by 2026 (Dias, Silva, Foppa, Aurélio Callegari, & Pierozan, 2018). Thus, the integration system has played a decisive role in building and communicating a general understanding of animal welfare in BPP (common usage). Concurrently, it has acted as a boundary organization in each industry to enable collaboration between science, policy, and practice in order to apply sectoral regulations in local contexts (tailored usage).

The integration system also influenced the emergence of an alternative boundary infrastructure element. Some large independent pig producers, not associated with industries and accounting for approximately 10% of BPP (Sebrae, 2016), in the mid-2000s developed their own organizational frame based on the integration system concept. The mini-integration system[12] provided an alternative interface

[12] The mini-integration system comprises large pig producers who sell their production on the spot market or establish a production contract with a slaughter company (ABCS, 2014). These large producers subcontract or make tacit agreements with smaller-scale pig producers, which often have been excluded from industry integration systems over time. In addition to the purchase contract, the mini-integrator can provide inputs and advisory services to its producers (Sebrae & ABCS, 2016).

where actors from science (such as independent consultants), policy (such as state departments of agriculture), and practice (such as independent pig producers), who often no longer participate in integration system actions, could collaborate to deploy in that particular area of pig production the things that had changed in the whole sector. For example, former university researchers specialized in animal health have worked together with the public advisory service to improve sanitary protocols in small pig producers who have had contracts with a mini-integrator in recent years.

Moreover, in the late 2000s, practice (producer associations) and policy (labour courts) actors started raising questions on whether the partnership established between industries and pig producers through contract farming was economically and socially fair. As a result, in 2009, a group composed of representatives from science, policy, and practice began to discuss general rules for the integration system in Brazil. In 2011, those debates turned into a bill, issued by the Brazilian National Congress in May 2016. The Integration Law changed the BPP socio-technical setting and also affected the vertical coordination international standards boundary infrastructure. It introduced two mandatory committees: the National Forum for Poultry and Pig Agroindustrial Integration (Foniagro), responsible for defining the general guidelines that guarantee an improved relationship between industries, producers, and suppliers; and the Integration Monitoring, Development, and Conciliation Commission (Cadec), which must be implemented in each integration system. Science, policy, and practice actors have equal representation in both to build mechanisms that enable the fair distribution of economic results obtained in each integration system and agreed definitions about technological changes in production processes. Thus, the Integration Law performs as a boundary object in the current BPP boundary infrastructure. Additionally, its mandatory two committees lend to it an officially established interpretative flexibility capacity – i.e., a common usage (general regulations debated in the national committee) and a tailored usage (local definitions based on each integration system reality).

Dynamics relating to the vertical coordination international standards socio-technical setting also played a part in determining which actors could operate as boundary spanners. Suppliers enhanced their importance as spanners as a consequence of the integration system enlargement. The international standards strategy enhanced the role played by NGOs linked to animal health and animal welfare issues as well, sparking collaboration between science, policy, and practice actors to translate and to apply international concepts and rules to BPP. For instance, the World Animal Protection office in Brazil fostered projects about animal transportation and pre-slaughter management that helped industries, producers, public organs, research institutions, and suppliers to build the Brazilian understanding of animal welfare in pig production (developed further within the integration system). Those actions were the practical starting point for the deployment of the animal welfare standardization process boundary object.

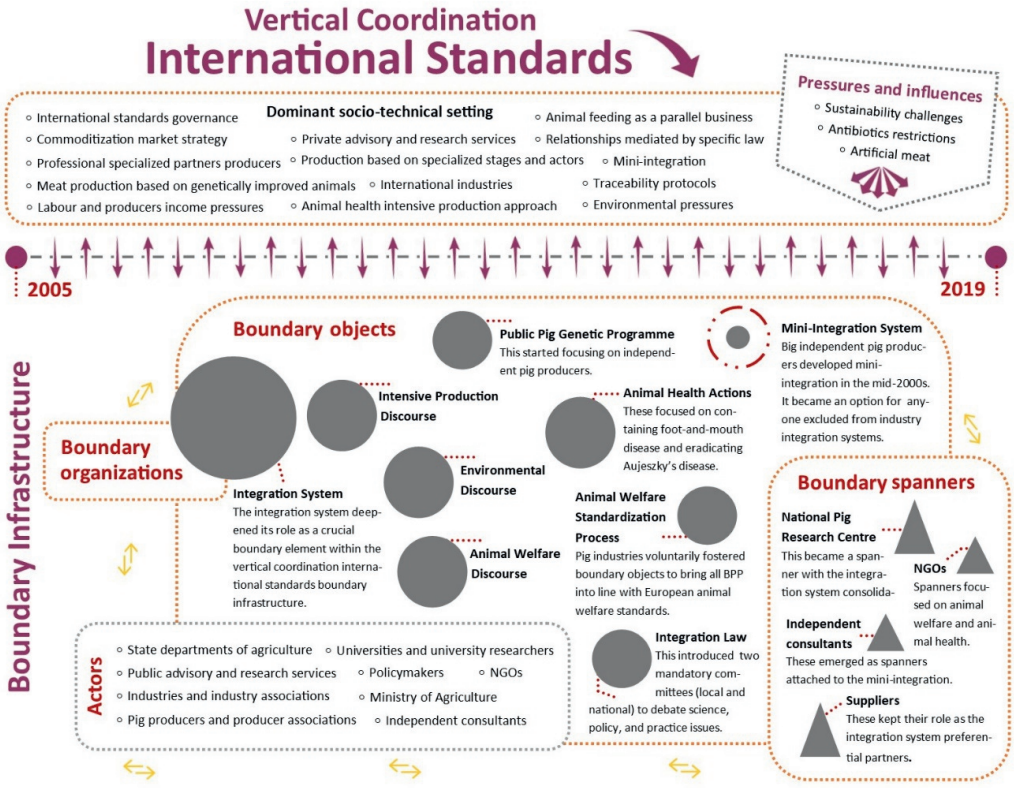
Moreover, the National Pork Research Centre lost its relevance as an institution capable of being a sectoral boundary organization, as it was from the mid-1970s to the mid-1990s. However, it maintained its importance as a boundary spanner and has played a remarkable role in specific issues, such as disease eradication and control projects (Aujeszky's disease and swine flu) and environmental actions (projects to develop new practices and equipment for manure treatment). As already highlighted, independent consultants also became relevant boundary spanners in BPP boundary infrastructure thanks to their role as mediators in the mini-integration system. The narratives from the interviews with BPP representatives also underlined the matters that have arisen recently in the BPP socio-technical setting and that may influence further changes in BPP boundary infrastructure in the coming years. The following quotes are illustrative:

*I have seen that sustainability will be the next guiding concept for pig production in Brazil. I mean, it already is. Food sectors will depend on sustainable production practices to survive. Brazilian pig production has to mobilize as many people and institutions as it can to find its way to being sustainable. (An industry executive).*

There is a significant worldwide debate on the use of antibiotics in animal production. Also, I have seen an increasing international pressure on Brazil, which has been charged to review its animal health protocols in pig production. Moreover, I guess that will change the whole way we produce pig meat over the next few years. (A pig production consultant)

*There are already successful experiments in meat developed in a laboratory. With society's growing pressure on animal welfare and the use of animals for human consumption, I believe artificial meat will soon bring new paradigms to agri-food sectors, and therefore to pig production in Brazil. (A researcher specialized in pig production).*

**Figure 3.6.** Socio-technical setting and boundary infrastructure evolvement linked to vertical coordination international standards.



## 3.5. Discussion

By using the concept of boundary infrastructures, this study aims to build a deeper understanding of boundary work in long-term transformative processes in agri-food sectors. In this section, we reflect on the theoretical and practical implications of our findings. Specifically, we add to previous literature by highlighting the 1) temporal evolution of boundary infrastructures in an agri-food sector; 2) complementarity of boundary infrastructure elements, i.e., how they reinforce one another and how interactions between them play a role in long-term agricultural transformative processes, and 3) fluidity of elements and structures that perform between science, policy, and practice boundaries.

### 3.5.1. The temporal evolution of boundary infrastructures in an agri-food sector

Previous studies focusing on the boundary infrastructure concept underlined that boundary infrastructures co-evolve with the sector socio-technical dynamics in which they are embedded, exercising a mutual influence (Fremont et al., 2019; Orsini et al., 2017; Steger et al., 2018). Scholars who have analysed transformative processes in agri-food sectors through boundary work conceptual lenses (despite focusing on single elements within boundary work or smaller change processes) have added that boundary infrastructure elements have often evolved as they increase their connecting capacity (Franks, 2010; Kimble et al., 2010; Klerkx et al., 2010; Tisenkopfs et al., 2015; Klerkx et al., 2012), meaning that boundary infrastructure elements reinforce one another (e.g., a boundary object is supportive of the work of a boundary spanner or organization). This study deepens the previous understanding of boundary infrastructure evolvement by adding new insights on 1) how a boundary infrastructure develops, simultaneously being shaped by, and shaping, the socio-technical setting; and 2) how further or improved connections between boundary elements modify boundary infrastructures over time in terms of their assemblage and composition.

As regards the first theoretical contribution, the Brazilian case described in the results section confirms previous literature regarding the reciprocal influence between socio-technical settings and boundary infrastructures (Orsini et al., 2017; Steger et al., 2018). However, this study shows in more detail how such interaction unfolds. Mostly, boundary infrastructure elements are shaped by technological, economic, social, cultural, and environmental pathways taken by a sector over time (e.g., the integration system boundary object that emerged linked to BPP moves towards vertical coordination governance; the National Pig Research Centre played a role as a boundary organization in the 1980s because of joint private and public actions in BPP). Our study indicates that a boundary infrastructure evolves by what could be called critical mirroring of the socio-technical setting in which it is embedded. This means that, as a mirror, it may reveal some imperfections in the image that it reflects vis-à-vis an idealized future image of what the sector should look like (these are powerful guiding devices – see Beers et al., 2010) and thus trigger correlated actions. Boundary infrastructures may also evolve, fostering alternative ideas or supporting social demands that will result in improved or new boundary infrastructure elements later on. Hence, boundary infrastructures reflect and approach tentative technological, social, and institutional features of evolving systems (see also Kuhlmann, Stegmaier, & Konrad, 2019) and, as they allow for a certain openness (relating to interpretive flexibility), they also open spaces for new boundary infrastructure elements to emerge and further develop the socio-technical system.

Two episodes in BPP boundary infrastructure evolvement described in the results section illustrate accurately how a boundary infrastructure evolves, critically mirroring the socio-technical setting in which it is embedded. First, as described in the analysis of the international standards strategy, boundary spanners (NGOs and the National Pig Research Centre) headed debates on animal welfare improvements in Brazil since the mid-2000s. This action was crucial for triggering science, policy, and practice actors' effective mobilization regarding animal welfare issues. As a result, in the early 2010s, the BPP boundary infrastructure added two new boundary objects (the animal welfare discourse and the animal welfare standardization process), which are closely linked to previous moves promoted by boundary infrastructure elements. Second, as underlined in the analysis of vertical coordination: a radical change – social claims relating to pig production's environmental impact – gained momentum in the early 2000s. A boundary spanner (policymakers) and a boundary organization (the National Pig Research Centre) underpinned that social claim and played a decisive role in establishing two new boundary objects (the environmental discourse and the Pig Production Environmental Adjustment Agreement).

As regards the second theoretical contribution, the BPP boundary infrastructure also evolved as it expanded connections between its boundary infrastructure elements. Previous studies have already highlighted the importance of connectivity for boundary elements associated to transformative processes in the agri-food sector (Franks, 2010; Kimble et al., 2010; Klerkx et al., 2010; Tisenkopfs et al., 2015; Betzold et al., 2018; Klerkx et al., 2012). This study goes beyond them by showing how wider connections between boundary elements build large-scale structuration. Such structuration takes place when a boundary infrastructure element underpins the emergence of another one (and connects to this new piece) in order to strengthen boundary infrastructure performance overall. Illustratively and metaphorically, one could say that a boundary infrastructure in an agri-food sector evolves as a sort of flexible skeleton that underpins the improvement of limbs attached to it and fosters the emergence of new ones as time goes by.

The BPP boundary infrastructure evolution trajectory reveals interesting episodes showing how new or improved pieces of boundary infrastructures are generated through further connections between boundary elements. For instance, the environmental discourse was a boundary object that functioned as a master narrative in the vertical coordination intensive production boundary infrastructure in the early 2000s. After consolidating some values and ideas between science, policy, and practice actors, it underpinned the emergence of other boundary infrastructure elements and connected these to them – such as a boundary object (Pig Production Environmental Adjustment Agreement) and a boundary spanner (policymakers). Another example of such expansion in the Brazilian case is the connection between the integration system (boundary object) and suppliers (boundary spanners). Both examples demonstrate that interconnected boundary infrastructure elements assume an active role in building interfaces between science, policy, and practice, and go beyond being supportive of change processes as often argued (Klerkx et al., 2012; Betzold et al., 2018; Tisenkopfs et al., 2015); they also consolidate into the new operation structure of the socio-technical system or sector whose formation they support.

### 3.5.2. The complementary roles of boundary infrastructure elements to connect and span the multitude of boundary transformative processes in agri-food sectors

Regarding ideas on mirroring and boundary infrastructure evolution, this study highlights the complementarity of boundary infrastructure elements. They reinforce one another through synergistic and catalytic interactions to convince actors and to support science, policy, and practice actors to collaborate and, in doing so, allow them to build improved or alternative working processes together. Indeed, earlier boundary work studies in agri-food sectors have already shown that sometimes boundary organizations create boundary objects, or that boundary objects gather a set of boundary spanners around them (Eden, 2011; Klerkx et al., 2012; Clark et al., 2016; Quark & Lienesch, 2016). However, this study deepens this insight by explaining further how boundary elements work together in boundary infrastructures.

Boundary infrastructure elements (i.e., objects, spanners, organizations) require one another's support because the tasks of convincing, guiding, and binding actors and building working processes in a sector are complex and exceed any one individual's capacity to accomplish them. From our study, it emerges that the boundary objects that focused on translating and communicating values present some limitations. In the BPP boundary infrastructure trajectory, they worked efficiently to convince science, policy, and practice actors about their shared visions and expectations. However, they had to be complemented by other boundary elements to bind actors further and to build new or improved working processes. Our findings show, for instance, that the intensive production discourse functioned as a boundary object in the 1970s to develop more efficient interfaces between science, policy, and practice focused on sector demands, such as the enhancement of lean pig meat availability. The National Pig Research Centre emerged and was attached synergistically to that discourse, and it became the first boundary organization in the BPP boundary infrastructure. In turn, the National Pig Research Centre headed the implementation and running of the National Pig Research Programme between 1978 and 1992, which functioned as a crucial boundary object to bring to the Brazilian context new or improved working processes, such as pig genetic standards, animal health protocols, technological packages, and animal feeding recommendations.

Therefore, the Brazilian case shows that boundary infrastructure elements reinforce one another through synergistic and catalytic interactions to turn shared values and ideas into concrete and connected further actions that materialize collaboration between science, policy, and practice. Additionally, our study shows how boundary infrastructure elements increase or decrease in strength over time, offering a more in-depth comprehension of the emergence and weakening of boundary objects, boundary organizations, and boundary spanners in agricultural transformations – a process already suggested by Star (2010). Some interactions between science, policy, and practice were long lasting and even consolidated into the eventual structure, as already mentioned in section 5.1 (e.g., the integration system boundary object described in our case and its influence in the Brazilian context), whereas others were more bounded (e.g., the pig public genetic programme boundary object, which lost support over time). The more a boundary infrastructure element functions synergistically and connects catalytically to other elements in a boundary infrastructure, the steadier it tends to be.

### 3.5.3. The fluidity and structural flexibility of boundary infrastructure elements

Inspired by notions of interpretive flexibility linked to boundary work (Bowker & Star, 2000; Star & Griesemer, 1989), we developed in this study a notion of interpretive flexibility adapted to boundary infrastructures, and indeed boundary infrastructures as a whole afford interpretive flexibility, in line with earlier work (e.g., Klerkx et al., 2012; Jakku & Thorburn, 2010; Tisenkopfs et al., 2015). However, we found a form of fluidity, or what could be called structural flexibility, that does not apply to the interpretive flexibility afforded by the different boundary infrastructure elements, but rather to how the categorization as boundary object, boundary organization, and boundary spanner is interpreted flexibly. Despite these categories often being pictured in the literature as separate and fixed, Betzold et al. (2018) found that boundary-object or boundary-organization categories may sometimes be more fluid as they develop, and our study extends and deepens those findings. In the our case, fluidity from one role to another one relates mostly to boundary infrastructure interpretive flexibility, which allows actors to use, interpret, and view boundary elements according to their interests. Thus, the same boundary element can perform a role in common usage (e.g., it can be a boundary object for most of the actors) and a distinct one in tailored usage (e.g., it can work as a boundary organization in specific contexts).

The integration system boundary object is a remarkable example of the structural flexibility of boundary infrastructure elements in the BPP boundary infrastructure trajectory. As described in our findings, with the emergence of the vertical coordination intensive production socio-technical setting, the integration system became an influential device for binding and organizing actors to tackle sector demands. In common usage, it functioned as a crucial boundary object, promoting large-scale collaboration between science, policy, and practice to approach challenging demands, such as guaranteeing a steady raw material flow. However, in its tailored usage, the integration system functioned mostly as a boundary organization. Each industry integration system performed as an organization focused on mediating boundary work between science, policy, and practice. In this endeavour, each integration system institutionalized long-term relationships between science, policy, and practice actors (such as private pig genetic improvement programmes), facilitated communication between them (through coordination of agenda setting), developed and used management tools (such as advisory service standards), and provided funding to foster shared actions (such as the efforts to adapt international traceability protocols to the Brazilian context).

Our findings also show another kind of structural flexibility, i.e., boundary infrastructure elements that work together in an alternative configuration to back parallel developmental actions. This arises because the BPP boundary infrastructure evolvement also defined the people and institutions that would benefit (e.g., suppliers became key actors in the vertical coordination setting) or be undermined (e.g., independent pig producers had to create their own science, policy, and practice interface to avoid their complete exclusion). This is the case in the BPP mini-integration system. From the mid-2000s, actors from science (such as independent consultants), policy (such as state departments of agriculture), and practice (such as suppliers) started to underpin the emergence of a parallel boundary infrastructure to capture actors excluded from the dominant way of producing pig meat in Brazil. However, they kept some links with the integration system (e.g., independent consultants also work with industry integration systems in particular areas, such as animal welfare; in turn, there are suppliers that sell a specific product such as medicines for industry integration systems and establish broader partnerships with mini-integrators, adding advisory and learning services to the product that they sell). This demonstrates that structural flexibility in the BPP boundary infrastructure also aimed to capture those excluded, i.e., those that could not connect to the original boundary infrastructures because of what Klerkx et al. (2012) call interpretive rigidity.

## 3.6. Conclusions

Our analysis has shown that the boundary infrastructure concept is a valuable tool to unravel boundary work in long-term agricultural transformative processes. Through tracking boundary infrastructure evolvement, we have deepened the understanding of how pig production in Brazil transitioned from the spot market to vertical coordination, and this enabled us to draw wider lessons on boundary infrastructures in relation to transformative change in agri-food sectors. Our analysis has shown the temporal evolution of boundary infrastructures, describing how the complementarity of boundary elements plays a role in large-scale changes in agri-food sectors and enhancing our understanding of the fluidity of elements and structures that perform between science, policy, and practice boundaries. Furthermore, the overall view provided by this study about structures linked to change gives to the boundary infrastructure concept the analytical virtue of contributing to elucidating how a socio-technical setting transitioned to another one over a long period.

The boundary infrastructure concept thus allows additional insights to be built on cumulative effects related to long-term transformative processes. Such kinds of insight provided by the application of the boundary infrastructure concept in the Brazilian case may also be useful for future studies in agri-food sustainability transitions. Although it is not the explicit objective of this study to look at transitions to sustainability, we believe that a next step could be to connect the boundary infrastructure concept more integrally to the sustainability transitions literature that, for example, has adopted the multi-level perspective (e.g., Lamine, 2011; El Bilali, 2018; Ingram, 2015; Gaitán-Cremaschi et al., 2019). Thus, one might unravel further how to drive science, policy, and practice in long-lasting socio-technical transformation processes towards more sustainable food production practices. This type of study may also be useful for looking at the broader political dynamics, as highlighting the interactions between science, policy, and practice actors in boundary infrastructures can provide insights about the dynamics of inclusion and exclusion in sector transformation, an issue often neglected in studies of agricultural innovation systems (Pigford et al., 2018).

As our empirical study focused on a single case and was explorative given that the boundary infrastructure concept has not yet been applied in agri-food settings, there are obviously limitations as regards generalizability. We focused on boundary infrastructures developed within a particular agri-food sector, pig production. We cannot be sure that boundary infrastructures function similarly in other sectors related to food production, and this would require studies in other agri-food sectors. Future work would need to substantiate our findings as regards boundary infrastructure complementarity and synergy, as well as the structural flexibility of boundary infrastructure elements. It would also be interesting to investigate boundary infrastructures from a scale point of view, thus studying whether and how sectoral and national boundary infrastructures interact, or whether sectoral infrastructures overlap.

# CHAPTER 4

Facilitating international animal welfare standards implementation in local contexts: the role of intermediaries in Brazilian pig production

# 4. Facilitating international animal welfare standards implementation in local contexts: the role of intermediaries in Brazilian pig production

**Abstract:** International agreements have been adopted in recent years to disseminate animal welfare standards worldwide. Scholars who have analysed such initiatives underline that this calls for contextualized strategies for a successful implementation of international animal welfare standards in specific settings, also emphasizing the relevance of individuals and institutions who function as intermediaries in these complex situations of change. However, previous studies do not provide empirical insights into how different intermediaries work in relation to international animal welfare standards implementation in local contexts. Focusing empirically on the implementation of EU animal welfare directives in Brazilian pig production, this chapter aims to connect the standards implementation and intermediation literatures to deepen the understanding of how intermediaries assembled and acted as an ecology of intermediaries to facilitate the implementation process for international animal welfare standards. The chapter aims to enrich debates on how to develop contextualized strategies that can translate recognized international regulations into practical local animal welfare improvements. Our findings provide evidence that collective intermediation efforts are pivotal in addressing demands (such as translation, adaptation, regulation) that emerge from the complex situation of change provoked by the implementation of international animal welfare standards in local contexts. The main implication of our study for theory on standards implementation is that the operationalization of a contextualized strategy linked to international animal welfare standards implementation is composed of a normative dimension and a technological dimension and that, to achieve their desired outcome, contextualized strategies also rely on connected and complementary intermediation actions.

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## 4.1. Introduction

The growing societal interest in how food is produced has provoked heated debates in recent decades (Henson and Reardon, 2005; Jongwanich, 2009; Darnhofer, 2015; FAO, 2018). One of those debates emerged from scientific findings and civil anxieties about industrialized farm animal production, prompting soaring concern on how to establish adequate controls that safeguard animal welfare[13] in the livestock industries scattered all over the world (Bennett, 1997; Fraser, 2008; FAO, 2009; Shepherd and Wilson, 2013; EU, 2017). Animal welfare within the international industrialized meat system is a multifaceted and interdisciplinary issue with ethical, economic, political, cultural, scientific, and religious implications (Giovanucci and Ponte, 2005; Webster, 2008; FMO, 2018). Increasingly, such complex matters are approached worldwide through bilateral agreements to disseminate international animal welfare standards[14] (Fulponi, 2006; Lundmark et al., 2018). However, despite their global acceptance, it is acknowledged that animal welfare standards fostered through treaties or intergovernmental organizations have been insufficiently applied in practice generally (Webster, 2005; More et al., 2017).

The European Union (EU) and the World Organization for Animal Health (OIE) have often been at the forefront of international agreements linked to animal welfare (Ingenbleek et al., 2012). Since the early 2000s, both organizations have started developing cooperation, particularly with non-EU countries, to promote high animal welfare standards through political and commercial agreements (Maciel and Bock, 2013). In this endeavour, international cooperation linked to animal welfare tackles various challenges, such as how to build agreed regulations among developed and emergent countries, standards implementation strategies, and assessment and labelling schemes (Bracke, 2009). Nonetheless, scholars who have analysed EU and OIE initiatives stress that the implementation of international animal welfare standards is a most challenging task because it is necessary to motivate diverse actors scattered over international, national, and local levels to reshape agri-food production processes in particular contexts (Sinclair, 2016; OIE, 2019; Khaneghahi Abyaneh et al., 2020). Indeed, previous studies have emphasized that active international animal welfare standards implementation relies on developing a contextualized strategy that translates general regulations into practical local measures (Thiermann and Babcock, 2005; FAO, 2009; Paranhos da Costa et al., 2012; EU, 2018).

The literature regularly understands implementation as one of the stages of the process of establishing and operating a standard (Hatanaka et al., 2005; Henson and Humphrey, 2010; Klerkx et al., 2012). Henson and Humphrey (2010) split the process of establishing and operating a standard into five steps.[15] The third one is the implementation step, where actors adhere to specific rules and procedures to bring the standard into practice. EU and OIE studies on international animal welfare standards dissemination emphasize that a successful implementation process depends on the building of different

[13] In this study, we follow the World Organization for Animal Health's (OIE) official definition of animal welfare. According to OIE, 'animal welfare is the physical and mental state of an animal concerning the conditions in which it lives and dies.' An animal enjoys good welfare if it is 'healthy, comfortable, well-nourished, safe, able to express innate behavior, and it is not suffering from unpleasant states such as pain, fear, and distress' (OIE 2019).

[14] Scholars stress that five main formats are applied to promote the use of good animal welfare practices worldwide (voluntary welfare codes, corporate programmes, product differentiation, legislated standards, and international agreements) (Fraser 2006). The latter rely on treaties or intergovernmental organizations that establish common standards among countries to prevent different standards from impeding international trade (Grethe 2007).

[15] Henson and Humphrey's (2010) five steps for establishing and operating a standard are: 1) standard setting (formulation of written rules and procedures); 2) adoption (a decision by an entity to adopt the standard); 3) implementation (the application of rules and procedures); 4) conformity assessment (documented evidence that the standard was implemented effectively); and 5) enforcement (procedures to respond to non-compliance and sanctions to withdraw recognition if corrective action is not taken). In this study, we focus on further disentangling the third step (implementation).

links at two domains of intervention: organizational and technical (Kahn and Varas, 2014; EU, 2018). These domains co-evolve, mostly entailing legislation adjustments (measures enacted by actors to adjust local organizational contexts to the scope of international animal welfare standards, such as legislation changes, policy building, and public and private agreements), technological catching-up (technological and practice shifts within the local production process applied by actors to comply with an international animal welfare standard), and actions in education, training, and communication (focused on building actors' capacity to tackle local issues linked to animal welfare standards implementation and operation) (EU, 2017; OIE, 2017).



Building the different links involved in an animal welfare standards implementation process is a complex task and often requires the assemblage of a particular socio-technical setting for mid- or long-term horizons (Huertas, Gallo et al., 2014; Gocsik et al., 2016; Zhou et al., 2019). In such settings, people or institutions that function as enablers fulfil a crucial role and are predominantly characterized as intermediaries (e.g., Stafford and Mellor, 2009; Yang, 2013; Klerkx et al., 2014; Koutsouris, 2014; Ortega and Wolf, 2018). Broadly, intermediaries are individuals or organizations that exert diverse mediating roles to facilitate any aspect of the interplay between two or more actors in change processes – previous literature is largely informed by insights from innovation management and often labels those change processes widely as innovation processes (Howells, 2006; Klerkx and Leeuwis, 2008; Haigh, Morton et al., 2015).

Recent research on intermediaries increasingly pays attention to how they take part in complex situations of change (Kivimaa et al., 2019a). This strand of literature underlines that multiple intermediaries sometimes function somewhat connectedly and complementarily within a sort of landscape of intermediation (Steyaert, Barbier et al., 2016). Thus, coming together, they can develop the capacity to coordinate a multitude of actors around challenging tasks (such as global climate change, sustainable food production, and clean energy transition), which would be rather demanding for a single intermediary organization or individual. Such a type of intermediation action was represented primarily by Stewart and Hyysalo (2008) using the concept of a dynamic ecology of intermediaries. Kivimaa et al. (2017a) further elucidated the concept and described an ecology of intermediaries as intermediaries linked to a change process in a specific context having differing roles that connect and complement one another, forming synergies (in the sense that their interplay achieves an effect greater than the sum of their separate efforts), and sometimes even struggling (for funding, relevance, technological paradigms) and overlapping (different intermediaries playing similar roles, intentionally or not).

Therefore, following earlier findings, this study assumes that intermediaries assembled as an ecology tend to emerge in support of a given complex situation of change provoked by the implementation of an international standard in a local context. However, previous studies lack empirical insights into how such collective intermediation efforts proceed in relation to standards implementation processes and the roles that they play in facilitating standards implementation in practice. Thus, the aim of this study is to connect the strands of literature on standards implementation and on intermediation to deepen the understanding of how intermediaries work together to facilitate the implementation process of international animal welfare standards in a particular context. In doing so, we contribute to enriching debates on how to develop contextualized strategies that can translate recognized international regulations into practical local animal welfare improvements (Maciel et al., 2015; Rahmat et al., 2016; EU, 2017; Bayne and Turner, 2019).

The empirical locus of this study is Brazilian pig production, as Brazil is the fourth-largest world producer and exporter of meat products (ABPA ,2019). Since the mid-2000s, animal welfare issues have provoked specific changes in Brazilian pig production regarding transportation, slaughter, and piglet handling (Paranhos da Costa et al., 2012). Eventually, in 2013, Brazil signed a technical cooperation agreement with the EU to deploy international animal welfare regulations in its production systems, thereby provoking further changes in Brazilian pig production. Moreover, four leading Brazilian pig industries agreed to comply voluntarily with the EU animal welfare directives by 2026. Both events triggered the effective implementation of international animal welfare standards in the Brazilian context (Dias et al., 2018b). Therefore, the question that guides this study is: How have intermediaries worked together as an ecology of intermediaries and contributed to the building of the different links needed to implement European animal welfare standards in Brazilian pig production?

The remainder of the chapter is structured in six sections. The conceptual approach is explained in section 2. Section 3 presents the methodology for applying the conceptual approach in the Brazilian pig production case. Section 4 presents the findings of the case study. Section 5 presents the analysis, a discussion, and lessons learned from the Brazilian case, and conclusions are drawn in section 6.

## 4.2. Conceptual understanding

### 4.2.1. Intermediation within complex situations of change

Scholars attempting to unravel intermediation actions in change processes have made great efforts to explain what individuals or organizations do while aligning two (or more) entities and bringing them into contact to address business information, technological issues, or social matters (Steyaert et al., 2016). Initially, previous studies sought to understand how intermediaries executed specific missions such as support brokering for either problem solving (Hargadon and Sutton, 1997) or technology transfer (Bessant and Rush, 1995); or how institutional intermediaries helped to address institutional failures in a particular situation (McEvily and Zaheer ,1999). Later, scholars broadened the intermediation perspective. They paid attention to intermediaries who act as agents who improve connectivity within and among innovation networks (Stewart and Hyysalo ,2008); this is highly important for systemic innovation (Van Lente et al., 2003). Recently, studies have increasingly investigated roles performed by intermediaries in complex situations of change (Steyaert et al., 2016). In this perspective, scholars have introduced an even broader problematization for intermediation actions – e.g., the role of intermediation when the degree of unknown is high (Agogué et al., 2017) and the role of intermediation in the transition to a circular economy (Barrie et al. 2017).

As already mentioned, such studies stress that complex situations of change, given their intrinsic challenging essence, naturally foster the emergence of equally complex intermediation actions, often performed by assemblages called ecologies of intermediaries (Stewart and Hyysalo, 2008; Kivimaa and Martiskainen, 2018). A vast array of intermediaries can take part in such assemblages. Some examples are research or innovation agencies, funding agencies, private consultancy companies, independent technological consultants, innovation platforms, knowledge advisors, non-governmental organizations (NGOs), industries and industry associations, research and technology organizations, producers, and local communities (Howells, 2006; Steyaert et al., 2016; Kivimaa et al., 2019b).

Such different people and organizations when assembled in an ecology of intermediaries function together as bridges between a range of actors and a range of actions needed to operationalize a complex situation of change (Kivimaa and Martiskainen, 2018). In doing so, they play different intermediary roles – e.g., policy building (Shaxson et al., 2012; Kivimaa et al., 2019b), coordination building and network building (Stewart and Hyysalo, 2008), knowledge brokering (Klerkx et al., 2014), innovation brokering (Howells, 2006), or finance brokering (Polzin et al., 2016), but somehow in a connected and complementary fashion. In practice, they articulate expectations, demands, and visions; build and broker networks; provide knowledge exchange and back learning processes; enable translation between different actors, interests, and contexts; foster capacity building; provide institutional support, such as advocacy or lobbying initiatives; and develop local technological strategies (Van Lente et al., 2003; Stewart and Hyysalo, 2008; Klerkx and Leeuwis, 2009; Kivimaa et al., 2019b).

Previous literature focusing on broadening the intermediation perspective also hints that ecologies of intermediaries evolve as dynamic assemblages (Stewart and Hyysalo, 2008; Kivimaa et al., 2019a; Manders et al., 2020). This means that intermediary roles and intermediation actions, and the need for them, may vary as a complex situation of change unfolds (Kivimaa and Martiskainen, 2018). Such dynamics imply that the composition of an ecology of intermediaries tends to fluctuate over time (Manders et al., 2020). Furthermore, ecologies of intermediaries are orchestrated to some extent. Although often they cannot be understood as a designed or seamlessly functioning assemblage, the connectivity and complementarity of their elements demonstrate that they are mobilized by shared influences (Stewart and Hyysalo, 2008; Kivimaa et al. 2019a). We now explain our research methods and, thereafter, we describe how intermediaries function together to implement EU animal welfare standards in Brazilian pig production.

## 4.3. Methodology

Studies focusing on intermediaries often take a qualitative approach based on an exploratory case study design to answer how and why individuals and organizations perform intermediary roles and activities in change processes (Maningas, 2006; Kilelu et al., 2011; Yang, 2013; Klerkx et al., 2014; Kivimaa et al., 2017a). This methodological construction has been associated mainly with intermediation research, as it allows enough freedom to explore insights that emerge during the empirical data collection that were not anticipated during the research design and also not identified from the literature review (Bryman, 2012). Moreover, exploratory case studies are suitable to approach phenomena that are not well known, have many facets, and require an in-depth perspective (Gray, 2004; Eisenhardt and Graebner, 2007) – circumstances that fit in our study.

The empirical case analysed in this study comes from the Brazilian agricultural context, a world leader in meat production, and because of that, a country where animal welfare issues became crucial recently (Molento, 2005; Chaddad, 2016). Animal welfare has been a sensitive issue in Brazilian pig production in particular. Different pressures ended up forcing Brazil to increasingly deploy changes in its pig production system until the most prominent Brazilian pig industries agreed to apply the EU animal welfare standards (Dias et al., 2018a). This compromise, taken in 2015, triggered an interesting case of implementation of international animal welfare rules in a local context, which is the focus of this study. Furthermore, Brazilian pig production has reliable databases (in private and public institutions, such as the

Brazilian Animal Protein Association and the Brazilian Agricultural Research Corporation) showing how animal welfare issues have evolved countrywide.

The primary data sources for this study were 27 in-depth interviews with influential actors involved with animal welfare issues in Brazilian pig production. They are representatives from varied interests, such as industries, producers, governmental institutions, NGOs, science institutions, and advisory services (see Appendix 1). Relying on previous knowledge about Brazilian pig production and additional information available in publications and on websites of industries, associations, public organs, NGOs, and science institutions, we compiled a list of 18 interviewees. We also applied the snowballing method (Kumar, 2011), and, from the initial round of interviews, we added another nine influential interviewees.

The interviews, conducted between July and December 2017 and March and April 2019, lasted between half an hour and two hours and were tape-recorded and transcribed verbatim. They followed an interview guide based on our literature review of international animal welfare standards, standards implementation processes, and animal welfare implementation in Brazilian pig production. The interview guide listed the high-level topics regarding our research, of which there are four main ones: 1) overall information about the animal welfare trajectory in Brazilian pig production; 2) implementation strategies linked to the EU standards in Brazil; 3) the actors that have taken part in the implementation process, the kinds of roles that they have played, and the kinds of activities that they have performed; and 4) how actors have interacted to implement the EU standards in Brazil. Core and additional secondary data were also collected. The core secondary data consisted of books, scientific papers, and policy briefs (see Appendix 2). Additional secondary data came from official public reports and media articles published in newspapers and magazines.

The interview content was interpreted in a twofold way: 1) from a historical perspective, connecting the storyline told by interviewees in a single trajectory of the implementation of international animal welfare standards in Brazilian pig production; 2) from an intermediation perspective, looking at the kinds of intermediation roles played in the implementation of international animal welfare standards in Brazilian pig production and who performed them. As suggested by Olsen (2004) and often applied in previous studies about intermediaries (Al-Sobhi et al., 2010; Yang, 2013; Schröter et al., 2015; Agogué et al. 2017), after interpreting the interview content, we triangulated it with secondary data. Thus, we could sharpen our understanding of the animal welfare trajectory in Brazilian pig production. Most importantly, this data triangulation allowed us to identify more precisely the actors who acted as intermediaries in the implementation process. Afterwards, the interview content and secondary data were interpreted using the theoretical framework as an analytical lens. In terms of possible biases, as regards internal validity, the findings rely on actors' representatives holding high positions (usually CEO or senior consultants). They were able to provide a broad view of animal welfare evolvement and functioning in the Brazilian context. In terms of external validity, a researcher specialized in animal welfare issues in the Brazilian context reviewed our findings. He validated the roles and activities performed by intermediaries and their interactions throughout the implementation process.

## 4.4. Findings

### 4.4.1. EU animal welfare standards within the Brazilian context

Economic and diplomatic relations between Brazil and the EU started in the 1960s and were strengthened politically and in terms of cooperation in the 1980s (Farina et al., 2005; Saraiva, 2017). This led to the establishment of a first framework cooperation agreement in 1992 (Afionis and Stringer, 2014). This agreement encompassed different areas and fostered sector dialogues between Brazil and the EU (van Loon, 2015). In 2007, the cooperation agreement evolved into a strategic partnership, formalized at the 1st EU–Brazil Summit held in Lisbon (4 July 2007). The objective of the strategic partnership between the EU and Brazil was to promote cooperation initiatives and a wider policy dialogue, with the overall aim of tackling global challenges such as sustainable development, climate change, human rights, poverty, and food security (EU, 2007). Within the strategic partnership, an EU–Brazil sector dialogue support facility was created, focused on agriculture and rural development, introducing a joint action plan composed of several projects that started to achieve practical results from 2008 onwards (Silva, 2011). However, it was only in 2013, during the 6th EU–Brazil Summit held in Brasilia, that animal welfare became one of the priority areas supported by the strategic partnership (Maciel et al., 2015). As a result, a Memorandum of Understanding (MoU 48) on technical cooperation in animal welfare was formalized between the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA) and DG SANTE.

Despite its transformative ambitions, the animal welfare agreement between the EU and Brazil assumed a purely advisory nature (Maciel and Bock, 2013). It did not include, for instance, any further consequences for political or economic relations between the two parties in the event of insufficient achievements. Mostly, MoU 48 provided a regular exchange of information and technical cooperation related to several animal welfare issues (e.g., horse welfare, asinine welfare, sheep farming, dairy cattle, pig and poultry transport handling, and laying hens) (EU, 2017). Despite its predominantly advisory character, MoU 48 had a relevant impact on the Brazilian pig sector (Dias et al., 2018a). For instance, it reinforced previous pressures coming from the scientific community, international buyers, and non-governmental animal rights organizations, stimulating further changes in production practices (Yunes, von Keyserlingk et al., 2018). Moreover, as already mentioned, it influenced four leading Brazilian pig industries (BRF S.A., JBS S.A., Cooperativa Central Aurora Alimentos, and Frimesa Cooperativa Central, which account for more than 50% of Brazilian pig production (ABPA, 2019) to announce in 2015 that they would comply voluntarily with the EU animal welfare legislative standards by 2026 (Dias et al., 2018b). Those pig industries took this decision as they realized that adhering to the Mou 48 recommendations would soften likely future international commercial barriers (Maciel et al., 2015).

In practice, this decision by the leading Brazilian pig industries reinforced the introduction of two EU animal welfare regulations in the Brazilian context: 1) Council Directive 98/58/EC (concerning the protection of animals kept for farming purposes); and 2) Council Directive 2008/120/EC (concerning laying down minimum standards for the protection of pigs) (Dias et al., 2018a). An assessment carried out by independent researchers on the implementation feasibility of both animal welfare directives showed that some characteristics of the Brazilian pig production would facilitate EU model adoption (Dias et al., 2015). They quoted the favourable climate and the abundance of natural resources, the availability of noble feed for pigs (such as maize and soya), and the high level of human resources linked to the pig industry, research institutions, and governmental organs (Dias et al., 2015). They also listed 36 items that should be changed in Brazilian pig production (Dias et al., 2015). These were split into four levels of complexity in the

application of EU regulations in Brazil (low, light, moderate, and high). Only four items were labelled as high complexity. Eight were labelled as moderate complexity, 11 as light complexity, and 13 as low complexity – Appendix 3 describes all 36 items and their levels of complexity (Dias et al., 2015).

The levels of complexity relating to the application of EU regulations in Brazil and influential actors' evaluations collected from the 27 in-depth interviews conducted in our fieldwork were used in this study as the basis on which to investigate the different links that should be built in the organizational and technical intervention domains to implement Council Directive 98/58/EC and Council Directive 2008/120/EC in Brazilian pig production. The links needed are presented in the second column of Table 4.1.

**Table 4.1.** Gaps and links needed in relation to the implementation of EU animal directives in Brazilian pig production (based on Dias et al. 2015 and fieldwork interviews).

| **Brazilian gaps (organizational, legal, technological, and capacity building) concerning EU animal welfare pig production requirements** | ***Links needed to be built to tackle gaps and fulfil EU animal welfare pig production requirements*** | **Domain of intervention** |
|---|---|---|
| 1) Absence of a specific regulation to establish animal welfare requirements in pig production | *Build a public/private coalition to establish national animal welfare legislation for pig production according to the EU directives* | **Organizational** |
| 2) Most facilities in pig farms do not meet EU rules in terms of minimum spaces for different types of pigs (boars, sows, piglets), minimum width between joists on slatted floors, and rest areas | *Develop a strategy to adapt existing facilities to the EU directives; set rules to orient the building of new facilities according to the EU directives* | **Technical** |
| 3) Accommodation of pregnant sows in groups; Provision of materials for sows to build the nest before giving birth; 4) Provision of handling materials for pigs of all ages; 5) Use of fibre in the diet of pregnant sows; 6) Abolish practices of tooth tip reduction, partial tail cutting, and castration of males prior to the seventh day in piglet management; 7) Adopt a minimum age of 21 days to wean piglets; 8) Reduce the mix of pigs coming from different properties in the nursery, growing, and finishing stages | *Set a public/private strategy to develop a Brazilian proposal to review technologies and practices linked to animal welfare issues* | **Technical** |
| 9) Proper euthanasia procedures | *Build a public/private coalition to establish national animal welfare legislation for pig production according to the EU directives* | **Organizational** |
| 10) Keep records of veterinary treatments and mortality for at least three years | *Build a public/private coalition to establish national animal welfare legislation for pig production according to the EU directives* | **Organizational** |

| | | |
|---|---|---|
| 11) Promotion of official animal welfare capacitation initiatives for farmers, extension technicians, animal transporters, and slaughterhouse workers | *Establish a public/private action to provide animal welfare capacity building linked to the EU directives* | **Technical** |
| 12) Development of research projects to endorse international animal welfare rules according to the Brazilian context | *Set a public/private strategy to foster research about animal welfare in the Brazilian context* | **Technical** |



### 4.4.2. Intermediation for the adjustment of Brazilian regulations to EU directives

Brazil had enacted a legal framework relating to animal welfare before starting the technical cooperation with the EU in 2013 (EU, 2017). In the case of farm animals, the Brazilian legal system established provisions on animal welfare within a comprehensive set of rules for animal health. Then, and more specifically between 2000 and 2011, three subject-specific regulations (in Brazil called Normative Instructions – IN) were released to set out in more detail local animal welfare standards also linked to pig production (Dias et al., 2018a). These regulations are IN nº 03/2000 (technical regulation for stunning methods and humane slaughter procedures) (MAPA 2000); IN nº 56/2008 (recommendations on good welfare practices in various stages of an animal's life) (MAPA, 2008); and IN nº 46/2011 (technical regulation for organic animal and plant production systems) (MAPA, 2011). Despite these moves forward, EU directives kept becoming more encompassing than Brazilian animal welfare regulations, and this triggered further actions to adjust local legislation to EU standards when MoU 48 came into practice (see Table 4.1.).

However, MAPA did not take coercive measures to adjust the Brazilian regulations to the EU animal welfare standards (EU, 2017). According to the narratives from the interviews with the Brazilian pig production representatives, at first the technical cooperation with the EU performed more as a tool to involve particularly pig industries in policy discussions on animal welfare. In practice, MAPA decided to postpone normative changes until the broadest possible consensus was reached. That position slowed down the EU directives implementation process. On the other hand, it ensured that the alignment of Brazilian animal welfare regulations with the EU directives would be underpinned by a public/private coalition. Moreover, setting the broadest possible consensus reinforced the importance of intermediaries, as intermediation actions were crucial to mediate the understanding between rather diverse actors and interests (e.g., MAPA and the EU were more interested in applying international regulations; industries mostly wanted to keep their international business; producers were worried about how much they would need to spend to adjust their pig production facilities).

Two committees undertook most of the intermediation actions to build a public/private coalition to establish national animal welfare legislation for pig production according to the EU directives. One of them is the Permanent Technical Committee on Animal Welfare (CTBEA). It was formally nominated by the Brazilian government to mediate the translation of the EU directives to the local context, to coordinate how they would be deployed, and to build local animal welfare legislation aligned with the European rules. In practice, CTBEA performed as an intermediary focused on policy building. It performed this role through an extensive dialogue with actors linked to animal production, becoming a crucial intermediary in terms of articulation of expectations, demands, and visions, and policy building. CTBEA mobilized actors mainly by means of workgroups focused on specific subjects (e.g., pet animal welfare, animal welfare applied to pig production, welfare standards for live animal transportation). These workgroups were composed of

representatives from actors that became involved in each subject and whose main assignment was to design normative instructions adjusted to EU directives.

In November 2018, a second committee linked to the implementation of EU directives in Brazilian pig production, called Workgroup Pig Production (GT Pigs), started working – it is composed of representatives from industries, producers, international animal welfare NGOs, research institutions, and the Brazilian government. Essentially, GT Pigs functions as an intermediary with two objectives: 1) to stimulate collaboration between pig production actors to translate EU animal welfare directives to the Brazilian pig production context; and 2) to build with pig production actors a proposal to harmonize Brazilian animal welfare standards with the EU directives. Accordingly, GT Pigs performs as an intermediary focused on translation between different actors, interests, and contexts (policy translation and policy building roles).

In 2019, GT Pigs released a draft for public consultation on animal welfare regulations applied to pig production. After receiving further suggestions from any actors interested in contributing to the draft, GT Pigs will present to CTBEA a proposal for an animal welfare normative instruction focused on pig production. The narratives from the interviews with Brazilian pig production actors stressed that a specific pig production animal welfare normative instruction will be likely issued in 2020. As both CTBEA and GT Pigs received official mandates from the Brazilian government to mediate how local animal welfare legislation would absorb EU directives, the synergy between them flowed naturally. Nonetheless, the building of a public/private coalition has also been driven by the decision of the four leading pig industries to comply voluntarily with the EU directives by 2026. Although they do not have this as their foremost aim, their resolution can be considered an intermediation action related to establishing national animal welfare legislation for pig production according to the EU directives.

The big four – BRF S.A., JBS S.A., Cooperativa Central Aurora Alimentos, and Frimesa Cooperativa Central – have contributed in a twofold way to building the organizational link needed. First, they legitimized the suitability of the EU regulations for the Brazilian context, and, in doing so, they performed as a bridge between European standards and other industries in the local context. Second, they established an agenda and a horizon (2026) to adjust Brazilian regulations to the EU directives. To some extent, pig industries that adhered voluntarily to the EU directives overlapped CTBEA's intermediation role in terms of articulation of expectations, demands, and visions.

### 4.4.3. Intermediaries and intermediation actions for changes in technologies and practices

The EU directives implementation provoked two broad technological adaptation debates in Brazilian pig production from 2013 to date. The first relates to animal husbandry and asks what kinds of innovations would be needed to guarantee that local production would provide ethical treatment and a healthy life for pigs from birth to slaughter (e.g., adequate food and water supply, adequate veterinary care, no rough management, proper pre-slaughter management) (Dalla Costa and Dalla Costa, 2015). The second focuses on the extent to which facilities where pigs are born, grow, and are slaughtered in Brazil should be changed to align with the EU directives (e.g., proper type of floor according to animal age, equipment for temperature and humidity control in pig facilities, husbandry systems that allow free movement of pregnant sows, improved handling procedures and equipment to transport pigs from

properties to slaughterhouses) (Ludtke et al., 2012). Those two debates have shaped how the technical intervention domain of the EU directives implementation has unfolded (see Table 4.1.). However, actors in Brazilian pig production chose to prioritize the development of a Brazilian model of housing pregnant sows in a group as a link needed in the technical intervention domain from 2015 onwards.

According to the narratives from the interviews with the Brazilian pig production representatives, independent consultants have mostly mediated interactions between industries, suppliers, and research institutions to find the best technological choice to deploy the housing of pregnant sows in a group in Brazilian pig production – three different technological routes have been trialled so far.[16] They create ties with national and international equipment suppliers or offer advisory services for industries and independent producers. In both cases, these independent consultants organize meetings to discuss technologies (such as electronic sow feeding), function as bridges to bring together researchers and industry technical teams, and help producers and industries to identify the most affordable manner to adapt pig facilities to the housing of pregnant sows in a group. Thus, independent consultants have performed as innovation brokers in the development of local technological strategies.



The Brazilian Agricultural Research Corporation (Embrapa) also can be seen as an innovation broker that has bridged the interplay between actors interested in building a Brazilian model of housing pregnant sows in a group. Embrapa has an acknowledged trajectory as a research institution in the animal welfare debate in the Brazilian context. However, as a further result of its research efforts, Embrapa has intermediated actors' collaboration to assess the technical and economic impact of housing pregnant sows in a group in the Brazilian context. Embrapa has also fostered the interplay between actors in particular circumstances. In the case of pre-slaughter management practices, Embrapa headed intermediation actions to bring together pig producers and equipment suppliers regarding improvements in pig transportation especially. From Embrapa's mediation, actors developed new designs for truck-trailers, as well as pig loading and unloading equipment.

### 4.4.4. Intermediation in relation to shared actions in education, training, and communication

Animal welfare became a usual subject of scientific events, and learning activities focused on pig production actors and the development of technical learning materials (such as brief guides and videos on pig pre-slaughter management on farms, animal transportation, and ethical slaughter) from the mid-2000s (Dias et al., 2018). Even animal welfare teaching in agrarian science colleges and universities strengthened in the same period, according to a survey in 130 faculties of veterinary medicine and animal husbandry registered at the Brazilian Federal Council of Veterinary Medicine (Borges et al., 2013). However, after MoU 48 was signed and after the decision of the four leading industries to comply voluntarily with the EU directives by 2026, animal welfare-specific actions in education, training, and communication became a

[16] Housing pregnant sows in a group has been the hottest debate concerning technological changes relating to animal welfare recently. Pig production actors in Brazil have discussed and applied three different methods of housing pregnant sows in a group; however, none of them has become hegemonic so far (Dias et al., 2018a). The first is the traditional model, where sows live in small numbers housed in a collective stall, with manual or automatic feed supply. The second is the minibox model, where sows share a collective stall with small boxes in its walls. These boxes have linear feeders or food is thrown directly on the floor, using manual or automatic equipment. The third model is electronic sow feeding, or a station with electronic power control. This system has an electronic chip applied to the sows' ear. This chip is read by the sensor present at the feed station entrance, which thus provides an amount of feed determined by the operator of the integrated farm system and adjusted to the needs of each matrix (MAPA, 2018).

mutual aim in Brazilian pig production. Thus, intermediaries interested in taking part in establishing a public/private partnership to build capacity in animal welfare issues were mobilized, especially from 2015 onwards.

From our interviews with pig production representatives, we found that some actors performed as knowledge brokers in a threefold way: 1) they brought together pig production actors at scientific events to discuss how to implement international animal welfare standards in the Brazilian context; 2) they elaborated consensually new and more focused technical learning materials on animal welfare (taking into account the EU perspective); and 3) they mobilized pig production actors to organize short-term courses and training on the content of new technical learning materials. CTBEA, the World Animal Protection (WAP), and the Brazilian Pig Producers' Association (ABCS) were the intermediaries that performed together as knowledge brokers.

They raised public and private funds and applied them in capacity building projects. For example, they mobilized actors from science and practice (national and international researchers, producers' representatives, consultants, international NGOs, industry representatives, and national and international supplier representatives) in 2015 to compile four handbooks to translate the European view on animal welfare – Animal welfare in pig production: slaughterhouse (ABCS, 2016a); Animal welfare in pig production: transportation (ABCS, 2016b); Animal welfare in pig production: the whole farm (ABCS, 2016c); and Housing pregnant sows in a group: good practices for welfare in pig farming (MAPA, 2018). They also mediated the production of three videos about animal welfare, supported diversified scientific events (such as the Workshop on Animal Welfare in Pig Farming – 2015 and the Animal Welfare International Symposium: a Sustainable Business Strategy – 2019), and in recent years took part in the organization of practical courses on animal welfare regulations, involving thousands of people (technicians, producers, and slaughterhouse employees) linked to pig production.

## 4.5. Analysis and discussion

The findings presented in this study provide evidence that the implementation of the EU animal welfare directives in Brazilian pig production has unfolded as a complex situation of change and has influenced the emergence of an ecology of intermediaries attached to it, as expected according to previous literature on standards implementation (EU 2018, OIE 2019) and on intermediation (Stewart and Hyysalo 2008, Kivimaa et al. 2019a). Mostly, the ecology of intermediaries has taken part in a contextualized strategy to realize the intention to implement the EU directives in Brazil. From the Brazilian case, we have learned that ecologies of intermediaries: 1) afford a multi-intermediary alliance to facilitate the fulfilment of different tasks related to international animal welfare standards implementation processes; 2) facilitate collaboration between actors from the different levels in which an international animal welfare standards implementation process in a local context unfolds. We now further discuss these main findings and distil implications for theory and practice.

### 4.5.1. Affording a multi-intermediary alliance to facilitate the fulfilment of different tasks related to implementation processes

The international animal welfare standards implementation process underway in Brazilian pig production triggered diverse and simultaneous demands from 2013 onwards – e.g., the establishment of national animal welfare legislation for pig production adjusted to the EU directives and the adaptation of technologies and production practices to European standards. The contextualized strategy to tackle these demands also included intermediation actions in which different individuals and organizations became involved. Despite not being purposefully gathered as a rule, individuals and organizations that fostered actor mobilization in Brazil created connections and complementarities among them over time. This joint action took place because no single intermediary would have been capable of playing all the intermediary roles required by the complex situation of change in Brazilian pig production. Thus, the intermediaries focused on specific demands and performed somehow combined collective actions. This confirms earlier findings presented by Kivimaa et al. (2017b) on why intermediaries that have not planned to work together sometimes end up assembled as an ecology of intermediaries.

Building on the Brazilian case, we infer that such connections and complementarities presented by intermediaries when they are assembled as an ecology assume a pivotal function within animal welfare standards implementation processes in local contexts. They perform as a multi-intermediary alliance, in which diverse intermediation roles are played with a certain degree of orchestration to fulfil tasks related to the implementation process. In practice, such multi-intermediary alliances unfold as a collective intermediation effort to bridge actors in the building of the links needed in each intervention domain. For instance, the multi-intermediary alliance in the Brazilian case brought together policy building intermediaries (CTBEA, GT Pigs, and industries), innovation brokers (independent consultants and Embrapa), and knowledge brokers (CTBEA, WAP, and ABCS) to back the EU directives implementation. In doing so, it can be seen as a pillar of a contextualized strategy to realize the intention to implement international animal welfare standards in Brazil.

Addressing the functioning of an ecology of intermediaries as a multi-intermediary alliance makes it easier to identify gaps in intermediation linked to the implementation of international animal welfare standards in local contexts. For instance, according to our findings, the multi-intermediary alliance in the Brazilian case could be improved if it undertook to fill the gaps in innovation brokering (to speed up needed changes in technologies and practices), network building (to enhance the building of partnerships between intermediaries and actors), and finance brokering (to improve the availability of resources for animal welfare research). In other words, investigating the intermediary roles that make up a collective intermediation effort reveals more clearly the strengths and weaknesses of the contextualized strategy attached to an international animal welfare standards implementation process.

### 4.5.2. Facilitating collaboration between actors from the different levels in which an international animal welfare standards implementation process in a local context unfolds

Previous literature emphasizes that the interaction needed between diverse actors scattered over different levels creates challenges for the implementation of international animal welfare standards in specific contexts (Sinclair, 2016; OIE, 2019; Khaneghahi Abyaneh et al., 2020). From our findings in the Brazilian case, we imply that ecologies of intermediaries contribute to facilitating collaboration between actors from international, national, and local levels. They play this role by building shared interfaces where these various actors can negotiate, exchange knowledge, and build agreed solutions to tackle demands raised by international animal welfare standards implementation processes – e.g., changes in local legislation; adaptation of technologies, practices, and facilities; development of local research in animal welfare issues. We found that ecologies of intermediaries (in order to play their diverse intermediary roles, such as policy building, innovation brokering, knowledge brokering) create multi-stakeholder committees, capacity building projects, research partnerships, and other interfaces that push the boundaries of the different levels in which an international animal welfare standards implementation process unfolds. These interfaces bridge actors vertically, making them extrapolate their – often horizontal – connections, i.e., within the level to which they belong.

To illustrate how ecologies of intermediaries facilitate collaboration among actors from international, national, and local levels, we recall two examples from the Brazilian case described in our findings. First, CTBEA functioned as the principal policy building intermediary in the EU directives implementation process. It deployed a committee (GT Pigs) composed of representatives from international (international animal welfare NGOs), national (research institutions and the Brazilian government), and local (industries and producers) levels. GT Pigs became a shared interface where actors collaborated to adjust Brazilian animal welfare legal regulations to European standards, a link that needed to be built in the organizational intervention domain. Second, CTBEA, WAP, and ABCS performed as intermediaries that mobilized national and international researchers, producer representatives, consultants, international NGOs, industry representatives, and national and international supplier representatives through capacity building projects. As a result, these diverse actors compiled agreed learning materials on animal welfare standards implementation in Brazilian pig production, creating a link that needed to be built in the technical intervention domain.

Our study makes two main contributions to theory on standards implementation: 1) it deepens the understanding of what a contextualized strategy to implement international animal welfare standards should be about and 2) it sheds lights on how intermediaries can help to operationalize contextualized strategies aimed at implementing international animal welfare standards. Regarding the first contribution, our study extends the understanding on contextualized strategies by showing that they are composed of a normative dimension (building local capacity to translate, adapt, and implement regulations according to the international standard chosen) and a technological dimension (building local capacity to innovate via adaptation or creation of technologies and practices to apply the chosen international standard to the production process). Therefore, our study increases the comprehension of how to operationalize contextualized strategies aimed at fostering the co-evolution of the two intervention domains (organizational and technical) of an international animal welfare standards implementation process. This refines earlier work (Kahn and Varas, 2014; EU, 2017; OIE, 2017; EU, 2018) that looks at several components

of animal welfare standards implementation and support strategies for their contextualization, but tends to see those more in isolation.

Regarding the second contribution, we have demonstrated that, to come about, contextualized strategies also rely on connected and complementary intermediation actions, as opposed to compartmentalized analysis of how individuals and organizations play intermediary roles in such interventions (e.g., the contribution of organizations focused on translating international animal welfare regulations in implementation processes; the importance of individuals and organizations interested in intermediating the adaptation of technologies in a local context to comply with international regulations) as addressed by other authors (Maciel et al., 2015; Rahmat et al., 2016; EU, 2017; Dias et al., 2018; Bayne and Turner, 2019). This implies that, in contextualized strategies, more proactive consideration should be given to how to enable intermediary actions aimed at facilitating the collaboration needed between multiple actors on different levels of the international animal welfare standards implementation process.



## 4.6. Conclusions

This study has demonstrated how to connect the strands of literature on standards implementation and intermediation to deepen the understanding of the functioning of contextualized strategies to implement international animal welfare standards. We have shown that collective intermediation efforts are pivotal in addressing the demands (such as translation, adaptation, regulation) emerging from the complex situation of change provoked by the implementation of international animal welfare standards in local contexts. Mediators play connected and complementary intermediary roles (such as innovation brokering, knowledge brokering, policy building) to bridge actors from different levels (international, national, and local) in the building of the links needed to effectively introduce in particular settings internationally recognized sets of animal welfare tenets and rules. The main implication of our study for theory on standards implementation is that the operationalization of a contextualized strategy linked to international animal welfare standards implementation is composed of a normative dimension and a technological dimension and that, to achieve their desired outcome, contextualized strategies also rely on connected and complementary intermediation actions.

Furthermore, our study provides in a twofold way a better understanding of how ecologies of intermediaries approach complex situations of change in practice. First, they perform as a multi-intermediary alliance, in which diverse intermediation roles are played with a certain degree of orchestration to fulfil tasks related to the complex situation of change. Second, they create shared interfaces (such as multi-stakeholder committees, capacity building projects, research partnerships) that push the boundaries of the different levels on which a complex situation of change unfolds. A main implication of our study for theory on intermediation is that, instead of the scattered support actions currently described by the literature, we should see the different intermediaries involved in standards implementation processes as a backing system enacted by an alliance between them. This gives a more integrated view on the fact that standards implementation is a layered process of linking, translating, and feeding back information between international standards setters and local adopters of these standards.

A key policy implication is that supporting international agreements as a strategy to improve animal welfare worldwide implies also fostering planning and funding mechanisms that allow a co-evolution of standards implementation processes and ecologies of intermediaries attached to them in local contexts. Furthermore, international animal welfare standards setters (such as the EU and OIE) could help local industries to better map ecologies of intermediaries associated with implementation processes and see where the gaps are. Given the generalizability limitations of our explorative case, future work would be needed to substantiate our findings as regards how ecologies of intermediaries would function to facilitate the international animal welfare standards implementation process in other local contexts, as well as to deepen our understanding about ecologies of intermediaries unfolding in practice as multi-intermediary alliances. It would also be interesting to investigate whether it is feasible to purposefully introduce collective intermediation efforts related to complex situations of change. Thus, one could analyse, for example, how to fill gaps in intermediation roles in multi-intermediary alliances focused on backing contextualized strategies to implement international animal welfare standards.

# CHAPTER 5

Public research and technology institutions (RTIs) and the embedding of imported technologies in receiver contexts: Embrapa's translation role in changing Brazil's pig genetics improvement model

# 5. Public research and technology institutions (RTIs) and the embedding of imported technologies in receiver contexts: Embrapa's translation role in changing Brazil's pig genetics improvement model

**Abstract::** The notion of simply transferring agricultural innovation (i.e., concrete technologies, methods, or concepts) from supplier contexts to receiver contexts as a strategy to improve agri-food systems globally has been strongly criticized and has raised diverse debates in the field of agricultural technology development and innovation. Previous studies have shown that translation work is required when an imported innovation enters the receiver's agri-food system. However, attention has not been paid to the dynamic processes behind embedding imported innovations in long-term transformative processes, and the translation roles that public research and technology institutions (RTIs) may play in such processes. This study aims to make a contribution this debate by focusing empirically on how Embrapa contributed to embedding the pyramid concept and the hybrid pig technology in Brazilian pig production, imported technologies that significantly changed Brazil's pig genetics improvement model during the transition from pork lard to lean meat. Through the theoretical lens of translation work and unpacking and repacking steps, our findings make a threefold contribution to theory on agricultural technology development and innovation: they 1) show how multiple, parallel, and reciprocally influential unpacking and repacking efforts unfold over time and assist in embedding imported innovations in receiver contexts; 2) refine the translation roles played by public RTIs depending on the positions that they assume in ecosystems related to the embedding of imported innovations in receiver contexts; and 3) demonstrate that public RTIs can assume stable and temporary translation roles over time.

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## 5.1. Introduction

Since the 1980s, the concept of merely transferring agricultural innovation (i.e., scientific knowledge turned into concrete technologies, methods, or concepts) from supplier contexts to receiver contexts as a strategy to improve agri-food systems globally has been sharply criticized, raising several debates in the field of agricultural technology development and innovation (Alexander et al., 2020; Barnard and Chaminade, 2017; Binz and Truffe,r 2017; Glover et al., 2019; Jansen, 2004). Scholars have used examples such as the Green Revolution, which did not take off in Africa, to argue that innovations need to be scrutinized, tinkered with, and adapted when they move from their original context to another one (Evenson and Gollin, 2003). In brief, when agricultural innovation travels from its original socio-technical setting to a new one, it often needs to go through a translation process to be appropriately absorbed (Basu and Leeuwis, 2012; Glover et al., 2017; Higgins et al., 2017).

Therefore, translation work is required when imported innovation (i.e., concrete technologies, methods, or concepts that move from supplier contexts to receiver contexts) is introduced in a different agri-food system. Scholars have described the translation work involved in the embedding of imported innovation in local agri-food systems chiefly as a regrounding process situated in time and space (Maat and Glover 2012; Orr 2018). Each context dedicated to food production can be understood as a single setting with specific technical, social, economic, and agroecological characteristics (Glover et al., 2017). Thus, a key reason why innovation often needs to undergo some degree of translation when it travels is that the socio-technical background underpinning local agri-food systems cannot be ignored. Reciprocally, local contexts experience some degree of adjustment when they receive an imported technology (Glover et al. 2019). Previous studies contend that the imported innovation regrounding process comprises two interlinked steps, one focused on achieving a comprehensive view of the innovation – called unpacking – and the second related to the ability to adjust the innovation to the receiver context – called repacking (Eastwood et al., 2017; Glover et al., 2016; Jansen, 2004). Unpacking and repacking are further discussed in section 2.

Authors have also investigated which actors contribute to the embedding of imported innovation (CEPAL, 2017; Correa and Schmidt, 2014; Dias et al., 2019). In particular, scholars have paid close attention to how public research and technology institutions (RTIs) – such as universities, technology institutes, public advisory services – have learned from suppliers' contexts and transferred knowledge, technologies, methodologies, and international food governance regimes to receivers' contexts (Biscola et al., 2017; Friederichsen et al., 2013; Kruss, 2019; Shaner et al., 1982; Sheth et al., 2019).

Although these previous studies provide valuable information, there is still room for further clarification of how agricultural imported innovations are embedded in receiver contexts and the role played in this by public RTIs (Furtado et al., 2011; Goyal and Nash, 2017; Iizuka and Gebreeyesus, 2016; Reardon et al., 2019). Two points require further investigation: 1) the literature has not addressed how unpacking and repacking steps unfold within regrounding processes related to agricultural imported innovations, nor elucidated the dynamics behind them in a long-term horizon; 2) the literature has not clarified translation roles played by public RTIs in the embedding of agricultural imported innovations in receiver contexts.

This study aims to contribute to this debate by looking at the transition from pork lard to lean meat, a long-term socio-technical transformative process that changed Brazil's pig genetics improvement model from the mid-1960s onwards. The embedding of imported innovation is a usual development strategy employed by Brazilian pig production, the world's fourth largest producer and exporter (Talamini and

Santos Filho, 2017). Regarding the transition from pork lard to lean meat, the embedding of two imported technologies was pivotal: 1) pig genetics improvement through the pyramid concept and 2) hybrid pig technology (boars and gilts). Different actors worked to move them from where they were conceived (Europe and the United States) to fit them into the Brazilian pig production context.

One of the actors that helped to unpack and repack these technologies was the Brazilian Agricultural Research Corporation (Embrapa), one of the most important public RTIs specializing in tropical agriculture (Nehring, 2016; Schmidt, 2017). Since the mid-1970s, Embrapa has been the leading public RTI linked to pig production, participating in its evolvement chiefly by contributing to the embedding of imported innovation (Souza et al., 2011; Talamini et al., 2014). Using a qualitative research approach based on a case study method, we examined Embrapa's roles in the transition from pork lard to lean meat by asking the following questions: How did the unpacking and repacking steps linked to the embedding of the pyramid concept and the hybrid pig technology unfold in Brazilian pig production and how did Embrapa participate in those steps? What translation roles did Embrapa play to embed the pyramid concept and the hybrid pig technologies in Brazilian pig production? Answering these questions is timely, as it enhances previous knowledge on how public RTIs can better deal with the global flows of knowledge and innovation, which have become pivotal in tackling current and long-term complex challenges that are putting pressure on agri-food systems worldwide, such as climate change and unsustainable agricultural practices (Kang, 2019; Nelson and Tallontire, 2014; Sharif and Baark, 2011; Thornton et al., 2017).



The remainder of the chapter is structured as follows. The study's conceptual approach and the methodology are explained in section 2. Section 3 presents the findings of the case study. Section 4 presents the analysis, a discussion, and lessons learned from the Brazilian case, and conclusions are drawn in section 5.

## 5.2. Conceptual framework and methodology

As already underlined, the translation work involved in the embedding of imported innovation in receiver contexts unfolds mostly as a regrounding process, in which what comes from abroad goes through interlinked unpacking and repacking steps (Jansen, 2004; Maat and Glover, 2012; Orr, 2018). Drawing upon Glover specifically (Glover et al., 2016; Glover et al., 2017), this study sees that the unpacking step involves achieving a comprehensive view of an imported innovation, throwing light on its technical, social, economic, and agroecological features. In practice, unpacking often implies building up local skills related to the imported innovation through actions such as the establishment of international research agreements, applied experimentation partnerships, and capacity building strategies (Stone and Glover, 2016).

The repacking step entails the ability to adjust imported innovation as far as necessary to the local technical, social, economic, and agroecological characteristics that shape receiver contexts (Glover et al., 2017). Repacking also implies adapting the local context to an imported innovation to a certain degree (Berger and Hofer, 2011). Thus, the repacking step can progress through an array of actions – e.g., from the development of projects focused on fostering an imported production model to the introduction of particular equipment or methodologies (Stone and Glover, 2016). Furthermore, unpacking and repacking steps are frequently operated by more than one isolated actor (Dutrénit and Vera-Cruz, 2018; Hainzelin et al., 2016). Every regrounding process presents particular demands and fosters particular interactions

between actors that become involved with it, often played out within a network with some degree of structuration. Such interactions may result in synergies between actors, although sometimes they may provoke competition and overlaps (Glover et al., 2016).

Previous literature in the field of agricultural technology development and innovation has mostly described contributions that public RTIs may make in the embedding of imported innovation, focusing on particular translation actions in terms of scope and time. By interpreting extant work, we found five specific translation roles played by public RTIs: knowledge translator, capacity building translator, international standard translator, product development translator, and sectoral development translator (see Table 5.1.). The knowledge translator role relates to how public RTIs absorb, interpret, and disseminate imported agricultural knowledge in the local context. They perform this role by capacitating their researchers abroad, entering into international research partnerships, promoting scientific events, publishing scientific articles, and offering consultancy services (Intarakumnerd and Chaoroenporn, 2013; Klerkx and Guimón, 2017; Prabhakar et al., 2019).

The capacity building translator role is performed when public RTIs focus on improving local capacity building related to the embedding of imported innovations. They exercise this role by offering training and education linked to imported innovation in the local context, such as theoretical and practical courses (via the internet or face-to-face), educational materials (books, guides, videos, leaflets), and advisory services (Biscola et al., 2017; Spielman et al., 2010). The international standard translator role refers to public RTIs' contributions to implementing international certification regimes. To do so, they undertake international standards implementation studies, consultancy services, certification services, and international standards capacity building (Giessen et al., 2016; Maciel et al., 2015).

The product development translator role refers to the relationship between public RTIs and the private sector in developing local technological solutions adapted from imported innovation (Ekboir and Parellada, 2002; Figueiredo, 2016; Klerkx and Guimón, 2017). Public RTIs, when playing this role, develop research and experimentation, establish local partnerships to adapt foreign technologies, offer consultancy services, and carry out market studies. Finally, the sectoral development translator role relates to RTIs learning and adapting foreign knowledge or technologies to build local development alternatives. They exercise this role by heading projects, or innovation networks, aimed at fostering the implementation of new socio-technical sectors or the reorientation of established ones (Klerkx and Guimón, 2017; Nelson, 2007; Renting and Wiskerke, 2010). We now explain the research methods and then analyse how Embrapa participated in the embedding of the pyramid concept and the hybrid pig technology in Brazilian pig production.

**Table 5.1.** Public RTIs' translation roles in regrounding processes of imported innovation described by previous literature.

| Translation role | What is it about? | Translation actions |
|---|---|---|
| **Knowledge translator**  | Learning, researching, and transferring content linked to imported innovation | International research partnerships, scientific events, scientific article publications, consultancy services |
| **Capacity building translator**  | Developing training and education linked to imported innovation in the local context | Practical courses (via the internet or face-to-face), educational materials (books, guides, videos, leaflets), advisory services |
| **International standard translator**  | Learning, interpreting, and implementing international regulations or certification labels | International standards implementation studies, consultancy services, certification services, and international standards capacity building |
| **Product development translator**  | Developing locally specific innovative products based on imported innovation | Research and experimentation, partnerships to adapt foreign technologies, consultancy services, and market studies |
| **Sectoral development translator**  | Heading wide initiatives based on imported innovation to develop a particular sector | Sectoral development projects based on imported innovation; sectoral innovation networks focused on adapting imported innovation locally |

This study's primary data sources are 21 in-depth interviews with key actors involved with Brazilian pig production. These key actors represent varying interests, such as industries, producers, pig genetics companies, NGOs, science institutions, and advisory services (see Appendix). Relying on previous knowledge about Brazilian pig production and additional information from publications and websites of industries, associations, public organs, NGOs, and science institutions, we compiled a list of 15 interviewees. We also applied the snowballing method (Kumar 2011), and, from the initial round of interviews, we added six additional influential interviewees.

The interviews, conducted between July and December 2017 and March and April 2019, lasted between half an hour and two hours and were tape-recorded and transcribed verbatim. They followed an interview guide based on our literature review of changes in pig genetics standards in Brazil from the 1970s

to the early 2000s. The interviews focused on two main issues: 1) overall information about the pig genetics trajectory in Brazilian pig production; 2) Embrapa's contributions to locally embedding the pig genetics improvement pyramid concept in the mid-1980s and the development of hybrid boars and gilts in the mid-1990s. Core and additional secondary data were also collected. The core secondary data consisted of books, scientific papers, and policy briefs. Additional secondary data came from official public reports and media articles published in newspapers and magazines.

As suggested by Olsen (2004), after interpreting the interview content, we triangulated it with secondary data, thus sharpening our understanding of Embrapa's contributions. The interview content and secondary data were interpreted using our conceptual understanding as an analytical lens. In terms of possible biases, as regards internal validity, the findings are based on respondents with a helicopter view (usually CEO or senior consultants), hence able to provide a broad perspective of the transition from pork lard to lean meat and also about Embrapa's role in this. Moreover, the first author has worked for Embrapa and headed socio-technical development projects in Brazilian pig production since 2000. This previous experience is reflected in the study design and data interpretation. Thus, we critically self-reflected on our preconceptions, relationship dynamics, and analytic focus, following hints from previous work related to researcher bias (Chenail, 2011; Galdas, 2017; Morse et al., 2002). Additionally, a researcher specialized in pig genetics issues in the Brazilian context reviewed and validated our findings.

## 5.3. Findings

This section discusses how Embrapa contributed to embedding the pyramid concept and the hybrid pig technology in Brazilian pig production. In this endeavour, we present: 1) how the transition from pork lard to lean meat took place in Brazil; 2) how the pyramid concept was unpacked and repacked; 3) how the hybrid pig technology was unpacked and repacked; 4) the translation roles played by Embrapa in both regrounding processes.

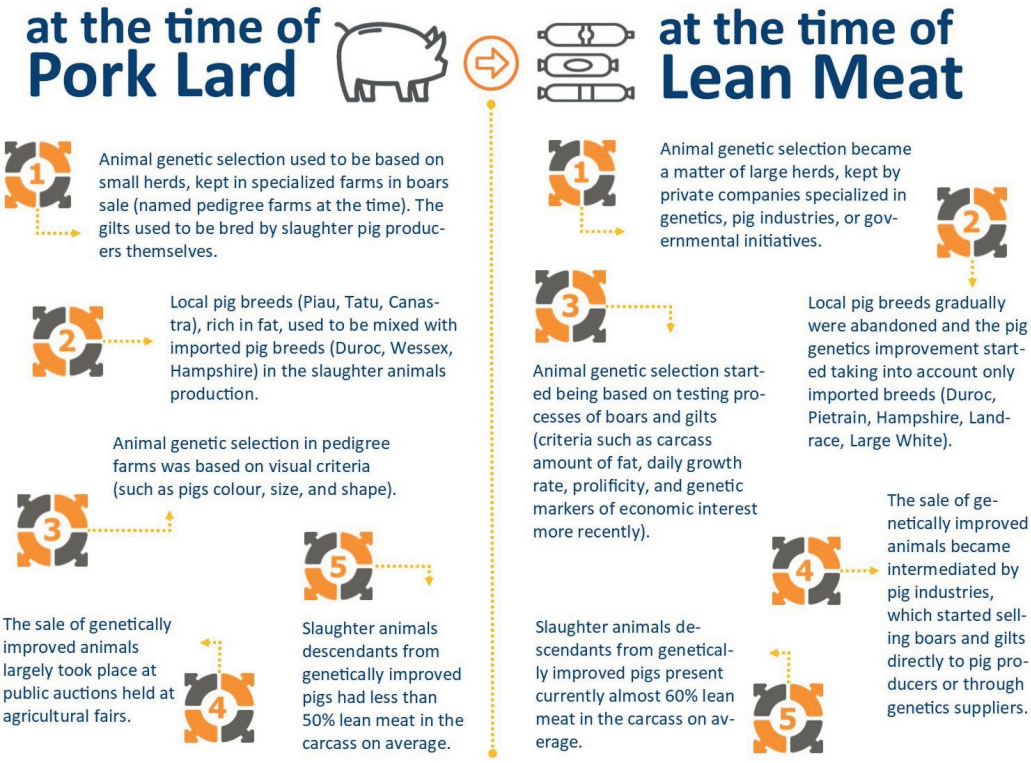
### 5.3.1. From pork lard to lean meat

Changes in the Brazilian economy and society, such as the popularization of domestic refrigerators and vegetable oils, prompted pig producers to consider new directions in the mid-1960s (Brabo et al., 2015; Brito, 2006). Gradually, pork lard ceased to be the Brazilian pig market's leading product, making room for processed products aimed at urban fast-food consumption – e.g., sausages and ham (Spies, 2003). Then, Brazilian pig production started turning to the improvement of lean meat availability, which is essential for this sort of market purpose (Souza et al., 2011). The replacement of pork lard by lean meat in terms of market focus provoked various shifts in Brazilian pig production. As expected, one of them concerned the pig genetics improvement model practiced in Brazil (ABCS, 2014).

This model went from a semi-professional setting (headed by pedigree farms up to the 1980s) to an industrial basis (dominated by pig industries and private genetics companies from the 1990s to date) – see in Figure 5.1. significant differences between Brazil's previous and current pig genetics improvement model. In this long-term transformative process, the embedding of two imported technologies played a decisive role: 1) the implementation of the pig genetics improvement pyramid concept in the 1980s; 2) the

development of hybrid boars and gilts in the mid-1990s. Embrapa participated in both regrounding processes.

**Figure 5.1.** Major differences between Brazil's pig genetics improvement models linked to pork lard and lean meat – based on researchers' own data, ABCS (2014), and Fávero et al. (2011).




### 5.3.2. Unpacking and repacking the pyramid concept in the Brazilian context

The pyramid concept was developed in the United Kingdom in the 1960s and adopted worldwide from the 1970s (Knox, 2016). Broadly, it structures pig genetics improvement programmes in three layers in the form of a pyramid (Brassley, 2007). At the top lies a small core herd, responsible for the genetic improvement of purebred pigs, through an intensive selection of economically essential characteristics. In the central part are the medium-sized multiplier herds, which focus on the production of boars and gilts to supply slaughter pig producers. The base of the pyramid is the large commercial herds, composed of animals that descend from the genetically improved pigs in the upper layers and bred by slaughter pig producers to provide the raw material for pig industries (Harris, 2000).

The pyramid concept focuses on improving pigs genetically in the core herd, employing measurable testing criteria (see item three, second column of Figure 5.1.), and subsequently scattering these selected characteristics within the whole herd to underpin market objectives (Knox, 2016). Pedigree farms used to have small herds and select pig characteristics following visual criteria (see item three, first column of Figure 5.1.), a method that provided low improvement rates (Fávero et al., 2011). This was the major weakness of the Brazilian pig genetics improvement model (based on pedigree farms) when lean meat became the pig industry's focus. In the late 1970s, pig industries, producer associations, research institutions, and state and federal governments strengthened their ties to bring to Brazil what the world's largest pig meat producers (the United States and Europe) had been doing in terms of genetics improvement (Sebrae and ABCS 2016).

Consequently, actors started collaborating to deploy the pyramid concept in Brazilian pig production. According to our interviews, Embrapa was, at the time, the primary reference in the Brazilian context in terms of agricultural research and innovation. Its pig research unit was created in 1975, and the genetics improvement research group was one of the first teams that Embrapa set up. Therefore, in the early 1980s, as might be expected, Embrapa became one of the central actors in the first actor network (composed of producers' associations, local and state public organs linked to agriculture, public universities, and pig industries) to embed the pyramid concept (see Figure 5.2. for a full description of the pyramid concept's regrounding process). It exercised technical and organizational leadership, guiding how the actor network built up the adjustments needed in the pyramid concept and the local context through unpacking and repacking steps (see Embrapa's contributions to this in Figure 5.2.).

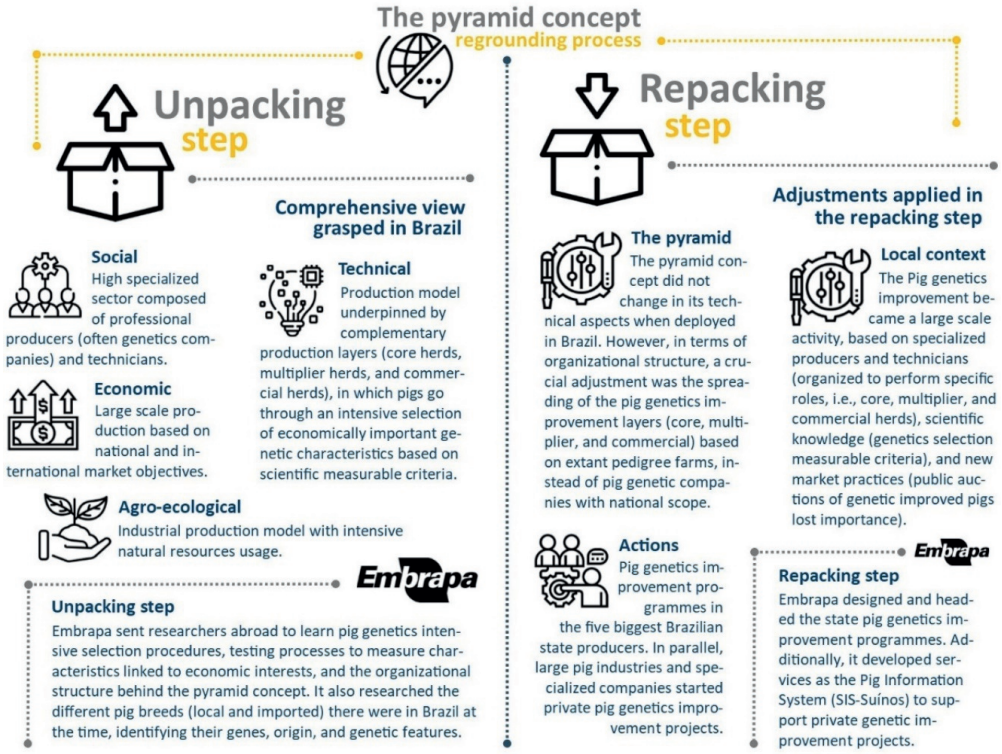
Notably, Embrapa worked to embed the pyramid concept, maintaining the importance of pedigree farms. Thus, it attempted to reconfigure the Brazilian pig genetics improvement model by deploying pig genetics improvement projects in the five biggest Brazilian state producers (Santa Catarina, Rio Grande do Sul, Paraná, São Paulo, and Minas Gerais) between 1980 and 1990. These were called state pig genetics improvement programmes and took place in partnership with producer associations, state governments, and the federal government. These state programmes attempted to implement the pyramid concept in each state territory, connecting pig herds as follows: 1) some pedigree farms (better organized and technologically more capable) comprised the core herds, applying testing and crossbreeding methods to put into practice an intensive selection of economically important characteristics in purebred pigs; 2) other pedigree farms contained the multiplier herds, becoming responsible for the production of boars and gilts genetically improved that would be sold to slaughter producers; 3) commercial herds were established in the farms that obtained genetically improved pigs from the upper layers, produced piglets, fattened them, and then sold adult animals to slaughterhouses.

However, the state pig genetics improvement programmes did not achieve the results desired by all involved actors. The following quote illustrates why the pyramid concept implemented through these programmes was not successful:

> *Unfortunately, despite all efforts made by producer associations and public organs, it was not possible to effectively organize the two upper layers of the pyramid. Pedigree farms had to truly collaborate to put into practice the intensive selection of economically important characteristics. Cultural, technological, and organizational differences between pedigree farms and the lack of knowledge on how to work cooperatively undermined the state pig genetics improvement programmes as time went by. (A former Embrapa pig genetics improvement researcher).*

According to fieldwork interviews, large pig industries (such as Sadia and Seara) and companies specialized in pig genetics (such as Agroceres PIC) formed an alternative actor network and, in parallel, started structuring private pig genetics improvement projects based on the pyramid concept from the mid-1980s. They configured a second effort to embed the pyramid concept, although they did not compete with or overlap the state pig genetics improvement programmes initially. On the contrary, Embrapa participated in that parallel network by responding to its demands about the Brazilian pig production setting and information services on pig genetics. As pig industries and pig genetics companies could successfully deliver what Brazilian pig production demanded at the time, in practice genetics selection took place mainly in core herds and multiplier herds, forcing the vast majority of pedigree farms to focus on commercial herds or to leave pig production (Fávero and de Figueiredo 2015). Embrapa maintained its research agenda linked to pig genetics improvement, although no longer attached to state programmes. Furthermore, it continued providing services such as the Pig Information System (SIS-Suínos) and scientific support to improve genetics selection procedures, which proved essential to consolidate private genetics improvement projects and research programmes in general (Fávero et al. 2011).

**Figure 5.2.** The pyramid concept regrounding process in Brazil and Embrapa's contributions – based on researchers' own data and Fávero and de Figueiredo (2015).



### 5.3.3. Embrapa's hybrid pigs: partnership focused on products innovation

In the early 1990s, after the consolidation of the pig genetics improvement model based on the pyramid concept, actors began to focus on embedding imported technologies that could enhance even more the availability of lean meat. This led to the development of crossbred boars and gilts adapted to the Brazilian context, following what had been happening in Europe and the United States since the 1980s (Fávero and de Figueiredo, 2015). Crossbred pigs are animals from different breeds intentionally crossed to emphasize desired characteristics, and they have some advantages over purebred pigs because of a genetic phenomenon called heterosis, also known as hybrid vigour (ABCS, 2014). Heterosis gives crossbred pigs an improvement over the average of its parent purebreds in a chosen trait – e.g., lower level of carcass fat (Knol et al., 2016).

Furthermore, an organizational shift influenced the embedding of crossbred pigs in the Brazilian context. In the early 1990s, most of the pig industries started paying a premium to pig producers depending on carcass characteristics – i.e., after slaughter, each pig had its fat thickness and other items related to lean meat measured, and the amount paid could increase if the carcass presented the required features (Sebrae, 2016). Linking part of the producers' remuneration to carcass characteristics caused a massive demand for boars and gilts genetically selected to produce more lean meat, and this encouraged actors to invest heavily in crossbred pigs (Guimarães et al., 2017). Such pigs became known as hybrid pigs or light swine. Often, they were developed by hybridizing three of these five breeds: Large White, Landrace, Duroc, Pietrain, and Hampshire – all of which came from abroad and were adapted to Brazilian agroecological conditions at the time (Fávero et al., 2011).

According to the interview narratives, the hybrid pigs' embedding process relied chiefly on pig industries' leadership (Figure 5.3. summarizes the hybrid pig regrounding process). The pig industries looked at how to strengthen their control over the whole pig meat production process, leading them to broaden their actions related to pig genetics improvement. This drove the pig industries in two directions. The biggest ones preferred to develop their hybrid pigs, building up the boars and gilts that best reflected their market interests. Others, which did not have enough financial resources to do that, established agreements with pig genetics companies and got non-exclusive hybrid boars and gilts. Nonetheless, both approaches reached similar results, playing a part in increasing lean pig meat availability, sharpening the pig genetics improvement process, and boosting the coordination of pig meat production.

Embrapa helped pig industries and pig genetics companies to develop hybrid pigs by providing data about imported breeds adapted to the Brazilian context and taking part in experiments to adjust genetics selection methods. However, it also had the technical capacity to, and interest in, developing hybrid pigs in the 1990s. It aimed to provide an alternative product that would represent a cheaper option for producers not associated with pig industries and not willing to pay what pig genetics companies charged for genetically improved boars and gilts (see Embrapa's contribution to unpacking and repacking the hybrid pigs in Figure 5.3.). For this, Embrapa established an agreement with Aurora, a central cooperative and the fourth largest pig industry in Brazil at the time, to develop a hybrid boar focused on high lean meat performance (the partnership between Embrapa and Aurora did not include the development of a hybrid gilt). Despite originating from an initiative associated with Aurora, Embrapa's hybrid pig, called MS 58, also became available for all Brazilian pig producers, as Embrapa used it as part of public policy to disseminate crossbred boars. Accordingly, Embrapa always applied a strategy of selling its hybrid pig at a lower price than that charged by private genetics companies. The following two quotes illustrate Embrapa's contribution to embedding hybrid pigs in the Brazilian context:

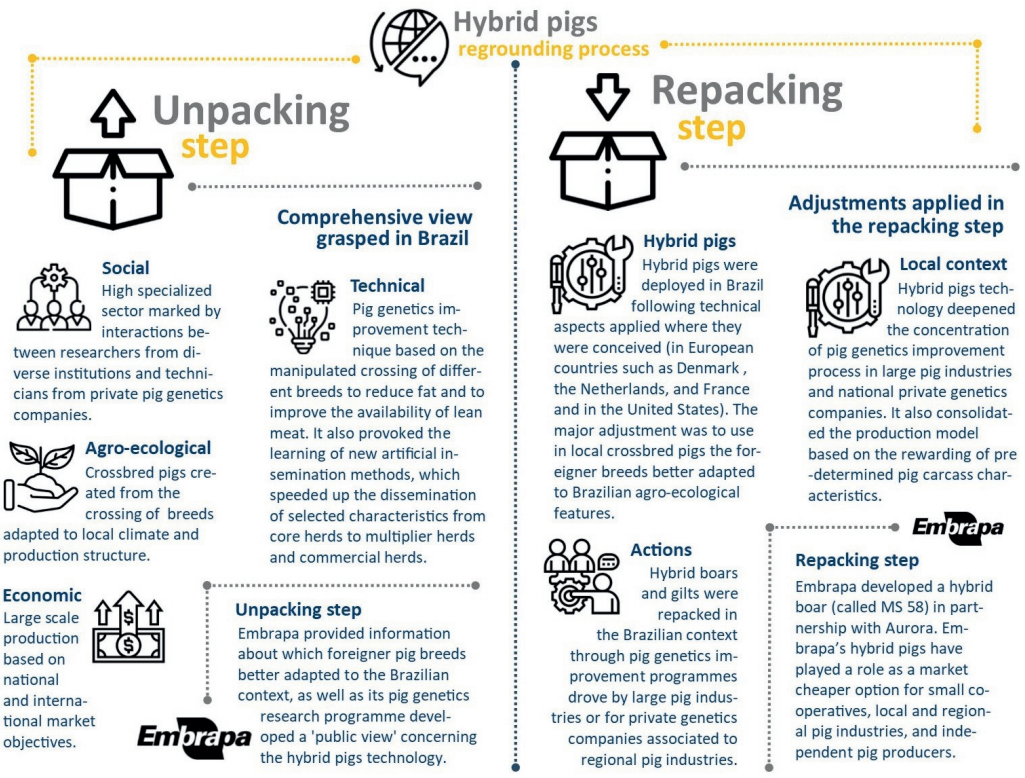
*Embrapa and Aurora adjusted an imported technology to a specific segment of Brazilian pig production in the 1990s. If Embrapa and Aurora had not worked to develop the MS 58, small cooperatives, local and regional pig industries, and independent pig producers would take much longer to acquire a hybrid pig that would give their offspring the capacity to produce more lean meat. (A pig industry executive)*

*In the late 1980s, we had studies anticipating that the payment of a premium depending on specific carcass characteristics would become standard. We knew that there would be a demand for genetic material capable of meeting the interests of industries and producers. Thus, we focused our pig genetics research programme on developing hybrid pigs. At the end of the 1990s, we carried out an analysis and came to the conclusion that, per year, the segment that benefited from MS 58 earned 3.2 million dollars more than it would have if it did not have access to a crossbred pig. Then, I guess what we did at the time was important for at least a specific sector of Brazilian pig production. (A former Embrapa pig genetics improvement researcher)*



Embrapa has launched three more hybrid pigs to date: MS 60 (in 2000, another partnership with Aurora), MS 115 (2008), and MO25C (in 2014, the first gilt developed in Embrapa's pig genetics programme). All of them updated imported knowledge on pig genetics improvement to introduce into the Brazilian market a cheaper option for small cooperatives, local and regional pig industries, and independent pig producers (not associated with pig industries), reinforcing Embrapa's strategy of developing alternative hybrid pigs. In recent years, Embrapa has assumed a new position in the embedding of imported innovation linked to pig genetics. Since 2010, it has been in partnership with BRF (the biggest pig industry in Brazil) to unpack and repack the pig genetics improvement model based on genetic markers. Embrapa has used its structure to co-develop and validate a genomic selection process adjusted to the Brazilian context.

**Figure 5.3.** The hybrid pigs regrounding process in the Brazilian context and contributions made by Embrapa – based on researchers' own data, Fávero et al. (2011), and Figueiredo et al. (2016).




### 5.3.4. Embrapa's translation roles in the embedding of the pyramid concept and the hybrid pig technology

Embrapa played three different translation roles in the embedding of the pyramid concept and the hybrid pig technology in the Brazilian context (Table 5.2. summarizes Embrapa's translation actions and roles). One of these roles was that of sectoral development translator. Embrapa performed as a sectoral development translator when it headed the actor network that brought together producer associations, state governments, and the federal government to implement the pyramid concept in the early 1980s. The unpacking and repacking steps of the pyramid concept resulted in the deployment of five state pig genetics improvement programmes, which aimed to reorient Brazil's pig genetics improvement model. Concerning the embedding of the hybrid pig technology, Embrapa mobilized partners and co-headed a parallel actor network to create an alternative hybrid boar in the mid-1990s. This means that Embrapa also played a role as a product development translator in the embedding of the hybrid pig technology, as it enabled collaboration to develop an innovative product locally, based on an imported innovation.

These two translation roles played by Embrapa differed in terms of scope. Embrapa assumed a broader translation role in embedding the pyramid concept when it performed as a sectoral development translator. However, it played a narrower role (product development translator) in embedding the hybrid pig technology. These differences in scope are related to the positions that Embrapa occupied in actor networks. According to the interview narratives, these positions differed over time because sometimes Embrapa did not succeed in delivering the outcomes expected by Brazilian pig production (e.g., in the implementation of the pyramid concept through state pig genetics improvement programmes). Furthermore, new actors (such as pig genetics companies) emerged and developed translation skills (such as assembling a pig research team, entering into international partnerships, and structuring laboratories to implement genetics tests) previously restricted to Embrapa.



Embrapa performed as a knowledge translator in embedding the pyramid concept and the hybrid pig technology, as demonstrated in sections 5.3.2 and 5.3.3. Parallel to its effort to implement the state pig genetics improvement programmes, Embrapa participated in the actor network composed of large pig industries and companies specialized in pig genetics by providing scientific support through information and research services mostly. In the early 1990s, Embrapa collaborated with the actor network headed by the pig industries and the pig genetics companies to develop hybrid pigs. It basically transferred content linked to hybrid pig technology (data about imported breeds adapted to the Brazilian context and knowledge about genetics selection methods). According to our interviews, Embrapa performed steadily as a knowledge translator over time because this role is more strongly linked to its original mission. The following quote illustrates this:

> *Embrapa was created by the Brazilian government to support the development of the pig sector. As imported innovations have always been very important for the growth of pig production in Brazil, in the 1980s Embrapa naturally assumed the role of being the main bridge between the knowledge that came from other countries and the pig sector. Later on, private companies arose and also started working with pig genetics and other topics related to pig production. We have to admit that we could not properly respond to all demands presented to us at the time, as expected given the several complex issues tackled to develop the pig sector in Brazil in recent decades. However, Embrapa's importance concerning this type of support is acknowledged to date. (A former Embrapa pig genetics improvement researcher).*

**Table 5.2.** Roles played by Embrapa to embed the pyramid concept and the hybrid pig technology.

| Imported innovation | What translation actions did Embrapa perform? | Embrapa's translation roles |
|---|---|---|
| The pyramid concept | Embrapa learned and interpreted how to apply the pyramid concept in the Brazilian context and translated it in reality through state pig genetics improvement programmes. | Sectoral development translator |
| | Embrapa learned, researched, and transferred content related to the pyramid concept by providing information services (Pig Information System - SIS-Suínos) and scientific support to improve genetics selection procedures. | Knowledge translator |
| The hybrid pig technology | Embrapa learned, researched, and transferred content related to the hybrid pig technology by providing data about imported breeds adapted to the Brazilian context and taking part in experiments to adjust genetics selection methods. | Knowledge translator |
| | Embrapa learned and interpreted how to apply the hybrid pig technology in the Brazilian context and translated it in reality through the development of an alternative hybrid boar. | Product development translator |

## 5.4. Discussion

### 5.4.1. Multiple, parallel, and reciprocally influential: a refined view on unpacking and repacking efforts behind the embedding of imported innovations in local contexts

Previous literature has claimed that, in practice, the embedding or not of imported innovations relies on failures or successes laid down throughout a specific (in terms of time and space) unpacking and repacking effort, aimed at simultaneously adjusting technical, social, economic, and agroecological aspects of imported innovations and receiver contexts (Glover et al., 2016; Glover et al., 2019; Jansen, 2004; Orr, 2018). We propose to refine this previous insight by seeing the embedding of imported innovations as an ecosystemic convergence built by actor networks through unpacking and repacking efforts. In doing so, we sharpen extant work by: 1) showing that a dynamic process unfolds over time in embedding imported innovations in receiver contexts, which may evolve through different and sometimes parallel unpacking and repacking efforts; 2) underlining that different unpacking and repacking efforts may generate alternative translations, which can interact and influence one another.

Regarding the first point, we found that the dynamics linked to regrounding processes of imported innovations may provoke the emergence of more than a single actor network over time, meaning that multiple unpacking and repacking efforts take place to build the needed convergence to embed locally what comes from abroad. This extends previous understandings of how interactions between actors that become involved with the embedding of imported innovation take place in reality (Glover et al., 2016;

Jansen, 2004). As the findings show in sections 5.3.2. and 5.3.3., multiple and sometimes parallel unpacking and repacking efforts played an essential role in how the embedding of both the pyramid concept and the hybrid pig technology evolved in Brazilian pig production. Section 5.3.2. demonstrates that actors in Brazil (such as pig industries, producer associations, research institutions, and state and federal governments) deepened their ties to implement the pyramid concept in the late 1970s. An actor network brought together producer associations, state governments, and the federal government to unpack and repack the pyramid concept as pig genetics improvement programmes in the five biggest Brazilian state producers. This actor network attempted to reshape the local context and tailor the concept taking into account a particularity of the Brazilian reality, hitherto dominated by pedigree farms maintained by pig producers – in its original context, the pyramid concept relied on leadership from private genetics companies.



Nonetheless, as pig genetics improvement programmes did not build up successfully the convergence needed to fully implement the pyramid concept in the pig sector, a different actor network (composed of large pig industries and companies specialized in pig genetics) emerged in parallel. It applied less significant changes in the pyramid concept to tailor it to the Brazilian reality (e.g., private genetics companies kept their original function). Furthermore, the network deepened changes in the local context, such as the establishment of bigger herds to improve the selection of desired pig genetics characteristics and the introduction of pig genetics improvement methods based on scientific methods. Thus, this other actor network proved more efficient in establishing the convergence needed to achieve the local implementation of the pyramid concept.

Section 5.3.3 demonstrated that the hybrid pig technology deployment was underpinned by more than a single unpacking and repacking effort. We found that an actor network headed by pig industries built the needed convergence to embed locally crossbred boars and gilts. This network mostly tailored the hybrid pig technology to Brazilian agroecological conditions – e.g., to emphasize desired characteristics, only imported breeds previously adapted to the local context were crossed. Furthermore, the network reconfigured the local context, which became structured around private pig genetics improvement programmes funded by large pig industries or maintained by pig genetics companies associated with medium or small pig industries. Despite the success of the actor network headed by pig industries, another one emerged in Brazilian pig production. It brought together a public organ and a large cooperative to provide an alternative hybrid pig. This network unpacked the hybrid pig technology similarly. However, its repacking initiative introduced a cheaper hybrid pig to the Brazilian market. Therefore, it unfolded as a public strategy to make available a new technology for small cooperatives, local and regional pig industries, and independent pig producers (not associated with pig industries). Despite specific interactions between actors and evolvement trajectories, the embedding of both imported innovations relied on a dynamic consisting of more than a single unpacking and repacking effort.

Regarding the second point, the different unpacking and repacking efforts described in sections 5.3.2 and 5.3.3 show that some elements were in flux during translation, whereas others remained stable. Our findings indicate that such fluctuation was due to how actor networks diverged concerning what remained untouched and what went through some degree of adjustment on both sides (the imported innovation and the local context) to achieve the needed convergence. In other words, they developed distinct views on the extent to which the imported innovation should be tailored (e.g., the pyramid concept was adjusted to take pedigree farms into account in one unpacking and repacking effort, whereas another kept it closer to its original configuration). They also diverged on how the local context reshaped its boundaries to receive the imported innovation (e.g., one unpacking and repacking effort developed

crossbred boars and gilts focusing on a specific aspect of Brazilian pig production). This insight extends the comprehension of synergies, competition, and overlaps between actors in the embedding of imported innovation (Glover et al., 2016; Glover et al., 2017), as it sheds further light on how translation roles are built over time, showing that there is a selection process in terms of what needs to be repacked. So, some elements may be unpacked but remain unchanged.

Furthermore, different unpacking and repacking efforts interacted in the Brazilian context, provoking mutual influences. This insight adds to previous literature on how actors' interactions unfold throughout the embedding of imported innovation (Glover et al., 2016; Glover et al., 2017; Maat and Glover, 2012), by indicating that the dynamic process in which imported innovations are embedded in receiver contexts also evolves from what actor networks learn from one another. Section 5.3.2 clearly presents this correlation when explaining that the effort headed by pig industries and pig genetics companies to implement the pyramid concept took advantage of mistakes made by the effort that kept pedigree farms at the centre of the Brazilian pig genetics improvement model. Moreover, our findings demonstrate that the mutual learning between different unpacking and repacking efforts might provide some degree of complementarity. Section 5.3.3 shows that the unpacking and repacking effort linked to the development of an alternative hybrid boar made available that new technology to actors that had not benefited from the previous unpacking and repacking effort. Therefore, it did not replace or compete with what was done before by the pig industries and pig genetics companies. It complemented the first unpacking and repacking effort by adjusting the same technology differently for a specific audience.

### 5.4.2. Orchestrator, supporter, and champion: ecosystem translation roles in embedding imported innovations

We showed in section 5.3.4. that Embrapa played different translation roles (sectoral development translator, knowledge translator, and product development translator) in embedding the pyramid concept and the hybrid pig technology, two milestones in the transformations undertaken by the Brazilian pig genetics improvement model for the transition from pork lard to lean meat. Thus, our findings confirm hints from previous literature concerning how public RTIs have played translation roles in embedding imported innovations locally (Ekboir and Parellada, 2002; Figueiredo, 2016; Intarakumnerd and Chaoroenporn, 2013; Nelson, 2007; Renting and Wiskerke, 2010; Klerkx and Guimón, 2017). However, and in connection with the ideas in section 5.4.1. on how multiple, parallel, and reciprocally influential unpacking and repacking efforts back the embedding of imported innovations in local contexts, we argue that public RTIs' translation roles need to be seen from an ecosystem point of view.

We argue that translation roles are more connected to how public RTIs engage in broader ecosystems of actors linked to embedding processes of imported innovations than to specific isolated translation actions. Here, we follow the social innovation literature and understand ecosystems as sets of interconnected actors whose collective actions produce a particular outcome in a local system – i.e., an ecosystem (de Vasconcelos Gomes et al., 2018; Liu and Stephens, 2019; Mair and Martí, 2006). Thus, actor networks related to unpacking and repacking imported innovations can be understood as ecosystems working to embed imported innovations. From the findings presented in sections 5.3.2, 3.3, and 5.3.4, we identified at least three ecosystem translation roles that public RTIs might play in embedding imported innovations in receiver contexts: 1) translation orchestrator, 2) translation supporter, and 3) translation

champion. Table 5.3. applies our proposed translation roles to Embrapa's trajectory in embedding the pyramid concept and the hybrid pig technology.

The translation orchestrator role relates to public RTIs' governance position in actor networks. When playing this role, public RTIs steer how unpacking and repacking steps unfold. The findings in section 5.3.2 show that Embrapa led how the actor network composed of producer associations, state governments, and the federal government unpacked the pyramid concept in the early 1980s. It also steered how the concept was repacked through state pig genetics improvement programmes. The translation supporter role refers to when public RTIs hardly influence the evolvement of unpacking and repacking steps. They often contribute to embedding processes by providing specific content, services, or structures demanded by actor networks to unpack and repack imported innovations. As section 5.3.2 demonstrates, Embrapa performed as a translation supporter in the parallel actor network headed by large pig industries and companies specialized in pig genetics to implement the pyramid concept. Section 5.3.3 shows that it played the same translation role in the actors' assemblage composed of pig industries and pig genetics companies to implement the hybrid pig technology in the 1990s (see Table 5.3. detailing how Embrapa performed as translation orchestrator and translation supporter in practice). Finally, the translation champion role applies to public RTIs that enable collaboration and facilitate the unfolding of the unpacking and repacking steps to implement a specific imported innovation, but do not entirely steer actor networks. As described in section 5.3.3, Embrapa performed this role when it participated in the actor network that developed a hybrid boar from the hybrid pig technology.



Moreover, our proposed translation roles show more clearly what it means in practice to exercise broader or narrower roles in embedding imported innovation. For example, the translation orchestrator role is broader than the translation supporter role. The first implies steering an actor network and taking direct control of how unpacking and repacking steps unfold. The second only involves providing knowledge to back actor networks in the unpacking and repacking steps. Applying the same reasoning, we argue that the translation champion role is broader than the translation supporter role and narrower than the translation orchestrator role.

### 5.4.3. More stable, more temporary: public RTIs' different translation roles over time

This study also adds to previous studies that have looked at more discrete translation events, by evidencing how public RTIs assume short and long-term translation roles (Furtado et al., 2011; Goyal and Nash, 2017; Iizuka and Gebreeyesus, 2016; Reardon et al., 2019). Although the Brazilian case analysed here covers just a first explorative effort, it suggests that public RTIs may perform some stable and some temporary translation roles over time. As our findings demonstrate in sections 5.3.2 and 5.3.3, in a long-term horizon, Embrapa kept a steady knowledge translator role, by learning, researching, transferring content, and providing information services through different ecosystems and embedding processes. The other two translation roles (orchestrator and champion) unfolded in specific circumstances (absence of other actors with the capacity to lead the embedding of the pyramid concept; emergence of a public–private partnership to develop a hybrid boar for particular pig industries and producers) and periods. This comprehension is helpful as it can orient public policies or public RTIs on how to approach the global flows of knowledge and innovation, which look like becoming even more intense in the coming decades (Kang, 2019; Thornton et al., 2017).

**Table 5.3.** Embrapa's translation roles in the embedding of the pyramid concept and the hybrid pig technology in Brazilian pig production.

| Embrapa's translation role | Imported innovation | Unpacking and repacking practical actions | Concrete results |
|---|---|---|---|
| Orchestrator  | The pyramid concept | Embrapa relied on the capacitation of its researchers abroad and its previous studies about the Brazilian pig genetics improvement setting to lead how the actor network unpacked the pyramid concept. It also designed state projects to adjust the pyramid concept to the Brazilian pig genetics improvement reality at the time. | Five state pig genetics improvement programmes. |
| Supporter  | The pyramid concept; the hybrid pig technology | Embrapa provided knowledge services and scientific support to the parallel actor network (headed by large pig industries and pig genetics companies) linked to the pyramid concept's implementation. Embrapa also provided knowledge assets (data on the adaptation capacity of imported pig breeds to Brazilian agroecological conditions and scientific support to improve pig genetics selection methods) to the actor network composed of pig industries and pig genetics companies to implement the hybrid pig technology in the 1990s. In both, it contributed mostly to the unpacking step. | Pig Information System (SIS-Suínos) service; the Brazilian pig breeds inventory. |
| Champion  | The hybrid pig technology | Embrapa performed mainly as an enabler in the parallel actor network established to develop an alternative hybrid boar in the mid-1990s. First, Embrapa used its structure and research team to unpack the technological and agroecological aspects of the hybrid pig technology according to the interests of Aurora central cooperative. Second, it mobilized public and private resources and other actors (small cooperatives, local and regional pig industries, and pig producers not associated with large industries) to repack the technology as an alternative hybrid pig. | Hybrid boar MS 58. |

Icons made by Pixel perfect from www.flaticon.com

## 5.5. Conclusions

Our study contributes to the literature on agricultural technology development and innovation by deepening the description of the dynamic process behind the embedding of imported innovation in receiver contexts and sharpening the understanding of translation roles played by public RTIs in these transformative processes. From the analysis of how the pyramid concept and the hybrid pig technology were introduced in Brazilian pig production, we add to the literature by: 1) showing how multiple, parallel, and reciprocally influential unpacking and repacking efforts unfold over time and help to embed imported innovations in receiver contexts; 2) refining translation roles played by public RTIs depending on the position that they assume in ecosystems related to the embedding of imported innovations in receiver contexts; and 3) demonstrating that public RTIs can assume stable and temporary translation roles over time.



Our deeper description of the dynamic process behind the embedding of imported innovations and our sharpened understanding of translation roles played by public RTIs provide a key policy implication that hints at the kind of contribution that can be expected from public RTIs in dealing with the global flows of knowledge and innovation. As our findings evidenced, public RTIs should be highly regarded in terms of how to approach imported innovation, as they can perform pivotal functions to assist actors who become marginalized by them in local contexts. Given the generalizability limitations of our explorative case, future work is needed to substantiate whether our findings regarding the translation roles played by Embrapa would apply to other public RTIs involved in embedding imported innovations in distinct agri-food receiver contexts. Furthermore, further studies could verify whether our insight about stable and temporary translation roles related to public RTIs would apply in other receiver contexts. It would also be interesting to investigate further the dynamics behind the embedding of imported innovation. Thus, one could analyse, for example, whether it is feasible to purposefully foster interactions between different and concurrent translations. Another interesting further study would be to broaden our knowledge on what local conjunctures have hampered public RTIs in playing translating roles concerning the global flows of knowledge and innovation.

# CHAPTER 6

General Discussion and Conclusions

# 6. General Discussion and Conclusions

## 6.1. Introduction

This thesis has investigated agri-food systems' directionality and its interactions with systemic governance by looking at Brazilian pig production evolving from the 1960s to date. In so doing, it explores a twofold objective:

- To deepen the understanding of how agri-food systems' directionality unfolds;
- To unravel how systemic governance elements contribute to steering agri-food systems' directionality.



This final chapter brings together the findings from the different chapters of the thesis, reflects on cross-cutting issues, analyzes the quality of the study design and the thesis style, and provides overall theoretical and policy implications. Section 6.2. presents an overview and discussion of the thesis' main findings. Section 6.3. comes up with cross-cutting issues and relates them to broader debates, reflecting on literature linked to transformative processes in agriculture. The chapter ends with reflections on the study design and the thesis style (section 6.4.), the policy and practical implications of this study (section 6.5.), suggestions for further research (section 6.6.), and some final remarks (Section 6.7.).

## 6.2. Overview and discussion of the main findings

### 6.2.1. Streams of directionality: a multifaceted guiding force that influences and modulates agri-food systems

Scholars who recommend sharpening agri-food systems' directionality argue that it is an intangible concept, what makes it difficult to comprehend directionality's steerability (Magrini et al., 2016; Pigford et al., 2018; Schot and Kanger, 2018; Darnhofer, 2019). As a conclusion this thesis proposed to address this gap by looking at a metaphor related to the natural flowing of water, similar to what Bos and Grin did while comparing modernization in pig husbandry in the Netherlands to 'the hard work of changing the course of a river' (Bos and Grin, 2008). Rivers are water masses that orient how ecosystems in their surroundings will evolve (Datry et al., 2014). If one wants to investigate what a river is (in terms of size, water quality, volume) and how it unfolds within an ecosystem, the sum of the different streams that nurture it is pivotal (Latrubesse et al., 2017). Agri-food systems' directionality functions similarly. Directionality is understood here as a river, which orients agri-food systems evolving and is composed of different streams that nurture it. Streams for rivers mean the different watercourses that discharge in them (Latrubesse et al., 2017). Streams for directionality mean the different guiding forces that influence and modulate how agri-food systems evolve (e.g., visions, technological breakthroughs, public policies, new markets, formal and informal rules, values, practices).

The 'streams of directionality' concept offers a more fine-grained comprehension of how directionality unfolds in agri-food systems by 1) arguing that the guidance directionality exerts on agri-food systems is multifaceted, and 2) implying that its multifaceted guidance unfolds through different levels and domains. The insight on the multifaceted guidance of directionality develops some clues presented in studies about how development pathways reach their full potential and establish a dominant directionality (El Bilali, 2019; Eastwood et al., 2019). The 'streams of directionality'-concept enriches these extant studies

by proposing that directionality becomes established when different guiding forces align to underpin a development pathway, leaving behind other alternatives that could not achieve similar convergence. Chapter 2 provided the initial evidence that socio-technical systems' directionality can be deeper understood by looking at the different guiding forces (streams) that make it up. It applied an analytical structure to unravel innovation direction dynamics, as previous literature emphasized the importance of analyzing to where innovation evolves to grasp socio-technical systems' directionality (Stirling, 2011; Devaux et al., 2016; Svensson and Nikoleris, 2018). Chapter 2 showed that an innovation direction is triggered by a discontinuity (positive or negative). After that, it is built by interactions between actors affected by the triggering discontinuity, and become consolidated when it reaches the status of being a set of influential practices, technologies, and rules that denote an institutionalized orientation for transformative processes.

While looking at innovation direction dynamics in Brazilian pig production, this thesis had its first hint regarding streams of directionality-concept by realizing that massive discontinuities that emerged from the 1960s to date (the collapse of the pig lard market, the supply crisis, the environmental crisis, and the domestic market crisis) provoked the emergence of more than a single guiding force. They fostered the introduction in Brazilian pig production of new visions (highly specialized production roles, capital-intensive production approach, centralized and large-scale production processes), breakthrough technologies and concepts (hybrid pigs, carcass typification, vertical integration production model), public policies (new environmental legislation, Integration law), new markets and products (focus on exportation, low-fat product lines), and new values (professionalization, environmentalism). Therefore, from the innovation direction point of view explored in chapter 2, the evolvement of Brazilian pig production presented a multifaceted guidance, which is adherent to the 'streams of directionality'-concept.

Despite focusing on systemic governance elements, chapters 3, 4, and 5 reinforced the streams of directionality concept. Chapter 3, focused on boundary infrastructures, also demonstrated that science, policy, and practice interfaces nurtured different streams simultaneously – e.g., visions (industrialization discourse), technologies and concepts (vertically integrated production model), and public policies (new environmental regulations). Chapters 4 applied the 'ecology of intermediaries'-concept to investigate the implementation of the European animal welfare standard in Brazilian pig production. It also described how the introduction of new markets has functioned as an influential stream of directionality, inducing the emergence of particular innovation priorities, such as animal welfare and animal health. Similarly, chapter 5 portrayed how the directionality followed by the transformative process that reshaped the pig genetics improvement model in Brazil relates to varied guiding forces. These include public policies (targeted to independent pig producers and small slaughterhouses, visions (centralized and large-scale production processes applied to pig genetics), and new markets (hybrid pigs market).

The streams of directionality concept proposed above also implies that the multifaceted guidance exerted by directionality unfolds through multiple levels and multiple domains. Here, levels are the different places where streams of directionality work to influence the direction of change – e.g., from an individual level to a systemic level. In turn, domains are the different fields where streams of directionality operate – e.g., cultural, technological, political, economic, social. Findings described in the chapters of this thesis do not uphold to elaborate more fine-grained labelling for levels and domains linked to streams of directionality, although they pointed out enough clues about their presence. As chapter 4 demonstrated, the introduction of new markets (based on exportation strategy mostly) became an influential stream of directionality in Brazilian pig production in the 2000s, inducing the emergence of particular innovation priorities, such as animal welfare and animal health. Roughly, it is feasible to assume that this stream has

functioned at a systemic level and affected chiefly three domains (technological, economic, social). In turn, chapter 5 showed that one of the streams of directionality in Brazilian pig production in the 2000s was a public policy targeted to include independent pig producers and small slaughterhouses in the hybrid pigs market. This stream functioned in individual and sectoral levels. Besides that, it went through four domains, mainly (technological, political, economic, and social).

Additionally, this thesis concludes that the streams of directionality concept facilitates to understand how socio-technical systems' directionality switches over time. Changes in it play out through the introduction of new streams. For instance, chapter 2 underpinned this comprehension by evidencing that an 'environmentally friendly stream' was added to the Brazilian pig production directionality in the 2000s. Chapters 3, 4, and 5 also suggested that agri-food systems' directionality evolves while adding new streams to it. All of them portrayed how new guiding forces established (visions such as industrialization discourse, concepts as the vertically integrated production model, public policies as the new environmental legislation) and became part of the multifaceted guidance related to the Brazilian pig production directionality.



### 6.2.2. Directionality and systemic governance interactions in agri-food systems: a matter of streams synchronization

The streams of directionality concept presented in the previous section also helps to unravel further how systemic governance elements contribute to steering agri-food systems' directionality. Previous studies in agricultural innovation and development mostly defined systemic governance as a synchronization matter, which builds tangible interfaces to harmonize actors and structures with often divergent interests to enable practical transformation in agri-food systems (Alrøe and Noe, 2008); Grin, 2012; Loorbach and Huffenreuter, 2013). Drawing upon the streams of directionality concept, this thesis offers a double understanding of the role of synchronization in the steering of change.

The first understanding is that agri-food systems' directionality is a coherent and harmonized synchronization of streams of directionality (such as visions, policies, technologies, formal and informal rules, practices) to enable transformative processes. The second understanding is that systemic governance is a deliberate action to steer how directionality synchronizes its streams. Both understandings habilitate this thesis to propose that systemic governance elements analyzed in chapters 3, 4, and 5 aimed to steer streams of directionality from a macro, meso, and micro point of view. Therefore, boundary infrastructures described in chapter 3 performed as a macro systemic governance element as they functioned as interfaces that contributed to steering different streams of directionality concurrently. For instance, boundary infrastructures evolved as interfaces between science, policy, and practice. They played a pivotal role in the establishment of streams of directionality in Brazilian pig production, such as the industrialization discourse, the vertically integrated pig production model, and the public policy named Integration law.

The ecology of intermediaries portrayed in chapter 4 performed as a meso systemic governance element. It focused on steering specific streams of directionality to facilitate the implementation of European animal welfare standards in Brazilian pig production (e.g., animal welfare legislation, technological breakthroughs linked to animal welfare improvement). In turn, translational work approached in chapter 5 performed as a micro systemic governance element as it steered the evolving of two particular streams of directionality (technological breakthroughs emerged in the 1980s and the 1990s). Boundary infrastructures, the ecology of intermediaries, and translational work also show that systemic

governance tends to go through a multi-level unfolding in reality. This finding confirms previous studies that emphasized 'the multi-level challenge' of governance (Newig and Fritsch, 2009; Pahl-Wostl, 2019).

## 6.3. Discussion of cross-cutting issues and conclusions

The findings of the thesis relate likewise to cross-cutting issues that contribute to several debates. Despite being focused on agri-food systems, thesis findings can be extrapolated to a certain degree and underpin broader discussions attached to socio-technical systems' directionality. This thesis reflects on four major cross-cutting issues:

- Streams of directionality, synchronization, and sustainability issues.
- A complementary dimension associated with concrete directionality.
- Reflexivity and monitoring through streams of directionality.
- Conceptual refinements: an improved view of boundary infrastructures, ecologies of intermediaries, and translation roles.

### 6.3.1. Streams of directionality, synchronization, and sustainability issues

Transition studies have often approached directionality with a twofold purpose (Røpke, 2012; El Bilali, 2018; Ingram, 2018). From one side, scholars have looked at how to foster a more sustainable directionality in locked-in socio-technical systems, specifically through strategies of discontinuation and 'exnovation' (Turnheim and Geels, 2012; Eksvärd and Marquardt, 2017). On the other hand, they have analyzed how to accelerate sustainable journeys based on niches of radical innovation (Smith and Raven, 2012; Kivimaa and Kern, 2016; Darnhofer, 2019). The main findings of this thesis add to extant work in transitions studies by 1) adding a dimension to the destabilization of locked-in socio-technical systems and 2) shedding light further on how to foster sustainable socio-technical journeys.

This thesis argues that development pathways reach their full potential when they synchronize enough streams of directionality to become dominant. It means that locked-in socio-technical systems went through a similar process, and its destabilization is related to the 'desynchronization' of its streams of directionality. Previous studies imply somehow the idea of 'desynchronization' while examining the destabilization of locked-in socio-technical systems through taxation or subsidization policies (Shiferaw and Holden, 2000, Bagstad et al., 2007; Eksvärd and Marquardt, 2017). However, this thesis broadens this perspective by inferring that active destabilization of locked-in socio-technical systems relies on reverting the synchronization between the different guiding forces that make up socio-technical systems' directionality - e.g., visions, policies, markets, rules, practices, technologies.

Similarly, this thesis argues that effectively fostering sustainable socio-technical journeys depends on synchronizing enough guiding forces to make feasible diverse development pathways. In practice, this synchronization effort demands the building of multifaceted initiatives, such as alternative visions, targeted policies, specific rules, updated practices, improved technologies. The understanding of this thesis regarding how to foster sustainable socio-technical journeys corroborates with what Weber and Rohracher (Weber and Rohracher, 2012) call 'certain corridors of acceptable development pathways' – i.e., a mix of

soft instruments of information, hard interventions like regulations and standards, and funding to guide forces of innovation, production, and consumption.

### 6.3.2. A complementary dimension associated with concrete directionality

Previous literature in mission-oriented innovation policy has emphasized the importance of making intended directionality concrete, measurable, and time-bound to facilitate the mobilization of public, private, and third sector actors (Mazzucato and Penna, 2016; Ziegler, 2020). In this endeavor, the definition of areas and projects associated with challenging missions have been pointed out as pivotal to set a clear directionality to tackle complex problems such as climate change and poverty (Mazzucato, 2018). The streams of directionality concept described above infers that guiding forces linked to directionality can be grasped as a complementary dimension to understanding better how to approach challenging missions.



This thesis showed in section 6.2.1 that socio-technical systems' directionality is composed of guiding forces (streams). Therefore, to build concrete, measurable, and time-bound directionality to address challenging missions also relies on analyzing which guiding forces (policies, values, technologies, practices, markets) should make it up. Furthermore, streams of directionality can refine the understanding of which areas and projects have to attach each challenging mission. As described before, streams denote levels and dimensions related to directionality. Thus, they deepen the understanding of where (areas) and how (projects) directionality can unfold. For example, if an intended directionality asks for promoting determined values to unfold in reality, as part of steering a socio-technical system, this connects to the social and cultural areas and educational projects.

### 6.3.3. Reflexivity and monitoring through streams of directionality

Scholars involved in studies dealing with socio-technical systems' directionality have underlined increasingly the importance of reflexivity and monitoring issues related to the steering of transformative processes (Arkesteijn at al., 2015; Schot and Kanger, 2018; Ghosh et al., 2020). There are mostly calls for developing indicators that could orient evaluations about directionality initiatives targeted to unlock socio-technical systems and build alternative development pathways (Ghosh et al., 2020). The streams of directionality concept developed in this thesis offers an additional perspective to reflect and monitor directionality by paying attention to the guiding forces that make it up.

Streams of directionality can be helpful for reflexivity and monitoring as it unravels how directionality unfolds through synchronization and desynchronization actions. Accordingly, the desynchronization of guiding forces is a promising criterion to reflect on interventions adopted to change locked-in socio-technical systems. The synchronization of guidance forces, in turn, is a potential criterion to monitor if an alternative pathway (nurtured in niches) has improved its capacity to spread by the system. Moreover, streams of directionality, due to their intrinsic ecosystemic view, facilitate to look into the technical, social, and environmental aspects associated with socio-technical systems' directionality.

### 6.3.4. Conceptual refinements: an improved view of boundary infrastructures, ecologies of intermediaries, and translation roles

Chapters presented previously allowed this thesis to grasp a broader understanding of directionality, systemic governance, and how they interact chiefly. Nonetheless, chapters 3, 4, and 5 also provided a deeper understanding of specific concepts, which were often performed as theoretical lenses designed according to each case study's particularities. Thus, chapters in this thesis developed parallel conceptual refinements by 1) affording a sharper description of boundary infrastructures, 2) showing how the ecology of intermediaries dynamics unfolds in reality, and 3) proposing an improved description of translation roles played by public research and technology institutions.

Besides showing how the unfolding of multiple interfaces between science, policy, practice shaped the unfolding of Brazilian pig production, chapter 3 beheld calls for developing more in-depth the comprehension and empirical appropriateness of the boundary infrastructures concept (Star 2010, Dagiral and Peerbaye 2016). Previous studies described boundary infrastructures as connected boundary objects on which actors rely while collaborating to achieve shared goals (Star and Ruhleder, 1996; Bowker and Star, 2000; Star and Bowker, 2006). Chapter 3 extended the understanding of boundary infrastructures and viewed them as comprised of three types of boundary infrastructure elements: boundary objects, boundary organizations, and boundary spanners. Furthermore, chapter 3 inferred that boundary infrastructures present a particular type of interpretative flexibility. It relates to their capacity to allow actors to develop equally valid different interpretations, views, and uses of their elements, according to contextual factors. Thus, interpretive flexibility enables actors to share uses and meanings of boundary infrastructure elements (common usage), while also allowing actors to apply them to their specific situation and give them a particular use and meaning (tailored usage).

Chapter 4 looked at how intermediaries assembled in ecologies have facilitated the implementation of the European animal welfare standards in Brazilian pig production. Concurrently, it showed how the 'ecology of intermediaries'-dynamics unfold in reality while taking part in complex situations of change, filling a gap pointed out by previous literature (Steyaert et al., 2016; Kivimaa et al., 2019). Chapter 4 shed lights on the 'ecology of intermediaries'-dynamics in a twofold way. First, it explained that the ecology of intermediaries performs as a multi-intermediary alliance, in which diverse intermediation roles are played with a certain degree of orchestration to fulfill tasks related to the complex situation of change. Second, it revealed that ecologies create shared interfaces (such as multi-stakeholder committees, capacity building projects, research partnerships) that push the boundaries of the different levels on which a complex situation of change unfolds.

Chapter 5 focused on translational work and analyzed how Embrapa (a public research and technology institution) contributed to embedding two imported innovations that changed the pig genetics improvement model in Brazil. Previous literature had not sharpened translation roles played by public RTIs in the embedding of agricultural imported innovations in receiver contexts (Goyal, 2016; Reardon et al., 2019). Chapter 5 filled this gap by explaining that translation roles are more connected to how public RTIs engage in broader ecosystems of actors linked to imported innovations' embedding processes than specific isolated translation actions. The study developed in chapter 5 identify at least three ecosystem translation roles that public RTIs might play in embedding imported innovations in receiver contexts: 1) translation orchestrator; 2) translation supporter; and 3) translation champion. Beyond giving a sharper description for translation roles played by public research and technology institutions, chapter 5 also showed more clearly what it means in practice to exert broader or narrower roles in embedding imported innovation.

## 6.4. Reflections on the study design and the thesis style

Previous work has recommended to scrutinize case study research from four quality perspectives: 1) construct validity; 2) internal validity; 3) external validity; and 4) reliability (Yin, 2009; Trainor and Graue, 2013). This section reflects on the quality of this thesis, including the design, data collection, and analysis steps. Construct validity alludes to ensuring that there are procedures that enable studies to produce a truthful presentation of the object approached in the study (Yin, 2009; Drost, 2011). Data triangulation, multiple sources of data, the establishment of a chain of evidence, and the interpretation validation by a key informant are actions to ensure construct validity (Yin, 2009). This thesis assured construct validity by 1) collecting data from varied and significative sources; 2) using multiple analytical procedures to triangulate the results. In terms of a chain of evidence, concepts selected through literature review were operationalized, thus the data collected matched the research questions. Furthermore, the data were thoroughly recorded and stored to ensure sources traceability. On the validation aspect, brief reports were prepared on the findings of each of the in-depth case studies and shared with crucial informants for feedback during and after the two fieldwork periods. Finally, drafts of scientific articles based on the case studies were sent to the respective informants for additional comments.



Internal validity concerns dealing with shortcomings relating to the challenging task of making inferences. Internal validity is most applicable for experimental or quasi-experimental studies that make causal inferences. However, it also affects case studies that make inferences based on interviews and documentary evidence (Yin, 2009). Pattern matching had a pivotal role throughout the analysis to improve the internal validity of this thesis, where expected patterns for particular processes were matched to the data examination (chapters 3 to 5). In turn, external validity deals with the generalizability of findings, precisely when they come to a single case study. Although this has been a recurrent criticism of case studies, scholars have noted that case studies are intended for analytical rather than statistical generalization (Maxwell and Chmiel, 1992; Bartlett and Vavrus, 2016). The chapters in this thesis approach conceptual research questions, which, according to Yin (Yin, 2009), provide the timeliness for analytical generalization. Finally, the reliability test relates to the extent of results that can be replicated if the same procedures are followed elsewhere (Yin, 2009). Despite effective measures taken to record and store the thesis data collection, the dynamic context in which this thesis collected data would make it difficult to replicate it.

Notwithstanding compliance with several of these quality tests, given the focus on the Brazilian context, some issues have to be mentioned concerning the interpretation of the results and their generalization to other countries. These include context biases and researcher biases (Podsakoff et al., 2012). Context biases refer in this thesis to the applicability of the study in other agricultural contexts, in light of all the case studies are situated in Brazil, which has one of the most industrialized food production systems among emerging and developing countries (Chaddad, 2016). Therefore, the findings presented in this thesis carry biases based on the specific development trajectory unfolded in Brazilian pig production. Researcher biases are related to the fact that the author of this study has worked for a public research and technology institution (Embrapa) and took part in developmental projects in Brazilian pig production since 2000. This previous experience somehow influences study design and data interpretation. Thus, I critically self-reflected on pre-conceptions, relationship dynamics, and analytic focus following hints from previous work related to 'researcher bias' (Galdas, 2017).

Finally, chapters 2 to 5 of this thesis were written in the form of articles and submitted to scientific journals throughout the last two years. Although not planned initially, this writing style also unfolded as a thinking process, in which each piece added to the thesis ended up bringing implications (expected or not) to what came before or after. While investigating agri-food systems' directionality, this thesis also learned by looking back to gaps left behind by articles written previously. Notably, the thesis general view about directionality evolved and changed somehow from the first article (chapter 2) to the fourth one (chapter 5) - although chapters 3 to 5 do not approach it primarily. The 'learning journey' described above, marked by discoveries and setbacks, was fundamental to the results achieved by this thesis.

## 6.5. Implications for policy and practice

From the above overview of the main findings and cross-cutting analysis, several implications for policy and practice can be discerned:

- Policymakers in Brazil and elsewhere have struggled to understand how they can actively steer transformative processes related to agri-food systems and socio-technical systems generally. Following Schot and Steinmuller's (Schot and Steinmueller, 2018) call for structural failures analysis in public policies as a starting point for elaborating more robust interventions in reality, this thesis provided a more profound comprehension of agri-food systems' directionality, what is deemed crucial to debates on the development of systemic conditions needed to build alternative pathways. To set concrete directionality actions, there is a need to pay explicit public policy attention to build systemic governance elements to promote the synchronization or desynchronization of the guiding forces linked to directionality. Supporting these sorts of elements will require public and private mobilization (in terms of cooperation and funding) to establish a long-term commitment linked to building desirable directionalities.
- Another critical implication relates to the steering of transformative processes from a proactive interaction between science, policy, and practice perspective. To advance this policy agenda, public research and technology institutions particularly should increase their connections with policymakers and entrepreneurs, assuming a leading position to synchronize actors and structures to tackle complex challenges such as climate change in several levels - e.g., local, national, international. Thus, governments everywhere need to better acquaint themselves with the roles they may perform to bring together science, policy, and practice in crucial issues for society, confirming policy recommendations mentioned by previous studies (Mazzucato 2015, Mazzucato 2018).
- There is an increasing call to set worldwide bilateral agreements to disseminate international animal welfare standards (Fulponi 2006, Lundmark, Berg et al. 2018). This thesis showed that bilateral agreements also depend on planning and funding mechanisms that allow a co-evolution of standards implementation processes and ecologies of intermediaries attached to them in local contexts. Furthermore, international animal welfare standards setters (such as the EU and OIE) should also consider the importance of helping local actors (such as industries, NGOs, associations, producers) to better map ecologies of intermediaries associated with implementation processes and see where the gaps are.
- A further key implication relates to which kind of roles public research and technology institutions may play in dealing with the global flows of knowledge and the traveling of innovation (orchestrator, supporter, and champion). This thesis demonstrated that they should

be considered as important in approaching imported innovations, as public research and technology institutions perform pivotal functions to assist actors who became marginalized by them in local contexts. Moreover, public research and technology institutions have to be funded to take part in embedding imported innovation in emerging or developing countries, where often local private sectors are unable to adapt what comes from abroad reasonably, as noted by extant work (Intarakumnerd and Chaoroenporn 2013).

## 6.6. Outlook for further research

This section formulates recommendations for further research based on the different chapters and the general conclusion. They relate to the interaction between directionality and systemic governance, as well as specific suggestions linked to boundary infrastructures, ecologies of intermediaries, and translational work.



- The streams of directionality concept described in section 6.2.1 opens three clear avenues for future research linked to socio-technical systems' directionality. First, it could be tested empirically - i.e., the streams of directionality concept might sharpen the understanding of why a specific socio-technical system follows a particular directionality. Second, further studies could map more precisely which type of guiding forces influence socio-technical systems' directionality (the streams). Such a contribution would help to determine how directionality unfolds in different levels and domains. Third, there is a promising opportunity to deepen the comprehension of how to steer the direction of change from the synchronization/desynchronization of the streams of directionality perspective. This possibility adheres mostly to calls for enhancing knowledge on creating and monitoring concrete directionality interventions (Mazzucato and Penna 2016, Ghosh, Kivimaa et al. 2020).
- Future research on the boundary infrastructures concept would need to substantiate thesis findings regarding boundary infrastructure complementarity and synergy, as well as the structural flexibility of boundary infrastructure elements. It would also be interesting to investigate boundary infrastructures from a scale point of view, thus studying whether and how sectoral and national boundary infrastructures interact, or whether sectoral infrastructures overlap.
- Further studies might reproduce the investigation about the implementation of the European animal welfare standard in Brazilian pig production in other local contexts, thus deepening the understanding of how ecologies of intermediaries function to facilitate transformative processes. This also would improve the understanding of how ecologies of intermediaries unfold in practice as multi-intermediary alliances. Moreover, future research could focus on analyzing whether it is feasible to purposefully introduce collective intermediation efforts related to complex situations of change.
- The translation roles associated with public research and technology institutions presented in chapter 5 would need to be applied to similar governmental companies involved in embedding imported innovations in distinct socio-technical systems. There are three other avenues for further studies: 1) to verify if stable and temporary translation roles related to public research and technology institutions observed in Brazilian pig production would come up in different receiver contexts, 2) to investigate further the dynamics behind the embedding of imported innovation, looking at whether it is feasible to foster interactions between different and

concurrent translations purposefully, and 3) to deepen the comprehension of how local conjunctures have hampered public research and technology institutions in playing translating roles concerning the global flows of knowledge and traveling of innovation.

## 6.7. Final remarks

Overall, this thesis showed that directionality is composed of streams, unfolds as a multi-level and multi-domain phenomenon, and establishes itself synchronizing different guiding forces (such as visions, values, rules, policies, technologies, practices). These contributions provided an in-depth overview of interactions between directionality and systemic governance to deeper understand issues related to the steerability of transformative processes in agri-food systems. This thesis also helped to make more concrete the intrinsic complexity of socio-technical systems' directionality, which has been underlined by several scholars (Lindner, Daimer et al. 2016, Schot and Kanger 2018, Ghosh, Kivimaa et al. 2020). Streams, levels, domains, and synchronization issues described in sections 6.2.1 and 6.2.2 confirmed how complex directionality is. On the other hand, they also revealed how 'touchable' directionality is to some extent. This does not mean that this thesis elaborated a recipe to steer socio-technical systems' directionality. Admittedly, an overarching conclusion is that the insights provided here reveal more about the impracticability of fully influencing directionality than the opposite.

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# Appendices

# Appendix 2.1. List of interviews, 2017

| Groups of Influential Actors | Interviewees | Position or Expertise | Total |
|---|---|---|---|
| **Industries** | BRF SA representative | sustainability, process management | 11 |
| | BRF SA representative | innovation, start-ups | |
| | Aurora Alimentos Central Cooperative representative | president | |
| | JBS Foods | corporate director of livestock | |
| | Pamplona Food SA | president | |
| | Frimesa Central Cooperative | executive director | |
| | Master Agriculture and Livestock | executive director | |
| | Sadia SA | former executive director | |
| | Perdigão SA | former executive director | |
| | Seara Alimentos | former executive director | |
| | Pig Production Industries Association | president | |
| **Producers** | Brazilian Pig Producers Association | executive director | 3 |
| | One the biggest Brazilian pig producers | pig producer | |
| | Santa Catarina Pig Producers Association | former president | |
| **Advisory Services** | BRF SA representative | executive director | |
| | Aurora Alimentos Central Cooperative representative | executive director | |
| | Aurora Alimentos Central Cooperative representative | innovation | |
| | Advisory service consultant | innovation and animal health | |
| | Advisory service consultant | innovation and communication | |
| **Science** | Research governmental company | economics | |
| | Research governmental company | genetics | |
| | Research governmental company | Environment and sociology | |
| | Research governmental company | animal health | |
| | Research governmental company | environment | |
| | University | education | |
| | Santa Catarina Company for Agricultural Research and Rural Extension | innovation | |
| **Non-governmental organizations** | Lambari Consortium | executive director | 4 |
| | World Animal Protection Brazil | sustainable agriculture and innovation | |
| | Santa Catarina Animal Health Institute | animal health, environment, and education | |
| | Santa Catarina Agriculture Association | president | |

| | | | |
|---|---|---|---|
| **Government/ policymakers** | Santa Catarina Agriculture, Livestock, and Fishery Department | secretary | 7 |
| | Santa Catarina Agriculture, Livestock, and Fishery Department | animal health | |
| | Brazilian Ministry of Agriculture, Livestock, and Supply | pig production director | |
| | Parliamentary Group of Agriculture in the Federal Chamber | federal deputy | |
| | Parliamentary Group of Pig Production in the Santa Catarina Chamber | state deputy and president | |
| | Parliamentary Group of Pig Production in the Santa Catarina Chamber | state deputy and former president | |
| | Parliamentary Group of Pig Production in the Santa Catarina Chamber | state deputy | |
| **Total** | | | 41 |

# Appendix 2.2. List of core and additional data, 2017

| Type of secondary data | Core secondary data | Additional secondary data | Total |
|---|---|---|---|
| **Books** | The economics and organization of Brazilian agriculture – Fábio Chaddad (2016) | | |
| | Mapping of Brazilian pork chain – SEBRAE and ABCS (2016) | | |
| | Pig production: theory and practice – ABCS (2014) | | |
| | Swine cooking in Brazil: Quality from the field to the table – Arthur Bosísio, Raul Lody, Jean Porto Vilas-Boas (2003) | | |
| | Sonho, desafio e tecnologia: 35 anos de contribuições da Embrapa Suínos e Aves – Jean Vilas-Boas, Dirceu Talamini, Gerson Scheuermann, Gilberto Schimidt (Harrison, Prenkert, Olsen, & Hoholm, 2011) | | |
| | Suinocultura e meio ambiente em Santa Catarina: Indicadores de desempenho e avaliação sócio-econômica – Cláudio Miranda (2009) | | 6 |
| **Scientific papers** | Dimensões Econômicas e Organizacionais da Cadeia Produtiva da Carne Suína – Marcelo Miele (2006) | | |
| | A sustentabilidade econômica e social da produção e frango e suínos em Santa Catarina e no Brasil – Jonas Irineu dos Santos Filho (2012) | | |
| | A contribuição da Embrapa na Geração de Novas Tecnologias para Suinocultura e Avicultura – Dirceu Talamini et al. (2014) | | 3 |
| **Policy briefs** | Integration Law – issued on May, 17, 2016. | | 1 |
| **Official public reports** | Censo Agropecuário Brasileiro – IBGE (2006) | | 1 |
| **Media articles published in newspapers and magazines** | Guia Gessulli da Suinocultura Industrial – Revista Suinocultura Industrial (2015) | | 1 |
| **Annual reports** | | ABPA Annual Report 2014 – ABPA (2014) | |
| | | ABPA Annual Report 2015 – ABPA (2015) | |
| | | Pig Production Magazine Nº 14 – ABCS (2015) | |
| | | Pig Production Magazine Nº 15 – ABCS (2015) | 4 |
| **Total** | | | 16 |

# Appendix 4.1. List of interviews, 2019

| Groups of influential actors | Interviewees | Position or Expertise | Total |
|---|---|---|---|
| **Industries** | BRF SA representative | sustainability, process management | 2 |
| | Pig Production Industries Association | president | |
| **Producers** | Brazilian Pig Producers Association | executive director | 2 |
| | Santa Catarina Pig Producers Association | president | |
| **Advisory services** | BRF SA representative | executive director | 4 |
| | Advisory service consultant | innovation and animal welfare | |
| | Advisory service consultant | communication and animal welfare | |
| | Advisory service consultant | animal welfare | |
| **Science** | Research governmental company | animal welfare | 3 |
| | University | animal welfare | |
| | University | education and animal welfare | |
| **Non-governmental organizations** | Humane Society International | animal welfare specialist | 4 |
| | World Animal Protection Brazil | executive director | |
| | Santa Catarina Animal Health Institute | animal health, environment, and education | |
| | Santa Catarina Agriculture Association | president | |
| **Government/ policymakers** | Brazilian Ministry of Agriculture, Livestock, and Supply | pig production director | 3 |
| | Brazilian Ministry of Agriculture, Livestock, and Supply | animal welfare department director | |
| | Santa Catarina Agriculture, Livestock, and Fishery Department | animal health and animal welfare | |
| **Suppliers** | GSI Brazil Industry and Equipment | director | 2 |
| | Schauer Brazil | business representative | |
| **Total** | | | 20 |

# Appendix 4.2. Theoretical level of complexity of implementing EU directives in the Brazilian pig industry (Dias, et al. 2015, p. 1082)

| Requirements of animal welfare | Level |
|---|---|
| • Unobstructed floor area available to each weaner or rearing pig in a group (m2/animal) | + |
| • Total unobstructed floor area available to each gilt and sow kept in a group after service (m2/animal) | + |
| • Minimum area of continuous solid floor in a gestation group (m2/animal) | + |
| • Maximum width of the openings and minimum slat width when concrete slatted floors are used for pigs kept in groups | +++ |
| • Freedom of movement: gilts and sows, tethered | ↓ |
| • Freedom of movement: housing pregnant sows in a group | +++ |
| • Access to manipulable material to build a nest during the week before the expected farrowing time | +++ |
| • Permanent access to sufficient stimulation and enrichment activities for all pigs | +++ |
| • Supply of wholesome food appropriate to their age and in sufficient quantity | ↓ |
| • Conception and use of feeders and drinkers to reduce the risk of contamination and negative effects of competition between animals | + |
| • Use high-fibre materials in the diet of gestation sows | ++ |
| • All pigs fed at least once a day | ↓ |
| • Simultaneous access to feed for all pigs fed in groups and not fed *ad libitum* | + |
| • Fresh water for all pigs over two weeks of age | ↓ |
| • Segregation of sick animals (hospital pens) with immediate and appropriate treatment | ↓ |
| • Appropriate euthanasia procedures when necessary to prevent needless suffering | ++ |
| • Sufficient number of trained people to take care of the animals | ↓ |
| • Staff training (training courses/certificates) | ↓ |
| • Low level of continuous noise (<85 dBA), constant or sudden noise shall be avoided | ↓ |
| • Light with an intensity of at least 40 lux during a minimum period of 8 h/dia | ↓ |
| • Lying area: physically and thermally comfortable, drained, clean and with space for all animals to lie down at the same time | ++ |
| • Floors smooth, not slippery, and stable + | |
| • Air circulation, dust level, temperature, relative air humidity and gas concentrations within limits not harmful to animals | ↓ |
| • Daily inspection of equipment essential to animal health and welfare and correction of damage | ↓ |
| • Provide emergency and alarm systems, when animal health and welfare depend on artificial ventilation systems | + |

| | | |
|---|---|---|
| • Procedures with piglets: avoid routine reduction of corner teeth | | + |
| • Procedures with piglets: avoid routine tail docking | | ++ |
| • Procedures with piglets: castration of males until 7 days (without anaesthesia and analgesia) | | + |
| • Procedures with boars: reduce the length of the tusks | ↓ | |
| • Housing of boars in pens (minimum 6 m2) | | ++ |
| • Farrowing pens should allow free movement of females and protection for piglets (farrowing rails). The area behind of the farrowing pen should allow natural or assisted farrow | | ++ |
| • Facilities for piglets: allow all piglets to lie down at the same time, floor solid or covered with bedding | | ++ |
| • Weaning at age 28 days or 21 days (nursery: all in/all out, separated from sows) | | + |
| • Minimum possible mixing of pigs in the nursery and growing and finishing | | ++ |
| • Daily inspection of animals | | ↓ |
| • Maintain records of veterinary treatments and mortality rates for at least 3 years | + | |

**Levels of complexity for implementation in Brazil:**

**↓ (Reduced): Natural Brazilian advantage due to climate, space, or availability of human resources and raw materials for food.**

**+ (Hajjar, Newton et al. 2019): Minor changes to management and/or low investment.**

**+ + (Moderate) Moderate changes to management and/or moderate investment.**

**+ + + (High): Major changes to management and/or high investment.**

# About the author

Jean Carlos Porto Vilas Boas Souza was born on June 7, 1971 in Concórdia, Brazil. He joined Ponta Grossa State University and obtained his bachelor in Social Communication in 1992. He went to the Rio Grande do Sul Federal University in 2003 to pursue his masters in Communication and Information, which was obtained in 2005. Since 1999, he has worked at the Brazilian Agricultural Research Corporation (Embrapa), taking part in varied initiatives focused on rural communication and technology transfer related to poultry and pig productions in Brazil, such as Ideal Piglet Project and Aurora Chicken Project. In January 2016, he joined the Knowledge, Technology, and Innovation Group (KTI) at Wageningen University & Research as a PhD candidate.

**Jean Carlos Porto Vilas Boas Souza**

**Wageningen School of Social Sciences (WASS)**

**Completed Training and Supervision Plan**


| Name of the learning activity | Department/Institute | Year | ECTS* |
|---|---|---|---|
| **A) Project related competences** | | | |
| Critical perspectives on social theory | WASS | 2016 | 4 |
| Innovation Management and Transdisciplinary Design, CPT 22806 | WUR | 2016 | 6 |
| Project meetings and workshops | KTI, WUR | 2016/2019 | 3 |
| **B) General research related competences** | | | |
| WASS introduction course | WASS | 2016 | 1 |
| Research Methodology - From topic to proposal | WASS | 2016 | 4 |
| PhD research proposal | KTI, WUR | 2016/2017 | 6 |
| Qualitative Data Analysis with Atlas.ti: a hands-on practical | WASS | 2017 | 2.5 |
| Scientific Writing | WGS | 2016 | 1.8 |
| **C) Career related competences/personal development** | | | |
| *'Unravelling innovation direction in socio-technical transitions: a framework and application'* | WASS PhD Day | 2019 | 0.5 |
| *'Unravelling directionality in socio-technical system transitions: a framework and application'* | 9th Int. Sustainability Transitions (IST) Conference, University of Manchester | 2018 | 1 |
| *'Intermediation for complex situations of change: the role of an ecology of intermediaries in animal welfare implementation in Brazilian pig production'* | 11th Int. Sustainability Transitions (IST) Conference, AIT Austrian Institute of Technology | 2020 | 1 |
| Ideas Seminar INRA (Paris) | INRA | 2020 | 1 |
| **Total** | | | **31,8** |

*One credit according to ECTS is on average equivalent to 28 hours of study load

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