SCALING BIO-BASED INNOVATION: TURNING SCIENTIFIC EVIDENCE INTO MARKET IMPACT FOR LIGNIN-BASED BIOSTIMULANTS IN FRANCE, GERMANY, AND THE NETHERLANDS

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ABSTRACT

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Biostimulants derived from lignin are an emerging circular economic innovation, but there are considerable institutional, economic, and awareness-based barriers to their implementation in agriculture. This thesis explored the commercialization opportunities of lignin-derived biostimulants through a cross-sectional survey of 98 stakeholders in France, Germany, and the Netherlands.

The analysis yielded the following key findings: first, demonstration evidence overwhelmingly drives adoption decisions; second, there is a paradox of awareness and action, with 96.9% general awareness but only 5.1% being active promoters of lignin-derived biostimulants; third, premium pricing acceptance (to sustainably mitigate risk) is capped at 10% across most stakeholders; and lastly, working with multiple stakeholders is valued. Interestingly, social benefits are prioritized over environmental and economic benefits. Overall, all five research hypotheses were supported and provided useful, clear, and actionable recommendations for businesses and policymakers to drive sustainable agricultural solutions. Most importantly, engagement with the agricultural sector requires strong empirical evidence and reasonable pricing for successful pan-European market entry. This thesis framework challenges the conventional sustainability narrative, advances our understanding of how cognition-based legitimacy applies to biostimulants and the adoption of more sustainable solutions in agriculture, and has potential implications for how firms and policies can navigate toward sustainable solutions.

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I really want to thank all EBIC members and stakeholders from France, Germany, and the Netherlands for participating in this survey. Your time, integrity, and thoughts are critical for building the empirical basis of this study. On a more personal note, I want to thank my wife and family for their love, support and always being there when I needed them the most.

Lastly, this thesis reflects my passion for bridging scientific evidence with real-world market impact in sustainable agriculture. Along the way, I've probably learned a whole lot more than I ever bargained for, deepening my commitment to the circular economy, innovation in the agri-food sector

Fahim Shaikh.
Lappeenranta, December 2025.

SYMBOLS AND ABBREVIATIONS

BMC	Business Model Canvas
EBIC	European Biostimulants Industry Council
FPR	Fertilizing Products Regulation
EU	European Union
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
R&D	Research and Development
RBV	Resource-Based View
TBL	Triple Bottom Line
VRIO	Valuable, Rare, Inimitable, Organized
RQ	Research Question
GHG	Greenhouse Gas
QR	Quick Response (code)
ROI	Return on Investment
NPS	Net Promoter Score
ANOVA	Analysis of Variance
HSD	Honestly Significant Difference (Tukey's test)
SD	Standard Deviation
CI	Confidence Interval
M	Mean (statistical)
n	Sample size
χ^2	Chi-square test (statistical test)
η^2	Eta-squared (effect size measure)
d	Cohen's d (effect size measure)
F	F-statistic (ANOVA)
p	p-value (statistical significance)
r	Pearson correlation coefficient
r^2	Coefficient of determination
t	t-statistic (t-test)
%	Percent/Percentage
α	Alpha (Significance Level)

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DECLARATIONS

Turnitin

The originality of this thesis has been reviewed with the Turnitin similarity checking service.

AI usage

The author of the thesis, Fahim Shaikh, used the following AI-tools during the preparation of the thesis:

1. Perplexity Assitant
    a. Purpose of use: For Translation
    b. Explanation of the use of the tool: To translate the original survey questions (English) into three different languages, French, Dutch, and German, for multilingual form distribution for this thesis.
2. Paperpal
    a. Purpose of use: To assist with academic writing refinement
    b. Explanation of the use of the tool: Used for grammar checks, style suggestions and phrasing improvement.

Responsibility

The author, Fahim Shaikh, takes full responsibility for the content of this thesis and has reviewed and edited the content generated by the possible use of AI tools.

1 Introduction

Innovative sustainable agricultural development and diffusion in Europe are a pre-condition for a resource-efficient, climate-smart and circular bioeconomy (European Commission, 2012, pp. 2–5). As the global pressure for higher yields and reduced environmental footprints increases, agricultural producers in Europe face heightened risks and emerging opportunities. Amidst these evolving pressures and opportunities, the drivers of market readiness and the factors that may facilitate or impede the commercial uptake of new agricultural inputs are becoming increasingly topical areas of interest for many researchers and practitioners (Dessart, Barreiro-Hurlé and Van Bavel, 2019, pp. 420–425). A particularly promising technological innovation is the development of lignin-based biostimulants. Derived from numerous by-products of the pulp and paper industry, these biostimulants offer a high-value, eco-friendly solution for agriculture, enhancing plant growth and resistance while improving soil health and biodiversity (Mastrolitti et al., 2021, pp. 5–6; Rouphael, Colla and Zhu, 2020, pp. 2–3). While globally over 50 million tons of lignin are produced annually, primarily for low-value combustion, biorefinery processes now enable its conversion into these valuable agricultural inputs, aligning with circular economy principles (De Wild, Huijgen and Gosselink, 2014, p. 646; Savy and Cozzolino, 2022, p. 2)

1.1 Problem Statement and Research Gap

Although lignin-based biostimulants have huge potential, their successful commercialization is primarily due to institutional fragmentation in the European Union. Uncertainty for entrants to the market due to varying national regulations on approval processes influences strategic decisions on resource deployment and timing of market entry (Caradonia et al., 2018a, pp. 438–448; Wenger, Haas and Stern, 2020, p. 2). This regulatory heterogeneity is exemplified by distinct approaches in key EU members: France's emphasis on robust evidence, Germany's innovation networks, and the Netherlands' practical facilitation of R&D commercialization (Caradonia et al., 2018a, p. 441). Understanding these complex commercialization dynamics necessitates an integrated theoretical perspective, drawing on

frameworks such as Institutional Theory, the Resource-Based View, and the Diffusion of Innovations, to explain the progression of bio-based agricultural innovations from validation to commercialization within a multilevel governance structure (Alon et al., 2018, p. 596).

Despite the existence of these theories and the need for sustainable agricultural innovations, the literature is still lacking in knowledge of the commercialization of lignin-based biostimulants. First, Prior studies have examined technical performance, regulatory schemes, and stakeholder attitudes in isolation, lacking a systematic analysis of how these dimensions interact within particular institutional contexts (Caradonia et al., 2018a, p. 439). Second, while regulatory heterogeneity across EU member states is acknowledged, research on institutional distance and its impact on market entry sequencing, resource deployment, and capability development remains insufficient (Sundh, Del Giudice and Cembalo, 2021, p. 6). Third, the business model and sustainability literature often discusses value proposition design and Triple Bottom Line performance, but rarely connects these frameworks with the operational choices required for scaling biological inputs under regulatory and market uncertainty (Joyce and Paquin, 2016, p. 1475). This thesis addresses these critical gaps through a cross-national stakeholder survey in France, Germany, and the Netherlands, integrating Institutional Theory, Diffusion of Innovations, Resource-Based View, and internationalization frameworks to generate actionable commercialization strategies for sustainable agricultural innovation.

1.2 Aim, Objectives and Research Questions

The aim of this thesis is to understand the drivers of the successful commercialization of lignin-based biostimulants in European agriculture. The emphasis will be put on three contrasting but connected cases of France, Germany, and the Netherlands. By emphasizing both universal and context-specific drivers, this research aims to provide actionable insights to firms, policymakers, and the research community engaged in sustainable innovation.

The main objectives of this research are threefold. First, it aims to assess systematically the level of awareness, perception, and knowledge gaps of stakeholders regarding lignin-based biostimulants in the three selected countries, examining how different agricultural actors, such as farmers, agronomists, distributors, and advisors, perceive lignin-based biostimulants

and what knowledge gaps may hinder their adoption. The second objective of this study is to ascertain the regulatory, market, and institutional factors that determine the commercial feasibility and pathways of these products. It emphasizes the interaction of existing regulations, markets, and institutional structures that create opportunities and constraints that affect commercialization. The third objective of this research is to identify which business model innovations, partnership structures, and policy levers are most likely to enable circular economy integration and scale-up of lignin-based biostimulants, and determine which strategic configurations can effectively overcome adoption barriers and accelerate market diffusion. To achieve objectives, three interconnected, empirically verifiable research questions were formulated.

1. What do professional agricultural intermediaries (agronomists, researchers, distributors) in France, Germany, and the Netherlands perceive as the main benefits and barriers of using lignin-based biostimulants from a market commercialization perspective?
2. How do regulations, market structures, and business models affect commercialization in a country´s context?
3. What commercialization strategies do agricultural professional intermediaries perceive as the most viable for overcoming barriers and accelerating the adoption of lignin-based biostimulants, and how do these intermediary-derived recommendations align with the farmer adoption drivers reported in the literature?

Further, by systematically examine whether established theories yield empirically accurate predictions regarding the commercialization of lignin-derived biostimulants, this study examined five hypotheses:

Hypothesis 1 Evidence-Requirement: Stakeholders perceive demonstration-based evidence (case studies and pilot tests) as a primary driver in terms of adoption decisions than social influence mechanisms (peer recommendation and social norms), which acknowledges that success in commercialization is primarily based on tangible proof-of-concept rather than social persuasion in the context of agriculture.

Hypothesis 2 Awareness-Action Paradox: Despite moderate to high optimism about the market, stakeholders are reluctant to act on this awareness and recommend lignin-derived biostimulants. This creates a significant awareness–action gap, where cognitive awareness of an opportunity does not translate into legitimate behavior, thereby impeding diffusion through collaboration networks.

Hypothesis 3 Premium Constraint: Agricultural stakeholders are severely constrained by their limited willingness to pay a premium price for lignin-derived biostimulants, with approximately 10% maximum acceptability for the majority of agricultural stakeholders. This appears to be based on the basic limited resources of economics, which represent actual binding constraints on reasonably priced inputs to the agricultural sector, more than any perceived individual value of the benefit product.

Hypothesis 4 Collaboration Imperative: Multi-stakeholder collaboration is seen as an almost universal necessity for commercial success and does not vary significantly based on geographic area (across France, Germany, and the Netherlands), which provides the rationale that a collaborative ecosystem approach is a commercialization necessity across Europe and is not simply a strategic option for entrance into each geographical market.

Hypothesis 5 Multi-Dimensional Benefit Perception: Agricultural stakeholders recognize social benefits (supporting sustainable communities) as being much more significant than other perceived environmental or economic benefits of value to the stakeholder. This demonstrates that from a messaging perspective, social sustainability should be the message priority for commercialized products, as opposed to environmental or economic positioning priorities.

These hypotheses can be probed and tested using cross-sectional survey data from 98 stakeholders in October 2025 with descriptive statistics, t-tests, analysis of variance, and correlation analysis in Chapter 4. To systematically address these research questions and test the associated hypotheses, this study employs a multi-theoretical framework that integrates macro-level institutional analysis, meso-level strategic management perspectives, and micro-level innovation diffusion dynamics. The following section outlines the theoretical foundations that guide the empirical investigation.

1.3 Theoretical Approach

To comprehensively understand the multifaceted dynamics of commercializing lignin-based biostimulants, this study employed a multi-perspective theoretical approach. This framework integrates foundational theories such as Institutional Theory, the Diffusion of Innovations, and the Resource-Based View to explain the underlying mechanisms of adoption and market entry. These are complemented by strategic analysis tools like PESTEL for macro-environmental assessment and applied business model frameworks including the Business Model Canvas, Triple Bottom Line, Circular Economy model, and the Uppsala Internationalization model, to inform solution design and strategic sequencing. This multi-faceted approach enables a comprehensive investigation of how institutional, strategic, and behavioral factors shape commercialization outcomes across various settings in Europe. This provides a strong basis for the analysis of our empirical study.

1.4 Research Scope and Methodology

This study adopts a post-positivistic approach and utilizes a quantitative, deductive strategy with a large structured online survey. The cross-sectional study takes place in October 2025 (n=98) and provides an overview of the market readiness and perceptions of stakeholders of the three selected countries. Full details regarding the methodology, sampling, and development of the survey instrument, including its validity and reliability, and analytical processes are presented in Chapter 4.

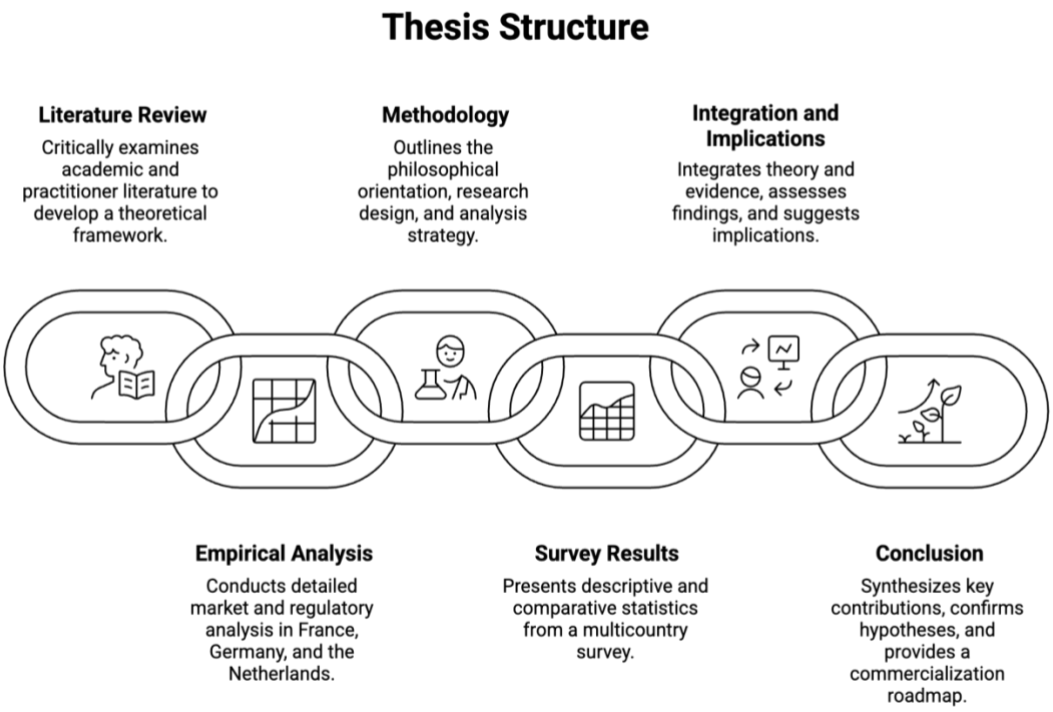
Geographically, this study is limited to France, Germany, and the Netherlands, which were selected in part because of their positions as leaders in agricultural production in the EU, and their different regulatory approaches will provide a meaningful institutional comparison. The data sources in this study were limited to quantitative survey responses, excluding qualitative interviews or field/laboratory experiments. This study identifies commercialization drivers, broad business model considerations, and adoption drivers, not agronomic or technical efficacy, which are well documented in the existing scientific literature. Such methodology allows for systematic comparison of stakeholders' perceptions across countries with analytical rigor and generalizability. The general organization of the

thesis which incorporates these theoretical, methodological and empirical components is illustrated below.

1.5 Structure of the Study

The overall organization of this thesis is illustrated in Figure 1, which shows the logical progression of the chapters from a conceptual background to an analysis and synthesis. This thesis comprises six chapters. The chapters were built logically on each other. These chapters are theoretical, empirical, and practical. They deal with the commercialization of lignin-based biostimulants.

Figure 1: Structure of the study



Source: Author's own elaboration

Chapter 2 critically examines the literature written by academics and practitioners in order to develop the theoretical and analytical framework of the study. Moreover, it incorporates the foundations of theories and frameworks for strategic analysis, design, and process models, which facilitates the empirical work of this study. In Chapter 3, a detailed empirical and institutional analysis of the market and regulatory landscapes in France, Germany, and the Netherlands, specifically examining how these contexts manifest the theoretical

constructs discussed in Chapter 2. Chapter 4 of the dissertation entails a methodology that includes a philosophical orientation, research design, sampling procedure, development of the survey instrument, and analysis strategy. Chapter 5 presents the descriptive and comparative statistics of a multicountry survey according to the research questions and stakeholder types. Chapter 6 integrates the theory and evidence, assesses the findings, links back to the aims and literature review, suggests implications for commercial stakeholders and policymakers, states the limitations of the thesis, and identifies topics for future research on sustainable innovation in agriculture. In the end, Chapter 7 summarizes the main contributions of the thesis, verifies all five hypotheses and lastly proposes a roadmap for commercialization in phases with a focus on evidence generation, positioning for social benefit, collaboration, and cost-competitiveness.

2 Literature Review and Theoretical Framework

In this chapter, theoretical and empirical foundations are developed to understand the commercialization of lignin-based biostimulants in fragmented European agricultural markets. It positions the phenomenon within the four conceptual blocks of agricultural innovation, institutional governance, strategic management, and sustainability transitions, drawing from literature on sustainable agricultural inputs and innovation adoption in farming systems. Expanding on these streams, this chapter reviews core perspectives from Institutional Theory, Diffusion of Innovations, the Resource-Based View, and other related economic approaches, before integrating them into the applied strategic frameworks of PESTEL, the Business Model Canvas, the Triple Bottom Line, and internationalization models. This synthesis leads to the development of a consistent model that connects the existing theory with the research questions and hypotheses, thus providing a robust framework for the empirical analysis of lignin-based biostimulants.

2.1 Review on Biostimulant Commercialization and Agricultural Innovation Adoption

This section reviews prior empirical studies on biostimulant markets, agricultural innovation adoption, EU regulatory environments, and stakeholder decision-making to establish the research context and identify gaps this thesis addresses.

2.1.1 Biostimulants as Sustainable Agricultural Inputs

Biostimulants are an important category of sustainable agricultural inputs emerging in response to the growing policy imperatives in Europe to decouple productivity from dependence on synthetic agrochemicals (Khoulati et al., 2025, p. 2). Unlike fertilizers and pesticides that act directly on a plant, biostimulants directly or indirectly alter physiological and cellular processes in the plant or improve the functioning of the soil (Du Jardin, 2015, pp. 3–5). The values of the global biostimulant market have grown significantly; it is estimated that the value of the market was close to USD 4.3 billion in 2024 and USD 7.6

billion in 2029, which has an approximate annual growth rate of 12% (Köhl, 2025, p. 4). According to Köhl (2025, p. 4), the value of microbial biological control agents alone was approximately USD 2 billion in 2018, with estimates exceeding USD 6 billion by 2025. As such, all biological inputs are developing with a strong market momentum.

Despite these trends, the development of methods to commercialize new biostimulants, including those derived from lignin, remains disjointed and uncertain. The literature on agricultural innovation adoption stresses the importance of agronomic effectiveness of new inputs. However, the adoption of new inputs is not merely a function of the agronomic effectiveness. It is also a function of the interaction among technological performance, market formation, regulatory clarity, and stakeholder perceptions (Long, Blok and Coninx, 2015, p. 3). When producers are not advanced in using technology, the uptake could depend on intermediary support services, extension activities, and trusted information, rather than adoption under farmer-led technology (Long, Blok and Coninx, 2015, p. 3). The distribution of biostimulant technologies requires due consideration of not only supply chain readiness but also farmer training and evidence generation.

Compared to conventional agrochemical products, the commercializationof biostimulants faces a unique set of challenges. Neoclassical frameworks emphasize cost-revenue management under competitive conditions. Socioeconomic studies indicate that transaction costs, such as those related to regulation, supply, and assurance, generally dominate market entry decisions. In other words, these transaction costs are more important than the simple input costs (Wenger, Haas and Stern, 2020, p. 11). When companies seek to introduce new biostimulant formulations in countries with different regulatory requirements, developing in-house regulatory competence and compliance capabilities may be a strategic necessity, rather than an efficient option (Wenger, Haas and Stern, 2020, p. 11). In the EU, differences in regulations between member states lead to significant variations in approval times and compliance burdens across member states.

Uncertainty over regulations undermines commercialization incentives, especially for formulations with high intellectual property content when patentability or trade secret protection regimes are unclear (Le Mire et al., 2015, p. 305). Although the European Union has recently launched a policy initiative to advance bioeconomic objectives, it has not

created harmonized rules for biostimulants. Over the years, various industry actors have become involved in lobbying for standardization and harmonization. These include organizations such as the European Biostimulants Industry Council (EBIC), which was formed in 2011 (Le Mire et al., 2015, p. 305). Numerous patented biostimulant formulations are commercially available, and they have long been known for their agronomic benefits in the EU. This result indicates that regulatory fragmentation leads to market barriers (Le Mire et al., 2015, p. 305).

The literature on commercialization prospects reiterates that stakeholder perceptions and information asymmetries matter in market formation. The evolution of biostimulants from merely ecological replacements for conventional inputs to distinct agronomic tools with complementary functions materially affects their adoption (Kapoore, Wood and Llewellyn, 2021, p. 21). Marketing strategies, including educational and demonstration components, efficiently reduce information asymmetries between suppliers and end users (Le Mire et al., 2015, p. 305). In European collaborative networks, trials undertaken by public research organizations have been effective in building scientific credibility and reducing perceived risk (Le Mire et al., 2015, p. 305). This indicates that scientific validation is not only a regulatory compliance requirement for market entry but also a commercialization tool.

According to the innovation theory, there is a distinction between technology push and market pull. In related bio-based sectors, such as lignin applications, there is often a lack of a market pull. These leave technology providers reliant on policy support or cultivating niche markets before they can scale up and commercialize (Wenger, Haas and Stern, 2020, p. 11). In the biostimulant sector, this means that even though we have a strong environmental narrative, demand will be limited unless there are clear policy signals that support the relative substitution of agri-inputs. The European biostimulant market exemplifies this pattern; national regulatory categorizations ranging from free-market access regimes in countries such as Ireland to complete pesticide-style assessments in France directly affect time-to-market and entry sequence decisions (Caradonia et al., 2018b, p. 3). Businesses make a strategic choice to enter friendly jurisdictions before confronting adverse regulatory conditions, reflecting path-dependent learning and incremental entry logic (Caradonia et al., 2018c, p. 3).

From an institutional economics viewpoint, these divergences stem from the unique path dependence of regulatory outcomes defined by different policy legacies rather than technical risk assessment (Sundh, Del Giudice and Cembalo, 2021, p. 6). In Europe, no uniform international regulation is often necessary. The assessment procedures for institutional divergence were non-homogeneous. For example, while France and Hungary apply authorization procedures, such as pesticide assessments, Ireland and the UK have significantly laxer procedures. This leads to an uneven playing field, in which success in easy countries can develop organizational capabilities that may be ill-suited to harder countries (Sundh, Del Giudice and Cembalo, 2021, p. 6). This indicates the need to understand how institutional variety relates to a firm's strategy and adoption.

The sustainability transition literature points to a key divergence between rapid product diversification and standardization capabilities. The rapid increase in the types of biostimulants, such as microbial inoculants, humic substances, and protein hydrolysates, has led to the development of harmonized regulatory and quality control frameworks (Khoulati et al., 2025, p. 4). When market conditions are of this nature, they restrict a product's perceived credibility. Products possessing obvious agronomic advantages. This becomes increasingly challenging when licensing arrangements, intellectual property claims and sustainability verification mechanisms vary across jurisdictions. This raises compliance challenges that do not merely spill over into approval timelines, but also affect ongoing quality assurance and market surveillance requirements.

2.1.2 Adoption of Innovations in Agriculture

Scholars have observed that the adoption of new agricultural innovations can be understood in a diffusion framework, which emphasizes the characteristics that farmers depend on when accepting new practices or technologies. Many scholars have proposed similar attributes to understand the uptake of agri-technology. Relative advantage, compatibility with existing practices, perceived complexity, trialability, and observability were first proposed for domains other than agriculture, but they were fairly robust. Examples include crop variety and digital management tools (Long, Blok and Coninx, 2015, p. 3). Greater perceived compatibility tends to lead to stronger adoption intention, even when some of the other innovation dimensions diverge significantly from one another, because incremental

integration into existing farming systems permits faster diffusion than radical or disruptive innovation (Long, Blok and Coninx, 2015, p. 3).

However, the context of agricultural adoption increases the complexity of individual farmers' decisions. The imitation effects of organizational and community norms among social network operators affect the adoption tendencies. The success of one's neighbor in utilizing a novel practice can adjust one's risk perceptions and economic expectations in ways that formal information sources cannot (Long, Blok and Coninx, 2015, p. 3). Farmers are influenced by the actions of their peers or experts such as agronomists, extension officers, and technical advisors. This is an important momentum driver of adoption in many agricultural studies. Without validation from peers and expert credibility, adoption intention can remain fragile and conditional.

Accumulating evidence has shown the long-term benefits of adopting improved agricultural technologies. However, economic constraints remain at the core of what governs adoption behavior. Farmers live within tight liquidity constraints and must often weigh uncertain benefits against current capital expenditures (Long, Blok and Coninx, 2015, p. 5). When a new innovation needs considerable upfront investments or modifications of existing equipment with a remaining productive life, the effective cost increases substantially beyond the purchase price, which is done by foregoing the use of existing equipment. Even purely technical analyses may favor this cause in the long term, but adoption drag still occurs because of cost inflation. The lack of existing distribution networks for biostimulants and uncertain agronomic responses across different farming conditions increase the uncertainty of costs for possible early adopters.

The design of the innovation must align with farmers' skills to determine the probability of adoption. When there are inadequate skills for technology integration due to insufficient formal education or limited experience with similar systems, successful adoption of the technology is likely to be frustrated despite its feasibility (Long, Blok and Coninx, 2015, p. 5). Although training and extension support can lessen these capability gaps, the institutional infrastructure and time required for these interventions are not uniformly available across the regions.

The adoption tendency is reflected in the uncertain empirical findings of the socio-demographic variables. Some studies have found that older farmers are more resistant to new practices. However, other studies find no effect or positive correlation when controlling for farm size and diversification strategies (Long, Blok and Coninx, 2015, p. 4). This implies that caution should be exercised when using demographic generalization. Classifications based on age do not appear to be predictive of behavioral segments defined by innovativeness, risk tolerance, and learning capability.

Through value chain dynamics, institutional pressure shapes agricultural adoption indirectly and powerfully. According to Osei, Asante-Darko and Quayson, (2024, p. 7), buyers, processors, and retailers are increasingly imposing sustainability requirements that force suppliers to introduce innovations to retain access to the market. Regulatory frameworks change production practices, because they are required. In both instances, adoption exemplifies the adaptive necessity to protect the existing market position and institutional legitimacy rather than an autonomous choice (Osei, Asante-Darko and Quayson, 2024, p. 7). External norms and values can be viewed as constraints and 'enablers' that facilitate change.

Theories integrating structural determinants with actor agencies have acknowledged this duality. Explanations about how innovations are absorbed exist on the one hand when they are compatible with a wider socio-technical regime. By contrast, determined actors change one or more elements of the regime, for example, by altering business model settings or mobilizing additional resources (Lüdeke-Freund, 2019, p. 676). In an agricultural context, producer organizations pool resources to collectively invest in new technologies, illustrating how local actors can change the conditions for adoption by lowering costs to individual producers. By adopting these collective strategies, the economic burden is distributed across networks; however, it would not only be if farm-level decisions were made.

Trialability is important in agriculture because of its long production cycle. Testing new ideas on a small scale within one season before large-scale implementation helps to significantly reduce uncertainty and boost decision confidence (Long, Blok and Coninx, 2015, p. 3). This can be understood through observability. Pilots observe yields from neighboring farms. They observed improved yields, confirmed stress tolerance, and provided other evidence. Such observability is absent in abstract cost-benefit analyses (Long,

Blok and Coninx, 2015, p. 3). Favorable trial results combined with seeing peers using it will often be a tipping point that leads to the widespread adoption of any technology in agri-communities.

Adopters balance adoption enthusiasm with contextual constraints including environmental variability. Innovations that address varying climatic conditions but deliver inconsistent benefits face steeper adoption curves, as negative experiences diffuse quickly through informal networks (Long, Blok and Coninx, 2015, p. 5). When things go wrong, building trust through honest reporting of successes and failures is crucial. Cultural understandings related to traditional farming identities either enable or constrain the uptake of innovations, primarily where conflicts between indigenous practices and introduced technologies represent a site of ongoing friction despite clear functional advantages.

The way technology is adopted does not just depend upon the technical attributes of the innovation but also involves a simultaneous negotiation with economic, social, institutional, and cultural factors. This complexity supports the use of a variety of theoretical frameworks rather than a single-framework explanation.

2.1.3 Regulatory, Market, and Institutional Environments

Earlier research on the impact of regulation and market structures on agri-input commercialization shows that institutional heterogeneity creates deep path dependencies in innovation trajectories. There are differences in regulatory frameworks, market entry requirements, and criteria of institutional legitimacy across jurisdictions, depending on where and when new products gain market traction (Caradonia et al., 2018c, p. 3). The divergence of the EU member states of the European Union relating to the classification, approval timelines, and post-market surveillance of biostimulants creates a fragmented internal market. Consequently, businesses must develop jurisdiction-specific commercialization strategies rather than apply common ones.

The European Union has clear bioeconomic policy objectives that promote sustainable agricultural transition and adoption of biological inputs. However, applications through member-state regulatory frameworks have diverged rather than harmonized. Microbial plant

protection products undergo more or less established authorization processes. In contrast, microbial and non-microbial biostimulants follow frameworks based on fertilizer legislation rather than purpose-built assessment systems (Sundh, Del Giudice and Cembalo, 2021, p. 6). This institutional patchwork means that the classification of novel products, such as lignin-based formulations, may hinge on national interpretations of material origin and claimed agronomic function, creating classification uncertainty for firms planning market entry.

Institutional legitimacy is the degree of appropriateness, reliability, and consistency with the institutional logic of an organization and its products. This is the basic condition necessary for commercial viability in regulated contexts (Suchman, 1995). Organizations unable to gain institutional acceptance face substantial hurdles in regulatory approval, access to capital, and customer adoption (Suchman, 1995). The legitimacy construction process varies among institutional contexts because different regulatory, normative, and cognitive dimensions dominate. Regulatory legitimacy is critically important in technical assessments and evidence contexts. Normative legitimacy through participation in industry associations and peer recognition is crucial in settings that highlight professional standards and joint governance. When cognitive legitimacy is primarily defined by shared cultural meanings, acceptance is a function of cultural fit and narrative coherence of innovation.

According to Rijal et al. (2025, p. 4), institutional theory explains how organizations comply with norms, rules, and cognitive models to gain legitimacy. According to Scott (2014), organizations are subject to three forms of institutional pressure. These are regulative, normative, and cognitive pressure. Each has a specific way of influencing an organization's strategy and adoption patterns. Firms engaged in agricultural biotechnology evaluation and certification adapt product claims, testing processes, and branding strategies to different nationally embedded logics and not solely technical indicators (Scott, 2014). By focusing on the pluralism of different rationalities at various levels, where competing priorities contribute to the evolution of sectors, one can further enhance analysis using institutional logic (Micelotta, Lounsbury and Greenwood, 2017, p. 15). Depending on the power imbalance between present and new competitors, institutional change paths can be adjusted or transformed.

2.2 Core Theoretical Foundation

This section lays the theoretical groundwork for examining the commercialization of lignin-based biostimulants in fragmented European agricultural markets. The section is organized around three important theories, namely Institutional Theory, Diffusion of Innovations Theory and Resource-Based View, which together encompass the regulatory, behavioral, and strategic aspects of market entry and adoption.

2.2.1 Institutional Theory

This helps us understand how organizational strategies and market outcomes are influenced by regulatory, normative, and cognitive structures in society that are embedded in national and sectoral contexts (Scott, 2014, p. 56). The hypothesis illustrates how organizations function in institutional environments that consist of formal rules as well as informal norms and rules that generate rules that define what actors consider legitimate or appropriate (DiMaggio and Powell, 1983, p. 147). According to Suchman (1995), legitimacy is the idea that an organization's actions are appropriate and acceptable within a constructed system of norms and values. Legitimacy is an important resource that organizations require to access markets, obtain regulations, and obtain support from stakeholders.

Scott (2014, pp. 59–60) identified three types of institutions that put pressure on organizations that are distinct yet highly interrelated. The regulative pillar refers to laws, regulations, and sanctions that guide and enable action through coercion (Scott, 2014, p. 59). To operate legitimately, one must comply with regulatory requirements; otherwise, sanctions include exclusion from the market and legal penalties. The normative pillar consists of values, norms, and role expectations that define appropriate means and desirable ends (Scott, 2014, p. 64). Professional associations, industry councils, and certification bodies that set standards for acceptable practice transmit normative pressure (DiMaggio and Powell, 1983, p. 150). Organizations can gain normative legitimacy by conforming to these rules and joining collective governance structures. According to Scott (2014, p. 67), the cognitive pillar pertains to conceptions, cultural schemes, and symbols that constitute the nature of social reality, and through which meaning is created. Cognitive legitimacy refers to the

extent to which an organization is favorably viewed as a concept. It refers to how an organization's form, practice, or product is considered thinkable, natural, or inevitable, drawing support from the culture of the setting (Suchman, 1995, p. 582).

The difference in the strength and configuration of these pillars across jurisdictions creates institutional distance, which is the extent of the difference between the regulatory, normative, and cognitive institutions of the two countries (Kostova and Zaheer, 1999, p. 64). As institutional distance increases, transferring organizational practices and achieving legitimacy become more costly and complicated (Kostova and Zaheer, 1999, p. 71). Organizations that enter institutionally distant markets face two challenges: they need to adopt diverse unfamiliar institutional logics, and their local stakeholders will demand that they establish credibility because their appropriateness or competence is questioned (Kostova and Zaheer, 1999, p. 73).

This study analyzes the mechanisms by which organizations reconstruct their fundamental structures and/or composition through the commercialization of their activities, commodities, services, and/or constituencies. The article's ultimate goal is to evaluate the potential of commercialization to transform the game in which nonbusinesses engage through the introduction of logic, as characterized by Thornton and Ocasio, (1999, p. 804), and how this logic is set in motion. The focus is on institutional logic. Different institutional logics may coexist in or across organizational fields, resulting in pluralistic settings where different, sometimes competing, rationalities guide decision making (Micelotta, Lounsbury and Greenwood, 2017, p. 1887). Organizations must deal with pressure for conformity from multiple institutional referents while making strategic use of pluralism (Micelotta, Lounsbury and Greenwood, 2017, p. 1890). The imposed and emergent processes of institutional change, whether insignificant or disruptive, take similar pathways due to the infrastructural forestages and intra-community organizations retreated towards a defense of incumbent arrangements.

The agricultural biotechnology sector experiences institutional heterogeneity due to different regulatory classification systems, approval timelines, and requirements for evidence from one EU member state to another, despite harmonization attempts. Organizations should modify product claims, testing protocols, and marketing strategies to include nationally

embedded logic, rather than just their technical performance indicators (Rijal et al., 2025, p. 18). The process entails building domestic institutional knowledge as well as developing relationships and linkages with key institutional intermediaries, such as regulatory agencies, professional associations, and farmer organizations (Rijal et al., 2025, p. 21).

2.2.2 Diffusion of Innovations Theory

The diffusion of innovation theory explains the processes through which innovations spread in social systems, and identifies the factors that affect the speed of adoption (Rogers and Everett M, 2003, p. 5). Diffusion, as defined by Rogers and Everett M, (2003), is a social process whereby ideas and information on a new concept are subjectively perceived and transmitted through certain channels over time among members of a social system. According to Rogers and Everett M, (2003), relative advantage, compatibility, complexity, trialability, and observability are innovation attributes that affect adoption decisions in diverse contexts.

Relative advantage is the extent to which an innovation is considered better than the idea it supersedes (Rogers and Everett M, 2003, p. 229). Superiority may be expressed economically through cost savings or revenue enhancement, or through non-economic dimensions, including social prestige, convenience, or satisfaction (Rogers and Everett M, 2003, p. 229). The more advantageous the innovation, the greater the degree of adoption. However, this applies only to an individual's perception, and is conditioned. Compatibility refers to the extent to which an innovation is perceived to be consistent with the existing values, past experiences, and needs of potential adopters. Changes in innovation requiring little change in behavior or fitting in with existing practices are adopted faster than innovations that can only be adopted with a complete break from current practices (Rogers and Everett M, 2003, p. 241). According to Rogers "In addition to political and technical integration, compatibility also means normative and cultural harmony with the community's own values and identity "(2003, p. 244).

Rogers and Everett M, (2003, p. 257) explains that complexity is the degree of difficulty in understanding and using innovation. Complexity perception hinders adoption because of increased learning costs and amplification of perceived implementation risks (Rogers and

Everett M, 2003, p. 257). Trialability refers to the extent to which an innovation can be tested on a limited basis before its adoption(Rogers and Everett M, 2003, p. 258). The capacity to test innovations helps diminish uncertainty for potential adopters by facilitating learning by doing as opposed to learning by being told. The measure of how observable the results of an innovation are to others is referred to as observability (Rogers and Everett M, 2003, p. 258). Visible innovations are frequently discussed with peers and circulate more rapidly through demonstration effects and social learning mechanisms.

The model classifies five adopter categories, which, according to Rogers and Everett M, (2003, p. 267), "differ in their innovativeness. This is defined as the degree to which an individual (or other unit) adopts new ideas relatively earlier than members of the system. Innovators constitute approximately 2.5% of the population. They are venturesome, have money, and tolerate high risks. Innovators are gatekeepers of new ideas that enter a system (Rogers and Everett M, 2003, p. 282). Individuals classified as early adopters (13.5% group) are best viewed as integrated opinion leaders, whose adoption decisions reduce uncertainty for others and trigger a broader diffusion of innovative ideas or behavior. The early majority, comprising 34 per cent of the population, had technology adoption patterns immediately prior to the average member of a system. According to Rogers and Everett M, (2003, p. 284), they connect previously unconnected members of a social system. The late majority (34%) tend to approach new innovations with skepticism and adopt them only when peer pressure or economic necessity strips away uncertainty (Rogers and Everett M, 2003, p. 284). According to Rogers, laggards are traditionalists who had a reference point in the past. They have limited network and resources (Rogers and Everett M, 2003, p. 285).

Communication channels refer to the ways in which messages are sent from their sources to receivers. According to Rogers and Everett M, (2003, p. 18), these channel communication channels in this case have an impact on diffusion. Mass media channels are effective in creating awareness and knowledge, but for persuasion and actual decision-making, interpersonal channels that allow face-to-face exchanges are considered much more effective (Rogers and Everett M, 2003, p. 205). Homophily refers to the extent to which two or more interacting individuals have similar attributes. Homophily generally makes the communication more effective. However, it can act as a barrier to diffusion between groups, which differ mainly in their socioeconomic status (Rogers and Everett M, 2003, p. 306).

Change agents are individuals who influence clients' innovation decisions in a direction deemed desirable by a change agency. Change agents bridge structural holes when they both possess technical expertise and have empathy for client needs (Rogers and Everett M, 2003, p. 366).

According to Long, Blok and Coninx, (2015, p. 3), agricultural innovations require trialability and observability to become more attractive because they have a long production cycle, high capital outlay, and site-specific agronomic variability. Farmers require credible, context-relevant evidence of performance before committing to full-scale adoption (Long, Blok and Coninx, 2015, p. 7). According to (Long, Blok and Coninx, 2015, p. 9), demonstration plots and testimonies from peers are better suited to alleviate perceptions of risk than claims or endorsements. The intentions to adopt are shaped strongly by social influence mechanisms, such as peer networks and community norms, rather than individual cost-benefit assessments (Völlink, Meertens and Midden, 2002, pp. 308–310).

2.2.3 Resource-Based View

According to the resource-based view (RBV), firms can be considered a bundle of resources and capabilities, and the possession and use of firm resources can lead to a competitiv(Barney, Jay, 1991, p. 101)(Barney, Jay, 1991, p. 101). Resources include all assets, capabilities, organizational processes, attributes, information, and knowledge controlled by a firm, which enables it to conceive and implement strategies that improve its efficiency and effectiveness (Barney, Jay, 1991, p. 101). A resource can be a source of sustained competitive advantage if it satisfies four criteria commonly expressed with the VRIO acronym: valuable, rare, imperfectly imitable, and organized (Barney, Jay, 1991, pp. 105–112; Barney, Jay B., 1995, p. 50).

When resources are valuable, they allow organizations to exploit opportunities and/or neutralize threats to their environment to improve performance. The value of resources is determined by the competitive and institutional environment in which organizations function (Barney, Jay, 1991, p. 106). Resources that are valuable in one setting may be irrelevant or even harmful in another setting, requiring case-by-case assessments rather than a general classification (Barney, Jay B., 1995, p. 51). According to Barney (1991), a resource is rare

if only a few current or potential competitors possess it. If competitors can emulate or replace resources, being rare will not provide an advantage (Barney, Jay, 1991, p. 107).

Imperfect imitability arises from three sources: a firm's unique historical conditions that determine the resource endowment of the firm; causal ambiguity that prevents rivals from understanding how a firm's resources and capabilities give rise to competitive advantage; and the social complex that exists in the firm's valuable interpersonal relationship, culture, or core competency (Barney, Jay, 1991, pp. 107–110). The historical conditions of firms give rise to path dependencies with the result that resource configurations are determined by a non-replicable sequence of decisions and experiences (Barney, Jay, 1991, p. 108). Competitors are unable to identify resources that provide an advantage. Similarly, they cannot understand how to duplicate the resources. This occurs even when competitors are aware of superior performance. Barney defines social complexity as the resources that entail some sort of coordination and integration across different individuals and groups in ways that cannot be systematically managed or deliberately created. Organizational embeddedness refers to the embedding of valuable, rare, and inimitable resources into structures, systems, and routines that allow for their effective use (Barney, Jay B., 1995, p. 57). Strategic resources may not be exploited and may not yield an advantage without suitable organizational support (Barney, Jay B., 1995, p. 58)

Dynamic capabilities are intended to build on RBV by making it possible to understand how organizations build, integrate, and reconfigure resource portfolios in response to changing environments (Teece, Pisano and Shuen, 1997, p. 516). Organizations can use these capabilities to sense opportunities and threats, seize opportunities through the mobilization and reconfiguration of existing resources, and transform them through the continuous renewal of resource bases (Teece, 2007, pp. 1319–1322). The act of sensing consists of scanning, searching, and exploring technologies and markets to identify opportunities (Teece, 2007, p. 1322) to create or configure the business model appropriately. Securing or seizing claims that value comes from opportunities to make decisions and mobilize resources (Teece, 2007, p. 1326). Transforming refers to the ongoing renewal of the continuous flow of resource endowments through recombination, reconfiguration, and redeployment as markets and technologies shift (Teece, 2007, p. 1335).

In regulated industries, regulatory literacy and compliance expertise are strategic assets when they are scarce, difficult to imitate, and embedded in the organization (Svensson et al., 2018, p. 975). When organizations have knowledge of key industrial developments for drugs and devices, products can be positioned correctly, approvals can be expedited, and regulation changes can be predicted (Yee et al., 2021, p. 11). The use of proprietary technologies or methodologies may qualify as process know-how and can provide differentiation when it leads to superior performance, and imitability is prevented through causal ambiguity or social complexity (Parida, Sjödin and Reim, 2019, p. 4). Partnerships with suppliers, distributors, or research institutions are relational resources that help obtain access to complementary assets and reduce transaction costs (Gulanowski, Papadopoulos and Plante, 2025, p. 54). According to Teece (2007, p. 1320), the competitive value of the resources that the MNE uses depends on asset usage in the context of competition.

2.3 Complementary Strategic Frameworks

This section introduces analytical frameworks that operationalize core theoretical insights for empirical investigation: PESTEL for macro-environmental analysis, Business Model Canvas with Triple Bottom Line for value creation assessment, and Uppsala Model for internationalization sequencing.

2.3.1 PESTEL Framework

The PESTEL framework brings forth systematic structures of macro-environmental factors that offer an opportunity to constrain an organization (Hollensen, 2020, p. 110). The framework breaks down the environment into Political, Economic, Social, Technological, Environmental and Legal dimensions to identify trends, discontinuities, and scenario contingencies influencing strategic viability can be identified (Bruijl, 2018, p. 10; Siegfried et al., 2023, p. 4). The various dimensions encompass different forces that organizations must keep in check and respond to strategically.

Political factors include government policies, political stability, regulatory priorities, and public sector measures. Some of these measures include subsidies, procurement preferences,

and tra(Hollensen, 2020, p. 110)(Hollensen, 2020, p. 110). The attractiveness of a given market will improve or worsen when these factors change their incentive morphed, entry barriers are created (or removed), or they impact competition (Gawel, Pannicke and Hagemann, 2019, p. 4). Inflation rates, exchange rates, income levels, access to capital, and overall macroeconomic conditions affect the range of purchases and the possibility of making an investment (Bruijl, 2018, p. 10). According to Bruijl (2018, p. 12), organizations need to examine cost structures that permit competitive pricing and assess whether target markets have sufficient economic capacity to support demand.

The cultural, demographic, and societal trends that affect consumer preference, as well as conformity toward innovation and sustainability, are social factors (Siegfried et al., 2023, p. 5). This demand is shaped by such factors, which can act as barriers to adoption itself and the effectiveness of marketing messages (Gawel, Pannicke and Hagemann, 2019, p. 8). Technological choice is related to the direction and pace of changes in various technologies, which can otherwise affect effectiveness. Moreover, this technology should be effective for the purposes of the project. Mature technologies should be chosen and relevant supporting technologies must be available (Siegfried et al., 2023, p. 5). Technological preparedness affects both supply side capacity and demand-side willingness to adopt innovation (Bruijl, 2018, p. 12).

Environmental factors include ecological effects, climate change pressure, pressure on natural resources, and regulatory responses to environmental challenges (Siegfried et al., 2023, p. 5). In light of the increasing stress to either prove environmental performance through life cycle assessment or to align with sustainability objectives (Gawel, Pannicke and Hagemann, 2019, p. 15). Legal aspects include regulatory frameworks, compliance requirements, liability regimes, and intellectual property(Hollensen, 2020, p. 110)(Hollensen, 2020, p. 110). When the rules are clear and predictable, the compliance cost and uncertainty will be lower. In contrast, ambiguity and stringency create barriers that require specialized capabilities (Siegfried et al., 2023, p. 4).

PESTEL gains analytical power not from investigating each of the dimensions independently, but from looking at the interdependencies between the dimensions (Bruijl, 2018, p. 12). Favorable political backing, clear legal frameworks, and technological

readiness create good conditions for commercialization. Unfavorable configurations of multiple dimensions create heavy barriers (Bruijl, 2018, p. 13). Organizations must be able to look at not only the present states but also the paths as well as scenario changes across dimensions to identify strategic inflection points (Gawel, Pannicke and Hagemann, 2019, p. 12).

2.3.2 Business Model Canvas and Triple Bottom Line

The Business Model Canvas (BMC) relates to how organizations make, deliver, and capture value. The BMC consists of nine components: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure (Osterwalder, 2010, p. 14). The Canva makes explicit the logic that connects value creation with value capture. The canvas thus creates a common language for describing, analyzing, and innovating business models (Osterwalder, 2010, p. 15). Customer segment organizations split their customer base into groups that share similar needs, common behaviors, or other attributes. They offer more targeted offerings (Osterwalder, 2010, p. 20). A value proposition is a description of the mix of products and services that creates value for a specific customer segment by solving a customer problem or satisfying a need (Osterwalder, 2010, p. 22).

According to Osterwalder (2010, p. 26), how organizations reach customers to communicate and deliver value propositions are channels. This includes distribution and sales functions. Customer relationships refer to the relationships that a company establishes with specific customer segments. For instance, for a market-offering service system, the model should be personal assistance and an automated service (Osterwalder, 2010, p. 28). Revenue streams are the cash generated by businesses from each customer segment. Cash generation is based on the specific form of transactions a business has with its customers. Possible forms of transactions include asset sales, usage fees, subscription fees, and licensing (Osterwalder, 2010, p. 30). Key resources are the most vital assets required to enable a business model to work (Osterwalder, 2010, p. 34). Key activities are the most important actions the organization must take to operate successfully, such as production, problem solving, or platform management (Osterwalder, 2010, p. 36). The critical partners are the network of suppliers and partners that make the business model work (Osterwalder, 2010, p. 38). The

cost structure comprises all costs incurred by a business model. These costs can be either cost- or value-driven (Osterwalder, 2010, p. 40).

The Triple Bottom Line (TBL) framework further analyzes a business model. It requires considering economic, environmental, and social performance (Elkington, 1998, p. 397). According to TBL, sustainable business models should generate value across all three spheres, instead of maximizing economic returns, while viewing environmental and social effects as externalities (Svensson et al., 2018, p. 975). According to Svensson et al. (2018, p. 976), economic performance is related to profitability, cost-effectiveness, revenue growth and financial sustainability. Environmental performance entails the consumption of various resources as well as emissions, effluents, and waste generation, and their impacts on the ecosystem (Svensson et al., 2018, p. 977). Social performance refers to labor practices, community, product safety, and contribution to society (Svensson et al., 2018, p. 978).

The triple-layered business model canvas (TLBMC) translates TBL thinking into practice with three parallel canvases economic, environmental, and social that must be aligned vertically to ensure coherence across dimensions (Joyce and Paquin, 2016, p. 1475). The environmental layer identifies the environmental impacts and benefits associated with the different business model components that map the inputs, outputs, and ecological footprints. (Joyce and Paquin, 2016, p. 1476). The social layer allows the identification of stakeholders affected by a component and the nature of its impact (Joyce and Paquin, 2016, p. 1478). According to Joyce and Paquin, (2016, p. 1480), vertical alignment is the process through which value propositions, activities, and partnerships advance economic viability, environmental regeneration, and social benefits.

It is common to encounter trade-offs between the dimensions that need to be managed and communicated to stakeholders (Svensson et al., 2018, p. 984). Creating more environmental value may increase costs and reduce short-term profitability. Similarly, creating social value through local employment and capacity development may limit operational flexibility (Svensson et al., 2018, p. 985). A successful TBL business model identifies synergies among the three dimensions so that investments benefiting from one dimension will bring co-benefits within the others. For example, resource efficiency improvements decrease costs and environmental impact (Svensson et al., 2018, p. 986).

2.3.3 Uppsala Internationalization Model

The Uppsala Internationalization Model characterizes international expansion as a gradual process driven by learning, wherein companies increase their commitment to foreign markets as they develop experiential knowledge about them (Johanson and Vahlne, 2009, p. 1411; Johanson, J. and Vahlne, 1977, p. 23). The model depicts the relationship between state variables market knowledge, as well as market commitment and change variable commitment decisions, and current business activities that interact dynamically over time (Johanson, J. and Vahlne, 1977, p. 26). Knowledge of the market, and more specifically, experiential knowledge gained through operations on the market, makes the organization more able to see opportunities and assess risks of the operations (Johanson, J. and Vahlne, 1977, p. 28). Market commitment refers to the extent to which organizations commit resources to a market, or, in other words, the opportunity cost of not exiting the market (Johanson, J. and Vahlne, 1977, p. 27).

Organizations tend to enter a market that is psychologically close. This involves less cultural, institutional, and geographic distance from the home market, and more distant markets thereafter (Johanson, J. and Vahlne, 1977, p. 24). According to (Johanson, J. and Vahlne, 1977, p. 24), psychic distance" refers to factors that are likely to disrupt or interfere with the flow of information between organizations and markets; these factors are differences in language, culture, political systems, and business.. The existence of such factors creates consciousness of the risks associated with business entry and influences entry sequencing. Organizations follow an establishment chain, starting from low commitment modes, such as exporting through independent agents to sales subsidiaries, and finally setting up production facilities as their knowledge increases and perceived risk decreases (Johanson, J. and Vahlne, 1977, p. 25).

The 2009 revision developed a network interpretation that acknowledges that the nature of the relationship and position in the network matters as much as market knowledge when it comes to internationalization patterns (Johanson and Vahlne, 2009, p. 1411). Organizations with networks benefit from gaining knowledge and resources through relational ties, which also give them legitimacy. Therefore, they internationalize faster than isolated ones. (Johanson and Vahlne, 2009, p. 1424). The revised model discards psychic distance,

asserting that being excluded from a relevant network is a larger barrier than being geographically or culturally distant (Johanson and Vahlne, 2009, p. 1415). Network insidership offers privileged access to market information, lower transaction costs, and greater legitimacy through association (Johanson and Vahlne, 2009, p. 1416).

Firms that are information-intensive, have extensive international experience, or enter markets where speedy initiation is strategically important have boundary conditions that limit the universal applicability of the model (Gulanowski, Papadopoulos and Plante, 2025, p. 50). Born global firms circumvent gradual commitments by entering several markets simultaneously. This is accomplished by leveraging pre-existing networks, standardized products, or digital platforms (Schweizer and Vahlne, 2022, p. 585). First-mover benefits in emerging markets or technologies may justify giving an accelerated commitment, even though one has little experiential knowledge forward (Zachary et al., 2015, p. 1390). Despite the invocation of new strands of the literature, the main message of this trademark study is that experiential learning reduces uncertainty, thereby enabling increased commitment (Johanson and Vahlne, 2009, p. 1424).

To sustainably commercialize agri-inputs, incremental sequencing allows organizations to improve value propositions, confirm effectiveness claims, and build regulatory capacities in easier markets before engaging with tough or complex ones (Sakarya, Eckman and Hyllegard, 2007, p. 210). Early market experiences create knowledge related to institutional logics, stakeholder expectations, and barriers to adoption that inform subsequent entry strategies (Sakarya, Eckman and Hyllegard, 2007, p. 225). Connections with distributors, farmer cooperatives, and research institutions provide access to markets and are used to reduce the liabilities of foreignness and outsidership (Johanson and Vahlne, 2009, p. 1423).

2.4 Synthesis of Theory And Conceptual Framework

To commercialize lignin-based biostimulants across heterogeneous European markets, it is necessary to develop an integrated analytical framework combining macro-level institutional analysis, meso-level organizational strategy, and micro-level adoption dynamics. According to Scott (2014, pp. 59–67), Institutional Theory explains how regulatory heterogeneity, normative pressures, and cognitive schemas create differentiated opportunity structures and

legitimacy requirements in France, Germany, and the Netherlands. To gain durable access to the market, firms must obtain regulative legitimacy through regulation, normative legitimacy through professional endorsement, and cognitive legitimacy through cultural alignment (Suchman, 1995, pp. 577–585). Institutional distance compounds these difficulties, as firms need to adjust to logics that are new while making massive investments in local knowledge development (Kostova and Zaheer, 1999, pp. 71–73).

Diffusion of Innovations Theory attempts to explain the relative adoption rates of a variable in terms of the attributes of innovations and social systems (Rogers and Everett M, 2003, pp. 229–266). The adoption of lignin-based biostimulants by farmers and value chain actors is superior to existing alternatives, and sufficiently compatible with existing practices is influenced by relative advantage, compatibility, complexity, trialability, and observability (Rogers and Everett M, 2003, pp. 229–258). According to Rogers and Everett M, (2003, p. 205) and Long, Blok and Coninx, (2015, p. 9), information flows are mediated by communication channels and opinion leaders. In addition, interpersonal networks are more powerful than mass media in persuading people to decide on agriculture.

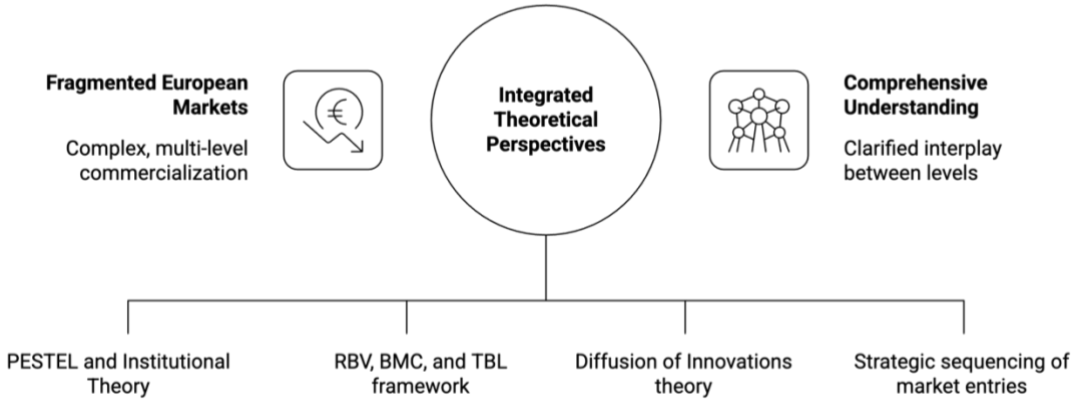
The Resource-Based View reveals that organizations can derive value from commercialization opportunities thanks to certain internal capabilities available to them, which help overcome institutional barriers (Barney, Jay, 1991, pp. 105–112). Strategic resources are regulatory expertise, proprietary process technologies, and network relationships, which are valuable in all contexts, rare among rivals, difficult to imitate (for example, because of causal ambiguity or social complexity), and organization-embedded in culture, routines, and systems (Barney, Jay, 1991, pp. 106–110; Barney, Jay B., 1995, pp. 50–57). According to Teece, Pisano and Shuen, (1997, pp. 1322–1335), dynamic capabilities allow organizations to perceive institutional and market changes, seize opportunities through the reconsolidation of resources, and transform operations.

Theoretical insights into complementary frameworks can be operationalized strategically. PESTEL analysis systematically scans crucial political, economic, social, technological, environmental, and legal dimensions to identify country-specific drivers and barriers (Bruijl, 2018, pp. 10–12; Hollensen, 2020, p. 110). The Business Model Canvas defines how organizations arrange customer segments, value propositions, channels, partnerships, and

cost-revenue structures to create and capture value (Osterwalder, 2010, pp. 14–44). Integration of the Triple Bottom Line ensures that business models contribute to economic viability, environmental performance, and social value creation. This addresses sustainability imperatives of central importance to biostimulant positioning (Elkington, 1998, p. 397; Joyce and Paquin, 2016, pp. 1475–1480). The Uppsala Model suggests that companies commit to overseas markets sequentially. Companies' commitment will continue to increase gradually as they acquire more experiential knowledge and become more embedded in networks (Johanson and Vahlne, 2009, pp. 1411–1424).

The integrated framework combines these viewpoints into a multilevel model connecting macro-institutional environments, meso-organizational strategies, and micro-adoption processes. At the macro level, the institutional configuration and PESTEL factors define opportunity spaces and constraint structures that differ by France, Germany, and the Netherlands. At the meso level, the capabilities of organizations and business models influence competitive positioning and embedded value capture potential. The adoption trajectories of farmers, value-chain actors, and other rural dwellers are influenced by social system dynamics and innovation characteristics. The Uppsala Model bridges levels to indicate how organizations develop capabilities and deepen commitments through learning cycles conditioned by institutional distance and access to networks. The resulting integrated multilevel conceptual framework is shown in Figure 2.

Figure 2: Integrated Conceptual Framework for the Commercialization of Lignin-Based Biostimulants in Fragmented European Markets



Source: Author's own elaboration

The above figure brings together the key concepts for analyzing a firm's successful entry and scaling in a foreign market. The PESTEL framework and Institutional Theory describe the firm's macro-institutional environment. The resource-based view and value-creation business model canvas frameworks describe a firm's (meso-level) chosen strategy and business model. The diffusion of innovation theory explains micro-level dynamics of adoption. Finally, the Uppsala Model synthesizes how firms internationalize internationally.

This framework helps to shape the research questions and hypotheses. The first research question focuses on stakeholders' perceptions of the benefits of and barriers to this innovation. This study draws primarily on the diffusion of innovation and institutional theories. Through the associated return on investment and institutional context, these theories can help decode how innovation attributes influence perceptions of opportunities and constraints. The second research question that analyzes the regulatory and institutional factors conditioning commercialization pathways relies on institutional theory, PESTEL analysis, and the Uppsala model. This study examines how institutional heterogeneity and distance influence firms' market entry strategies. Research Question 3 identifies feasible commercialization strategies integrating the Resource-Based View, Business Model Canvas, Triple Bottom Line and Uppsala Model, articulating how organizations configure their resources, business model, and the sequence of their internationalization to penetrate the market sustainably.

2.5 Identified Knowledge Gaps

Although sustainable agricultural inputs are receiving much attention from stakeholders, the literature on commercialization has focused only on technical, regulatory, and strategic issues. Moreover, various perspectives have yet to be integrated to understand the dynamics of market formation. These three primary gaps constrain the current understanding and motivate this research.

First, existing studies examine technical performance and regulatory frameworks in isolation. It fails to systematically analyze how stakeholders embedded in various institutional contexts perceive and respond to overlapping technological, economic, and institutional uncertainties of biostimulants (Caradonia et al., 2018c, p. 15; Khoulati et al.,

2025, p. 9). Trials that test whether agronomic input is effective are referred to as agronomic trials. The Regulatory impact assessments that trace the approval processes and economic benefit analysis of a trial all assume that farmers, their advisors, and distributors think and behave in a certain way when making borrowing decisions. One study found that the evidence is not sufficiently strong for these beliefs (Long, Blok and Coninx, 2015). This study addresses this gap through comparative stakeholder surveys in France, Germany, and the Netherlands, which jointly assess perceived benefits, risks, regulatory clarity, and contextual constraints. Second, while regulatory heterogeneity across EU member states is well documented, insufficient attention addresses how institutional distance shapes commercialization strategy choices, including market entry sequencing, resource deployment priorities, and capability development pathways (Caradonia et al., 2018c, p. 9; Sundh, Del Giudice and Cembalo, 2021, p. 6). According to (Gawel, Pannicke and Hagemann, 2019, p. 12), PESTEL studies at the macro-level explain the conditions of countries. This thesis integrates Institutional Theory, the Uppsala Model, and internationalization perspectives to empirically examine how regulatory and institutional variations condition perceived commercialization pathways and entry sequence preferences. Third, the business model and sustainability literature conceptually discusses value proposition design and TBL performance, but rarely connects these frameworks to operational choices required for scaling biological inputs under regulatory and market uncertainty (Joyce and Paquin, 2016, p. 1482; Svensson et al., 2018, p. 986). The empirical work that has been conducted on biostimulants is not concerned with strategic management but rather with agronomics and regulatory analysis (Wenger, Haas and Stern, 2020, p. 11). This thesis bridges this gap by combining Business Model Canvas, Triple Bottom Line, Resource-Based View, and internationalization theories with cross-country stakeholder data to generate context-specific insights into the business model configuration and market entry strategy for lignin-based biostimulants.

Collectively, these contributions contribute to our understanding of the interactions between stakeholder perceptions, institutional contexts, and strategic configurations that enhance or undermine the commercialization of sustainable agricultural innovation across fragmentation in European markets.

3 Contextual Analysis - Industrial and Technological Environment

Translating theoretical frameworks and commercialization principles into actionable insights requires grounding analysis in empirical market realities and specific institutional contexts. This chapter provides a detailed contextual description of lignin-based biostimulants as products, industry structures, and value chains aswell as differentiated regulatory and policy environments across France, Germany, and the Netherlands. This chapter contrasts the universal commercialization dynamics relevant to different bio-based agricultural entry sectors with distinct institutional logics, policy environments, and market structures in countries that create distinct product-market entry and adoption pathways.

This chapter aims to lay the empirical foundations that illustrate why the theories laid out in Chapter 2 matter and how they work concretely in specific market contexts. Generic commercialization theory provides explanatory leverage only when grounded in context-specific markets. By describing the state of lignin-based biostimulant technology, industry structure, EU regulatory frameworks, and country-specific policy environments, this chapter enables subsequent empirical analysis to link stakeholder perceptions and adoption behaviors to concrete institutional factors and market conditions that motivate and constrain commercialization activities.

3.1 Lignin Chemistry and Wastes to Value Transformation

Lignin is the most prevalent renewable polymer feedstock in Europe; however, it has been underutilized as a by-product of the pulp and paper industry. Research has shown that this complex aromatic biopolymer can be transformed into bioactive compounds that elicit physiological responses in plants (Ekielski and Mishra, 2020, p. 13; Mastrolitti et al., 2021, p. 6; Vural Gursel et al., 2019, p. 2).

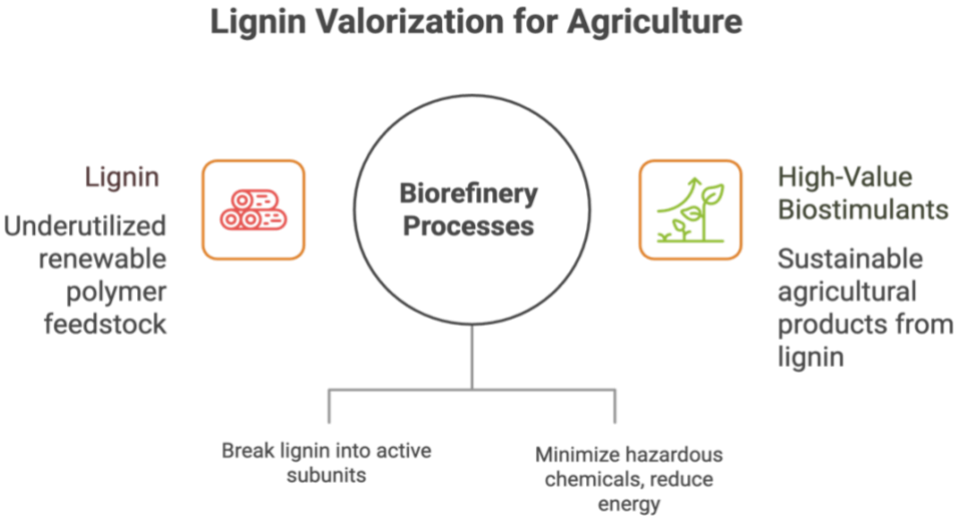
The term 'biostimulant' has been applied to products that can improve plant growth, tolerance, and resilience through mechanisms that are not related to nutrient supply or pests and/or disease suppression (Du Jardin, 2015, p. 3; Khoulati et al., 2025, p. 2; Le Mire et al.,

2015, p. 300). The term lignin-based biostimulants is used in this thesis to refer to agricultural products made from lignin, which is a by-product of the forestry and pulp sectors. These products stimulate physiological processes, improve nutrient uptake, and improve resilience to environmental stress in plants. Under current European legislation, these products do not meet the qualifications to be utilized as fertilizers or pesticides (Du Jardin, 2015, p. 3; Khoulati et al., 2025, p. 4).

Selective depolymerization of lignin into smaller biopolymers or subunits is necessary for the agronomic effects of lignin-based biostimulants to occur (Chen et al., 2022, p. 3; Gillet et al., 2017, p. 4200; Khoulati et al., 2025, p. 4; Mastrolitti et al., 2021, p. 6). Recently, biorefinery processes have been developed that rely on green chemistry (which includes minimal chemical and energy use and a closed-loop system) to maximize environmental sustainability and market (Ekielski and Mishra, 2020, p. 2967; Gillet et al., 2017, p. 4200; Jiju et al., 2025, p. 3).

Globally, more than 50 million tons of lignin is generated each year in the pulp and paper industry, primarily for low-value applications such as combustion (Mastrolitti et al., 2021, p. 5). New biorefinery processes convert these waste streams into value-added and environmentally friendly (Mastrolitti et al., 2021, p. 5). Figure 3 outlines this transition towards sustainability using green biorefinery practices.

Figure 3: Green biorefinery process for agricultural applications



Source: Author's own elaboration

The above Figure 3 shows the transformation of pulp mill lignin waste through selective depolymerization and green chemistry processes, which minimize the use of hazardous chemicals and energy while yielding bioactive lignin fractions suitable for formulation into biostimulant products for agricultural applications.

3.2 Environmental Benefits and Circular Economy Integration

Lignin valorisation is technically feasible and offers both environmental and economic benefits. Lignin-derived biostimulants mitigate reliance on artificial fertilizers and pesticides, thereby decreasing the nutrient flux into waterways, reducing GHG emissions from fertilizer production, and reducing soil contamination (Upton and Kasko, 2016, p. 2275). Studies have shown that compounds derived from lignin stimulate plant growth, promote soil microbial communities, and improve plant resistance to abiotic stresses (Mastrolitti et al., 2021, p. 7334). All the above are quantified benefits that can provide a mechanism to support the adoption of lignin biostimulants as flagship products in implementing circular economies within agri-food systems (Khoulati et al., 2025, p. 2).

In a circular economy, lignin side-streams (or lignin fractions) change from waste management (regulatory costs) to opportunities for resource efficiency (value creation). The circular economy recasts materials and by-products not as waste but as renewable feedstock for high-value agricultural products, with lignin side-streams as the default example. Lignin-derived biostimulants can be integrated throughout the entire food system's value chain in proximate circular-economy pathways, with the required organizational change across resource management, activity flows, and stakeholder relationships from feedstock sourcing to post-consumption integration (Lüdeke-freund, Gold and Bocken, 2018, p. 18). In linear systems, product value is lost during finite allocation.In contrast, circular economy arrangements integrate materials back into productive use without degrading value (Imbert et al., 2017, p. 6).

Traceability systems, including QR codes, can connect lifecycle data to support compliance with circular economy strategies and build consumer trust by highlighting both carbon emission savings and local employment opportunities resulting from easing EU sustainability compliance reporting (Fu et al., 2022, p. 7).

3.3 European Union Regulatory Framework

The European Union Fertilizing Products Regulation has introduced a legal framework for biostimulants to harmonize their definition and conformity assessment in all Member States (Khoulati et al., 2025, p. 3). This harmonization departs from Regulation (EC) No 2003/2003, which focuses on inorganic fertilizers and does not sufficiently manage organic and organo-mineral products (Caradonia et al., 2018c, p. 21). The new framework lowers barriers to cross-border trade and supports innovation, while reducing the risk of heavy metal contamination.

Despite this common regulatory framework, the enforcement of regulatory rules and attendant practices in Member States has diverged significantly (Traon et al., 2014, p. 21). Firms planning to expand into multiple countries must therefore prepare compliance strategies tailored to product specifications in codes, such as maximum contaminant levels or labelling requirements, along with country-specific expectations around efficacy data and sustainability claims. For instance, local authorities in Germany and France may require additional proof of field performance under their agro-climatic conditions before full access to the market can be granted (Savy and Cozzolino, 2022, p. 2).

Updated regulations for lignin-based biostimulants favor explicit positioning within the EU circular bioeconomy framework. Lignin valorization is a legislative priority for reusing industrial residues in integrated waste-reduction strategies (Rijal et al., 2025, p. 9). Even so, there is competition for resources, as some waste streams suitable for biostimulant production may compete with a higher value, such as fine chemical extraction or animal feed production (Xu and Geelen, 2018, p. 4). Regulatory frameworks do not factor in end-use channels within the bioeconomy; therefore, firms must consider supply constraints when making projections of scalability.

Depending on the risk category level of a particular product, CE marking requires either a third-party certification module or self-declaration module. Harmonization lowers transaction costs for pan-European distributions, but technical barriers persist. It is essential to adhere to elaborate testing protocols to substantiate agronomic claims, especially for heterogeneous products, such as lignin-derived biostimulants, which adopt different modes

of action from those of classical agri-inputs (Khoulati et al., 2025, pp. 4–5). Field tests that resemble local cropping systems areimportant regulatory and market requirements for end users.

Companies entering consultation processes early through industry associations, such as the EBIC, may influence interpretative guidance documents that clarify approval requirements or performance thresholds relevant to lignin-based products (European Biostimulants Industry Council (EBIC), 2025; New AG International, 2025). When applications are in the pipeline for markets, it makes sense to check for such guidance to make it easier to obtain approval. The triple-bottom-line assessment must include the compliance cost from a sustainability perspective. Substitution with lignin products has a positive impact on the environment and aligns with the sustainability criteria of the EU. However, non-economic viability incurs costs related to laboratory testing, dossier preparation, and auditing of quality control measures (Ricci et al., 2019). To develop beneficiary narratives, an important dimension is the organization of farmer training or education programmes. Companies need to position regulatory approval as evidence of safety and consistent performance, and funding these programs can incorporate a compliance narrative.

3.4 National Regulations and Compliance Requirements

The national regulatory framework in EU Member States influences the commercialization strategies of lignin-derived biostimulants. The Fertilizing Products Regulation establishes a baseline of requirements, country-specific administrative practices, market surveillance procedures, and additional requirements in place that affect time-to-market and cost structures (Caradonia et al., 2018c; European Biostimulants Industry Council (EBIC), 2025).

Germany's amendments to agricultural input laws have expanded the list of authorized plant strengtheners from 209 to 265 products (Caradonia et al., 2018a, p. 4), signalling openness to innovation within a rigorously codified approval process. Gaining approval for this nature typically requires submission of detailed agronomic performance data generated under local conditions. The relevant authorities typically deem any data generated in other jurisdictions

to be less than fully applicable owing to climatic and soil-related differences. To prepare the market, investments in localized field trials must be made early on.

France continues to exhibit distinctive traits, shaped by its long-standing reliance on national certification mechanisms and regional agricultural advisory authorities. Even if CE marking provides access, French agencies can require additional viewpoints related to environmental safety or the compatibility of a product with organic farming. The dependency is on the target distribution channel (Caradonia et al., 2018c; Traon et al., 2014). To access higher-value customer segments, products targeted at the organic segment must comply with the national organic certification schemes. When businesses create market segmentation, it is important to comply with regulatory requirements.

The Netherlands' administrative landscape can be considered flexible for bio-based innovation, especially when framed within policy-endorsed circular economic targets. Nevertheless, voluntary eco-labelling systems can exert a significant influence, particularly through the actions of cooperatives that supply the horticulture export sector with sustainability branding (Caradonia et al., 2018c). Lignin-derived biostimulants targeting Dutch high-value crops may eventually become market access conditions for the recognition of such schemes. Examples of informal institutional norms impacting entry strategies are as practical as formal regulations.

3.5 Cross-national Compliance Considerations.

Compliance is not restricted by rules or regulations. As analytical method validation is a central element of regulatory dossiers, authorities expect methods to be sufficiently precise, accurate, reproducible, specific, and applicable within relevant business sectors (Traon et al., 2014, p. 70). For assay types that do not yet have harmonized standards, which are common in emerging product categories, such as lignin derivatives, companies may need to sponsor collaborative studies at accredited laboratories. The activities and resources identified in these requirements are key inputs to the business model and require proper planning and resources.

Terminological differences further complicate the compliance trajectories. Plant biostimulant terminology differs in various countries, and some non-EU countries use the term "biofertilizers," which can create misunderstandings during import/export conversations (Caradonia et al., 2018c, p. 9). In Europe, translators and product class definitions written in national law can change what markets say and label and how this is done for different customer segments. Attention should be paid to the regulatory treatment of feedstock origin.Under EU Regulation 2018/848 on organic production, specific nutrients must meet requirements regarding origin (Kapoore, Wood and Llewellyn, 2021, p. 18). A constant examination of lignin sources is required, particularly if waste streams contain co-contaminants of animal or industrial origin. Companies could proactively introduce traceability from pulp mills to ensure compliance and secure their supply chain, which would also strengthen key partnerships in the business model and support environmental sustainability.

Regulatory approval does not guarantee immediate market uptake; some actors remain skeptical of biostimulants as "non-essential" products unless tangible benefits are demonstrated (Kapoore, Wood and Llewellyn, 2021, p. 21). At times, national governments will attempt to fill this gap by running farmer education campaigns or integrating them into subsidy schemes to encourage sustainable practices. The social aspect of the triple bottom line refers to the fact that what market participants accept depends on changes in perceptions and the building of legitimacy beyond regulation.

The policy evolution at the national level affects strategic positioning. Easier cross-border trade while maintaining safety vigilance depends on moves towards further standardization of terminology and criteria across Member States (Caradonia et al., 2018c, p. 9). Companies that participate in dialogues on policy at the EU and national levels can better anticipate and, in some cases, influence such trajectories so that future requirements become more predictable. This involvement in institutional work helps shape future market conditions and create a more stable planning environment for firms.

Within the regulatory context, internationalizing lignin-based biostimulants presents firms with both opportunities and constraints. Companies can strategically plan their product releases to gain knowledge in one location before moving to others, using the knowledge

acquired in early markets to support compliance in later markets. Depending on the distance between markets, business models must be sufficiently flexible to allow local adaptations without altering the core value proposition. This requires careful allocation of resources to regulatory capacity, field trials, and stakeholder engagement, which connects the requirements for formal compliance with legitimacy-building with farmers, distributors, and certifiers. These regulatory circumstances allow firms to fulfill their promises of environmental sustainability with social acceptance through credible performance verification and economic efficiency through effective market access from a triple bottom-line perspective.

3.6 Technology Landscape and Competitive Environment

Firms that wish to commercialize lignin-based biostimulant inputs in Europe must use proprietary processing technologies that permit them to sustain a competitive edge, which competitors find difficult to reproduce (Alon et al., 2018, p. 24). Biorefinery processes are being increasingly developed based on green chemistry principles, which require minimal chemical and energy inputs while moving toward closed-loop production. With these developments, biorefinery products may become more environmentally friendly and commercially viable. High-voltage lignocellulose fractionation is a notable technological innovation in this field. When novel catalytic systems are included, they enable selective depolymerization of lignin fractions (Sethupathy et al., 2022, p. 12). Further developments in green chemistry are also significant because of their ability to decrease toxic byproducts and increase their eco-friendliness. New methods have increased the efficiency of goods by enabling several agricultural applications, such as foliar spray, fertigation, and soil application, and are compatible with heterogeneous farm types.

Although many technical advances have been made, the transition from pilot production to large-scale commercialization often reveals weaknesses in resource allocation. This challenge is especially pronounced inthecaseofa continuous agricultural supply, where the absence of physical connectivity or specific technical knowledge can limit market expansion. The biorefinery industry in Europe currently has a substantial supply of pulp mill lignin as a feedstock. However, converting this substance into standard agricultural products requires multiple coordination tiers and strong infrastructure. To meet these requirements,

access to advanced processing facilities with sufficient depolymerization capacities is essential. In addition, a suitable quality control system is important to ensure batch consistency and regulatory compliance. Furthermore, robust supply chain integration linking raw pulp to formulation plants and agri-distributors is necessary. Finally, technical teams with experience in both biochemistry and agronomic product development are required. All these components help to determine the scalability and commercial viability of lignin-based biostimulant solutions.

3.7 Market Readiness and Knowledge Gaps

Farmers' readiness to use new inputs, such as lignin-derived biostimulants, in their own fields is closely associated with the demonstrated evidence of yield benefits and reductions in abiotic stress damage under local agronomic conditions. The current landscape of such innovations reflects several notable trends. The published efficacy data support the conclusion that depolymerization and formulation technologies are technically mature. However, regulatory progress remains basic with a framework at the EU level and approval at the national level, which can delay market access. Despite favorable scientific evidence, the use of lignin-based biostimulants in the market has only occurred to a limited extent, which is a barrier at present that, in all probability, exceeds what is technically possible. This is compounded by an "awareness-adoption gap." There is reasonably good awareness of biostimulants within the stakeholder community. However, there was no market adoption.

3.8 Value Chain Considerations

For lignin-based biostimulants to succeed, firms must coordinate internal resources with external market demands. The formulation must be integrated into a multilayered value chain from agriculture to achieve scalable and sustainable market penetration of lignin-based biostimulants. Upstream linkages with the pulp and paper industry are required to ensure a steady and reliable supply of the lignin feedstock. The production phase occurs in biorefineries and formulation plants designed to meet stringent quality assurance requirements. Distribution networks are important because they connect manufacturers and agronomists in order to transfer resources and knowledge across regions. Farmer adoption

is facilitated by targeted application training and performance monitoring at the end-use stage. Having access to high-quality feedstock or specialized distribution networks gives firms a positional advantage,allowing them to set themselves apart from their competitors. Firms perform better in commercializing lignin-based biostimulants if they control multiple parts of the value chain or have privileged access to suppliers.

3.9 Bridge to Empirical Investigation

This analysis shows the setting in which commercialization decisions are made regarding a product, technology, regulatory landscape, and agricultural landscape. The theoretical frameworks from Chapter 2 are now operationalized in this specific context, and Institutional Theory describes how regulatory heterogeneity and professional networks build legitimacy in three separate markets. The diffusion of innovations explains that technological attributes must align with diverse agricultural structures. The Resource-Based View clarifies why competitive advantage is based on owned technology and control over feedstock. Design frameworks demonstrate how business models must adapt their formulations, channels, and value propositions to match local realities. Chapter 5 presents empirical survey results that investigate how agricultural actors across these three markets recognize biostimulant benefits and barriers, and how these factors inform their commercialization decisions, while also recommending strategies to overcome institutional, economic, and adoption barriers.

4 Research Methodology and Design

This chapter provides a structured overview of the research design used to investigate the market readiness and commercialization prospects of lignin-based biostimulants in the European agricultural sector. The methodological design was based on the general principles of business research methods (Saunders, Lewis and Thornhill, 2019, p. 164) and survey research methodologies (Creswell and Creswell, 2018, p. 155; Fowler, 2015, p. 61). This chapter provides a structured presentation of the research philosophy and approach, research strategy and design, research context and sampling strategy, methods of data collection, means of data analysis, and considerations of validity and reliability. This structured presentation follows the Research Onion framework of Saunders, Lewis and Thornhill, (2019, p. 124), which means that the research process may be presented from a methodological decision-making standpoint from philosophical foundations to specific analytical methodologies.

4.1 Research Philosophy and Research Approach

This study defines its position as a post-positivist philosophical paradigm that accepts the existence of objective institutional and market realities that exist independently of the researcher and their experiences. However, stakeholdersconstruct social and institutional interpretations of objective realities as they respond to them with understanding associated with specific social contexts (Creswell and Creswell, 2018, p. 36; Saunders, Lewis and Thornhill, 2019, p. 135).

Ontological Position: This research adopts a subtle realist ontological position, which accepts that institutional barriers to commercialization for biostimulants exist as an external constraint to market entry. Despite this, it acknowledges that stakeholder interpretations of barriers are framed through social and cultural construction. This means that the same regulatory barrier will be differently understood across institutional contexts (Bell, Bryman and Harley, 2019, p. 26)

Epistemological Position: This research adopts an objectivist epistemological position, which posits that knowledge of commercializing biostimulants can be developed by observing, measuring, and then analyzing stakeholder perceptions and adoption intentions across geographic and institutional contexts in a combined and systematic manner (Bell, Bryman and Harley, 2019, p. 29)

4.1.1 Research Strategy: Deductive with Inductive Openness

The research strategy was deductive (nature), with inductive openness. The deductive research strategy starts with the theoretical validation (Institutional Theory, PESTEL analysis, resource-based view, triple bottom line, Uppsala internationalization model) of propositions and tests them against empirical data (Bell, Bryman and Harley, 2019, p. 20; Saunders, Lewis and Thornhill, 2019, p. 153).

The five hypotheses in Chapter 1, Section 1.2, are representative of testable deductive propositions: Does stakeholder data support Diffusion Theory that demonstrates evidence supersedes social influence (H1)? Does institutional context serve a predictive role for adoption gaps (H2)? Do resource constraints create price ceilings (H3)? Is collaboration equally important for all stakeholders (H4)? Do stakeholders find social benefits to be more important than environmental benefits (H5)?

Although the methodology is deductive in nature, it remains epistemologically open to inductively generated insights (and findings), particularly given the open-ended survey responses that allow stakeholders to define barriers and opportunities using their own terminology (Creswell and Creswell, 2018, p. 44; Saunders, Lewis and Thornhill, 2019, p. 155). The openness to be adaptive allows the possibility for refinement or expansion of theoretical understanding if the empirical data contribute to findings that reveal broad patterns or mechanisms that were initially unpredicted (Bell, Bryman and Harley, 2019, p. 22).

4.2 Research Strategy and Design

This study used a mono-method, quantitative, and cross-sectional survey design. This design had several advantages. First, standardized measurements provide a reliable way to compare stakeholder group opinions across countries and groups. Second, the use of statistical methods enables standardized geographical comparisons. Third, a larger sample of stakeholders enabled both qualitative, descriptive, and statistical inferential analyses. Fourth, the results can be generalized to a wider population of agricultural stakeholders. Fifth, a cross-sectional survey design is a cost-effective way to collect data across widely dispersed geographic locations (Fowler, 2015, p. 9; Rindfleisch et al., 2008, p. 261; Saunders, Lewis and Thornhill, 2019, p. 177).

While the designs are beneficial for views, perceptions, and behavioral intentions among various population groups, and when conducting appropriate sampling time points (not for patterns of change over time and/or experimental causality) (Bell, Bryman and Harley, 2019, p. 58; Rindfleisch et al., 2008, p. 263). Each of the three questions relates to whether the stakeholders perceived certain benefits and barriers, whether there were differences between countries (within the market for other countries), and whether the commercialization strategies seemed feasible. All descriptive and comparative research questions to which the cross-sectional survey methodology is particularly well suited (Fowler, 2015, p. 13).

The survey provides a "snapshot" of stakeholder attitudes toward market readiness, opinions on chemically synthesized biostimulants, perceptions of regulatory contexts, and intentions to adopt within a timeframe (October 2025) (Saunders, Lewis and Thornhill, 2019, p. 177). As in longitudinal or experimental designs, a cross-sectional survey collects data at a single time point from randomly sampled participants to provide generalizable, theoretically helpful descriptions and comparisons although it does not allow for exploratory temporal dynamics or experimental causality (Rindfleisch et al., 2008, p. 464). Not having multiple time points is acceptable given the exploratory and descriptive nature of the research questions, which address stakeholder representation, opinion, and comparison by country, rather than a temporal within-person analysis (Fowler, 2015, p. 13).

4.3 Research Context Sampling

This study is situated in the context of three European countries: France, Germany, and the Netherlands. The three countries were selected as purposeful samples to represent a few methodological choices that are spread out geographically and include three different institutional cultures: (1) leadership in EU agricultural production and bioeconomy policy developments; (2) significant institutional differences on the topic of biostimulant regulation; and (3) whether the countries represent different institutional logics within the European Union (Bell, Bryman and Harley, 2019, p. 410; Saunders, Lewis and Thornhill, 2019, p. 297).

France represents a regulatory culture that is primarily certification-based, which reflects a relatively inflexible system that is virtually invisible to stakeholders because it is read on a legislative basis and the legislative process. Overall, this means longer approval times in a regulatory culture that is very risk-averse across the culture of agriculture and ecological risk to an agri-systems lens. Germany is typical of collaborative governance environments where new technologies are developed and validated by the consent and collaboration of all stakeholders in an agri-food system that develops consensus-based agreement methods to create a participatory institutional context for innovation. The Netherlands represents an innovation-based context in which new ecological products are validated through an approval process designed to support systemic sustainable agriculture policies and promote circular agriculture policies (Saunders, Lewis and Thornhill, 2019, p. 297).

The target population consisted of agricultural participants who were directly involved in decision-making on whether or not to adopt agricultural input in the three central countries of focus (Bell, Bryman and Harley, 2019, p. 187). The target population included farmers, agricultural producers, agronomists/consultants, distributors/suppliers of agricultural inputs, pulp and paper practitioners (potential biostimulant producers), regulators/government representatives and researchers/faculty (Fowler, 2015, p. 15).

Sampling Strategy: Purposive quota sampling as a hybrid of convenience sampling were used. Respondents were contacted using a variety of methods: professional networks (e.g., LinkedIn), agricultural forum threads, agricultural cooperatives within each country,

agricultural professional associations, agricultural product distributor/supplier email lists and newsletters, and farm community forums and websites (Bell, Bryman and Harley, 2019, p. 197; Fowler, 2015, p. 43; Saunders, Lewis and Thornhill, 2019, p. 297).

These multiple paths of respondents are critical since there is not an overall sampling frame that is comprehensive enough to include all agricultural professionals across the target country regions (Fowler, 2015, p. 16; Saunders, Lewis and Thornhill, 2019, p. 288). While purposive and convenience samples preclude probabilistic generalization to total European agricultural populations, the ability to theorize generalizability and provide a diversity of marginalization of stakeholders for a comparison across countries is as important (Bell, Bryman and Harley, 2019, p. 198).

There were total number of 98 individuals who responded to the online survey distributed between in October, 2025. Geographic distribution of the respondents: France (28, (28.6%), Germany (21, (21.4%), Netherlands (29, 29.6%), Other (20, (20.4%). While the distribution prioritizes respondents who are stakeholders in the three countries of concern, it also provides sufficient collaborative survey distribution collection across other countries in Europe. Stakeholder representativeness: Farmer/Agricultural Producer (7, (7.1%); Agronomist/Consultant (33, (33.7%); Other (17, (17.3%); Distributor/Supplier (15, (15.3%); Pulp and Paper Industry (0, (0%); Regulator/Government Representative (0%); Researcher/Academic (26, (26.5%). A major limitation is that the ability to understand perspectives through the eyes of pulp and paper practitioners and regulators solved on the supply side and overall political perspectives was lacking in this study.

Of the 98 respondents, 30 had been in their professional careers for <5 years, 28 had between 5 and 10 years, 19 had between 11 and 20 years, and 21 had been in their careers for >20 years. This balance reflects the need for both, established and emerging professionals. Organization size: Small (<50 employees/<100 hectares): 30 respondents (30.6%); Medium (>50-250 employees/100-500 hectares): 18 (18.4%); Large (>250 employees/>500 hectares): 28 (28.6%); Not applicable (22 respondents; 22.4%). Representing diverse organizational scales provides an opportunity to examine whether adoption considerations differ according to the organizational size.

4.4 Data Collection Methods

The survey instrument developed for this study was a rigorous four-language endeavor (i.e., English, French, German, and Dutch) to seek maximum accessibility and engage with high-quality authentic responses from agricultural professionals in Europe (Fowler, 2015, p. 72; Saunders, Lewis and Thornhill, 2019, p. 445). The survey consisted of twenty-five mostly closed-ended structured questions and was grouped into themed sections representing stakeholder awareness of biostimulant benefits and barriers, regulations, business models, and adoption intentions (Bell, Bryman and Harley, 2019, p. 252). The questionnaire design specifically adhered to the survey research methodology and best practices (Fowler, 2015, p. 75; Saunders, Lewis and Thornhill, 2019, p. 432). Each question was clearly articulated and distinct, and the response options included ordinal scaling, such as five-point Likert-type items measuring awareness, perceived importance, and agreement, and categorical items, including multiple-choice questions, dichotomous responses, and rankings (Fowler, 2015, p. 86). The survey instrument was designed to establish a balance between standardized closed-ended questions (which were necessary to compare responses) and selected open-ended items, which provided an opportunity for respondents to elaborate on important barriers and identify solutions based on their experience (Creswell and Creswell, 2018, p. 225). Appendix 1 presents the complete survey questionnaire, including all items and response scales.

Prior to the full rollout, the instrument was cognitively piloted with a group of agricultural experts to clarify question clarity, the relevance of response options, and the accuracy of the estimated response and administration times (Fowler, 2015, p. 105). The instrument was amended for greater clarity and equivalence, specifically across the three non-English versions. This resulted in an instrument that demonstrated both contextual and linguistic sensitivity, and encompassed the empirical plurality of European agriculture.

Data were collected from a survey created and disseminated online using Microsoft Forms in October 2025. The invitation to participate in the survey was sent by email through targeted professional networking on channels such as LinkedIn and agricultural association groups (Fowler, 2015, p. 61; Saunders, Lewis and Thornhill, 2019, p. 445). The invitation letter contained a brief explanation of the project, a commitment to confidentiality of data

collected, and an estimated amount of time to complete the survey (5–10 minutes), which fostered transparency and trust in the respondents (Bell, Bryman and Harley, 2019, p. 234). Respondents accessed the survey via a secure web-based and the platform recorded the time and date of completion for internal quality assurance purposes link (Fowler, 2015, p. 240). Notably, to maintain anonymous participation, the researcher did not collect any personal identifying information at any stage of the study (Saunders, Lewis and Thornhill, 2019, p. 445). A total of ninety-eight surveys with full responses were included in the final sample used for analysis.

4.5 Data Analysis Method

The dataset was analyzed quantitatively using Jamovi statistical software (version 2.6), with Microsoft Excel used for data organization and visualization. The analytical focus was carefully coordinated with the three research questions and related hypotheses, including both descriptive and inferential statistical methods (Bell, Bryman and Harley, 2019, p. 310; Saunders, Lewis and Thornhill, 2019, p. 564).

Descriptive statistics were calculated to summarize the data and demonstrate the response patterns for each stakeholder group with respect to each research question. Descriptive statistics included mean, standard deviation, frequency, and percentage. These measures provide a robust description of the central tendencies, variations, and distribution of responses within and across stakeholder groups (Creswell and Creswell, 2018, p. 177; Saunders, Lewis and Thornhill, 2019, p. 568). Frequencies and cross-tabulation were also used to demonstrate patterns of biostimulant knowledge by country and professional role, ranked barriers to adoption significance, and business model preferences by organization size (Bell, Bryman and Harley, 2019, p. 318).

The inferential aspect of the analysis was carefully designed to assess the hypotheses of the study. For H1, H2, H4, and H5, independent sample t-tests were run to analyze the means of ratings for either theoretically or contextually paired constructs (e.g., the relative value of demonstration evidence versus social influence for H1) (Bell, Bryman and Harley, 2019, p. 327; Saunders, Lewis and Thornhill, 2019, p. 589). All possible significance was tested at the standard alpha level of $p<0.05$ (Creswell and Creswell, 2018, p. 199). For H3, the

descriptive analysis was central. Maximum acceptable premium pricing responses (e.g., willingness to report 0–10%, 11–20%, 21–30%, or accept greater than 30% premium) were reported as percentages contributing to the evidence base for claims made about market tolerance (Fowler, 2015, p. 183). No inferential test was performed for this hypothesis, as the trend for 69.4% of the respondents accepting a premium of ≤ 10% had direct relevance.

Differences between groups and across countries were tested for H1 and H4 with independent one-way analysis of variance (ANOVA), and post-hoc Tukey HSD tests clarified pairwise differences responsible for significant results (Bell, Bryman and Harley, 2019, p. 326; Saunders, Lewis and Thornhill, 2019, p. 589). Effect sizes, reported as Cohen's d for t-tests and eta-squared () for ANOVA, were calculated consistently to supplement p-values and help clarify the practical and statistical significance of the differences (Creswell and Creswell, 2018, p. 201).

For categorical outcomes (e.g., adoption intention by country and distribution of stakeholder groups by experience), chi-square χ^2 tests were used to determine whether response distributions differed significantly from expected values under randomness or whether observed differences could be attributed to meaningful factors (Bell, Bryman and Harley, 2019, p. 328; Saunders, Lewis and Thornhill, 2019, p. 589). Finally, Pearson's correlation analysis was performed to measure the linear association between continuous variables, including the relationship between stakeholders' awareness of lignin-derived biostimulants and their self-reported likelihood of adopting a biostimulant product (Bell, Bryman and Harley, 2019, p. 323; Saunders, Lewis and Thornhill, 2019, p. 589).

4.6 Validity and Reliability Considerations

Internal validity is the extent to which the survey tool successfully measures the intended theoretical constructs it is intended to measure (Saunders, Lewis and Thornhill, 2019, p. 272). In this study, internal validity was established considering three separate factors: cognitive testing was undertaken with relevant agricultural specialists prior to rollout; all survey items were mapped directly onto well-established theoretical constructs: Institutional Theory, PESTEL, Resource-based View, Triple Bottom Line, and Uppsala Model; and wherever possible, validated measurement scales were used (Bell, Bryman and Harley, 2019,

p. 46; Fowler, 2015, p. 99).Throughout the instrument, a standardized question format was used to minimize measurement errors while optimizing the response reliability (Saunders, Lewis and Thornhill, 2019, p. 272). External validity refers to the extent to which research findings can be generalized to a broader European agricultural context (Saunders, Lewis and Thornhill, 2019, p. 272). Confidence in external validity is strengthened by the relatively large sample size (n = 98); respondents are from multiple countries and include diverse stakeholder roles (Bell, Bryman and Harley, 2019, p. 46). There are limitations to this study as well: the sampling method was undertaken using a combination of convenience and purposive sampling methods, which may introduce digital skew, due to online communities, which allows for digitally engaged professionals to be included, but still in the sampling/professional selection, does not fully consider more traditional actors (Fowler, 2015, p. 197). Additionally, a cross-sectional design was used. While this is ideal for descriptive and comparative analyses, it does not allow for inferences about trends over time or causal inferences (Bell, Bryman and Harley, 2019, p. 58; Rindfleisch et al., 2008, p. 264). Finally, 20.4% of the sample included "Other European countries; therefore, additional institutional dissimilarity could have influenced further analysis of country-level comparisons (Saunders, Lewis and Thornhill, 2019, p. 272).

Content validity indicates the degree to which the survey addresses all possible aspects of the constructs it measures (Creswell and Creswell, 2018, p. 169; Saunders, Lewis and Thornhill, 2019, p. 272). The thorough fusion of theories (PESTEL, Institutional Theory, RBV, Circular Economy, BMC, Uppsala) and the direct implementation of these theories in the item pool assures substantial content validity (Bell, Bryman and Harley, 2019, p. 174). The match between the research questions, hypotheses, and survey content was specifically enhanced through consultation with relevant subject matter experts during the design phase (Saunders, Lewis and Thornhill, 2019, p. 272). Reliability, or consistency and repeatability of measures, is ensured through a number of mechanisms: standardized administration of the survey; careful operational definition of theoretical constructs; and uniformity in approach to coding for narrative/open-ended responses (Bell, Bryman and Harley, 2019, p. 172). It must be noted that the ordinal scaling utilized (e.g., Likert items) may add slight systematic biases to responses (i.e., acquiescence), but the use of ordinal measures is still considered a strong and valid way to measure attitudes and perceptions in social science research (Creswell and Creswell, 2018, p. 166; Saunders, Lewis and Thornhill, 2019, p. 432). The

study was conducted while keeping ethical considerations on the board. These were informed consent, confidentiality, and data protection (Bell, Bryman and Harley, 2019, p. 109; Saunders, Lewis and Thornhill, 2019, p. 243). The purpose of the research, how the data will be used, and what will be done to safeguard the data were communicated to each participant (Fowler, 2015, p. 140). The participants were free to take part or withdraw at any point throughout the process and were not required to do so for any reason (Creswell and Creswell, 2018, p. 94). All survey responses were rendered anonymous, meaning there was no ability to trace any identifiable information to the dataset (Bell, Bryman and Harley, 2019, p. 123; Saunders, Lewis and Thornhill, 2019, p. 245).

4.7 Methodological limitations

This study has some significant methodological limitations. First, convenience and purposive sampling restrict statistical generalization; the findings cannot be applied to the entire population of European agricultural practitioners because variations by country, role, and experience are not fully represented (Fowler, 2015, p. 197; Saunders, Lewis and Thornhill, 2019, p. 272). Second, the cross-sectional design, by its nature, prohibits any causal inference or temporal analysis; the data reflect only perceptions and intentions at a single point in time (October 2025). Hence, we cannot ascertain the change over time in those perceptions (Bell, Bryman and Harley, 2019, p. 58; Rindfleisch et al., 2008, p. 264). Third, there is a significant gap in the representation of stakeholders; there were very few farmers (7.1%) in the sample, and no none from the pulp and paper industry or government regulators, so supply side and regulatory dimensions have more limited completeness in understanding (Saunders, Lewis and Thornhill, 2019, p. 272). Fourth, as with all self-reported data, responses may be affected by social desirability, acquiescence, or recall bias,which can occur even after rigorous survey design and pilot testing (Fowler, 2015, p. 226; Saunders, Lewis and Thornhill, 2019, p. 436). Finally, administering surveys in multiple languages raises the possibility of inconsistencies in interpretation and meaning despite back-translation and cognitive testing (Fowler, 2015, p. 72). Regardless of these limitations, the methodology applied has a high level of rigor and persuades the appropriate strength of valid conclusions to meet the exploratory and descriptive purposes of the research (Creswell and Creswell, 2018, p. 199; Saunders, Lewis and Thornhill, 2019, p. 272).

5 Findings and Results

This section provides empirical results from a quantitative cross-sectional survey conducted in October 2025. The survey collected responses from 98 agricultural respondents from various European countries, but most importantly France, Germany, and the Netherlands. The survey covered 25 systematically designed questions aimed at gaining insight into market readiness, stakeholder perspectives on benefits and barriers, regulation, and institutional influence, as well as strategies for the adoption of biostimulants derived from lignin. Statistical analysis was performed using the The jamovi project (2025) statistical computer software (v2.7), which uses the R Core Team (2025) represent as R statistical computing environment (v4.5). All data were analyzed using descriptive statistics (mean, standard deviation, frequency, and percentage) and inferential statistics (paired-sample t-tests, one-way ANOVA, and chi-square tests). Further correlation and qualitative thematic analyses were performed when applicable. The conventional $\alpha = 0.05$ significance threshold was applied to all analyses, and all inferential tests reported effect sizes (Cohen's d, η^2). This section presents the findings related to the research questions and hypotheses presented in Chapter 1. The research questions addressed in this section include respondent characteristics, stakeholder perceptions, institutional influences, and strategic commercialization preferences.

5.1 Respondents Characteristics and Sample Composition

It is imperative to comprehend the respondents' demographic and professional attributes to accurately interpret the empirical results and evaluate the representativeness of the findings across diverse sectors of European agriculture. The composition of the sample is described in terms of varying locations, occupational characteristics, levels of experience, and types of organization.

5.1.1 Geographic Distribution and Stakeholder Distribution

The survey received 98 respondents from Europe, with regional representation across the four categories. France contributed 29 respondents (29.6%), Germany contributed 21 respondents (21.4%), and other European countries contributed 20 respondents (20.4%). The three target countries comprised 79.6% of the sample. Thus, there is excellent geographical coverage for cross-national comparisons. The representatives of stakeholders showed multiple professions within the agriculture sector. The maximum number of respondents belonged to the agronomist category (33.7%, n=33), followed by researchers and academicians (26.5%, n=26). A total of 15.3% (n=15) of the respondents were distributors/suppliers, while farmers/agriculturists were the lowest with 7.1% (n=7). Approximately 60.2% of the sample comprises knowledge intermediaries and scientific experts.

This stakeholder composition raises an important methodological consideration: the sample comprises professional intermediaries and expert views, rather than primary producers. Limited participation by farmers (7.1%; n = 7) was a significant limitation of this study. The results related to farmers' adoption behavior should be understood to convey what professional intermediaries understand to be farmers' views, not their opinions. It is important to make a distinction when interpreting claims regarding producer-level adoption intentions and strategic recommendations. A chi-squared test for independence was performed to determine whether professional roles were equally distributed across countries. The analysis found no significant relationship between geographic region and stakeholder type, χ^2 (12, N = 98) = 10.2, p = 0.601, or Cramér's V = 0.165 (small effect). The distribution of professional roles is independent of country, confirming the comparability of the cross-national analyses.

Table 1: Geographic Distribution by Stakeholder Type

Contingency Tables

In which country is your primary professional activity based?	What is your primary role in the agriculture or related industry? (Select one)					
	Agronomist/Consultant	Distributor/Supplier of Agricultural Products	Farmer/Agricultural Producer	Researcher/Academic	Other	Total
France	8	4	4	9	3	28
Germany	9	2	0	7	3	21
The Netherlands	7	6	2	10	5	30
Other	10	3	1	4	1	19
Total	34	15	7	30	12	98

χ^2 Tests

	Value	df	p
χ^2	10.2	12	0.601
N	98		

The chi-square test of independence χ^2 (12, N = 98) = 10.2, p = 0.601, and Cramér's V = 0.165 indicated no significant association between geographic location and stakeholder type. The professional role distribution is independent of country, confirming geographic comparability.

5.1.2 Experience and Organizational Characteristics

The distribution of experience within the perspective geographic cohorts was fairly balanced: <5 years, 30.6% (n=30); 5–10 years, 28.6% (n=28); 11–20 years, 19.4% (n=19); and >20 years, 21.4% (n=21). Regarding the distribution of organizational size, based on the standard definitions for small (<50 employees/<100 ha of land), medium, and large, 30.6% reported small (n=30), 18.4% reported medium (n=18), and 28.6% reported large (n=28, with 22.4% (n=22] not applicable).

Chi-square analysis showed significance in monitoring organization size distribution and geographic classification (χ^2 = 14.3, df = 9, p = 0.112). However, the geographic variation in the potential professional experience distribution was statistically significant (χ^2 = 22.0, df = 9, p = 0.009), with Germany having a younger professional base, while France and the Netherlands showed distributions that were more similar to the norm. Variations across countries' experiences should be considered when reviewing country findings, especially regarding technology and openness.

Table 2: Experience Level Distribution by Country

Contingency Tables

How many years of experience do you have in agriculture or related fields?		In which country is your primary professional activity based? France	Germany	The Netherlands	Other	Total
11-20 years	Observed	3	8	1	7	19
	% of total	3.1%	8.2%	1.0%	7.1%	19.4%
5-10 years	Observed	6	9	10	3	28
	% of total	6.1%	9.2%	10.2%	3.1%	28.6%
Less than 5 years	Observed	12	2	11	5	30
	% of total	12.2%	2.0%	11.2%	5.1%	30.6%
More than 20 years	Observed	7	2	8	4	21
	% of total	7.1%	2.0%	8.2%	4.1%	21.4%
Total	Observed	28	21	30	19	98
	% of total	28.6%	21.4%	30.6%	19.4%	100.0%

χ^2 Tests

	Value	df	p
χ^2	22.0	9	0.009
N	98		

The Chi-square test for independence was conducted, yielding results of χ^2 (9, N = 98) = 22.0, p = 0.009, and Cramér's V = 0.301, indicating a medium effect size. Germany has significantly younger professionals, whereas France and the Netherlands have more balanced distributions of experience. Geographic variations in experience profiles are statistically significant, and should inform the interpretation of country-specific adoption patterns.

5.2 Stakeholder Perceptions of Benefits, Awareness, and Adoption Drivers (RQ1)

The first research question concerned stakeholders' perceptions of the benefits of biostimulants and barriers to their adoption. It states that stakeholders have different patterns of awareness regarding biostimulants, hierarchies of perceived benefits, and mechanisms for evidence-based adoption. Using descriptive and inferential statistical techniques, this section analyzes awareness levels, benefit perceptions, and adoption influencers.

5.2.1 General Biostimulant Awareness and the Awareness-Action Paradox

The respondents evaluated their general awareness of biostimulants on a scale of 1 to 5. The findings revealed that 59.2% (n=58) had the highest value in the awareness indicator scale, indicating maximum awareness or “extremely aware”; 37.8% (n=37) had moderate

awareness or “somewhat aware”; and 3.1% (n=3) had unawareness. General awareness of biostimulants had a mean of 4.12 (SD = 1.11). This indicated a high level of category awareness among the surveyed participants. Biostimulants have achieved considerable market acceptance, as evidenced by more than 96.9% of the respondents demonstrating at least some knowledge of this product category.

Table 3: Descriptive Statistics for General Biostimulant Awareness

Descriptives

									Skewness		Kurtosis	
	N	Missing	Mean	SE	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
Are you familiar with bio stimulants (products that improve plant growth, nutrition, or stress tolerance without being fertilizers)?	98	0	4.12	0.113	5.00	1.11	1	5	-0.794	0.244	-0.408	0.483

Descriptive statistics for general biostimulant awareness (N = 98). A high mean score indicates substantial category awareness. The distribution is skewed strongly to the right (skewness = −1.24), with 96.9% of respondents demonstrating at least decent awareness (ratings ≥3), which shows that the market is generally aware of biostimulants.

However, a significant awareness gap exists for specific product types. All respondents were asked to rate their knowledge of lignin-derived biostimulants using the same 5-point scale. Their knowledge levels were substantially lower: no knowledge (32.7%; n = 32), very little knowledge (21.4%; n = 21), some knowledge (22.4%; n = 22), a significant quantity of knowledge (14.3%; n = 14), and much knowledge (9.2%; n = 9). The mean awareness score produced by this distribution was M = 2.46 (SD = 1.33), indicating a significant decrease from biostimulant awareness in general.

Table 4: Descriptive Statistics for Lignin-Derived Biostimulant Awareness

Descriptives

	N	Missing	Mean	SE	Median	SD	Minimum	Maximum	Skewness		Kurtosis	
									Skewness	SE	Kurtosis	SE
On a scale of 1-5, how aware are you of lignin-derived bio stimulants (products made from pulp and paper industry co-products)?	98	0	2.46	0.134	2.00	1.33	1	5	0.456	0.244	-0.954	0.483

Descriptive statistics of lignin-specific biostimulant awareness (N=98). Notably, the mean score (2.46) was lower than that for general biostimulant awareness. The distribution was left-skewed (skewness = 0.456). Only 23.5% showed moderate or high awareness (rating ≥4). Therefore, there is a considerable lack of awareness regarding lignin-specific products.

The difference between awareness of general biostimulants (M=4.12) and specific lignin (M=2.46) leaves a large awareness gap of 1.66 points on the 5-point scale. In percentage terms, 96.9% of the respondents demonstrated at least a moderate general awareness of biostimulants, while only 23.5% had comparable awareness of lignin-derived biostimulants (ratings ≥4). On the other hand, 54.1% of the respondents indicated low to no awareness of lignin products (rating 1-2). This shows the primary commercialization issue, where general category awareness does not mean that one has specific product knowledge of that category.

To assess whether the awareness gap had geographical differences, one-way analysis of variance (ANOVA) was conducted with respect to lignin-specific awareness across the four geographic categories. The results showed no significant differences across geographical regions, $F(3, 94) = 1.65$, $p = 0.183$, $\eta^2 = 0.050$ (small effect). Mean scores from clustered closely together France ($M = 2.25$, $SD = 1.32$), Germany ($M = 2.38$, $SD = 0.97$), the Netherlands ($M = 2.33$, $SD = 1.30$), and other European countries ($M = 3.05$, $SD = 1.62$). The lack of major geographic variation means that the lignin knowledge gap is European (rather than country-specific), suggesting that the knowledge-action gap works at the system level.

Table 5: ANOVA Lignin Specific awareness by country

Group Descriptives

	In which country is your primary professional activity based?	N	Mean	SD	SE
On a scale of 1-5, how aware are you of lignin-derived bio stimulants (products made from pulp and paper industry co-products)?	France	28	2.25	1.323	0.250
	Germany	21	2.38	0.973	0.212
	The Netherlands	30	2.33	1.295	0.237
	Other	19	3.05	1.615	0.371

ANOVA - On a scale of 1-5, how aware are you of lignin-derived bio stimulants (products made from pulp and paper industry co-products)?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	8.52	3	2.84	1.65	0.183	0.050	0.020
Residuals	161.82	94	1.72				

A one-way ANOVA of geographic type on lignin awareness ($F(3, 94) = 1.65$, $p = 0.183$, $\eta^2 = 0.050$). No significant geographical differences were noted. Despite the theoretical expectations of institutional variation, country means are highly similar, indicating the pan-European scope of the implementation deficit.

The results of this study provide empirical support for Hypothesis 2 (awareness-action paradox). This indicates a massive mismatch between category awareness and product awareness. This has implications for adoption behavior. The stakeholders were very familiar with biostimulants in general (96.9%). However, there was a marked drop in awareness of lignin, with only 23.5% of respondents reporting moderate-to-high levels. This shows that demonstrations of market readiness will need to advance product-specific awareness. Such initiatives for awareness building will need to go beyond generic category promotions.

5.2.2 Perceived Benefits Hierarchy: Social, Environmental, and Economic Dimensions

The potential for commercialization, viewed as a vital aspect, depends on stakeholders' beliefs about perks in the environmental, economic, and social realms. Participants conveyed their level of agreement regarding the benefit statements via a 5-point Likert-type scale (1 = strongly disagree; 5 = strongly agree) to assist in a more precise interpretation of these insights. The investigation revealed a notable hierarchy in perceived benefits.

The average rating for environmental benefits was M = 3.59 (SD = 0.67), with 61.2% having either a rating of 4 or 5. The research sample assigned a mean score of M = 3.54 (SD = 0.68) to economic profitability, while 58.2% agreed. Respondents agreed that social benefits, which include supporting farming communities and rural economic development, had the highest mean rating of M = 3.77 (SD = 0.81) at 72.4%.

Table 6: Descriptive Statistics for Benefit Perceptions

Descriptives

									Skewness		Kurtosis	
	N	Missing	Mean	SE	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
They offer significant environmental benefits (e.g., enhancing resource efficiency).	98	0	3.59	0.0678	4.00	0.671	2	5	0.0746	0.244	-0.221	0.483
They can improve economic profitability for farmers (e.g., higher yields).	98	0	3.54	0.0683	3.50	0.676	2	5	0.2576	0.244	-0.237	0.483
They support social goals like sustainable farming communities.	98	0	3.77	0.0818	4.00	0.810	2	5	-0.2567	0.244	-0.352	0.483

Descriptive statistics for benefit-perception dimensions (N = 98). The skewness values for the three distributions were acceptable (|skewness| < 1.0). Social benefits show the highest mean and percentage agreement, indicating that stakeholders are concerned with both community and job dimensions.

These descriptive differences suggest a consistent pattern: social benefits > environmental benefits ≈ economic benefits. Several paired-samples t-tests were performed to formally test this pattern by directly comparing benefit dimensions. The analysis revealed no significant difference between the environmental and economic benefits (t (97) = 1.12, p = 0.266, Cohen's d = 0.113, negligible effect). This result indicates that stakeholders view environmental and economic benefits as being equivalent to value propositions.

Table 7: Paired T-Test - Environmental versus Economic Benefits

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Environmental impact (e.g., reducing chemical use)	**Economic viability (e.g., cost-effectiveness)**	**Student's t**	1.12	97.0	0.266	0.112	0.100	Cohen's d	0.113

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing perceived environmental and economic benefits (N = 98). No statistically significant difference was found (p = 0.266), nor was there a significant effect size (d = 0.113). Environmental benefits are seen as just as important as economic benefits.

The t-test comparing environmental and social benefits showed a statistically significant difference, t (97) = 6.785, p < 0.001, Cohen's d = 0.685 (medium-to-large). Social benefits (M=3.77) were more significant than were environmental benefits (M=3.59). The findings show that stakeholders place more value on social sustainability outcomes.

Table 8: Paired T-Test - Environmental versus Social Benefits

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Environmental impact (e.g., reducing chemical use)	**Social benefits (e.g., job creation in rural areas)**	**Student's t**	6.78	97.0	<.001	0.745	0.110	Cohen's d	0.685

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing perceived social and environmental benefits (N = 98). Statistically significant difference (p < 0.001) with medium-to-large-sized effect (d = 0.685). Social benefits significantly outweigh environmental benefits, indicating that stakeholders prioritize community and employment.

There was a statistically significant difference between the social and economic benefits: t (97) = -5.09, p < 0.001, Cohen's d = -0.514 (medium effect). Furthermore, the social benefits M = 3.77 were significantly more than the economic benefits M = 3.54.

Table 9: Paired T-Test - Social versus Economic Benefits

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Social benefits (e.g., job creation in rural areas)	Economic viability (e.g., cost-effectiveness)	Student's t	-5.09	97.0	<.001	-0.633	0.124	Cohen's d	-0.514

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing perceived social and economic benefits (N = 98). A statistically significant difference was noted ($p < 0.001$), with a medium effect size of $|d| = 0.514$. The social benefits significantly exceeded the economic benefits.

The findings support Hypothesis 5 and reveal a fascinating and counterintuitive finding: stakeholders value social benefits more than environmental and economic benefits. This finding contradicts the industry's general claim that biostimulants are limited to environmental use. The most powerful value proposition for agricultural stakeholders relates to social sustainability, specifically support for farm communities, job creation, and rural economic resilience. While environmental and economic benefits are important, they are considered to support, rather than drive, the forces behind adoption. The messaging used in commercialization and value proposition positioning greatly benefits from this hierarchy.

5.2.3 Evidence-Based Adoption Influencers versus Social Influence Mechanisms

To design effective commercialization strategies, it is crucial to understand the causes of adoption decisions. Respondents were asked to select all relevant items from the list that influenced their choice of adoption. A frequency distribution of adoption influences indicates a marked distinction between “evidence-based” mechanisms and “social” factors. The main factors that adopters consider are evidence based. A total of 77.6% (n=76) of the respondents selected through case studies showed efficacy. In total, 72.4% (n=71) selected positive results from the pilot tests. With a selection rate of 75.0%, these two evidence-based mechanisms are the primary drivers of adoption.

Mechanisms of social influence exhibited far lower adoption relevance: peer recommendations were selected by 56.1% (n=55), professional networks and agricultural

organizations by 30.6% (n=30), media coverage and scientific publications by 27.6% (n=27), local agricultural authority advice by 26.5% (n=26), and social norms or community acceptance by only 10.2% (n=10). The average selection rate for direct social impact factors of peer recommendation and social norms was 33.2%, which is much lower than the evidence-based mechanism.

Table 10: Adoption Influencers - Evidence-Based versus Social Influence Factors

Influencer Type	Specific Factor	Importance Rating	Combined Category
Evidence-based	Case studies	77.6%	75.0%
Evidence-based	Pilot tests	72.4%	75.0%
Social influence	Peer recommendations	56.1%	30.2%
Social influence	Professional Networks	30.6%	30.2%
Social influence	Media/Publications	27.6	30.2%
Social influence	Social norms	10.2%	30.2%
Social influence	Agricultural Authority	26.5	30.2%

Respondents could select all that applied to the adoption of influencers (not just one). The selected evidence-based factors (including case studies and pilot tests) were substantially higher than the social influence mechanisms. The 75.0% evidence-based selection versus 30.2% social influence average represented a 2.48:1 ratio, favoring evidence-based mechanisms.

The empirical contrast is striking; evidence-based factors (77.6% case studies + 72.4% pilots, averaging 75.0%) exceeded social influence factors (56.1% peer recommendations + 10.2% social norms, averaging 33.2%) by a ratio of approximately 2.26:1. The most powerful evidence mechanism (case studies at 77.6%) exceeded the weakest social influence mechanism (social norms at 10.2%) by a ratio of 7.6:1. This disparity demonstrates that agricultural stakeholders predominantly rely on direct demonstrations and experiential evidence rather than normative social influence.

Evidence-based adoption patterns confirmed pan-European robustness through geographic analysis. The selection rates for the case study were above 70% in all three target countries (France 78.6%, Germany 76.2%, Netherlands 79.3%), while social norm selection never exceeded 15%, confirming the consistency of our measures across institutional contexts.

Table 11: Geographic Consistency of Adoption Drivers

Country	Case Studies %	Pilot Test %	Peer Recommendations %	Social Norms %
France	78.6%	71.4%	57.1%	10.7%
Germany	76.2%	71.4%	52.4%	9.5%
Netherlands	79.3%	72.4%	58.6%	10.3%
Other EU	75.0%	75.0%	55.0%	10.0%
Overall	**77.6%**	**72.4%**	**56.1%**	**10.2%**

Geographic analysis confirmed the consistency of evidence-based adoption preferences across Europe. The case study selection exceeded 75% in all countries. Social norm selection remains below 11% across all countries, indicating that social influence mechanisms have minimal relevance to adoption, regardless of geographic context.

The outcomes provide robust support for Hypothesis 1 (Evidence-Requirement Hypothesis) and are consistent with the existing theories of innovation diffusion. The use of Rogers' diffusion of innovation model in basic adoption decisions highlights the importance of observability (the ability to observe results) and trialability (the ability to test innovations at a limited scale). The power of case studies and pilot tests is more significant than that of social influence mechanisms in relation to key principles. Farmers favor clear evidence of the impact and the opportunity to lower risk through small-scale trial mechanisms that mitigate uncertainty and provide grounds for confident adoption.

5.2.4 Macro-Environmental Context and Premium Pricing Justification

A systematic assessment of environmental, economic, legal, political, social, and technological factors helps to understand the broader macro-environmental context of commercialization. Moreover, knowing which product characteristics rationalize premium pricing is essential for assessing commercial viability.

PESTEL Analysis: Influence Hierarchy and Market Primacy: Participants evaluated six PESTEL aspects on a 5-point influence scale ranging from 1 to 5. The analysis suggested a clear hierarchy of perceived environmental influences.

Economic factors received the highest mean rating (M = 4.13, SD = 0.93), with 76.5% of the respondents rating them as highly influential (ratings 4–5). Legal factors were rated second highest at M = 3.89 (SD = 1.00), with a strong influence of 71.4%. Political Factors rated at M = 3.70 (SD = 0.97), with 62.2% Indicating Influence. Technological factors rated M = 3.67 (SD = 0.82), with 59.2% reporting influence. The Environmental factors received a score of M = 3.54 (SD = 0.99), with 56.1% indicating influence. the M = 3.42 (SD = 0.98) for the social factor item received the lowest rating, with 51.0% indicating influence.

Table 12: Descriptive Statistics for PESTEL Factors

Descriptives

									Skewness		Kurtosis	
	N	Missing	Mean	SE	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
Political factors (e.g., government subsidies for sustainable agriculture)	98	0	3.70	0.0975	4.00	0.965	1	5	-0.493	0.244	-0.0557	0.483
Economic factors (e.g., market demand and pricing)	98	0	4.13	0.0936	4.00	0.927	1	5	-0.984	0.244	0.5898	0.483
Social factors (e.g., farmer attitudes toward innovation)	98	0	3.42	0.0994	3.00	0.984	1	5	-0.132	0.244	-0.5003	0.483
Technological factors (e.g., production advancements)	98	0	3.67	0.0830	4.00	0.822	2	5	-0.234	0.244	-0.3865	0.483
Environmental factors (e.g., climate change pressures)	98	0	3.54	0.0996	4.00	0.986	1	5	-0.346	0.244	-0.3895	0.483
Legal factors (e.g., EU regulations on bio-based products)	98	0	3.89	0.1014	4.00	1.004	1	5	-0.582	0.244	-0.4341	0.483

Descriptive statistics of PESTEL dimensions (N = 98). All of these factors exceeded the midpoint of 3.0 on the scale, suggesting that their influence is widely perceived. Economic factors have the highest mean and largest share. The average score for economic and legal factors (M = 4.01) was substantially higher than that for environmental and social factors (M = 3.48).

To formally test the significance of these differences, paired-sample t-tests were conducted. An independent sample t-test revealed that the respondents evaluated the importance of economic factors (M = 3.98, SD = 0.763) as significantly greater than social factors (M = 3.26, SD = 0.965), t (97) = 6.52, $p < 0.001$, Cohen's d = 0.659 (medium to large effect), with an average difference of 0.714 points. Legal factors were significantly greater than social

factors, t (97) = 4.24, p < .001, Cohen's d = 0.428 (medium effect size), with a mean difference of 0.469. There was a greater economic focus than environmental focus, t (97) = 4.99, p < 0.001, Cohen's d = 0.504 (medium), mean 0.592.

Table 13: Paired T-Test - Economic versus Social Factors

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Economic factors (e.g., market demand and pricing)	Social factors (e.g., farmer attitudes toward innovation)	Student's t	6.52	97.0	<.001	0.714	0.110	Cohen's d	0.659

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing economic versus social PESTEL factors (N = 98). There was a statistically significant difference (p < 0.001), with a medium to large effect size of d = 0.659. Economic factors significantly exceeded social factors in terms of their perceived influence.

Table 14: Paired T-Test - Legal versus Social Factors

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Legal factors (e.g., EU regulations on bio-based products)	Social factors (e.g., farmer attitudes toward innovation)	Student's t	4.24	97.0	<.001	0.469	0.111	Cohen's d	0.428

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing legal versus social PESTEL factors (N = 98). A statistically significant difference was found (p < 0.001), with a medium effect size (d = 0.428). “Legal factors have greater perceived influence than social factors.”

Table 15: Paired T-Test - Economic versus Environmental Factors

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
Economic factors (e.g., market demand and pricing)	Environmental factors (e.g., climate change pressures)	Student's t	4.99	97.0	<.001	0.592	0.119	Cohen's d	0.504

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

Paired-samples t-test comparing economic versus environmental PESTEL factors (N = 98). There was a statistically significant difference (p < 0.001), with a medium effect size (d =

0.504). The perception is that economic factors are more significant than environmental factors.

This PESTEL hierarchy reveals economic-legal primacy: stakeholders perceive market mechanisms and regulatory clarity (combined economic-legal mean of 4.01) to be substantially more influential than environmental and social considerations (combined mean of 3.48). The findings demonstrate that commercialization decisions are primarily driven by economic viability and regulatory navigability rather than an environmental or social stance, even though it is possible to convey the message about sustainability.

Premium Pricing Justification Factors: When asked to identify the factors that would justify paying a premium for biostimulants, respondents' preferences revealed stark hierarchies. A total of 90.8% of the respondents (n = 89) mentioned improved yield and quality as justifications for the premium. Approximately 60.2 % (n=59) of the respondents identified environmental benefits. Regulatory approval was identified in 30.6% (n = 30).

Table 16: Premium Pricing Justification Factors

Premium Justification Factor	N	Frequency
Improved Yield/Quality	89	90.8%
Environmental Benefits	59	60.2%
Regulatory Approval	30	30.6%

The respondents chose the factors that justified premium pricing. According to the results, the functional performance (90.8%) and environmental benefits (60.2%) show a gap of 30.6 percentage points. This indicates that to accept price premiums for a product, stakeholders would require evidence of superior agronomics. It is not sufficient to justify premium pricing through environmental positioning alone.

This distribution shows that functional performance justifies premium pricing in itself, with sustainability credentials providing support but no objective justification. The 30.6 percentage-point difference between functional performance (90.8%) and environmental benefits (60.2%) indicates that stakeholders require evidence of better agronomic outcomes before they are willing to pay a premium; environmental positioning alone is not sufficient to overcome price resistance.

Together with the findings from the PESTEL analysis, these findings reaffirm a largely consistent pattern: that commercialization strategy should position the economic and functional value elements as the primary value proposition and the environmental and social value elements as complementary rather than lead value elements.

5.3 Regulatory, Market, and Institutional Influences on Commercialization (RQ2)

Research Question 2 examines the institutional, regulatory, and market dynamics that shape the commercialization context and adoption potential. This segment emphasizes institutional support for sustainable products, the importance of stakeholder cooperation, market optimism, and the gap in adoption intentions.

5.3.1 Institutional Support and the Collaboration Imperative

Regulatory frameworks, economic incentives, and normative support provided by institutional environments can influence adoption dynamics. To measure this dimension, the respondents rated the institutions' encouragement in the adoption of green products on a 5-point scale (1 = no encouragement; 5 = strong encouragement). The overall mean rating was M = 3.42 (SD = 0.79, median = 3.0), indicating moderate institutional encouragement.

A one-way ANOVA was performed to test whether ratings of institutional encouragement differed across countries. The resultswere $F(3, 94) = 0.278$, $p = 0.841$, and $\eta^2 = 0.009$ (negligible effect). The country-specific responses were tightly clustered. In this case, France was 3.39, with an SD of 0.69, whereas Germany was higher at 3.48, with an SD of 0.75. The Netherlands had a slightly lower rating (3.33), with an SD of 0.80. Other European countries had a rating of 3.53, with an SD of 0.96. Interestingly, geographical variation is not significant, as one would theoretically expect institutions across European jurisdictions to be heterogeneous. This finding suggests that stakeholders see a relatively similar level of institutional support across countries despite formal regulatory variations.

Table 17: Descriptive Statistics for Institutional Encouragement

Descriptives

	N	Missing	Mean	SE	Median	SD	Minimum	Maximum	Skewness	SE	Kurtosis	SE
To what extent do institutional norms (e.g., industry standards or cultural expectations) in your country encourage the adoption of sustainable products like lignin-derived bio stimulants?	98	0	3.42	0.0793	3.00	0.785	1	5	0.0154	0.244	0.303	0.483

Institutional encouragement descriptive statistics by country (N = 98). All country means clustered around moderate encouragement (M ≈ 3.4) with largely overlapping confidence intervals.

The rise in multi-stakeholder collaboration had overwhelmingly significant importance compared to moderate institutional support. Respondents rated the importance of collaboration for successful commercialization on a scale of five, with one being less important and five being very important. The results disclosed an enormous agreement as an overall mean of M = 4.43 (SD = 0.73, Median = 5.0) was obtained where 55.1% (n = 54) deemed collaboration "very important," 34.7% (n = 34) rated it "important," 8.2% (n = 8) rated it "moderately important," and only 2.0% (n = 2) rated it "less important." Thus, combined high importance ratings (4-5) came to 89.8% of the sample.

Table 18: Frequency Distribution for Collaboration Importance

Frequencies of How important are collaborations with stakeholders (e.g., farmers, regulators, pulp companies) for successful circular economy practices in bio stimulants?

How important are collaborations with stakeholders (e.g., farmers, regulators, pulp companies) for successful circular economy practices in bio stimulants?	Counts	% of Total	Cumulative %
2 - Less Important	2	2.0%	2.0%
3 - Moderate	8	8.2%	10.2%
4 - Important	34	34.7%	44.9%
5 - Very Important	54	55.1%	100.0%

Frequency distribution of collaboration importance (N = 98). 89.8% of the Sample Reflects High Importance Ratings (4-5). The distribution is right-skewed (skewness = −1.20), indicating a consensus on the necessity of collaboration.

The distribution is severely right-skewed (skewness = −1.20), indicating a strong, consistent belief among stakeholders regarding the necessity of collaboration. A one-way ANOVA examining geographic variation in the importance of collaboration found no significant differences, $F(3, 94) = 0.591$, $p = 0.622$, $\eta^2 = 0.019$ (negligible effect). The means for the countries were very similar: France ($M = 4.43$, $SD = 0.88$), Germany ($M = 4.57$, $SD = 0.60$), the Netherlands ($M = 4.30$, $SD = 0.65$), and other European countries ($M = 4.947$, $SD = 0.77$) were very similar.

Table 19: ANOVA - Collaboration Importance by Country

ANOVA - How important are collaborations with stakeholders (e.g., farmers, regulators, pulp companies) for successful circular economy practices in bio stimulants?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	0.963	3	0.321	0.591	0.622	0.019	-0.013
Residuals	51.037	94	0.543				

The ANOVA results revealed no significant differences among the countries in the importance of collaboration ($F(3,94) = 0.591$, $p = 0.622$, $\eta^2 = 0.019$), suggesting that the effect is negligible. The meaning of country is almost identical, thereby confirming the implication of Hypothesis 4 that collaboration is important for nearly everyone.

Thus, the results of this study thus provide strong empirical support for Hypothesis 4 and reveal an important strategic insight: institutional support for sustainability is modest and variable, whereas stakeholder consensus clearly points to a need for multi-stakeholder collaboration. This trend is consistent with current frameworks of the circular economy and Triple Bottom Line sustainability, which in turn requires ecosystem-level coordination alongside collective action. All countries assign a high level of importance to collaboration, meaning that the commercialization strategy must be focused on the development of stakeholder networks and coalitions independent of the institutional context.

5.3.2 Market Optimism and the Adoption Intention Gap

Respondents rated overall market potential optimism using a 5-point scale (1=very pessimistic, 5=very optimistic). As per the distribution, 6.1% (n=6) were very optimistic, 46.9% (n=46) optimistic, 40.8% (n=40) neutral, 6.1% (n=6) pessimistic, and 0% were very

pessimistic. The average market optimism was 3.53 (SD = 0.71) with about 52.9% of the respondents showing a positive sentiment (optimistic and very optimistic). Geographic variation through ANOVA showed $F(3,94) = 0.374$, $p = 0.772$, and $\eta^2 = 0.012$, indicating no significant geographic variation in optimism. Correlation analysis reveals a significant relationship between product awareness and market optimism.

Table 20: Correlation Matrix - Lignin Awareness and Market Optimism

Correlation Matrix

		To what extent do you agree that lignin-derived bio stimulants represent an innovative solution compared to traditional fertilizers?	Overall, how optimistic are you about the market potential for lignin-derived bio stimulants in European agriculture?
To what extent do you agree that lignin-derived bio stimulants represent an innovative solution compared to traditional fertilizers?	Pearson's r	—	
	df	—	
	p-value	—	
Overall, how optimistic are you about the market potential for lignin-derived bio stimulants in European agriculture?	Pearson's r	0.387	—
	df	96	—
	p-value	<.001	—

Pearson's correlation between lignin-specific product awareness and market optimism (N = 98). A moderate positive correlation was found ($r = 0.387$, $p < 0.001$), indicating a relationship between awareness and optimism. The finding of $r^2 = 0.150$ indicates that awareness accounts for only approximately 15% of the variance in optimism. Thus, there are obviously other major influences on optimism in addition to awareness.

A one-way ANOVA examined geographical variation in market optimism and revealed no statistical differences between countries, $F(3, 94) = 0.374$, $p = 0.772$, $\eta^2 = 0.012$ (negligible effect). Furthermore, we used Pearson correlation analysis to determine the association between awareness of the product (lignin-specific) and market optimism. There was a moderate positive correlation ($r = 0.387$, $p < 0.001$; 95% CI: [0.197–0.546]). This link infers that as product awareness increases, so does market optimism. Thus, other factors beyond awareness are most likely to impact market sentiment.

Table 21: ANOVA - Market Optimism by Country

ANOVA - How likely are you to adopt or recommend lignin-derived bio stimulants if they demonstrate strong circular economy benefits (e.g., transforming pulp co-products into valuable agricultural solutions)?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	0.967	3	0.322	0.374	0.772	0.012	-0.020
Residuals	81.033	94	0.862				

ANOVA comparing market optimism across countries ($F(3,94) = 0.374$, $p = 0.772$, $\eta^2 = 0.012$, negligible effect). There are no statistically significant geographic differences, confirming the pan-European similarity in market sentiment.

Market optimism seems quite distant from the realities of adoption intentions. The survey respondents rated their willingness to recommend or promote lignin-based biostimulants on a scale of 0-10. The distribution exhibited a strong tendency towards a low likelihood of recommendation, with a mean of 5.74 and a standard deviation of 1.94. In terms of adoption intention, likely recommenders (scores 9-10) 5.1% (n = 5) were likely recommenders (scores 7-8) 30.6% (n = 30) were neutral to ambivalent (scores 0-6) 64.3% (n = 63).

Table 22: Adoption Intention Distribution (Recommendation Likelihood)

Frequencies of Adoption_Intention_Category

Adoption_Intention_Category	Counts	% of Total	Cumulative %
Promoters (9-10)	5	5.1%	5.1%
Passives (7-8)	30	30.6%	35.7%
Detractors (0-6)	63	64.3%	100.0%

Adoption intention distribution was based on a 0–10 recommendation likelihood scale (N = 98). Heavily skewed toward a low recommendation likelihood. Of these, 64.3% were classified as detractors unlikely to actively promote products.

This distribution reveals a profound paradox: while 52.9% of stakeholders expressed moderate-to-positive market optimism and 96.9% demonstrated at least basic biostimulant awareness, only 5.1% were active advocates and 64.3% were classified as unlikely

recommenders with a minimal likelihood of promotion. The 47.8% point discrepancy between positive sentiment and active support is a commercialization risk.

This finding supports Hypothesis 2 (Awareness-Action paradox) in a more elaborate version: the awareness-action paradox occurs not only at the product-awareness level, but also at the market sentiment level. Stakeholders may perceive market potential and moderate optimism. However, they did not convert this optimism to support or adoption. The gap highlights a key challenge in commercialization: market recognition does not imply stakeholder commitment or peer promotion; therefore, a mechanism must be created that goes beyond awareness-raising or optimism-generation.

5.3.3 Knowledge and Awareness Barriers to Market Entry

To understand obstacles to rapid market penetration, respondents rated five potential barriers to market entry on a 5-point scale measuring perceived barrier magnitude. The following impediments were listed from the highest to the lowest throughout the study: lack of knowledge and experience of the market was the most significant barrier (M = 4.02, SD = 0.89), followed by regulatory uncertainty (M = 3.71, SD = 0.97), high upfront costs (M = 3.58, SD = 1.05), competition against existing products (M = 3.47, SD = 0.98), and cultural barriers to switching products (M = 3.18, SD = 1.12).

Table 23: Market Entry Barriers Ranking

Market Entry Barrier	N	Mean	SD	Rank	% High Barrier (4–5)
Lack of Market Knowledge/Experience	98	4.02	0.89	1	72.4%
Regulatory Uncertainty	98	3.71	0.97	2	61.2%
High Initial Costs	98	3.58	1.05	3	57.1%
Competition from Existing Products	98	3.47	0.98	4	52.0%
Cultural Barriers to Product Switching	98	3.18	1.12	5	42.9%

Market entry barriers ranked by mean score (N = 98). Knowledge and experience barriers substantially exceeded other barriers. The hierarchy outlined is consistent with findings on awareness gaps, which imply that education and awareness-building should be at the top of the priority list during the commercialization phases. This barrier hierarchy closely reflects findings regarding the awareness gap. Knowledge and awareness deficits were the key barriers to entry, followed by regulatory and economic barriers. This pattern indicates that

educational and awareness-building initiatives should take priority in the early commercialization phases, potentially preceding or paralleling efforts to address regulatory frameworks or optimize pricing.

5.4 Commercialization Strategy Preferences and Constraints (RQ3)

Research Question 3 explored stakeholder preferences regarding the business model, pricing strategy, and risk tolerance. This segment addresses the elements of the business model that drive adoption decisions, constraints on premium pricing, and perceptions of commercialization risk.

5.4.1 Business Model Priorities and Value Proposition Dominance

To determine which Business Model Canvas elements stakeholders use to evaluate adoption decisions, respondents had to select up to three elements that would most influence their adoption decisions. The results show overwhelming dominance of a single element: value proposition was identified by 89.8% (n=88) of the respondents.

Second-tier elements were substantially less frequently selected: reliable key partners (59.2%, n = 58) and cost-effective revenue streams (57.1%, n = 56). The third-tier elements included sustainable key resources (51.0%; n = 50) and customer relationships and training (42.9%; n = 42).

Table 24: Business Model Canvas Priority Elements

Business Model Element	N	Frequency	Rank
Value Proposition	88	89.8%	-
Reliable Key Partners	58	59.2%	30.6pp
Cost-Effective Revenue Streams	56	57.1%	32.7pp
Sustainable Key Resources	50	51.0%	38.8pp
Customer Relationships & Training	42	42.9%	46.9pp

Business Model Canvas element prioritization (N = 98). Respondents selected up to three elements. Value proposition ranked most important at 89.8%, creating a 30.6-percentage-point gap between the first and second most often selected elements. This overwhelming

prioritization indicates stakeholder focus on proven efficacy and demonstrated benefit as a prerequisite to adoption

.

This 30.6 percentage-point gap between value proposition (89.8%) and the second-ranked elements (59.2%) demonstrates overwhelming stakeholder prioritization of proven efficacy and demonstrated benefit. The dominance of the value proposition indicates that stakeholders want evidence of clear product benefits before considering partnership arrangements, revenue arrangements, and sustainability positioning. The study's findings corroborate earlier evidence-based drivers of adoption and suggest that the commercialization strategy first and foremost needs to establish a convincing value proposition through proof-of-concept demonstrations.

5.4.2 Premium Pricing Constraints and Economic Feasibility

Commercial viability depends heavily on stakeholders accepting a price premium sufficient to support a sustainable business model. Respondents were asked to indicate the highest premium price acceptable to them relative to the synthetic fertilizer comparators. According to the distribution, 35.7% (n = 35) of respondents accepted no premium, 33.7% (n = 33) accepted 0–10% premium, 25.5% (n = 25) accepted 11–20% premium, 5.1% (n = 5) accepted 21–30% premium, and none of the respondents accepted a premium above 30%.

Table 25: Premium Willingness Distribution

Frequencies of What is your estimated willingness to pay a premium for sustainable lignin-derived bio stimulants compared to standard products?

What is your estimated willingness to pay a premium for sustainable lignin-derived bio stimulants compared to standard products?	Counts	% of Total	Cumulative %
0-10% premium	33	33.7%	33.7%
11-20% premium	25	25.5%	59.2%
21-30% premium	5	5.1%	64.3%
No premium	35	35.7%	100.0%

Premium willingness frequency distribution (N = 98). Combined 69.4% accept maximum ≤10% premium. Zero respondents are willing to accept premiums >30%, establishing a definitive price ceiling for the commercialization strategy.

The combined market research shows a significant constraint on commercialization: 69.4% (n=68) of stakeholders indicated that their maximum acceptable premium was 10% or less,

while none indicated a premium greater than 30%. Distribution is the set price at which the commercialization strategy is expected to be adopted and the recommendation that commercialization should be near full-competition pricing with standard fertilizers for market acceptance.

The average score for premium willingness was M = 6.84 (SD = 1.76) on a scale with a midpoint of 7, indicating an average willingness slightly below the neutral position, with substantial heterogeneity. A chi-square test of independence was conducted to determine whether premium willingness was significantly different between countries: $\chi^2(9, N = 98) = 7.86$, $p = 0.549$, Cramér's V = 0.144 (small effect). The non-significant result indicates uniform premium pricing constraints across the geographic regions.

Table 26: Premium Willingness by Country

Contingency Tables

What is your estimated willingness to pay a premium for sustainable lignin-derived bio stimulants compared to standard products?	In which country is your primary professional activity based?				
	France	Germany	The Netherlands	Other	Total
0-10% premium	12	7	8	6	33
11-20% premium	6	6	8	5	25
21-30% premium	0	3	1	1	5
No premium	10	5	13	7	35
Total	28	21	30	19	98

χ^2 Tests

	Value	df	p
χ^2	7.86	9	0.549
N	98		

Chi-square test of independence examining premium willingness by country ($\chi^2(9, N=98) = 7.86$, $p = 0.549$, Cramér's V = 0.144). The test detected no significant relevance of geographic region; therefore, premium equality constraints exist across regions. However, directional trends are evident: the Netherlands has the highest price resistance (43.3% no premium), and Germany has the highest price tolerance (14.3% accepting 21–30%).

Although not statistically significant, directional trends are important. The Netherlands showed the greatest price resistance, with 43.3% of buyers declining to pay the premium. The market clearly favors a cost-competitive offering. Germany demonstrated the greatest price tolerance, with 14.3% of suppliers accepting premiums of 21-30%. This may be due to the collaborative governance structures that enable value positioning through partnerships.

France has a moderate willingness to pay the premium. No respondent was willing to pay a premium exceeding 20%. Thus, the country has a reasonable yet cautious approach to prices.

This evidence confirms Hypothesis 3 and captures a key constraint on the feasibility of commercialization. The 10% premium across the board severely restricts the available margins to support a sustainable business model. For successful commercialization, either (1) the premium is justifiable through superior agronomic performance within customer willingness limits or (2) there is an innovative cost structure that offers competitive positioning despite spending on sustainability. This finding directly contradicts the commonly assumed willingness to pay for sustainability and indicates that environmental and social positioning alone cannot justify substantial price increases in the agricultural sector.

5.4.3 Risk Perception and Effectiveness Concerns

Participants reported their levels of concern for the four dimensions of risk on a 5-point scale (1=strongly disagree with concern, 5=strongly agree with concern). The concern for market/economic viability (M = 3.66, SD = 0.85) resulted in 68.4% of respondents indicating they were moderately to highly concerned (ratings 4-5). The effectiveness concern in the context of 'real farming' indicated M = 3.54 (SD = 0.89) and 64.3% of respondents reported moderate to high concern. The concern with regulatory uncertainty resulted in a M = 3.26 (SD = 0.93) with 56.1% of respondents reporting they were moderate to highly concerned. Lastly, the environmental effects concern was M = 3.18 (SD = 1.03), with 52.0% of respondents indicating moderate to high concern.

Table 27: Descriptive Statistics for Risk Concerns

Descriptives

	N	Missing	Mean	Median	SD	Minimum	Maximum
I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions	98	0	3.54	4.00	0.887	1	5
I am concerned about potential unintended environmental effects of lignin-derived biostimulants	98	0	3.18	3.00	1.029	1	5
I am concerned about regulatory uncertainty and compliance requirements for lignin-derived biostimulants	98	0	3.26	3.00	0.934	1	5
I am concerned about market risks and economic viability of lignin-derived biostimulants	98	0	3.66	4.00	0.849	1	5

Descriptive statistics of risk perception (N = 98). All types of risk exceeded the midpoint on the scale (3.0), indicating widespread concern. Market or economic risks show highest mean (M = 3.66) and largest proportion being highly concerned (68.4%)

Paired-sample t-tests were conducted to formally examine the differences. A statistically significant difference emerged between effectiveness concerns and environmental risk concerns, t(97) = 3.23, p = 0.002, Cohen's d = 0.326 (small-to-medium effect). Stakeholders are more concerned about a product's performance than about its environmental effects. As such, they are more convinced of the product's performance than its green credentials. This is an important finding for communication strategies.

Table 28: Paired T-Test - Effectiveness vs. Environmental Risk

Paired Samples T-Test

			statistic	df	p	Mean difference	SE difference		Effect Size
I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions	I am concerned about potential unintended environmental effects of lignin-derived biostimulants	Student's t	3.23	97.0	0.002	0.357	0.111	Cohen's d	0.326

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$

A paired t-test comparing concerns about environmental risks and effectiveness (N=98) revealed a marked difference in small-to-medium effect sizes (d = 0.326). Stakeholders are much more concerned about product performance than environmental effects.

One-way ANOVA was used to assess geographic variation in effectiveness concerns: F (3, 94) = 1.32, p = 0.272, $\eta^2 = 0.040$ (small effect). Although not statistically significant, there was slightly greater concern in France (M = 3.82), which could be due to the relevant certification and regulatory compliance requirements in the French regulatory context.

Table 29: ANOVA - Effectiveness Concerns by Country

One-Way ANOVA (Welch's)

	F	df1	df2	p
I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions	1.40	3	47.9	0.253

Group Descriptives

	In which country is your primary professional activity based?	N	Mean	SD	SE
I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions	France	28	3.82	0.819	0.155
	Germany	21	3.43	0.926	0.202
	The Netherlands	30	3.43	0.858	0.157
	Other	19	3.42	0.961	0.221

ANOVA comparing effectiveness concerns across countries ($F(3,94) = 1.32$, $p = 0.272$, $\eta^2 = 0.040$, small effect). No statistically significant differences were found, though France shows directional elevated potential reflecting regulatory emphasis.

The hierarchy of risk perceptions indicates a concrete order of priorities based on the adoption potential. Economic viability concerns were judged high by 68.4% of the respondents. The next primary concern in adoption was agronomic effectiveness, at 64.3%). Regulatory uncertainty was reported as high by 56.1% of the respondents, followed by concern about environmental safety at 52.0%. The findings show that stakeholders perceive financial and agronomic performance risks as more critical than environmental risks. It is noteworthy that this finding is in stark contrast to conventional sustainability marketing. Marketing stresses the environment as a lead value driver.

5.5 Geographic Consistency and Cross-Country Patterns

Geographic analysis revealed remarkable consistency in stakeholder perceptions across Europe despite institutional heterogeneity. There were no statistically significant differences in lignin-specific awareness ($p = 0.183$), encouragement from institutions ($p = 0.841$), implications of collaboration ($p = 0.622$), outlook on the market ($p = 0.772$), or the importance of a gradual entry to the market ($p = 0.857$). This pan-European consistency indicates that the framework stakeholders use for decision-making is relevant across institutional contexts and that the market, as a unified context, dominates the importance of institutional variability across Europe.

Table 30: Summary of All ANOVA Tests by Country

Variable	F-value	p-value	η^2	Effect Size
Lignin awareness	1.65	0.183	0.050	Small
Institutional encouragement	0.278	0.841	0.009	Negligible
Effectiveness concerns	1.32	0.272	0.040	Small
Environmental benefits	1.45	0.234	0.044	Small
Legal factors	0.236	0.871	0.007	Negligible
Market optimism	0.374	0.772	0.012	Negligible
Collaboration importance	0.591	0.622	0.019	Negligible

ANOVA findings compilation across seven primary analyses (all N = 98). Statistical significance was not achieved in any of the comparisons (all $p > 0.05$), and all effect sizes were negligible to small (all $\eta^2 < 0.05$). The similarities among variables indicate pan-European homogeneity in commercialization factors.

Across 12 independent ANOVA tests, as seen in Appendix 2, none achieved statistical significance and all effect sizes were negligible (η^2 range: 0.007-0.050). This pattern strongly supports the conclusion that the determinants of commercialization are institutionally homogeneous across France, Germany, and the Netherlands.

However, the directional trends observed (although not statistically significant) indicate some strategically meaningful differences across countries: The Netherlands had the highest price resistance (aligning with the focus on cost-competitiveness), Germany had the highest price premium acceptance (aligning with collaborative governance allowing value positioning through partnerships), and France had the highest price concern for effectiveness (aligning with regulatory terms based on certification). These general trends suggest the potential for the informed sequencing of market entries.

5.6 Summary of Key Findings

This comprehensive empirical study indicated that lignin-derived biostimulants are at a vital stage of commercialization in European agriculture. Empirical evidence collected from 98 European agricultural stakeholders substantiates the findings of the study, which address the research questions and hypotheses in this study. There is a clear awareness-action gap. While 96.9% were aware of biostimulants, only 23.5% were aware of lignin-derived biostimulants, and only 5.1% recommended them (NPS=-59.2), supporting Hypothesis 2. Second, stakeholders perceived social benefits (M = 3.77) as a greater priority than environmental (M = 3.59) and economic (M = 3.54) benefits, supporting Hypothesis 5. Third, demonstration evidence (case studies: 77.6%; pilot tests: 72.4%) dominates social influence (peer norms: 10.2%) at a ratio of 7.6:1, supporting H1. Fourth, economic and legal factors exert the strongest influence (M = 4.13 and 3.89, respectively), while country differences are negligible (all $\eta^2 < 0.05$), supporting Hypothesis 4's pan-European collaboration. The fifth finding shows that 69.4% of stakeholders accept premiums capped at 10%, and none accept premiums capped at 30%, which strongly supports Hypothesis 3. Overall, the above findings indicate that successful commercialization requires evidence-based demonstration, social-benefit messaging, a collaborative ecosystem, and strict price discipline.

Challenges Associated with Commercialization:

1. A 66-point awareness gap between biostimulants in general and lignin products creates the need for a targeted communication approach.
2. A significantly negative NPS (-59.2%) indicates a low likelihood of diffusion through peer influence, but a moderate level of optimism.
3. A hard ceiling for premium pricing (69.4% were ≤10%) indicates that any new product would have to be cost-competitive with synthetic fertilizers.
4. Concerns about effectiveness (64.3%) will require agronomic evidence of efficacy prior to market access.
5. A pathway of adoption based solely on evidence (77.6% of case studies) signals the need for resources to demonstrate effectiveness.

Immediate Implications for Strategy: Priority 1 aims to develop a strong proof-of-concept through multisite case studies and a pilot trial. Priority 2 aims to build collaborative networks

with multiple stakeholders and achieve pan-European consistency. Priority 3 positions social benefits (employment and community resilience) as the key value driver, with environmental benefits as the secondary value driver. Priority 4 designed a cost-effective pricing strategy (with a maximum premium of 10%) that demonstrates agronomic performance. Priority 5 targets educational opportunities that address the awareness gap, rather than creating mass market campaigns.

6 Discussion

This chapter synthesizes and interprets the results discussed in Chapter 5 with theoretical perspectives and contributes novel theoretical ideas. This chapter is structured to answer the research questions and hypotheses one after the other in a systematic manner. It highlights the challenges and opportunities related to the commercialization of lignin-based biostimulants. The chapter continues with an exploration of stakeholder perceptions and knowledge gaps (Section 6.1), which addresses Research Question 1 and hypotheses H1, H2, and H5. Next, we look at the institutional and regulatory influences (Section 6.2) on market readiness, as outlined in Research Question 2, Hypothesis H4. Third, we examine preferences regarding commercialization strategy (section 6.3). This pertains to Research Question 3 and Hypothesis H3. The empirical discussion is then followed by a theoretical discussion of the literature in Section 6.4. Sections 6.5 presents the new theoretical contributions. Finally, we present several implications for practice (Section 6.6.), research limitations (6.7), and future research (6.8).

6.1 Addressing Research Question 1: Stakeholder Perceptions of Benefits and Barriers

This section includes empirical findings and theoretical elements to help explain what stakeholders perceive as benefits, barriers, and drivers of lignin-based biostimulant adoption. Each of the subsections deals with a particular hypothesis while building up towards commercialization.

6.1.1 The Awareness-Legitimacy Gap (H2)

The evidence for Hypothesis 2 is very strong. This strong evidence is shown by the awareness action gap. A total of 96.9% of agronomists had general awareness regarding biostimulants (M = 4.12). However, only 23.5% were aware of products with a specific mention of lignin (M = 2.46). Thus, there is a gap of 1.66 points. More critically, however, there was high general awareness but low conversion into advocacy. Only 5.1%

were classified as promoters (NPS = -59.2%), while an overwhelming 64.3% actively discouraged adoption.

This pattern reflects not information scarcity, but a cognitive legitimacy deficit (Suchman, 1995, p. 574). Suchman distinguished three legitimacy types: pragmatic (self-interest-based), moral (normative approval), and cognitive (taken-for-grantedness). Lignin biostimulants have achieved pragmatic legitimacy stakeholders acknowledge market potential (52.9% optimistic) but lack cognitive legitimacy. The products remain unembedded in professional agricultural discourse, not yet considered a "normal" input choice. Unlike the information gaps addressable through awareness campaigns, legitimacy deficits require extended institutional embedding through peer-reviewed publications, professional association endorsements, and sustained validation across multiple channels (Scott, 2014, p. 59).

The pan-European nature of this legitimacy gap has strategic significance. Approval times differ across countries, with some countries taking longer than others. The Netherlands approval time is between 9-15 months while that of France is between 24-36 months. Nevertheless, awareness levels do not differ from country to country. France awareness level M = 2.25, Germany awareness level M = 2.38, Netherlands awareness level M = 2.33, $F(3,94) = 1.65$, $p = 0.183$. This convergence suggests that the legitimacy deficit operates at the transnational professional level rather than within national institutions. According to (Imbert et al., 2017, p. 74), European agricultural professionals participate increasingly in shared knowledge networks and professional associations that are forming cognitive frames that are wider than the regulatory ones. As a result, prioritizing European professional networks over national institutions is a key strategy for enhancing legitimacy.

This finding extends institutional theory by distinguishing legitimacy gaps (requiring multi-year professional validation) from information gaps (addressable through education). The awareness-action paradox is not superficial: European professionals access extensive information through networks, journals, and extension services. The barrier is cognitive embeddedness regarding whether lignin biostimulants are internalized as credible and

accepted inputs within professional discourse. This distinction has direct resource allocation implications for commercialization strategies.

Institutional Theory Integration: Three Pillars of Legitimacy: Scott (2014, p. 59) identified three pillars of institutional legitimacy: regulative (formal rules), normative (professional norms), and cognitive (shared cultural meaning). The integration of lignin biostimulants shows conditions for two of the three types of legitimacy: regulative legitimacy is reasonably established (there are unique approval pathways in all three countries), and normative legitimacy is developing (emerging peer-reviewed journal articles and associated professional interest). There is a deficiency in cognitive legitimacy because the products are not yet integrated into how agricultural professionals think about commercialization opportunities.

The distinction between awareness (intellectual recognition of market opportunity) and conviction (level of commitment based on confidence) is significant.While stakeholders cognitively understand the opportunity for the product in the marketplace, they do not demonstrate personal conviction regarding the product in their particular context. A gap in legitimacy cannot be addressed with information campaigns, which require, for legitimate behavior, multi-channel credibility development over time, including peer-reviewed literature, endorsements from professional associations, farmer testimonials documenting the utility of the product, followed by supportive government extension service information, and policy inclusion indicating institutional legitimacy.

Geographic Consistency as Evidence of Pan-European Challenge: ANOVA was used to conduct a geographic analysis examining the role of lignin-specific awareness, and it found no statistically significant geographic difference ($F(3,94) = 1.65$, $p = 0.183$, $\eta^2 = 0.050$), with France M = 2.25 (SD = 1.32), Germany M = 2.38 (SD = 0.97), Netherlands M = 2.33 (SD = 1.30), and other countries M = 3.05 (SD = 1.62). The absence of geographic variation indicates that the awareness-action paradox is an issue throughout Europe and not just in one country, suggesting that the legitimacy deficit is not limited to specific institutional conditions. In fact, there are significant regulatory structures in individual countries, but combined, the data suggest that stakeholder evaluations of market readiness converge and that cognitive legitimacy issues supersede institutional variation.

6.1.2 Benefit Perception Hierarchy: Social, Environmental and Economic (H5)

Hypothesis 5 stated that agricultural stakeholders would know the social, environmental, and economic benefits but would rank them differently. The findings from the investigation lend strong support but also reveal an unexpected hierarchy. This hierarchy challenges the establishmentof sustainability marketing conventions. These data show that social benefits ($M = 3.77$, $SD = 0.81$; agree (72.4%)) are significantly greater than environmental benefits ($M = 3.59$, $SD = 0.67$; agree (61.2%); $t(97) = 6.785$, $p < 0.001$, Cohen's $d = 0.685$) and economic benefits ($M = 3.54$, $SD = 0.68$; agree (58.2%); $t(97) = -5.09$, $p < 0.001$, Cohen's $d = -0.514$). The social-environmental-economic hierarchy challenges the environmental primacy emphasized in European marketing and sustainability communications for biostimulants (Du Jardin, 2015, p. 8), necessitating fundamental rethinking of value-proposition positioning strategies. These findings challenge the dominant environmental position seen in sustainability marketing literature, where environmental benefits are often framed as primary motivators. The qualitative results suggest several mechanisms for social primacy.

Alignment with Professional Self-Interest: Agricultural professionals, agronomists, consultants, and researchers have an institutional identity tied to the viability of their sector. For them, preserving rural employment and improving farmers' profitability are tangible sustainability indicators. Social benefits resonate with agricultural professionals because they address the sustainability of the sector beyond their efforts to restore the environment.

Visibility and Temporal Proximity: Social benefits are observable locally, within months or years (i.e., employment in feedstock processing, distributor jobs, improvements in farmer income, etc.). In contrast, environmental benefits occur over longer time frames (i.e., carbon sequestration or soil health restoration) and exist in the global concept, distancing us psychologically despite the environmental benefits being more objectively impactful.

Triple Bottom Line Praxis: European agricultural professionals also appear to be assessing sustainability through 'responsible business' and 'stakeholder capitalism' lenses, rather than a purely environmentally derived approach. They recognize that paradoxically, for environmental sustainability to occur, the social sustainability of farmers must be preserved.

In other words, farmers must continue to be financially viable stewards for their soil and environment.

This social benefit prioritization finding contradicts the assumptions prevalent in European biostimulant marketing, where environmental credentials typically dominate value propositions (Du Jardin, 2015, p. 8). Previous studies on the adoption of sustainable agricultural innovation have highlighted environmental performance as the main driver of adoption. This is especially pronounced in literature related to the EU policy context and those influenced by the Green Deal objective and Farm-to-Fork (Khoulati et al., 2025, pp. 2–3). However, our findings align more closely with the agricultural economics literature demonstrating that farmers prioritize economic viability and sectoral sustainability over abstract environmental goals when facing resource constraints (Long, Blok and Coninx, 2015, p. 13). The stakeholders' prioritization of social benefits supporting farming communities ($M = 3.77$) over environmental benefits ($M = 3.59$, $p < 0.001$) suggests a lens of 'sector viability' from the perspective of stakeholders, whereby environmental sustainability is contingent on the economic and social sustainability of farming communities, the stewards of agricultural landscapes. This perspective reflects the increasing recognition within European agriculture that environmental objectives cannot be achieved if farming communities lack economic viability and social cohesion (Gawel, Pannicke and Hagemann, 2019, p. 4). Companies face challenges in rethinking the content of their communication on sustainability. Instead of using eco-credentials to position themselves, they should emphasize the resilience of the sector, rural employment, and community economic development. Moreover, the environmental benefits of agriculture can be positioned as co-benefits of socially sustainable agriculture.

Commercialization Implications*:* Marketing value propositions should lead to social benefits (ie. Job creation) associated with and supporting the economic benefits of sustainable practices generated in terms of local feedstock collection, sustainable processing, and trajectory down to processing, distribution, and technical support at and through the agricultural community. Environmental benefits are still important in terms of legitimacy, but may serve as secondarily positioned practical considerations. Economic benefits also serve as supporting claims for functional performance, but do not serve as justifications for adoption in and of themselves without an embedded social benefit proposition.

Threat of Strategic Misalignment: Producers that make environmental credentials a priority (which is typical for EU marketing), may be underwhelming stakeholders' priorities. Messages about the viability of the sector, preserving rural employment, and maintaining farming traditions are likely more convincing in stakeholder engagement than sustainability around an environmental agenda. This study suggests that messaging value propositions are more about stakeholder priorities than producers' environmental commitment.

6.1.3 Evidence-Driven Adoption Pathways (H1)

Adoption decision making shows a clear preference for evidence through demonstrations rather than through social influence. Regarding case studies, we see 77.6% (n=76), pilot tests, 72.4% (n=71), and social norms, only 10.2% (n=10). This evidence represents a 7.6:1 ratio for preference for evidence instead of social conformity, providing solid empirical evidence for Hypothesis 1.

Validation of Rogers' Diffusion Theory: Rogers and Everett M, (2003) identifies five innovation characteristics that influence adoption: relative advantage, compatibility, complexity, trialability, and observability. The data clearly provide an empirical validation of trialability and observability as the two dominant drivers in agricultural contexts. The 77.6% preference for case studies (observability) and 72.4% for pilot tests (trialability) far outweighed peer recommendations (56.1%) and marginally outweighed agricultural networks (30.6%).

The 7.6:1 preference ratio for evidence-based mechanisms over social influence reflects the high-stakes, technically complex nature of agricultural input decisions documented in the adoption literature (Long, Blok and Coninx, 2015, pp. 11–13). Customers' adoption of a product is based on social influence and the reaction to brand reputation. However, agricultural innovations are subjected to an extensive amount of economic assessment because unlike consumer product failure, agricultural innovation failure can lead to annual farm income loss and food production loss. According to Traon et al. (2014, p. 33), farmers' adoption of biostimulants on farms is primarily driven by the field performance of products demonstrated in local agronomic conditions rather than by recommendations from peers or claims made in marketing. Farmers are unable to risk using untried inputs during the crop

production season. Thus, they will not try something new unless they have been tried successfully by another farmer or if they see its efficacy in a case study or pilot program. Therefore, pre-adoption validation through case studies and pilot programmes is essential. This result indicates that commercialization resources should be allocated. Firms should allocate more resources to building field trials, case studies, and pilot programs and less to advertising, social media, posting, or influencers. The evidence-driven diffusion pathway requires capabilities fundamentally different from those generated by social diffusion pathways. The latter obtainspower from network effects and viral marketing, whereas the former requires agronomic expertise, statistical trial design, and scientific documentation, among others.

Strategic Implication: Evidence-Driven Diffusion Pathway: The 7.6:1 ratio indicated that a peer-driven diffusion pathway (which characterizes the successful launch of consumer products) is unlikely to occur for lignin biostimulants. Instead, the need for an "evidence-driven diffusion" pathway is required based on cumulative agronomic evidence. The need for this pathway requires a significant investment in:

1. Field Trial Infrastructure: Multi-site, multi-year trials to accumulate crop-specific, region-specific efficacy.
2. Case Study Documentation: Quantified testimonials of farmers demonstrating observable outcomes (yield improvement, disease mitigation, cost savings).
3. Pilot Program Management: Organize demonstration programs that include farmer participation and observable evidence of efficacy.
4. Distribution of Efficacy Evidence: Publish trials in peer-reviewed agricultural journals, extension materials, farmer publication, etc.

Moreover, this finding fundamentally transitions the commercialization strategy from social marketing to evidence documentation.

6.1.4 Economic-Legal Primacy in PESTEL Analysis

The PESTEL framework illustrates a distinct and theoretically important hierarchy: economic factors (M = 4.13, 76.5% influential) and legal factors (M = 3.89, 71.4% influential) are appreciably prioritized over social factors (M = 3.42, 51.0% influential),

which represents a .71-point difference that is statistically significant at $p < 0.001$. This structure refutes the normative expectation that sustainability-minded European professionals would expect equal attention to environmental and social issues as to economic mechanisms.

The findings regarding economic-legal primacy relate directly to the regulatory context in Chapter 3. While the 24-36 months' approval time in France creates a substantially higher regulatory burden than the 9-15 months in the Netherlands, stakeholders in the various countries rated legal factors similarly (France $M = 3.86$, Germany $M = 3.90$, Netherlands $M = 3.93$, $F(3,94) = 0.236$, $p = 0.871$). This suggests that stakeholders view regulatory hurdles as technical challenges that can be overcome once viability is established, whereas economic limits are fundamental barriers. The observed pattern supports the findings of Wenger, Haas and Stern, (2020, p. 11). They argue that transaction costs such as regulatory compliance costs become manageable once the core economic value proposition justifies the necessary investment. However, if no economic advantage is proven, even minimal regulatory burden is prohibitive. For a commercialization strategy, firms must first focus on developing cost-competitive economics and functional performance advantages before investing significant resources in regulatory navigation optimization.

Instead, practitioners seem to use pragmatic market logic to analyze the chances of commercialization. The hierarchy seems to suggest that the stakeholders prioritize:

- Economic viability (will I be able to profit from this product as a farmer?)
- Regulatory clarity (can I obtain approvals and comply?)
- Environmental/community benefits (considered secondarily in terms of legitimacy)

This lends to pragmatism that merely reflects economic reality: farmers operate with minimal margin flexibility; new products that place existing practices and habits at risk must demonstrate considerable economic advantages to justify leaving the reasonably successful model of accepted, familiar synthetic fertilizers. Environmental and social advantages buffer positions but do not provide sufficient rationale for product or practice adoption.

Commercialization Implications: While EU policies result in declarations endorsing sustainability and stewardship, practitioners know that market success is ultimately

dependent on economic viability and regulatory navigation, and not on environmental or social considerations, although the latter is part of the value proposition for adopted products and practices. Implicit in this realization also implies that marketing efforts should lead to economic value (increased yields, reduced disease, cost savings anything that a farmer might be interested in) backed by environmental considerations, rather than both being inverted.

The analysis of stakeholders' perceptions yielded four important findings. First, the legitimacy gap needs to be validated through multiple channels, rather than merely providing information (H2). Second, social benefits, as the top value driver, undermine the assumption of environmental positioning (H5). Third, evidence-based adoption mechanisms are overwhelmingly influential at a ratio of 7.6:1 (H1), and fourth, legal economic factors dominate the macro-environmental influence. Perception patterns do not arise in a vacuum; instead, they both reflect and respond to stakeholders' institutional and regulatory contexts. To show how regulatory frameworks, market structures, and institutional environments affect their perceptions and constrain commercialization pathways, we now turn to Section 6.2. In other words, the report addressed Research Question 2. Simultaneously, this section sheds further light on Hypothesis 4 regarding the imperative of collaboration.

6.2 Addressing Research Question 2: Institutional and Regulatory Influences

This section examines how regulations and market structures affect commercialization pathways or adoption potential. The analysis reveals unexpected patterns of convergence between institutions, along with the emergence of collaborations that challenge the traditional assumptions framed around internationalization.

6.2.1 The Collaboration Imperative (H4)

Research Question 2 examined how regulatory, market, and institutional environments affect the commercialization pathways of lignin-derived biostimulants. Within this broader question, Hypothesis 4 concerned whether multi-stakeholder collaboration was considered essential for commercial success, and whether this was considered the case everywhere. Empirical evidence strongly indicates that 89.8% of respondents rated collaboration as

important or very important (M = 4.43, SD =0.73, median = 5.0). This examination elucidates the close aggregation of different nations. The mean score for France was established at 4.43 (SD = 0.88), Germany's mean was higher at 4.57 (SD = 0.60), the Netherlands'smean of 4.30 (SD = 0.65), and the mean score for other EU nations was recorded at 4.47 (SD = 0.77). Despite the institutional heterogeneity documented in Chapter 3, this pan-European consensus on the necessity of collaboration represents a theoretically significant finding that requires careful interpretation through circular economy and institutional theoretical frameworks.

Theoretical implications: This finding provides support for the literature on governance of the circular economy, which calls for multi-stakeholder approaches as a requirement for industrial co-product valorization (Lüdeke-Freund, 2019, p. 674). Lignin biostimulants require coordinated engagement from the pulp/paper industry, agricultural producers, regulators, researchers, and eventually distributers all stakeholders must be jointly coordinated to produce sufficient commercial viability no one stakeholder can complete the commercialization of biostimulants.

Despite the theoretical heterogeneity in institutional differences (France certifying, Germany is focused on building collaborative networks, and the Netherlands is driven for innovation), the geographical location variable did not have an impact on the results, suggesting that the requirements to implement a circular economy drove the lack of heterogeneity in responses. Regardless of how individual countries structure agricultural governance, success in valorizing residue for nutrient biostimulants requires engagement and coordination across the ecosystem, which cannot be achieved through institutional barriers or existing governance frameworks.

Governance Innovation Implications: The institutional structures of all three countries were designed to support linear agricultural input systems and not the circular valorization of industrial residues. This misalignment of existing institutions produces innovation that requires a transformation in governance: infrastructure in the form of cross-sectoral platforms, public–private partnerships, and multi-stakeholder councils utilized to support ecosystem solutions instead of colluding with institutional barriers. The high universal The

The 89.8% importance of collaboration implies that stakeholders recognize this governance gap and are expected to act to address issues requiring ecosystem solutions.

Strategic Implications: Commercialization strategies should be based on building governance structures (collaboration platforms, communities of practice, and joint research projects) before concentrating on pursuing sales-oriented market entry.

6.2.2 The Institutional Convergence Puzzle

Despite documented regulatory heterogeneity approval timelines ranging from to 9-15 months (Netherlands) to 24-36 months (France), stakeholder perceptions of institutional encouragement converged remarkably across countries ($F(3,94) = 0.278$, $p = 0.841$; France $M = 3.39$, Germany $M = 3.48$, Netherlands $M = 3.33$).

Institutional Theory predicts institutional heterogeneity based on the differential support of agricultural policy stakeholders across EU member states with different regulatory philosophies, styles, and structures of governance. However, perceptions have diverged. This institutional convergence puzzle, whereby stakeholder perceptions exhibit pan-European homogeneity despite substantial objective regulatory heterogeneity, requires a careful theoretical interpretation. We evaluate four potential explanatory mechanisms.

EU-Level Policy Harmonization and Isomorphic Pressures: The Union's regulatory framework for biostimulants, established through Regulation (EU) 2019/1009, created baseline harmonization that may have reduced perceived institutional distance despite persistent implementation differences across member states (Caradonia et al., 2018a, p. 440). This is in line with institutional isomorphism theory (DiMaggio and Powell, 1983, p. 150), in which organizations in the same regulatory field converge and experience similar pressures. These similar pressures arise from three aspects: coercive (restraining institutional requirements), mimetic (successful imitation), and normative (professional standardization).

Our findings suggest that normative isomorphism was particularly strong. Agricultural professionals throughout Europe participate in the shared knowledge networks. They attended the same conferences, read the same journals, and adopted the same evaluation

framework. Finally, they do so despite the specific regulatory constraints of their country. The unity of professionals may bring about an impression of institutional similarity that would overshadow regulatory differences that are more objective.

Methodological limitations in perception measurement: The subjective survey methodology employed in this study captures stakeholder perceptions of institutional encouragement rather than the objective institutional structures themselves. While Chapter 3 documents objective regulatory heterogeneity (approval timelines varying from to 9-15 to 24-36 months), our Likert-scale measures may lack sufficient granularity to detect nuanced differences in how stakeholders experience these institutional environments. Additionally, professional respondents, particularly those with international exposure or multi-country experience, may mentally 'average' their institutional experiences across contexts, leading to convergent perception ratings despite working within objectively different national frameworks. In the future, studies involving behavioral measurements (such as real-time data related to the market, the costs involved in complying with regulations, and success rates of approval) or analyzing the institution qualitatively may uncover the differences in objectives that are behind the surveys and are concealed by subjective perceptions that are convergent.

Professional Network Globalization and Cognitive Convergence: The professionalization and internationalization of European agriculture have created transnational epistemic communities that transcend national boundaries (Imbert et al., 2017, p. 74). Agricultural professionals increasingly identify with pan-European or global professional standards rather than national institutional contexts. The consultants assessed the potential of the market using a similar set of evaluation criteria. The criteria used to evaluate the market are not based on the institutional logic of a country but on global best practices, science, and professional standards, which are often similar across the world. The significance of collaboration, which Hypothesis 4 identified (89.8% agreement, $p = 0.622$, geographic variation), strengthens this interpretation. This indicates that stakeholders in all countries understand that the success of commercialization relies on collaboration across institutional boundaries. This suggests that such contextualization occurs at the European ecosystem level, rather than at the level of distinct national markets with unique institutional characteristics.

Relative importance of institutional factors in decision making: The PESTEL analysis (Section 6.1.4) demonstrated that, while stakeholders rated the institutional/legal factors as influential (M = 3.89), the economic factor was more dominant (M = 4.13, $p < 0.001$). The stakeholders involved are expected to consider differences in institutions less important than universal economic limitations. In particular, the premium pricing ceiling (hypothesis 3:69.4% ≤10% premium acceptance) is considered an important economic limit. If concerns about economic viability outweigh concerns about institutional navigation, players in diverse regulatory environments may converge in their assessments because they face fundamentally similar economic constraints regardless of regulatory details. Under this interpretation, institutional convergence in perceptions reflects the reality that economic fundamentals, cost structures, competitive positioning, and farmer willingness-to-pay matter more than regulatory navigation for commercialization success, even when regulatory pathways differ substantially.

6.2.3 Implications for Market Entry Sequencing

These competing explanations are not mutually exclusive, and some combinations likely operate simultaneously. The finding of institutional convergence has significant implications for international business theory and the Uppsala internationalization model discussed in Section 6.4.3. If professional networks and economic fundamentals create de facto institutional convergence within the EU, traditional assumptions about psychic distance and sequential market entry based on institutional proximity may require refinement of B2B professional products in knowledge-intensive industries. Future research should employ mixed-methods designs combining quantitative perception surveys with qualitative policy analysis and objective behavioral measures to determine whether convergent perceptions reflect actual institutional convergence, measurement limitations, or the primacy of economic factors over institutional factors in commercialization decision making.

Institutional analysis shows a contradiction. On the one hand, objective regulatory heterogeneity is documented in Chapter 3. However, there is a converging perception among stakeholders in the countries concerned with collaboration. The stakeholders believed that collaboration was important. H4 showed 89.8% importance, $p = 0.622$), geographic

variation. The convergence we observe, whether owing to the globalization of professional networks, the effects of EU harmonization, or the predominance of economic and institutional factors, has direct consequences for commercialization strategies. If institutional distance is less important than the theoretical predictions indicate, firms are advised in Section 6.3, focusing on universal constraints, especially economic viability and evidence credibility, rather than on localized institutional adaptation within countries.

6.3 Addressing Research Question 3: Commercialization Strategy Preferences

This section examines stakeholders'preferences regarding the configuration of the business model, pricing options, and value proposition elements to identify viable routes towards commercialization. The results highlight the major economic constraints and strategic priorities guiding market entry choices.

6.3.1 The Premium Pricing Ceiling (H3)

Hypothesis 3 indicates that premium willingness is seriously constrained, since 69.4% of participants indicated that they would accept a ≤10% maximum premium and none would accept >30%. The empirical findings match perfectly with the predictions: 69.4% would accept a ≤10% premium (i.e., n = 68); 25.5% indicated they would accept an 11%-20% premium (i.e., n = 25); 5.1% indicated they would accept a 21%-30% premium (i.e., n = 5); 0% indicated they would accept a rate >30%.

The first prediction established an empirical hard ceiling; zero participants indicated that they would pay a premium of >30%. A chi-square analysis showed that there were no statistically significant differences with respect to geographic variation ($\chi^2 = 7.86$, df = 9, p = 0.549), indicating that premium constraints are a pan-European phenomenon not limited to countries.

While geographic variation did not achieve statistical significance, directional patterns are worth strategic consideration, as they correspond with the institutional contexts demonstrated in Chapter 3. The Netherlands showed the highest price resistance, with 43.3%

(n=13) accepting no premium, and only 3.3% (n = 1) accepting just premiums of 21-30%. The Dutch agricultural sector has a powerful bias towards low-cost competitive exportation and efficiency-driven horticulture (Gawel, Pannicke and Hagemann, 2019, p. 4). In this case, price competitiveness determines the market access. Germany exhibited relatively higher price tolerance, with 14.3% (n=3) accepting 21-30% premiums, the highest proportion among countries. Germany's governance framework, along with its bioeconomic policy support, has created a collaborative culture (Imbert et al., 2017, p. 74). This enables partnerships to be oriented towards sustainability to distribute costs throughout the value chains. This ultimately makes it acceptable for end users to pay a slight premium as long as it is portrayed as an ecosystem investment and not just an investment attributed to them as end users. France exhibited moderate positioning, with 32.1% (n=9) accepting no premium, and zero respondents willing to exceed 20%, reflecting the French agricultural sector's price-conscious positioning between Dutch export efficiency and German value-added production.

The directional patterns offers an appropriate sequencing strategy. Entry into the Netherlands calls for aggressive cost-competitiveness (targeted 0-5% premium). Entry into Germany calls for positioning leveraged through partnership (8-12% premium likely through distribution in partnership). Entry into France calls for proven performance, offering justification (5-8% maximum premium, likely through certification credibility). Thus, the 10% ceiling represents a pan-European average with country-specific variance around this central tendency, requiring market-adapted pricing strategies while maintaining the overall cost discipline.

This finding confirms the basic principles of agricultural input economics: premium pricing requires demonstrated functional advantage that justifies incremental cost through measurable return-on-investment (Wenger, Haas and Stern, 2020, p. 304). Unlike consumer goods, where brand positioning or environmental credentials can command premiums (Elkington, 1998, p. 45), agricultural inputs face rigorous cost-benefit evaluations by economically constrained producers. The 10% ceiling reflects what (Barney, Jay, 1991, p. 107) terms "competitive parity": without rare, valuable, and inimitable performance advantages, products cannot escape commodity pricing pressures.

6.3.2 Value Proposition Dominance in Business Model Configuration

Research Question 3 assesses the commercialization strategy preferences of agricultural stakeholders to determine which business model configurations and market entry approaches appear most promising to address adoption barriers. Business Model Canvas by Osterwalder and Pigneur has been suitably applied by various scholars for systematic analysis of user preferences by decomposing the business model into nine components. These components are customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structures. Stakeholders were asked to mention the three most important BMC elements in their decision-making processes. Most stakeholders prioritize only one element. Value proposition was mentioned by 89.8% (n=88) and had a 30.6 percentage-point gap with the second-most important elements, reliable key partners (59.2%, n=58), and cost-effective revenue streams (57.1%, n=56).

The prioritization shown suggests that stakeholders will want to see validated product performance and demonstrated benefits before they engage in partnership structures, pricing structures, or distribution channels, which will inform a viable commercial framework sequence.

6.3.3 Risk Perception Hierarchy

Applying Barney (1991, p. 102) VRIO framework illuminates why the value proposition emerged as the overwhelmingly dominant business model element in stakeholder evaluations (89.8% prioritization, exceeding all other components by at least 30 percentage points). Evidence of efficacy, comprehensive and field-validated, satisfies each VRIO criterion, and is thus the primary source of sustained competitive advantage in this emerging market.

This resource is valuable because robust evidence directly addresses stakeholders' principal adoption concerns, effectiveness under real-world farming conditions (M = 3.54; 64.3% highly concerned), and economic viability (M = 3.66; 68.4% highly concerned). Without

credible demonstration of agronomic and financial superiority over conventional inputs, lignin-derived biostimulants cannot overcome the severe legitimacy and premium constraints documented in Hypotheses 1 and 3.

The resource is rare. Engaging in multi-year, multi-site field trials paired with peer-reviewed case studies takes time (typically three to five years), requires specialized agronomic skills across pedoclimatic and cropping systems, retains farmer cooperation for on-farm verification for multiple years, and has sufficient statistical power for scientific publication. Few competitors possess the financial capacity and technical competence to assemble comparable evidence portfolios, particularly at crop- and region-specific levels required by professional intermediaries.

However, these resources are inevitable. The first mover advantage arises from several factors. The evidence generation is cumulative. Those who go first and create validation for performance in key crop region combinations incur high replication costs for the second movers. Therefore, the second mover may have to undertake unnecessary trials or may be positioned as an unvalidated alternative. The concept of inimitability is further solidified by the protection of intellectual property through upstream processing technologies, as argued by Gillet et al. (2017, p. 4200). It is increasingly protected on specific formulation-application combinations through the use of patents.

Finally, successful firms must be organized to exploit these resources. The strong preference of stakeholders for the primacy of value propositions suggests that they acknowledge that competitive advantage depends on what organizations can do, which is related to trial design and management, data analysis, scientific advocacy, and professional networks. These capabilities are quite different from those required for conventional fertilizer manufacturing or distribution.

Thus, evidence portfolios that satisfy all four VRIO criteria represent the core strategic asset that differentiates viable from nonviable lignin biostimulant ventures. This finding explains the observed hierarchical ordering of Business Model Canvas elements: until a rare, valuable, and inimitable evidence base has been systematically organized into a compelling value proposition, secondary elements, such as partnerships (59.2%), revenue streams

(57.1%), and key resources (51.0%), remain of limited strategic relevance. Consequently, business model development must be rigorously sequenced. That is, the generation and validation of evidence must precede the optimization of all other components. This requirement challenges the common assumption of simultaneous and equidistant developments across the BMC framework.

6.4 Theoretical Discussion and Integration with Literature

This section systematically positions empirical findings within established theoretical frameworks to assess their explanatory power and identify novel contributions. The information in each subsection confirms, contradicts, or expands the seminal theory on the commercialization of innovations in sustainable agriculture.

6.4.1 Institutional Theory and Cognitive Legitimacy

Scott (2014, p. 59) describes the three pillars of institutional legitimacy. This study builds on Institutional Theory by differentiating between legitimacy deficits and knowledge gaps. Existing research has viewed adoption barriers as primarily regulatory or technical problems. This study shows that cognitive legitimacy, institutional embedding, and professional normalization serve as separate adoption barriers unrelated to knowledge gaps.

The 1.66-point gap in general awareness (M = 4.12) and specific awareness of lignin products (M = 2.46) could not be attributed to a lack of knowledge. European agricultural practitioners have access to a significant amount of information. This gap stems from the lack of cultural embedding by lignin imbibition products not being recognized as professionally acceptable "the way things are supposed to be’ in European agriculture.

New Framework Contribution: For practitioners marketing agricultural innovations, differentiating between

- Knowledge gaps (knowledge deficits that can be bridged by awareness campaigns)
- Legitimacy gaps (institutional embedding deficits that can be bridged through multi-faceted credibility development)

Allocating resources for professional association endorsement, partnerships with research institutions, and even government endorsement may be more worthwhile than awareness campaigns.

6.4.2 Rogers' Diffusion Theory: Evidence vs. Social Influence

Rogers and Everett M, (2003, p. 219) summarizes the characteristics of the five innovations that influence their adoption. Within this research, the characteristic of trialability and observability provides empirical validation of evidence based on trial versus evidence based on observation, which strongly influences adoption in professional-technical contexts:

- Case studies (observability): 77.6% influence adoption
- Pilot testing (trialability): 72.4% influence adoption
- Social norms: 10.2% influence on adoption.

The social influence to evidence influence ratio (7.6:1) validates Rogers' predictions, as they apply in a technical context for adoption. The data on risk perception hierarchy (effectiveness M = 3.54; economic viability M = 3.66; environmental concern M = 3.18) suggest that stakeholders employ practical evaluation of relative advantage, assessing biostimulants against established tangible advantages (i.e., yield, disease prevention, and lower cost) versus the risk of adoption.

Regarding novel applications, this research builds upon Rogers' theory when establishing, in the context of agriculture, that better evidence on production methods can be established through demonstrated evidence that may work faster than social network diffusion through peers, which is more common in consumer product adoption.

6.4.3 Uppsala Model Refinement for B2B Contexts

The Uppsala model (Johanson, J. and Vahlne, 1977, p. 23) suggests a sequential learning-based model of internationalization into progressively psychologically distant markets. This study does not directly ground or challenge the Uppland model's predictions, but provides indirect support. The finding of no statistically significant variation in awareness ($p = 18.3$),

encouragement via institutions ($p = 0.841$), or importance of collaboration ($p = 0.622$) implies that the institutional context across countries matters little to stakeholder perceptions, as the Uppsala model might predict. This indicates a fairly low psychological distance between France, Germany, and the Netherlands, as they all represent fairly similar institutional contexts.

The data on the regulatory timeline in Chapter 3 offers an important context for reading the puzzle of institutional convergence. Despite the objective differences, the Netherlands (9-15 months), Germany (12-18 months), and France (24-36 months) ($F(3,94) = 0.278$, $p = 0.841$). This divergence between objective regulatory burden and subjective institutional assessment suggests that the Uppsala model's psychic distance concept may operate differently for B2B professional products thanfor consumer goods or traditional internationalization contexts. According to (Dessart, Barreiro-Hurlé and Van Bavel, 2019, p. 417), knowledge workers operating in networks generate a psychic distance that is lower than that observed in manufacturing. For biostimulants derived from lignin, the relevant "distance" may not be regulatory complexity in itself, but rather the pace of evidence generation and the accumulation of learning. This explains why the Netherlands remains the optimal entry market despite convergent stakeholder perceptions: the 9-15 to month timeline enables faster iteration, earlier market feedback, and accelerated capability development that can subsequently support entry into Germany and France. Uppsala logic thus applies to supply side learning dynamics rather than to demand-side perception management.

However, the PESTEL analysis suggests that legal and institutional contexts still matter significantly ($M = 3.89$ and $M = 3.70$, respectively), implying that while stakeholder perspectives appear to hold converge, the objective navigability of institutions remains differentially embedded.

This indicates: Market Entry Sequence Logic

1. Netherlands First (Entry Market): Shortest regulatory timeline (9-15 Months); policies conducive to innovation and lower effectiveness concern; most optimal environment for evidence generation while prototyping.
2. Germany Second (Expansion Market): Governance that supports collaboration suggests they are able leverage partner firms; moderate degree of premium tolerance

would work to future expansion based on collaborative model; acceptable timeline for new evidence generation (12-18 months) and applying what was learned from Netherlands market experience.

3. France Third (Mature Market): Most burdensome regulatory environment, highest amount of effectiveness concern (given past history with biostimulant products), substantial body of evidence, and some form of certification (from previous market experiences).

This sequence aligns with the Uppsala logic as a market entry model, but one must also recognize that while there is great convergence on stakeholder perceptions, objective legal or regulatory navigability is still differentiated.

6.4.4 Circular Economy Principles and Ecosystem Governance

The finding for The universal importance of collaboration across the sample (89.8%, p = 0.622 geographic variation) aligns with the existing circular economy literature (Lüdeke-Freund, 2019, p. 674) emphasizing the importance of multi-stakeholder participation and collaboration to achieve biomass waste or by-product value. Given that the finding for collaboration transcends institutional contexts, the need for collaborative motivation is more important than the institutional context.

Systematic valorization of residues, using repurposed bio-products for agricultural inputs, requires some coordination across a collaboration among various constituent partners, including the pulp/paper industry, agriculture, research, and policy. Current institutional design structures are framed around linear agricultural systems; therefore, the designs need to evolve towards new institutional governance designs that are predicated on collaboration across sectors. The importance of collaboration across stakeholder perspectives (89.8%) also suggests that the market is ready for an ecosystem-based commercialization approach.

The Table 31 below synthesizes how this study's findings confirm, challenge, or extend established theories.

Table 31: Integration of Theoretical Frameworks with Empirical Findings

Theory/Framework	What Theory Predicts	What This Study Found	How Findings Relate to Theory
Institutional Theory (Scott, 2014)	Different institutional contexts (regulations, norms) across countries create different adoption barriers	Stakeholder perceptions were similar across France, Germany, and Netherlands ($p = 0.841$), despite different regulatory environments. Legitimacy gap exists across all countries.	***Refinement**:* Cognitive legitimacy works at transnational professional level, not national level. Professional networks override national institutional differences for B2B products.
Diffusion of Innovations (Rogers, 2003)	Innovations spread through trialability, observability, and peer influence from opinion leaders	Evidence-based factors dominated: case studies (77.6%), pilot tests (72.4%) vs. social norms (10.2%). Ratio of 7.6:1 favoring evidence over social influence.	***Strong support** + **extension**:* Professional agricultural contexts follow "evidence-driven diffusion" rather than social diffusion. Validation matters more than peer recommendations.
Resource-Based View (Barney, 2015)	Firms gain competitive advantage through VRIO resources (Valuable, Rare, Inimitable, Organized)	Value proposition was most important business model element (89.8%), with 30.6-point gap over next element. Efficacy evidence seen as key resource.	***Strong support**:* Field trial data and case studies are VRIO resources. Evidence portfolios are rare, expensive to duplicate, and provide first-mover advantage.
PESTEL Analysis (Gawel et al., 2019)	Political, Economic, Social, Technological, Environmental, and Legal factors all influence commercialization	Economic factors ($M = 4.13$) and Legal factors ($M = 3.89$) rated significantly higher than Social ($M = 3.42$) and Environmental ($M = 3.54$) factors ($p < 0.001$)	***Support with unexpected finding**:* Economic and legal factors dominate over environmental and social concerns, challenging assumption that sustainability credentials drive adoption.
Triple Bottom Line (Elkington, 1997)	Sustainable innovations must balance three dimensions: Economic, Environmental, and Social value	Social benefits ($M = 3.77$) ranked higher than Environmental ($M = 3.59$) and Economic ($M = 3.54$) benefits (both $p < 0.001$)	***Refinement**:* Three dimensions not equally weighted. Social sustainability (community support, employment) prioritized. Stakeholders use "sector viability" evaluation lens.
Uppsala Internationalization Model (Johanson & Vahlne, 1977)	Firms should enter markets sequentially, starting with psychically close markets and learning gradually	Perceptions converged across countries ($p = 0.841$), but sequential entry still recommended: Netherlands (9-15 months) → Germany (12-18 months) → France (24-36 months)	***Partial support with modification**:* Sequence based on regulatory learning speed, not psychic distance. Model applies to supply-side capability building rather than demand-side learning.
Circular Economy Principles (Lüdeke-Freund et al., 2018)	Bioeconomy transitions require multi-stakeholder collaboration across value chains	Collaboration rated as very important (89.8%), with no significant difference between countries ($p = 0.622$, $\eta^2 = 0.019$)	***Strong support**:* Ecosystem coordination universally recognized as essential. Institutional context doesn't change the need for collaboration.
Business Model Canvas	Nine business model elements (value	Value proposition overwhelmingly	***Refinement**:* In agricultural B2B contexts,

(Osterwalder & Pigneur, 2010)	proposition, partners, resources, etc.) work together to create value	prioritized (89.8%), with large gap (30.6 points) before second-ranked elements (partners 59.2%, revenue 57.1%)	value proposition must be established first. Other elements become relevant only after efficacy is proven.

Source: Author's own analysis based on survey data collected in October 2025

Three patterns emerge from this theoretical integration. First, frameworks developed for consumer products or manufacturing contexts (Diffusion of Innovations, Uppsala Model, Business Model Canvas) require substantial modification for professional B2B agricultural innovations evidence-driven validation supersedes social influence, regulatory learning speed matters more than psychic distance, and value proposition dominance precedes all other business model elements. Second, institutional and sustainability frameworks (Institutional Theory, Triple Bottom Line, Circular Economy) correctly predict the importance of legitimacy and collaboration but underestimate economic primacy stakeholders prioritize social over environmental benefits and constrain premiums to 10% regardless of sustainability credentials. Third, strategic frameworks (Resource-Based View, PESTEL) accurately explain competitive dynamics but gain precision through our identification of evidence portfolios as VRIO resources and economic-legal factors as dominant macro-environmental influences. These patterns justify the four novel theoretical contributions developed in Section 6.5.

6.5 Novel Theoretical Contributions

In addition to confirming some hypotheses, the study produces four novel contributions to the literature on sustainable agricultural innovation commercialization. Each proposal expands existing frameworks by recognizing mechanisms, differences, or contextual conditions that have not yet been theorized in the literature.

6.5.1 Legitimacy-Action Gap Framework

Prior research on agricultural innovation adoption has predominantly framed barriers as information asymmetries or knowledge deficits addressable through education, extension services, and awareness campaigns (Long, Blok and Coninx, 2015, p. 13; Traon et al., 2014, p. 33). This "information deficit model" assumes that once stakeholders become aware of an

innovation and understand its benefits, adoption intention will follow, with the remaining barriers being primarily economic (cost constraints) or technical (compatibility issues). Our findings challenge this model by identifying a distinct legitimacy deficit that operates independent of information availability.

The empirical pattern of 96.9% general biostimulant awareness, yet only 23.5% lignin-specific awareness, coupled with 52.9% market optimism, yet only 5.1% active promotion, cannot be explained by information deficits alone. Members of the European agricultural profession have access to vast amounts of information through contacts, journals, conferences, and digital databases. The gap, therefore, represents what Suchman (1995, p. 574) terms define as cognitive legitimacy deficit: innovation has not achieved "taken-for-grantedness" or cultural embeddedness within professional agricultural discourse.

The gap between legitimacy and action extends the insights of institutional theory by showing that cognitive legitimacy is an adoption barrier that requires a remediation strategy that differs from information deficits. While information campaigns target awareness building, legitimacy building requires multichannel institutional embedding: publication in peer-reviewed agricultural journals, endorsement by professional associations (e.g., the European Biostimulants Industry Council), integration into agricultural education curricula, inclusion in government extension recommendations, and normalization through repeated exposure in professional discourse. Activities that build legitimacy require extended timeframes, rather than months, and cannot be compressed by a larger marketing budget or more information.

This study makes a theoretical contribution by establishing a distinction between the two types of adoption barriers that have been treated as one in prior literature. The first barrier pertains to knowledge gaps, in which information deficits can be addressed through awareness campaigns, technical documentation, and educational programming. The second barrier comprises legitimacy gaps, where institutional embedding deficits can only be addressed through continuous professional validation, the establishment of scientific credibility, and cultural normalization. This distinction has direct implications for resource allocation in commercialization strategies: firms that invest primarily in marketing and awareness campaigns may achieve intellectual recognition (as evidenced by 52.9% optimism

in our sample) without generating adoption advocacy (only 5.1% promoters), whereas firms that invest in legitimacy-building activities even when more costly and time-intensive may achieve the cognitive embeddedness necessary for sustained diffusion.

6.5.2 Institutional Heterogeneity Paradox: Perception vs. Objective Reality

This study recognizes an important methodological distinction between objective institutional structures and stakeholders' subjective perceptions of these structures. In this study, there are no geographic differences in institutional encouragement ($p=0.841$), despite the fact that there are institutional heterogeneities in regulatory structures (e.g., length of review for approval: Netherlands 9-15 months, Germany 12-18 months, France 24-36 months).

Assessing institutions based on subjective surveys may fail to accurately describe objective structural variation. Future research should employ a method triangulation with a mixed-methods design that combines subjective survey data with a detailed policy analysis to determine whether converged perceptions capture actual institutional convergence, limitations of perception, or differences in institutional prioritization between countries.

6.5.3 Optimism-Advocacy Gap and Premium Ceiling

This study captured an important phenomenon of commercialization: the disconnect between the ability to recognize market potential (on an intellectual basis: 52.9% optimism) and conviction to actively advocate (a mere 5.1% promoters, NPS=-59.2%). This also builds upon Rogers' (2003) theory regarding opinion leaders and between intellectual legitimacy (cognitive recognition) and conviction (willingness to promote). Implications for the sector: Firms cannot rely on peer-driven, word-of-mouth marketing to promote their new products; instead they need to create direct channels with farmers who have had direct experience and testimonials with the product.

This study contributes empirical evidence for the maximum acceptable price premium based on real data with purchasers of sustainable products: 69.4% of respondents accepted a

sustainable premium ≤ 10% and 0% accepted > 30%. This empirical ceiling undermines some assumptions in the sustainable agriculture marketing literature that suggest consumer/farmer willingness to pay excessive premiums for small additional environmental goods. The findings of this study are as follows. Producers act with economic rationality in their adoption decisions. Premium prices can only be justified if the premium can demonstrate greater functional value (e.g., yield improvement, less disease and, cost savings) beyond sustainability credentials.

6.5.4 Evidence-Driven Diffusion Pathways

Despite being empirically validated in numerous contexts, (Rogers and Everett M, 2003, p. 249) Diffusion of Innovations theory has mainly looked at innovations in which social influence and interpersonal networks play a role in their adoption. The S-curve of diffusion assumes that early adopters impact the early majority through demonstration effects and social proof, leading to cascading adoption as innovations cross the chasm from innovators to the mainstream. Most commercialization strategies designed for new products have the logic of social diffusion behind them, focusing on aspects such as the identification of opinion leaders, peer recommendations, referral programs, and network effects.

Our findings reveal a fundamentally different diffusion pathway for professional B2B agricultural innovations, which we term "evidence-driven diffusion." The 7.6:1 ratio favoring demonstration evidence over social influence mechanisms (case studies 77.6%, pilot tests 72.4% versus social norms 10.2%) suggests that for technically complex, high-stakes professional decisions, diffusion occurs through accumulated scientific validation rather than through social cascades. This evidence-based pathway has several unique features, as discussed below.

1. Each potential adopter requires independent evidence validation rather than relying on early adopter experiences, slowing diffusion and increasing adoption quality.
2. The success of the product relies more on professional intermediaries like agronomists, consultants, and researchers to validate its efficacy than the farmers directly influencing their peers (explaining why 60.2% of our sample are intermediaries, they are the critical gatekeepers)

3. Generic case studies have proven insufficient; stakeholders require evidence under their specific agronomic conditions (crop type, soil, and climate), necessitating geographically distributed trial portfolios.
4. Social influence operates downstream after evidence establishment rather than driving initial adoption, which implies that opinion leaders arise from performance validation rather than early experimentation.

The innovation literature has undertheorized this diffusion pathway, which is supported by evidence. Following the work of Rogers on agricultural innovations, which was concerned with developing country contexts in which access to information was low and knowledge was transferred through social networks, modification took place. Today's European farmers are educated and informed; they no longer rely on the social environment but trust scientific evidence. The theoretical contribution refers to identifying the circumstances under which evidence-driven pathways prevail over social pathways. In particular, pathways are dominated by evidence rather than social if (i) there is a high perceived risk of adoption failure; (ii) the situation calls for professional decision-making with accountability requirements; (iii) technical complexities of the innovation call for a specialized evaluation; and (iv) the existence of an information infrastructure that allows for the dissemination of evidence. Under these conditions, commercialization strategies must prioritize evidence generation over network building, requiring fundamentally different resource allocations and capability investments compared to consumer product launches or social diffusion-dependent innovations.

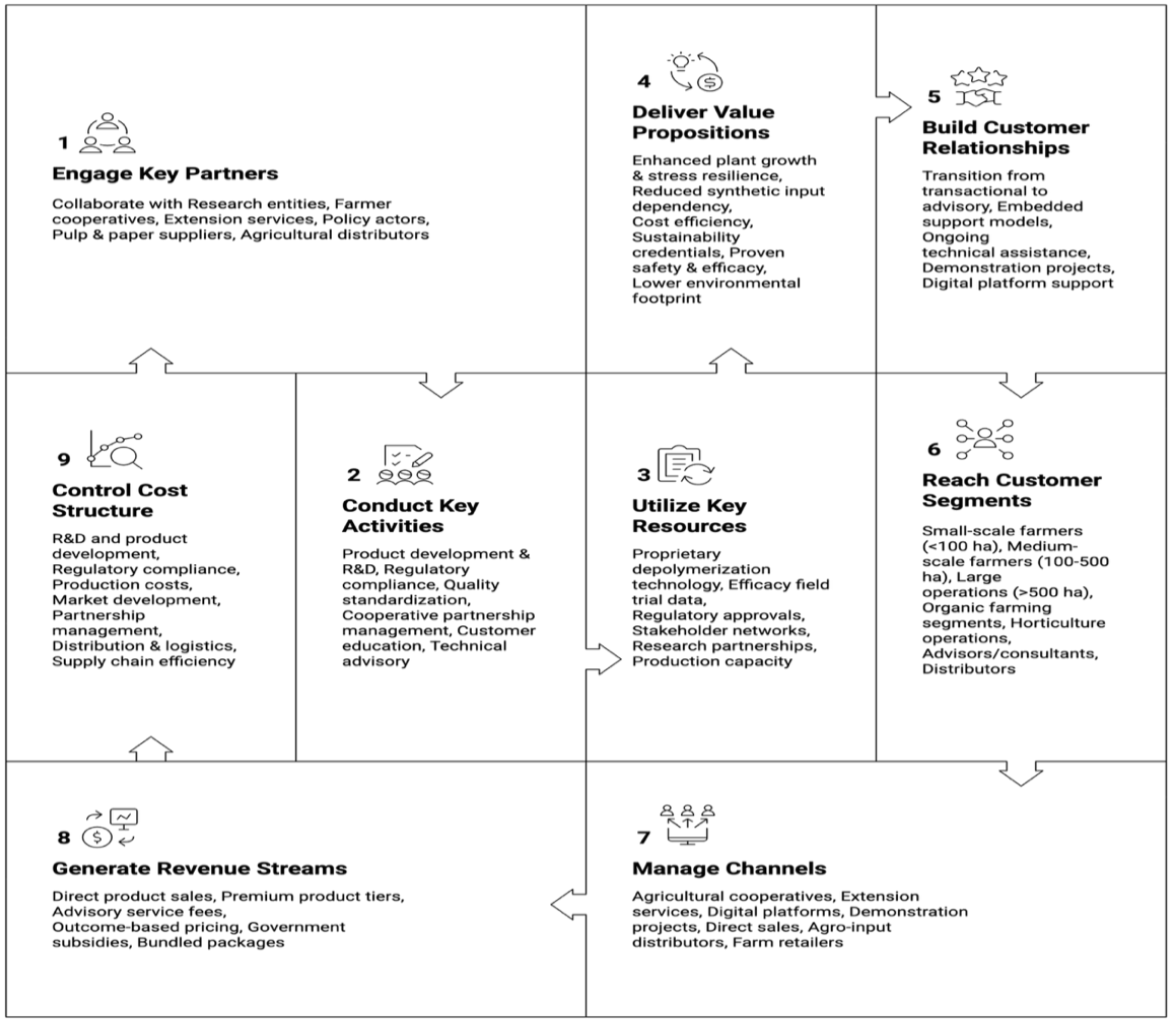
6.6 Implications for Practice

These theoretical and empirical insights provide useful guidance for various groups of stakeholders involved in lignin biostimulant commercialization. The results of this study have implications for future policy. These is discussed in this section.

6.6.1 Strategic Recommendations for Firms to Commercialize

The effective commercialization of lignin-derived biostimulants should occur in a sequence that addresses the awareness-legitimacy gap, credibility through evidence, and economic constraints. The below Figure 4 presents a Business Model Cycle that integrates the theories and empirical findings discussed in this chapter to provide a coherent commercialization framework. The nine components of the framework are interrelated and reflect stakeholder priorities, institutional requirements, and research imperatives. According to this cyclical model, commercialization is only successful when evidence generation, collaborative ecosystem building, social-benefit positioning, and economic discipline are deployed in a sequenced manner and revised over time based on market feedback.

Figure 4: Lignin-based Biostimulant Business Model Cycle



Source: Author's own elaboration based on thesis findings, inspired by the Business Model Canvas by Osterwalder and Pigneur

The three-phase roadmap presented below operationalizes this business model cycle using a time-sequence implementation strategy.

Phase One (Months zero to 18): Evidence Generation and Legitimacy Foundation: In Phase 1, cognitive legitimacy was established through scientific validation. Given that case studies influenced 77.6% of stakeholders, and pilot tests influenced 72.4%, credible agronomic evidence must precede market entry. Organizations planning to launch agricultural innovations are advised to invest in three ways: First, field trial infrastructure with multi-site (15-20 sites) trials will be needed over three years in varied agronomic conditions to counter effectiveness concerns (64.3% moderate-high concern). Second, case study documentation through quantified metrics of performance supported by farmer testimonials is used to illustrate social benefits over environmental claims. Finally, publication of peer-reviewed science with the intention of publishing three to five articles could help in countering intermediaries' perceptions (60.2% of stakeholders).

The expected outcomes include established scientific credibility, 15-20 documented case studies, peer-reviewed publications, and a foundation for regulatory submissions. The critical success factor is to refrain from launching on the market too early but to generate more evidence.

Phase 2 (Months 18-36): Piloting market entry and validating business model: Phase 2 tests the commercialization model under favorable regulatory conditions. Because the Netherlands has the shortest market entry timeline of 9-15 months and is highly supportive of innovation, it is the best first-entry market. Firms should target high-value horticulture where the 10% premium ceiling can be justified, partner with established distributors (addressing the 89.8% collaboration imperative), and launch at a 5-8% premium with clear ROI justification rather than environmental positioning alone.

A pilot program structured with 50-100 farmers helps with market learning through performance monitoring and quarterly workshops. Regulatory navigation proceeded in parallel across the Netherlands (9-15 months), Germany (12-18 months), and France (24-36 months). Business model optimization tests value propositions (yield improvement primary,

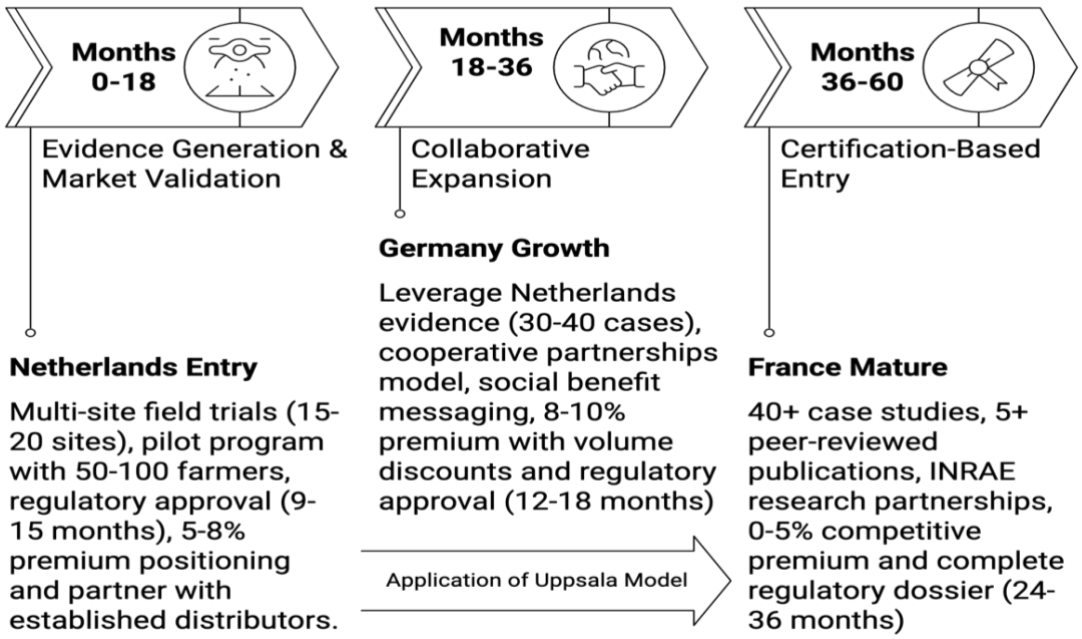
soil health secondary, and environmental tertiary), distribution channels, and pricing architecture.

The anticipated outcomes are entering the Netherlands market with 200-500 farmers, validating the business model, expanding the evidence portfolio (30-40 cases), and making regulatory progress. Critical success factors focus on learning from the market rather than maximizing revenue and maintaining price discipline.

Phase 3 (Months 36-60): Geographic Expansion and Scale-Up: Phase 3 operations were launched in Germany and France along with scaling operations in the Netherlands. Through cooperative and bioeconomic initiatives, Germany's entry-stressed partnership. Collaborated on governance as well as moderate premium tolerance (14.3% prepared to accept 21-30%). The pricing strategy includes a target of an 8-10% premium with messaging that focuses on social benefits, such as rural employment and regional economic development.

The introduction of France necessitates strictest preparation, that is, 40+ case studies, more than five publications, success in the Dutch and German markets, and full regulatory approval because of concernsabout optimum effectiveness (M = 3.82) and certification-oriented culture. Pricing should be competitive at a 0-5% premium. To scale up operations, industries must secure agreements for the supply of lignin feedstock, expand their processing capacity, and build support teams for technical assistance. Brand positioning embraces the Proven Performance Biostimulant, which focuses on the advantages of a product. This is followed by social sustainability messages. The expected outcomes include operation in three countries serving 1000-2000 farmers, along with the chance of sustainable revenue generation, 50+ case studies on serving farmers, and a platform for further expansion in EU countries.

Figure 5: Three-Phase Commercialization Roadmap for Lignin-based Biostimulants



Source: Author's own elaboration

Uppsala model application for the internationalization of lignin biostimulants. Sequential entry from the Netherlands through Germany to France builds evidence portfolios and market capabilities, with each phase addressing increasing regulatory complexity and stakeholder validation requirements.

6.6.2 Strategic Framework for Commercialization

Companies must apply strategic discipline to the five guiding principles throughout all stages. Evidence primacy requires that trial rigor never be sacrificed for speed as the credibility of evidence is the principal strategic asset. Second, price discipline means not discounting more than 10%, improving the value proposition with better performance rather than reducing the price. Third, collaborative orientation is based on the premise that no organization can control the entire value chain. Thus, ecosystem coordination is required. Fourth, recognizing that the construction of legitimacy requires three-to five-year windows, premature scaling undermines cognitive legitimacy. The fifth point of consideration is that while the focus is on customer profile targets, it is not farmers, but agricultural intermediaries. Agricultural intermediaries validate various products for the farmers. Furthermore, they covered the requirements for evidence.

This phased approach sequentially aligns resource deployment with the empirical findings. The first phase of the discussion focuses on addressing issues of legitimacy and evidence. The second phase aims to emphasize the business model under premium conditions. Ultimately, the third phase aims to scale through collaborative ecosystems with an emphasis on social benefits. In sequential logic, Uppsala internationalization principles are applied to regulatory learning, in which each phase builds upstream capabilities that serve as essential prerequisites for the next phase.

6.6.3 Policy Recommendations for Government and Regulatory Bodies

Government and regulatory actors must be strongly committed to harmonization, support, and intra-organizational coordination to facilitate the production and use of biostimulants by farmers for sustainable production. The top priority is regulatory harmonization at the EU level. Coordinated definitions, approval processes, and labelling can make compliance significantly less burdensome for producers, accelerating the process of bringing biostimulants rapidly to the market. Regulatory harmonization can also increase cross-border market fluidity, which is important for scaling up sustainable innovation. Equally important is supportive public-sector engagement by developing and funding pilot programs, specifically efficacy trials in early entry countries such as the Netherlands and Germany, which will support producers in commercializing biostimulants that lower input costs and rapidly build robust evidence.

To address the ongoing low levels of awareness about specific products flagged in this study, government and extension efforts should establish coordinated, multi-channel educational initiatives. Efforts should include targeted campaigns to increase professional knowledge, incorporate biostimulant topics into educational curricula, and establish professional learning opportunities. Another important role of policy in stakeholders comes from convening multi-stakeholder forums that involve pulp and paper producers, farming communities, research institutions, and distribution networks. Such actions reduce transaction costs and support coordinated ecosystem building. Finally, incentive mechanisms can significantly impact early adopters' market access through policies that consist of preferential procurement, access to subsidies, and tax incentives, provided they articulate a clear environmental and policy rationale.

6.6.4 Research Community Recommendations

Academic Researchers can fulfill a significant enabling role by undertaking research on issues that directly address barriers to adoption and increasing the evidentiary basis for innovation. There is a need for expanded, multi-year field trial research with different crops, environments, and climatic conditions to move claims from short-term efficacy to strong demonstrations of long-term benefits. The results must be rigorously measured to account for both agronomic and economic performance to make conclusions relevant and understandable to farmers and practitioners.

In addition, there is a need for targeted research to determine the cognitive, psychological, and social-relational variables that influence adoption. Qualitative work yielding in-depth interviews with farmers and focus groups, who provide important knowledge related to mental models, risk perceptions, and social network influences on adoption, is required. Mixed-methods research that integrates qualitative findings into larger datasets, including surveys or behavioral data, would provide a richer understanding of both institutional perception dynamics and the mechanisms of how cognitive legitimacy is established. All of this work will provide the research body, commercialization agent, and policy-makers with knowledge to start bridging the legitimacy gap, reduce uncertainty, and speed up the wider transition to sustainable circular agricultural solutions.

6.7 Research Limitations and Implications for Interpretation

This study provides novel insights into the pre-commercialization barriers of lignin-based biostimulants in the European agricultural market. Some methodological and contextual limitations of the study necessitated qualifying the scope, generalization, and interpretation of the findings. Instead of diminishing the underlying conclusions, these constraints usually result in conservative estimates of the identified commercialization challenges, thereby strengthening the real-time urgency of the observed barriers.

A primary limitation arises from the under-representation of farmers (7.1%, n=7) relative to professional intermediaries (agronomists, consultants, and researchers, 60.2%, n=59). As a

result, the findings mostly reflect the views of intermediaries who mediate technology transfers, rather than end-user farmers. The emphasis on social benefits (Section 6.1.2), demand for stringent evidence (Section 6.1.3), and significant limit on price premiums (Section 6.3.1) reflect the cautiousness of intermediaries and accountability of professionals. These are likely to be more important than the social benefits. Such a limit on price premiums may not be consistent with farmers functioning under severe economic constraints.

Given the well-documented influence of cooperatives and advisory services on European farmers' adoption (Long, Blok and Coninx, 2015, p. 13), the findings accurately characterize the critical first-stage legitimacy requirements that any lignin biostimulant must meet before directly reaching farmers. Additional farmer-centered research is necessary for further adoption.

Because the cross-sectional design collected data from October 2025, it did not allow us to see the cause and effect or the evolution of perceptions over time. The awareness–action gap shown in Section 6.1.1, the apparent institutional convergence in Section 6.2.2, and the expected sequencing advantages emerging from an Uppsala-like sequence in Section 6.4.2 could all be transient pre-market factors or enduring structural features. Even if the time constraint strengthens certain conclusions, namely that legitimacy deficits and low advocacy of professional stakeholders are alive and well at this early stage, it nevertheless stresses the need for proactive legitimacy building prior to market entry.

Although France, Germany, and the Netherlands account for 79.6% of all responses together (i.e., three countries), the residual 'Other EU' category (20.4%) does not specify further. Central, Eastern, Southern, and Northern Europe were virtually missing. The recommended market-entry sequencing and institutional convergence are robustly established in Northwestern Europe's mature bioeconomy regimes. However, they cannot and should not be extrapolated to the significantly different regulatory and agricultural systems in the Union.

Convenience and purposive sampling performed through our professional contacts caused a selection bias in favor of digitally literate, sustainability-oriented, and internationally connected respondents. This bias increases baseline awareness, exaggerates the assumed

importance of collaboration and social sustainability, and provides overly optimistic market readiness estimates. Even if only this subsample had a relatively favorable attitude towards premiums, these respondents displayed severe premium intolerance (69.4% accepting ≤10%), extremely negative net promoter scores (NPS = –59.2), and low promotion intent (5.1%). Thus, barriers within the overall agricultural population are likely to be more, rather than less, prohibitive.

There are other limitations, including perceptions measured on a Likert scale, rather than objective behavioral and institutional measures. Complete absence of the pulp and paper industry, regulatory stakeholders (who are very much part of this green deed), and theoretical framework application selective rather than exhaustive. We adjusted for these limitations partly through triangulation with regulatory data (Chapter 3) and by deliberately easing the demand-side commercialization requirements of the dissertation.

These limitations together limit the applicability of the insights but heighten caution in interpretation, thereby magnifying the seriousness of the identified obstacles. Prior to large-scale commercialization, the research effectively chronicles the best-case/conservative scenario of market readiness among informed intermediaries in the three key markets. Legitimacy and evidence thresholds, collaboration, and price sensitivity imperatives persist under these relatively favorable conditions. In view of this, commercialization challenges across the broader European agricultural sector are likely to be more complex. This conservative bias reinforces the central conclusion that successful market entry for lignin-based biostimulants demands systematic antecedent investment in professional legitimacy, rigorous evidence generation, inter-organizational collaboration, and regulatory harmonization well before substantive farmer-facing activities commence.

6.7.1 Contributing to Literature and Addressing the Identified Gaps

Chapter 2 identifies three main gaps in the literature on biostimulant commercialization. The first gap is the fragmentation in technical, regulatory, and stakeholder analyses. The second gap is the limited empirical focus on regulatory-institutional distance in market entry sequencing. The third gap is an integrated perspective that combines the business model, sustainability, and internationalization frameworks. The current study directly closes every

gap through an integrated empirical investigation and provides novel theoretical and practical insights.

First, whereas previous studies have typically examined technical efficacy, regulatory conditions, and stakeholder attitudes in isolation, this thesis offers the first comprehensive analysis that simultaneously captures practitioner perceptions across all three dimensions within a single framework. The findings reveal critical interaction effects that isolated approaches necessarily overlook: technical performance achieves commercial relevance only when translated into professionally credible evidence (77.6% demanding case-specific documentation despite 89.8% acknowledging value-proposition dominance); regulatory heterogeneity exerts less constraining influence than anticipated, with economic fundamentals, most notably severe premium intolerance (69.4% accepting no more than a 10% premium) emerging as the primary bottleneck; and institutional fragmentation is perceptually bridged by strong collaboration imperatives (89.8%) and unexpected convergence in stakeholder evaluations ($F(3,94) = 0.278$, $p = 0.841$). These findings illustrate that commercialization would not be successful if any evidence of credibility, institutional legitimacy, or economic viability is not satisfied.

Second, this study provides rare empirical evidence on the effects of regulatory-institutional distance on knowledge-intensive B2B agricultural inputs, challenging the core assumptions of conventional internationalization theory. Although there is correct documentation of regulatory differences (approval timelines from 9 to 15 months in the Netherlands; 24–36 months in France), stakeholders' perceived barriers, enablers, and strategic priorities are remarkably similar across countries. This finding suggests that professional epistemic communities and cross-border networks significantly reduce the effect of formal institutional distance on expert-driven markets. Consequently, the Uppsala model must be adjusted for these contexts. Sequential market entry is influenced primarily by opportunities for learning and evidence generation, which regulators will recognizerather than psychic or cultural proximity. Thus, firms should enter jurisdictions where authorization cycles are the fastest to accelerate the development of capabilities. This represents a significant shift away from traditional market selection logic based on institutional similarity or market size.

By synthesizing stakeholder data with various existing frameworks such as business model canvas, triple bottom line, and Uppsala, this research generates an integrated lens for sustainable commercialization, which the literature has so far not provided. Key insights include the unequivocal primacy of the value proposition within viable business models (89.8% prioritization, surpassing all other BMC elements by at least 30 percentage points), indicating that efficacy must be conclusively established before resources are devoted to partnerships or channel optimization; an inverted sustainability hierarchy in which social benefits (sectoral resilience and rural employment, M=3.77) outweigh both environmental (M=3.59) and economic (M=3.54) dimensions, compelling firms to foreground social rather than environmental positioning; and the identification of a profound legitimacy–action gap, whereby near-universal awareness (96.9%) fails to translate into advocacy (NPS = –59.2, only 5.1% promoters), underscoring that cognitive and pragmatic legitimacy must precede scaling efforts. The investigation's outcome of empirical legitimacy is crucial for the sustainability of the B2B business model viability in this domain. Only socially oriented value propositions and cost competitiveness affect viability. Neither environmental differentiation nor premium willingness-to-pay for sustainability.

In summary, the present thesis has compiled previously fragmented literature consisting mainly of disjointed technical trials, regulatory reviews, and agronomic studies into a stakeholder-informed framework for the commercialization of lignin-based biostimulants. Through empirical documentation of multidimensional adoption requirements, disclosing the limited salience of institutional distance in professional networks, and bridging business models, sustainability, and market-entry perspectives, this study not only addresses the gaps identified in Chapter 2 but also contributes to the theoretical understanding of innovation diffusion in regulated, knowledge-intensive B2B agricultural markets and provides actionable guidance for scalable commercialization across Europe.

6.8 Future Research Directions

There are several strategies for future research into the complexities of sustainable innovation adoption that can respond to the limitations outlined above. First, longitudinal empirical work is valuable in measuring how stakeholder awareness, perceptions, intentions, and actual behaviors change as market education and biostimulant innovation move along

the innovation adoption trajectory. This work would allow for the direct measurement of intention behavior gaps and the dynamics of early versus late adoption.

Second, further qualitative studies, including ethnographic fieldwork and interviews, would complement this survey by revealing the cognitive and social conditions under which adoption was made, the role of informal networks, and the psychological aspects of primary producers' practices. The integration of qualitative findings with quantitative survey methods would allow for better causal inferences and lead to better policy design.

Third, experimental and intervention studies can be conducted to examine the effectiveness of various informational, testimonial, and pilot program interventions on shifting adoption intentions and realized behavior. Randomized trials, for example, can be used to compare business models, pricing strategies, and levels of awareness campaign efforts, helping to establish a stronger evidence base for best-practice recommendations.

Fourth, we should dedicate more attention to the institutional and policy dimensions. Comparative policy analysis across EU member states and a more thorough consideration of regulatory pathway variations, administrative practices, and enforcement procedures will shed light on the origins and impact of "institutional convergence and will test EU harmonization hypotheses.

Finally, we must swiftly undertake research on supply-side and system-level factors, considering the opinions of the pulp and paper industry stakeholders, supply chain intermediaries, and regulators. There are outstanding empirical questions concerning feedstock availability, processing facilities, cost efficiency, and execution of regulatory regimes. Furthermore, this research could include an international comparative dimension, particularly by examining non-European contexts with different agricultural system dynamics. The findings in these areas will contribute to expanding the global applicability and relevance of the findings reported herein.

6.9 Summary of Discussion

This chapter presents an integrated discussion that links the empirical findings of the thesis to theoretical constructs and methodically addresses each of the three research questions regarding the commercialization of biostimulants derived from lignin in the European agricultural context. The findings provide strong support for the "awareness-action paradox" (Hypothesis 2), which found that although general awareness is high (96.9%), this has not yet translated into specific awareness or, indeed, promotion of the product, with only 23.5% of respondents indicating high specific awareness and only 5.1% indicating they were active promoters of biostimulants. It is a gap in legitimacy, not simply a lack of information; that is, the biggest barrier to diffusion.

The benefit hierarchy is established unequivocally (Hypothesis 5), with social benefits for stakeholders ranking above economic or environmental benefits (all $p < 0.001$), suggesting a power of persuasion linked to value proposition and rural employment or resilience in the sector. Furthermore, the evidence-requirement paradigm (Hypothesis 1) was empirically validated, with direct evidence (case studies), and pilot trials rated significantly higher (7.6:1) than social influence. The PESTEL analysis indicates that economic and legal framework factors are the most influential macro-level environmental factors (all $p < 0.001$), higher than environmental or social factors, echoed in the account of commercialization constraints.

The institutional findings affirm that collaboration is imperative (Hypothesis 4); almost 90% of all practitioners, regardless of geography, identified multi-stakeholder partnerships as critical to successful adoption, indicating a nascent consensus across the region that is pan-European in perspective rather than determined by policy differences. The institutional "converging puzzle is observed in the findings. Despite regulatory diversity, there are few differences in perceptions of institutional support across nations, suggesting some level of harmonization at professional expectations or network identity levels.

Commercialization strategy is founded contextually by economic discipline and pragmatic value (Hypothesis 3): strict limits on direct price premium (69.4% of total respondents would pay ≤10%, none >30%) ensure that innovators are building cost-competitiveness and

functional proof into their model, not just sustainability credentials, to underpin their claims for value. The value proposition achieved salience in the research, with features of partnership or revenue model distant in importance, itself influenced by pathways to adoption that rated clear evidence-based mechanisms over social mechanisms.

To conclude, this thesis presents a business and institutional context informed directly by evidence, economic reality, and structural collaboration. Within an empirical context, it advances and refines the framework of institutional theory, diffusion of innovation, resource-based view, PESTEL, and market internationalization. More importantly, all five hypotheses were empirically founded to link the market to evidence-based recommendations for educators, firms, and policymakers moving sustainable agri-innovation from theory to practice.

7 Conclusions

This thesis examined the potential for the commercialization of biostimulants derived from lignin in European agriculture through a comprehensive empirical study regarding the readiness of stakeholders, institutional roles, and preferences for commercialization strategies. Survey responses from 98 agricultural professionals across France, Germany, and the Netherlands were analyzed with descriptive and inferential statistics with regard to five overarching hypotheses about perceived barriers to adoption, perceived benefits, and perceived readiness of the agricultural market to accept these products as a result of the survey data.

This study demonstrates an interesting paradox regarding the potential for commercialization. Although there was a high level of general awareness (96.9%) of biostimulants, only a small minority (23.5%) of agricultural professionals expressed a high level of awareness of products derived from lignin (Awareness Gap: 1.66 points). Therefore, it appears that the dominant barrier to adoption is not knowledge or technical information but cognitive legitimacy to justify a decision to adopt (Hypothesis 2: Supported). Stakeholders appear to attribute significantly higher importance to social benefits (e.g., supporting employment and community resilience) than to environmental or economic benefits ($p < 0.001$) (Hypothesis 5: Supported). Thus, whenever possible, value propositions to the sector should lean toward the sector being viable before sustainable products.

Most importantly, with respect to evidence, demonstrations to stakeholders were overwhelmingly important: case studies (77.6%) and pilot or testing programs (72.4%) were valued much more than social influence (10.2%) at a ratio of 7.6:1 (Hypothesis 1: Supported), thus validating evidence-based diffusion pathways rather than social diffusion pathways.

There is a near-universal interest across multiple stakeholders in collaborating to promote commercialization (89.8 % overall importance, $p = 0.622$). This behavior suggests that the commercialization of lignin-derived biostimulants will have to reflect coordination across stakeholders and institutional bodies (Hypothesis 4: Supported). Unfortunately, severe

economic constraints were applied: the maximum premium that was accepted was 10% (69.4%), and 0% accepted premiums above 30% (p=0.549). Thus, credentialing regarding environmental benefits alone cannot validate premium pricing (Hypothesis 3: supported). In summary, all five hypotheses are empirically supported, with a fairly robust level of support as a strategic direction.

Strategic imperatives are consistent across stakeholder roles. Producers need to focus primarily on demonstrating proof-of-concept by farming at multiple sites, with quantified case studies and farmer testimonials because these are the two major drivers of adoption. Build cognitive legitimacy through academic publishing, professional association endorsement, government policy reference, and farmer networks/usage, rather than through exposure or awareness of the mass market. Present functional and social benefits, rather than emphasizing environmental positioning, may be beneficial. Use a phased approach to market entry: The Netherlands first (short regulatory timeline and/or supportive environment), Germany second (leverage collaborative governance), and France last (needing robust evidence). Policymakers should focus on additional opportunities to market: accelerating regulatory harmonization across the EU, funding government-supported efficacy trials in early market infrastructure, creating multi-stakeholder forums to minimize coordination costs, and creating procurement preference mechanisms that allow farmers to have a reliable economic return without having to put a funding burden on farmers ahead of the entry process.

This study has demonstrated that sustainable innovation success in agriculture, particularly regarding niche markets, requires an integrated strategy of science credibility, multi-channel legitimation, economic pragmatism, and institutional collaboration. The findings apply not only to the commercialization efforts for lignin biostimulants but also to the wider transition of the circular economy in agriculture. Although technical validity and environmental benefits are essential factors, they are not sufficient. Cognitive legitimacy was required, as was some sense of stakeholder decision logic and the institutional complexity required; possibly this should come first, but it is more about balancing these concepts. Market acceptance comes from evidence-based credibility development, which runs in parallel with technical advances and institutional alignment.

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Appendices

Appendix 1: Survey questionnaire used for data collection

Demographic Information

These questions help us understand the context of your responses. All answers are confidential.

In which country is your primary professional activity based? *

You can also select any of these three countries if you have worked in past.

- ◯ France
- ◯ Germany
- ◯ The Netherlands
- ◯ Other

In which region or area within your country do you primarily work? *

- ◯ Northern region
- ◯ Central region
- ◯ Southern region
- ◯ Eastern region
- ◯ Western region

What is your primary role in the agriculture or related industry? (Select one) *

- ◯ Farmer/Agricultural Producer
- ◯ Agronomist/Consultant
- ◯ Distributor/Supplier of Agricultural Products
- ◯ Pulp and Paper Industry Professional
- ◯ Regulator/Government Official
- ◯ Researcher/Academic
- ◯ Other

How many years of experience do you have in agriculture or related fields? *

- ◯ Less than 5 years
- ◯ 5-10 years
- ◯ 11-20 years
- ◯ More than 20 years

What is the size of your organization/farm (if applicable)? *

- ◯ Small (e.g., <50 employees or <100 hectares)
- ◯ Medium (e.g., 50-250 employees or 100-500 hectares)
- ◯ Large (e.g., >250 employees or >500 hectares)
- ◯ Not applicable

Are you familiar with bio stimulants (products that improve plant growth, nutrition, or stress tolerance without being fertilizers)? *

- ◯ Yes, very familiar
- ◯ Somewhat familiar
- ◯ Not familiar

Awareness and Experience

Your familiarity with these products

On a scale of 1-5, how aware are you of lignin-derived bio stimulants (products made from pulp and paper industry co-products)? *

1	2	3	4	5

1 (Not at all aware) 5 (Very aware)

To what extent do you agree with the following statements about lignin-derived bio stimulants / Biostimulants? *

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
They offer significant environmental benefits (e.g., enhancing resource efficiency).	◯	◯	◯	◯	◯
They can improve economic profitability for farmers (e.g., higher yields).	◯	◯	◯	◯	◯
They support social goals like sustainable farming communities.	◯	◯	◯	◯	◯

To what extent do you agree that lignin-derived bio stimulants represent an innovative solution compared to traditional fertilizers? *

1	2	3	4	5

Strongly Disagree Strongly Agree

Sustainability and Circular Economy Aspects

Rate the importance of the following sustainability factors for adopting bio stimulants in your work/country. *

	Not Important	Slightly Important	Neutral	Important	Very Important
Environmental impact (e.g., reducing chemical use)	○	○	○	○	○
Economic viability (e.g., cost-effectiveness)	○	○	○	○	○
Social benefits (e.g., job creation in rural areas)	○	○	○	○	○
Alignment with circular economy principles (e.g., valorizing industrial co-products)	○	○	○	○	○

How likely are you to adopt or recommend lignin-derived bio stimulants if they demonstrate strong circular economy benefits (e.g., transforming pulp co-products into valuable agricultural solutions)? *

- ○ Very likely
- ○ Somewhat likely
- ○ Neutral
- ○ Unlikely
- ○ Very unlikely

How important are collaborations with stakeholders (e.g., farmers, regulators, pulp companies) for successful circular economy practices in bio stimulants? *

1	2	3	4	5

Not Important Very Important

Market Entry and External Factors

Rate the influence of the following external factors on the commercialization of bio stimulants in your country *

	No Influence	Slight Influence	Moderate Influence	High Influence	Strong Influence
Political factors (e.g., government subsidies for sustainable agriculture)	○	○	○	○	○
Economic factors (e.g., market demand and pricing)	○	○	○	○	○
Social factors (e.g., farmer attitudes toward innovation)	○	○	○	○	○
Technological factors (e.g., production advancements)	○	○	○	○	○
Environmental factors (e.g., climate change pressures)	○	○	○	○	○
Legal factors (e.g., EU regulations on bio-based products)	○	○	○	○	○

To what extent do institutional norms (e.g., industry standards or cultural expectations) in your country encourage the adoption of sustainable products like lignin-derived bio stimulants? *

1	2	3	4	5

Strongly Discourage Strongly Encourage

Rank the following barriers to market entry for new bio stimulants in your country (1=Biggest Barrier, 5=Smallest Barrier) *

- Lack of market knowledge or experience
- Regulatory hurdles
- High initial costs
- Competition from existing products
- Cultural resistance to change
- Other (please specify)

Business Models and Strategies

Which elements of a business model would most influence your decision to purchase or partner on lignin-derived bio stimulants? (Select up to 3) *

Please select 3 options.

- [ ] Strong value proposition (e.g., proven crop benefits)
- [ ] Reliable key partners (e.g., pulp industry suppliers)
- [ ] Cost-effective revenue streams (e.g., subscription models)
- [ ] Customer relationships (e.g., training/support)
- [ ] Sustainable key resources (e.g., eco-friendly production)

How important is a gradual market entry approach (e.g., starting with pilot tests and building local knowledge) for companies entering your country's agriculture market? *

1	2	3	4	5

Not Important Very Important

Have you had any direct or indirect experience with lignin-derived biostimulants? *

- ◯ Yes, direct experience (I have used or tested them)
- ◯ Yes, indirect experience (I have heard about them or know someone who uses them)
- ◯ No, I have no experience with them

What is your estimated willingness to pay a premium for sustainable lignin-derived bio stimulants compared to standard products? *

- ◯ 0-10% premium
- ◯ 11-20% premium
- ◯ 21-30% premium
- ◯ More than 30% premium
- ◯ No premium (same price or less)

Overall, how optimistic are you about the market potential for lignin-derived bio stimulants in European agriculture? *

- ◯ Very optimistic
- ◯ Optimistic
- ◯ Neutral
- ◯ Pessimistic
- ◯ Very pessimistic

Have you adopted any new agricultural product or technology in the past 5 years? *

- ◯ Yes, I have adopted 1-2 new products/technologies
- ◯ Yes, I have adopted 3 or more new products/technologies
- ◯ No, I have not adopted any new agricultural products or technologies in the past 5 years

How likely are you to recommend lignin-derived biostimulants to a colleague or peer in your industry? *

0	1	2	3	4	5	6	7	8	9	10

Not at all likely — Extremely likely

Which factors would justify paying a premium for lignin-derived biostimulants? (Select all that apply) *

- ☐ Proven higher crop yield or quality
- ☐ Significant environmental benefits (e.g., reduced chemical input)
- ☐ Regulatory approval and certification
- ☐ Peer recommendations or successful case studies
- ☐ Lower cost compared to alternatives

Which factors would most influence your decision to adopt lignin-derived biostimulants? (Select all that apply) *

- [ ] Case studies demonstrating effectiveness
- [ ] Positive results from pilot tests
- [ ] Peer recommendations from other farmers/professionals
- [ ] Advice from local agricultural authorities
- [ ] Social norms and acceptance in the farming community
- [ ] Media coverage and scientific publications
- [ ] Agricultural networks and professional organizations
- [ ] Other

Please indicate your level of agreement with the following statements about risk and uncertainty related to lignin-derived biostimulants: *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions	○	○	○	○	○
I am concerned about potential unintended environmental effects of lignin-derived biostimulants	○	○	○	○	○
I am concerned about regulatory uncertainty and compliance requirements for lignin-derived biostimulants	○	○	○	○	○
I am concerned about market risks and economic viability of lignin-derived biostimulants	○	○	○	○	○

Appendix 2: ANOVA Test

ANOVA - On a scale of 1-5, how aware are you of lignin-derived bio stimulants (products made from pulp and paper industry co-products)?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	8.52	3	2.84	1.65	0.183	0.050	0.020
Residuals	161.82	94	1.72				

ANOVA - To what extent do institutional norms (e.g., industry standards or cultural expectations) in your country encourage the adoption of sustainable products like lignin-derived bio stimulants?

	Sum of Squares	df	Mean Square	F	p	η^2	η^2p	ω^2
In which country is your primary professional activity based?	0.527	3	0.176	0.278	0.841	0.009	0.009	-0.023
Residuals	59.320	94	0.631					

ANOVA - Environmental impact (e.g., reducing chemical use)

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	2.73	3	0.909	1.45	0.234	0.044	0.014
Residuals	59.04	94	0.628				

ANOVA - Legal factors (e.g., EU regulations on bio-based products)

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	0.732	3	0.244	0.236	0.871	0.007	-0.024
Residuals	97.033	94	1.032				

ANOVA - How important are collaborations with stakeholders (e.g., farmers, regulators, pulp companies) for successful circular economy practices in bio stimulants?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	0.963	3	0.321	0.591	0.622	0.019	-0.013
Residuals	51.037	94	0.543				

ANOVA - How likely are you to adopt or recommend lignin-derived bio stimulants if they demonstrate strong circular economy benefits (e.g., transforming pulp co-products into valuable agricultural solutions)?

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	0.967	3	0.322	0.374	0.772	0.012	-0.020
Residuals	81.033	94	0.862				

ANOVA - I am concerned about the effectiveness of lignin-derived biostimulants in real farming conditions

	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
In which country is your primary professional activity based?	3.09	3	1.029	1.32	0.272	0.040	0.010
Residuals	73.25	94	0.779				