

1 **A conceptual knowledge transfer model for blockchain technology adoption**
2 **in wine supply networks**

3
4 Michael Paul Kramer¹ and Jon H. Hanf²

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6 ¹ Hochschule Geisenheim University, Institute for Wine and Beverage Economics, Von-Lade-
7 Strasse 1, 65336 Geisenheim, Germany, Email: michael.kramer@hs-gm.de

8 ² Hochschule Geisenheim University, Institute for Wine and Beverage Economics, Von-Lade-
9 Strasse 1, 65336 Geisenheim, Germany, Email: jon.hanf@hs-gm.de

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11
12 Correspondence concerning this article should be addressed to Michael Paul Kramer
13 Hochschule Geisenheim University, Institute for Wine and Beverage Economics, Von-Lade-
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29 **Abstract**

30 Effective adoption of blockchain technology in supply networks depends significantly on inter-
31 organizational knowledge transfer, particularly in the pre-adoption phase when stakeholders
32 must be convinced of its perceived benefits. This conceptual study introduces the Evolutionary
33 Knowledge Transfer Model (EKTM), a novel framework which explains how explicit and tacit
34 knowledge about blockchain dynamically evolve across vertically coordinated multi-tier wine
35 supply networks. Different to previous models, it integrates dyadic, firm, and network
36 perspectives while highlighting the essential role of tacit knowledge transfer, two aspects often
37 overlooked in existing frameworks. Methodologically, the study adopts the design approach of
38 Jaakkola for conceptual research combining knowledge management, complex network, and
39 strategic management theories. The study contributes to supply chain management literature,
40 demonstrating the crucial role of tacit knowledge transfer in blockchain adoption. It further
41 provides practical implications by showing how trust, attitude towards technology, and
42 absorptive and disseminative capacities interact across dyadic, firm, and network levels
43 impacting knowledge transfer in the pre-adoption phase, while providing managers with a
44 conceptual tool to assess knowledge flows and balance explicit and tacit knowledge transfer with
45 the objective to accelerate technology adoption across the supply network.

46 **Keywords:** Knowledge Transfer, Tacit Knowledge, Blockchain, Supply Chain, Wine Industry

47 **JEL Classification:** Q13

48 **1. Introduction**

49 In the knowledge economy, businesses must prioritize continuous innovation with knowledge
50 as a critical, transferrable resource for creating products, services, and processes [73]. Effective
51 knowledge sharing between firms in modern supply networks is essential for growth and
52 competitiveness, particularly in the context of technology adoption [89, 16, 61]. In recent years,
53 knowledge sharing has received significant attention, which has profoundly contributed to the
54 understanding of its potential to enhance the overall network value [51]. This is particularly
55 relevant in the agri-food sector, where knowledge acts as an important coordination mechanism
56 [10].

57 With the advent of disruptive digital technologies such as blockchain and artificial intelligence
58 traditional supply chains have the potential to transform into dynamic, decentralized supply
59 networks, enhancing transparency and real-time data exchange. This transformation underlines

60 the importance of promoting a culture of knowledge sharing among participating firms as
61 suggested by Dremel [24] and Assur and Rowshankish [6], particularly considering the
62 adoption of digital technologies across a network of interacting firms. The adoption of
63 technologies in agricultural sectors often faces significant barriers. A recent bibliometric
64 analysis on alternate wetting and drying (AWD) for rice cultivation highlights major adoption
65 barriers in current literature, particularly related to profitability concerns and localization [80].
66 However, while the adoption of disruptive digital technologies in the broader agri-food sector
67 is growing [46], it remains limited in the wine sector [45, 59, 9, 19, 79]. Existing studies focus
68 primarily on technical implementations or economic barriers [66], leaving knowledge transfer
69 insufficiently explored. This imbalance highlights the need to explore how knowledge about
70 disruptive digital technologies evolves in an industry deeply rooted in tradition [43, 40], where
71 interpersonal trust and social networks play a significant role. Innovation adoption in the wine
72 sector is significantly impacted by these dynamics as social networks and knowledge sharing
73 mechanism are key performance drivers. A recent study for the Argentinian wine industry
74 reveals that social networks and interpersonal knowledge transfer are critical success factors
75 for export performance [22].

76 While existing studies have explored general knowledge sharing mechanisms [51] and
77 technology adoption in agri-food firms [46], they do not address the specific challenges of
78 knowledge transfer in traditional industries such as the wine sector. Most existing agricultural
79 knowledge management frameworks focus on explicit knowledge transfer, offering valuable
80 insights. However, they often overlook factors such as varying knowledge levels among
81 stakeholders, differing attitudes towards innovation, absorptive capacities, and the role of trust
82 in decision-making [30]. They further neither focus on inter-firm knowledge transfer and the
83 integration of disruptive technologies [66], nor on the tacit knowledge dimension, which is
84 critical in the wine industry where interpersonal trust and social networks prevail [43, 40].
85 Consequently, a critical research gap exists in understanding how knowledge about disruptive
86 technologies such as blockchain evolves and is transferred within traditional, vertically
87 coordinated, multi-tier wine supply networks. This gap is particularly evident in the wine
88 industry where research examines knowledge transfer through networks, SECI spirals, and
89 channel effectiveness (23, 88, 14). However, these studies overlook the tacit dimension of
90 knowledge flow, particularly in the context of disruptive technologies such as blockchain.
91 While they address general knowledge transfer mechanisms, such as network structure and
92 explicit knowledge transfer, they fail to explore how tacit knowledge driven by trust,

93 interpersonal relationships, and social networks impact blockchain adoption in traditional,
94 multi-tier wine supply networks. This oversight is particularly relevant in the pre-adoption
95 phase where sharing knowledge about perceived benefits is essential for convincing
96 stakeholders to adopt new technologies. Blockchain relies on stakeholder cooperation to
97 function effectively and provide value for all involved. Without addressing these complexities,
98 the agri-food sector and especially traditional industries such as wine risks lagging in innovation
99 while failing to leverage the potential of blockchain [46]. This study bridges the gap by
100 proposing a multi-tier framework for the wine sector that examines how knowledge about
101 blockchain evolves and transfers considering not only the firm and dyadic, but also the network
102 level. To address this gap, this study asks the following research question:

103

104 *How does knowledge about disruptive digital technologies evolve within a*
105 *vertically coordinated multi-tier upstream wine supply network?*

106

107 To answer this question the study proposes the Evolutionary Knowledge Transfer Model
108 (EKTm), which extends the Barabási-Albert network model to represent multi-tier wine supply
109 networks and integrates explicit and tacit knowledge utilizing the SECI (socialization,
110 externalization, combination, internalization) model of Nonaka [56]. The EKTm addresses a
111 key gap in literature by integrating dyadic, firm, and network-level perspectives on knowledge
112 transfer, while advancing theory through emphasizing the critical role of tacit knowledge in
113 adopting disruptive technologies with blockchain serving as the primary object of analysis, due
114 to its transformative potential in the wine sector [59], particularly for improving traceability
115 and transparency in the supply chain. The EKTm combines three complementary theoretical
116 frameworks to conceptualize the dynamics of knowledge transfer: knowledge management
117 [57], which emphasizes tacit and explicit knowledge flows, complex network theory [8], which
118 explains network structure and dynamics, and dynamic capabilities from strategic management
119 [77], which accounts for how firms sense, seize, and transform knowledge.

120 Practically, the study provides actionable insights for practitioners and stakeholders in the wine
121 industry. Specifically, managers should establish structured feedback loops with wine producers
122 to align knowledge about blockchain with operational needs and focus on tacit knowledge
123 transfer through personal meetings, training sessions, and mentorship to build trust, reduce
124 adoption barriers, and enhance collaboration among stakeholders.

125

126 Although the research is conceptual rather than empirical, it utilizes empirical data from a prior
127 exploratory study to support the development of the framework [7]. That previous research
128 includes a structured literature review on existing knowledge transfer models and expert
129 interviews with stakeholders from the wine industry. It identifies attitude towards technology,
130 absorptive and disseminative capacity, and trust across dyadic, firm, and network levels as
131 critical factors in transferring knowledge.

132

133 The manuscript is structured as follows: the subsequent section introduces the theoretical
134 background, followed by the methodology. The following sections focus on conceptual model
135 development, results and discussion, complemented by a summary and suggestions for future
136 research.

137 **2. Theoretical Background**

138 Among the different models within complex network theory, the models of Barabási-Albert,
139 Erdős-Rényi, and Watts-Strogatz are considered as benchmark of real-world networks such as
140 supply networks [62, 83]. Extending the Barabási-Albert algorithm, Holme and Kim introduced
141 the formation of triads [39]. Moreover, the Evolutionary Network, characterized by its dynamic
142 and evolving nature over time, is considered a relevant framework for studying complex systems
143 [1]. Capaldo and Giannoccaro [13] base their research on the Watts-Strogatz small-world
144 network model and model the supply chain as a set of decisions.

145 Within the context of strategic management, particularly within dynamic capabilities, the
146 concepts of absorptive and disseminative capacities guide strategic decisions related to sensing,
147 seizing, and transforming [77]. Notably absorptive capacity focuses on the acquisition,
148 assimilation, transformation, and integration of knowledge. Zahra and George [87] emphasize
149 that transitioning from just assimilating knowledge to actively utilizing it is not an automatic
150 process and introduced the potential and realized absorptive capacity model with the objective
151 to manage external knowledge acquisition and application. Therefore, within the absorptive
152 capacity framework, the study focuses on potential absorptive capacity [87]. This concept is
153 complemented by disseminative capacity, which is the ability of a firm to share knowledge
154 effectively across firm boundaries [48]. Within the SECI (socialization, externalization,
155 combination, internalization) model of Nonaka [56], both, absorptive capacity and
156 disseminative capacity are enhancing the overall process of knowledge creation and
157 transformation [26] and are essential for effective knowledge transfer [21]. They are relevant

158 in agri-food networks for driving innovation and improving total productivity [79]. However,
159 limited research has explored how these capacities interact with network structures, such as
160 triadic closure and multi-tier architectures to facilitate knowledge transfer during disruptive
161 technology adoption [21], a gap this study addresses through the EKTM.

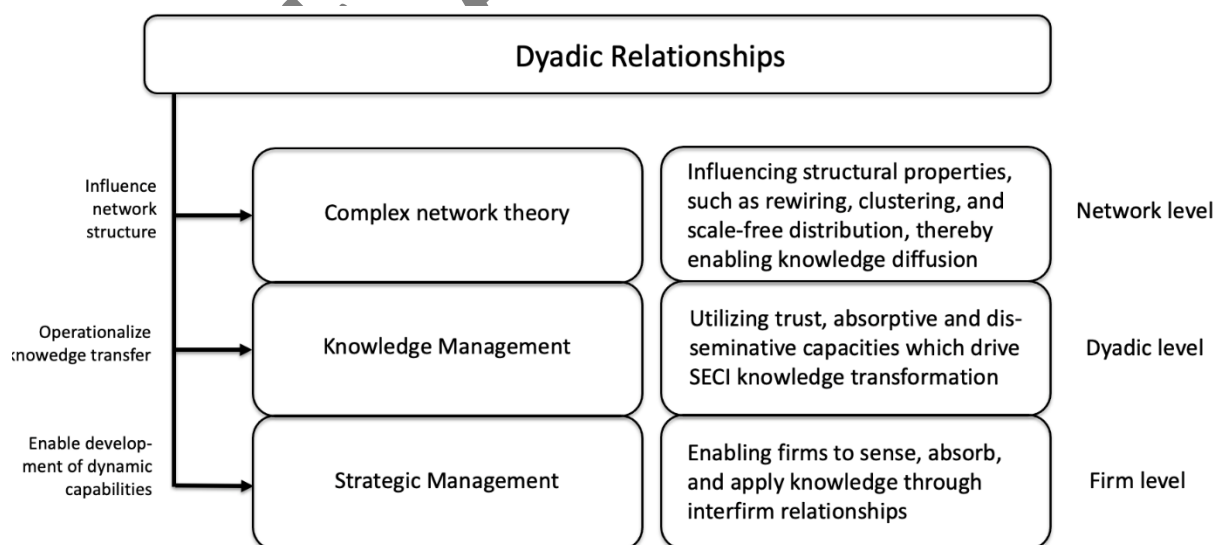
162 Recent studies in the wine sector identify collaboration, transparency, trust, dynamic
163 capabilities, absorptive capacity, and interorganizational partnerships as central enablers of
164 blockchain adoption, particularly in overcoming barriers such as capability deficits and limited
165 digital readiness. Complementary supply chain research further shows that absorptive capacity
166 and strong connections between buyers and suppliers support the adoption of digital innovation
167 across interconnected firms [74, 29, 70, 19, 68]. Building on these insights, forthcoming
168 research of the authors [7] based on expert interviews in the wine industry and literature
169 reviews, identifies attitude toward technology, absorptive/disseminative capacity, and trust as
170 critical factors in inter-firm knowledge transfer, providing empirical grounding of the EKTM.
171 Building on these capacities, trust as a fundamental concept within strategic management,
172 acting as a relevant facilitator in knowledge transfer processes will now be discussed.

173 Trust has been studied in various scientific areas where each offers its own definition. It is an
174 important element in economic transactions both between humans and information technology
175 systems such as blockchain. This study primarily focuses on the concept of interpersonal trust,
176 which is a key attribute in relationships that enables the acquisition and sharing of knowledge
177 in business networks [1]. Among employees it facilitates the creation and sharing of knowledge
178 within organizations, which is critical for innovation and strategic management [57]. In
179 networks, particularly among small and medium sized enterprises who rely on external
180 knowledge sources [34], trust is fundamental for decision-making under uncertainty [52] and
181 enables collaboration [75]. The rationale for developing the EKTM is based on Gulati [36], who
182 argues that the analysis of strategic networks should integrate dyadic, firm, and network
183 perspectives when examining cooperation and coordination and effects. While Gulati focuses
184 in his research on strategic alliances and inter-firm networks, his findings can be applied to
185 supply networks. Both share similar attributes relevant for cooperation and coordination such
186 as trust, absorptive and disseminative capacities, and reliance on relationships, attributes, all
187 highly relevant in inter-firm knowledge transfer [5, 70, 74]. However, a framework integrating
188 the three perspectives remains absent, a gap identified by Duysters et al. [25] and confirmed in
189 recent research [7].

190 The study adopts the analytical framework proposed by Gulati [36], distinguishing between
191 dyadic, firm, and network levels. While knowledge management serves as the central theoretical
192 lens, complex network and dynamic capabilities theories are integrated to support the
193 examination of knowledge transfer in supply networks. Figure 1 illustrates how dyadic
194 relationships integrate knowledge management, dynamic capabilities, and complex network
195 theory following the theory integration approach proposed by Okhuysen and Bonardi [60]. It
196 uses dyadic relationships as primary knowledge transfer mechanism between firms and as the
197 linking element connecting dyadic, firm, and network perspectives, integrating the three
198 theories. The EKTM focuses intentionally on pre-adoption phase of inter-firm knowledge
199 transfer. This scope is intentional as it focuses on the relational, capability, and structural
200 mechanisms that are responsible for knowledge exchange about the perceived benefits of a
201 technology. The rationale to focus on these three theories lies in their compatibility through dyadic
202 relationships and their ability to support analytical clarity without causing theoretical dilution,
203 which can occur when too many theories are integrated. To address potential theoretical tensions
204 and following the recommendation of Okhuysen and Bonardi [60], this study applies each theory
205 at the level where it is most relevant, dyadic, firm, and network, while using dyadic relationships
206 as the shared linking mechanism across all three perspectives. Specifically, knowledge
207 management theory through the SECI model suggest that socialization and externalization
208 processes enable interfirm trust building and knowledge sharing at the dyadic level. At the firm
209 level, dynamic capabilities theory explains how firms sense, seize, and transform knowledge.
210 Finally, complex network theories provides for the structural dynamics at the network level with
211 insights into how dyadic knowledge transfer evolves and is impacted by clustering, rewiring,
212 and scale-free properties. This approach integrates theories through shared constructs and
213 aligned assumptions, which is here the dyadic relationship. This keeps the logic of each theory
214 intact, avoiding theoretical dilution while leveraging complementary strengths. The EKTM
215 ensures consistency across dyadic, firm, and network levels by linking each theory at its relevant
216 level through the concept of dyadic relationships.

217 The EKTM operates through four core mechanisms. Dyadic relationships serve as the core
218 linking mechanism, enabling trust-based knowledge flows across all levels. The SECI model
219 explains tacit and explicit knowledge conversion process through trust and collaboration at the
220 dyadic level. Dynamic capabilities enable firms to absorb, disseminate, and apply knowledge
221 resulting from dyadic exchanges. The Barabási-Albert network model enhanced through
222 dynamic edge rewiring, facilitates knowledge transfer through power hubs in scale-free

223 networks. Triadic closure enables tacit knowledge sharing within power hub ecosystems through
 224 dynamic edge rewiring. These core mechanisms are supplemented by aggregate dimensions,
 225 which are knowledge flow and social dynamics, dynamics of implementation, tacit knowledge
 226 and collaboration, knowledge transfer drivers, absorptive/disseminative capacity, and attitude
 227 toward technology adoption, enhance core knowledge transfer processes through trust,
 228 collaboration, and implementation dynamics stemming from qualitative data [7]. Furthermore,
 229 supply chain structure serves as auxiliary mechanism. The Barabási-Albert model extended by
 230 two tiers represents a vertically coordinated supply network. The supply network structure used
 231 with the EKTM is specific to the wine sector but is exchangeable, enabling the model to adapt
 232 to strategic networks in other sectors. These relationships are summarized in the model in Figure
 233 1. Building on these core and supplementary mechanisms the EKTM further operationalizes
 234 knowledge transfer at dyadic, firm, and network levels as follows. At the dyadic level,
 235 disseminative and absorptive capacities facilitated by trust enable knowledge transfer between
 236 firms linking knowledge management with dynamic capabilities. The SECI model builds the
 237 basis for knowledge conversion and flow in networks, connecting the oscillation of explicit and
 238 tacit knowledge with dyadic exchanges. At the firm level, dynamic capabilities emphasize how
 239 firms sense and absorb knowledge in networked environments, linking dyadic and firm
 240 perspectives to ensure that knowledge is effectively sensed, absorbed, disseminated, and applied
 241 within organizations. At the network level, complex network theory provides insights into how
 242 these dyadic exchanges dynamically evolve through



243
 244 **Figure 1.** Integration of key theories (Source: Developed by the authors)

245

246 clustering, rewiring, and scale-free connectivity. This way the integration of knowledge
247 management, dynamic capabilities, and complex network theory adheres to Okhuysen and
248 Bonardi [60] by maintaining theoretical integrity while emphasizing their complementary
249 strength. This resulting conceptual framework is integrated through dyadic relationships as the
250 common knowledge transfer mechanism.

251 **3. Methodology**

252 This study develops the Evolutionary Knowledge Transfer Model (EKTm), which
253 conceptualizes how explicit and tacit knowledge about the perceived benefits of blockchain
254 technology is transferred among stakeholders in vertically coordinated wine supply networks
255 during the pre-adoption phase.

256 This conceptual study is empirically grounded in a preceding exploratory study [7], which
257 utilizes a structured literature review following the Preferred Reporting Items for Systematic
258 Reviews and Meta-Analysis (PRISMA) method [54] and semi-structured interviews with
259 German wine industry stakeholders intentionally sampled across supply network tiers and
260 analyzed through the Gioia methodology [31] to ensure rigor and replicability.

261 Following the structured approach to conceptual research proposed by Jaakkola [42], this study
262 follows a theory synthesis approach by integrating key theories from knowledge management
263 [57], complex network theory [8], and strategic management, particularly the dynamic
264 capabilities perspective [77]. The research design follows three sequential phases: first,
265 applicable theories are identified. In the second phase the selected theories are assessed for
266 compatibility. Their mutual emphasis on network structure, knowledge transformation, and
267 inter-firm capabilities, where each is operationalized through the mechanism dyadic
268 relationships, supports their integration within the conceptual framework. The stakeholder is
269 adopted as the unit of analysis since knowledge is sensed, seized, and transformed by individuals
270 who act on behalf of organizations. This aligns with the focus of the study of inter-firm
271 knowledge transfer mechanisms. In the third step the conceptual model is constructed.

272 To identify a suitable network model, a comparative analysis was conducted [76] by identifying
273 key structural attributes relevant to supply chain networks, specifically focusing on key
274 attributes supply chain governance, network configuration and dynamics, and vertically
275 coordinated supply network suitability. The model that closest reflected the requirements was

276 qualitatively selected. This approach aligns conceptually with Tantardini et al. [76], even
277 though it is applied without quantitative metrics.

278 **4. Conceptual Model Development**

279 The model integrates knowledge management, applying the SECI model at the dyadic level
280 [56], dynamic capabilities at the firm level [77, 87], and complex network theories [8, 62], at
281 the network level with empirical findings from both literature and qualitative data on blockchain
282 adoption in wine supply networks. From the interviews, the preceding exploratory study
283 identified five aggregate dimensions impacting knowledge transfer, which are knowledge flow
284 and social dynamics, dynamics of implementation, tacit knowledge and collaboration,
285 knowledge transfer drivers, absorptive and disseminative capacity, and attitude towards
286 technology adoption [7].

287
288 At the dyadic level, studies show that interfirm trust and transparency [72], knowledge sharing
289 [81], organizational capabilities of cooperating supply network stakeholders such as absorptive
290 and dynamic capacities, their resources, and collaborative readiness to engage in digital
291 transformations [78], and trust dynamics [27] are relevant factors of adoption. Qualitative
292 findings extend this by revealing the salient role of knowledge flow and social dynamics as well
293 as tacit knowledge transfer and collaboration are applied in practice. Data shows that trust
294 emerging from collaborative initiatives enables the socialization and externalization process of
295 the SECI model, facilitating blockchain related tacit knowledge transfer between firms and that
296 informal networks, knowledge leaders, and peer influence create trust based channels for
297 blockchain knowledge transfer [7].

298
299 At the firm level, dynamic capabilities and absorptive capacity directly and positively impact
300 blockchain adoption in wine supply chains, enhancing resilience and traceability [68].
301 Perceived usefulness of blockchain adoption for enhancing productivity, with food safety,
302 traceability, transparency, and cost are seen as key considerations [69]. Data from the
303 qualitative study also extend these by showing the important role of the aggregate dimensions
304 absorptive and disseminative capacity where firms build absorptive capacity through targeted
305 training to enhance knowledge absorption and develop disseminative capacity to transfer
306 knowledge through frequent exchanges. Moreover, the dimension attitude toward technology

307 adoption reveals three distinct technology adoption behaviors that determine their engagement
308 with digital solutions [7].

309

310 At the network level, structural complexity and diversity of supply networks [20], stakeholder
311 interactions [17] and network cooperation, which is essential for agricultural innovation [11],
312 impact adoption. Qualitative findings enhance this by underscoring the critical role of
313 knowledge transfer drivers and dynamics of implementation with knowledge being unequally
314 distributed among firms in the In addition, knowledge flow and social dynamics impact network
315 structures, with knowledge transfer drivers and dynamics of implementation determining
316 diffusion patterns. The data demonstrates a scale-free network architecture where influential
317 firms act as knowledge leaders distributing blockchain insights within their ecosystem while
318 triadic closure operationalized by rewiring processes that dynamically reassign connections
319 impact adoption decisions [7].

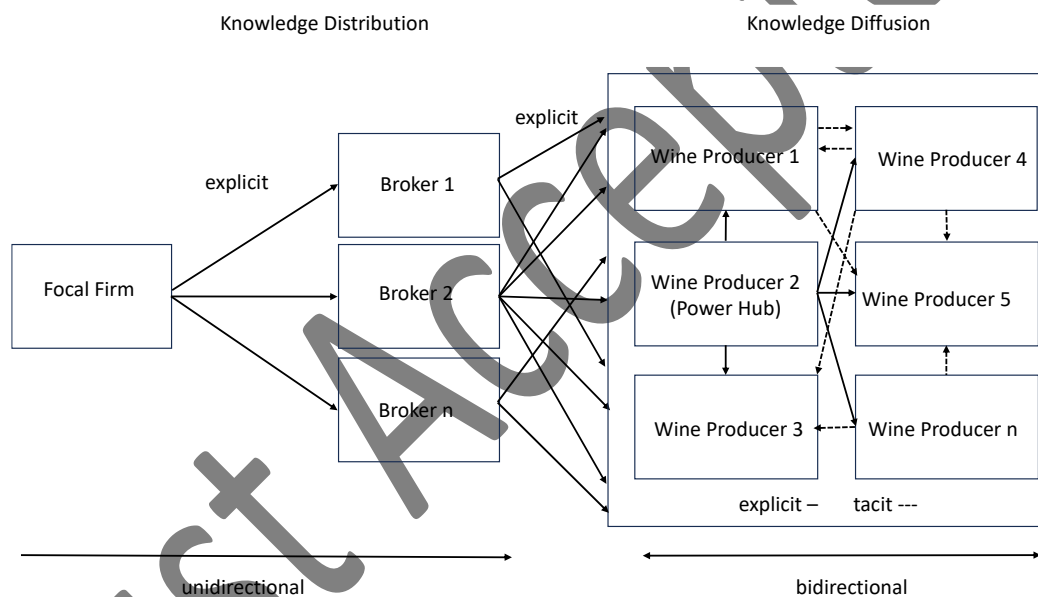
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321 Dyadic relationships serve as the primary knowledge transfer mechanism of the EKTm, with
322 compelling evidence from the wine industry. Fani et al. [27] demonstrated that trust evolves
323 along specific dyadic relationships from upstream to downstream. Saurabh and Dey [71] found
324 that disintermediation, traceability, trust, and coordination are key factors of adoption decisions.
325 Cricelli et al. [19] further confirmed that wine SMEs rely on dyadic partnerships with inter-firm
326 knowledge transfer at the dyadic level being the primary mechanism through which perceived
327 blockchain knowledge enters firms and evolve across the network. These studies highlight the
328 critical role of dyadic relationships as mechanism for integrating knowledge transfer across
329 dyadic, firm, and network levels, ensuring a holistic understanding of how knowledge about
330 blockchain evolves in vertically coordinated supply chains. qualitative findings reveal that trust
331 and communication at the dyadic level (where informal networks facilitate knowledge flow,
332 collaboration transforms tacit to explicit knowledge, and peer influence accelerates decisions),
333 absorptive capacity and innovation readiness at the firm level (through dynamic capabilities
334 like knowledge absorption and technology attitudes), and governance and coordination
335 mechanisms at the network level (via scale-free structures, rewiring, and triadic closure) jointly
336 impact knowledge transfer, empirically validating SECI processes, dynamic capabilities, and
337 complex network theory while demonstrating how dyadic relationships bridge all three EKTm
338 levels.

339

340 Drawing on established theories complemented by qualitative data from a previous study [7],
 341 it explains how knowledge dynamically evolves across firms in vertically coordinated
 342 networks. The decision to focus on the upstream wine supply network is due to it often being
 343 centrally managed by a focal firm which is responsible to purchase grapes, must, or wine for
 344 production and further distribution under its brand. This firm is not only responsible for the
 345 coordination and strategic direction of the network but also for the distribution of knowledge
 346 among interacting firms which positively impacts overall network performance [37, 44]. Figure
 347 2 illustrates unidirectional knowledge flow from the focal firm to brokers who then distribute
 348 knowledge unidirectionally to wine producers. Among wine producers, bidirectional
 349 knowledge diffusion occurs.

350
 351



352

353 **Figure 2.** Knowledge transfer processes in a three-tier upstream wine supply network (Source: Developed by the
 354 authors)

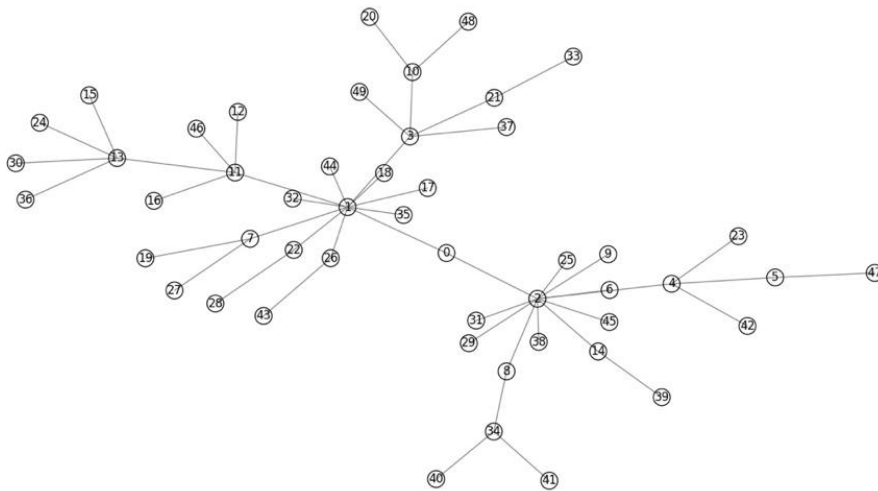
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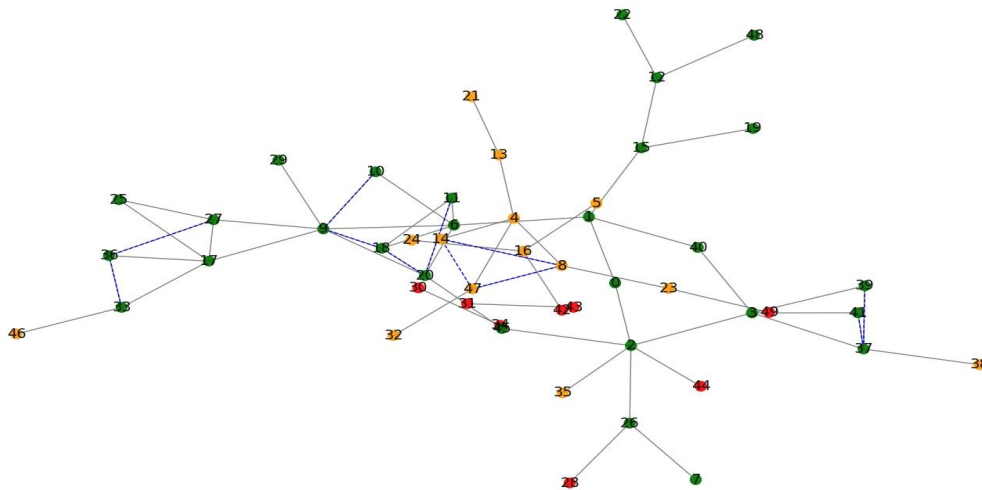
357 4.1 Extending the Barabási-Albert network model

358 The Barabási-Albert network model (BANM) represents an appropriate starting point for
 359 examining vertically coordinated supply networks. The choice of BANM for knowledge
 360 transfer is justified first, as among the network models evaluated, this model provides for the
 361 most effective approach towards modelling complex interactions among wine producers (Table
 362 2), second, for its ability to mirror characteristics of how wine producer firms are interconnected

363 and share knowledge, confirmed in a previous study [7], and third, because supply networks
 364 can be viewed as scale-free networks [38]. Barabási and Albert introduced the concept of scale-
 365 free networks, described by a structure in which a few influential firms have a significantly
 366 higher number of connections compared to most firms in the network [8]. This behavior, known
 367 as preferential attachment, explains how new firms are more likely to connect to already highly
 368 connected firms, a pattern observable in social networks and the internet [2]. In this study, these
 369 highly connected and influential firms are called “power hubs”, as they disproportionately attract
 370 the connection of new firms during the network formation. The BANM does not consider the
 371 structure of a vertically coordinated supply network and the tacit knowledge exchange
 372 mechanism relevant for knowledge flows. As shown in Figure 3, the BANM is extended by
 373 implementing two additional tiers to represent a three-tier supply network representing focal
 374 firm (node 0) and broker firms (nodes 1 and 2) and triadic closure operationalized by edge
 375 rewiring, to reflect trust-based exchanges (Figure 4). Triadic closure, a mechanism of building
 376 edges in social networks, refers to the tendency of two entities to connect to each other when
 377 both share the same neighbor, thus enabling personal and informal interactions [35].



378
 379 **Figure 3.** Extended Barabasi-Albert network model (explicit layer) with 50 firms, degree $m = 1$ (Source: Developed by the
 380 authors)
 381



382
 383 **Figure 4.** Evolutionary Knowledge Transfer Model (explicit and tacit layer), 50 firms, degree $m = 1$ (Source: Developed by
 384 the authors)

385
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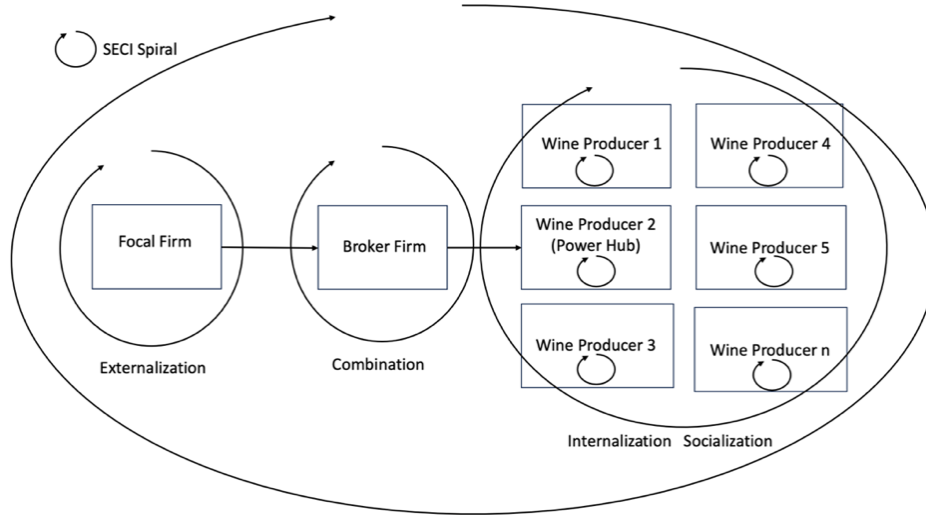
387 *4.2 Application of the SECI model*

388 While the extended BANM represents the structure of the network, the SECI model
 389 (socialization, externalization, combination, internalization) developed by Nonaka and
 390 Takeuchi [57] serves as a conceptual framework focusing on knowledge creation and sharing
 391 through the dynamic interaction of explicit and tacit knowledge occurs within organizations. It
 392 facilitates continuous knowledge creation, innovation, and technology adoption. According to
 393 SECI, tacit knowledge can be converted to explicit knowledge and vice versa, within an
 394 organization through the mechanisms of both individual and collective learning experiences.
 395 SECI explains the dynamic conversion between explicit and tacit, operationalized in this study
 396 through dyadic exchanges. Within the three-tier supply network, the SECI knowledge
 397 conversion processes take place in Ba, which ensures continuous knowledge transfer in a spatial
 398 and temporal environment, where tacit and explicit knowledge oscillate within a single
 399 communication channel [57, 58]. While SECI primarily operates on dyadic and firm levels,
 400 particularly its socialization processes create and facilitate network level dynamics by
 401 enhancing trust and collaboration between wine producers, which impacts network structure
 402 and stability. The SECI initially dealt with knowledge conversion between tacit and explicit
 403 knowledge within organizations, but it is also applicable in supply chain contexts to study

404 interorganizational knowledge creation [28]. Furthermore, Rice and Rice [65] applied the SECI
 405 model to multi-organizational projects and Wu [86] explored in his research amongst others the
 406 impact of technology adoption and supplier relationship management on knowledge creation
 407 within a supply chain.

408 In the conceptual framework, each firm is assigned to one specific phase of the SECI knowledge
 409 conversion process, while still participating in the full SECI cycle. Figure 5 illustrates that this
 410 allows to simultaneously simulate intra- and inter-firm knowledge transfer.

411



412

413 **Figure 5.** SECI applied to vertically coordinated supply network (Source: Developed by the authors)

414

415 A further consideration is, that all SECI knowledge conversions are transmitted through a single
 416 communication channel. This approach was chosen based on four key considerations. First, the
 417 characteristic and type of explicit and tacit knowledge can fluctuate significantly due to the
 418 inherent differences between tacit and explicit knowledge [56]. Modeling separate channels for
 419 explicit and tacit knowledge would not reflect the repeating and spiraling characteristic of the
 420 SECI model. Second, within organizations only a smaller portion of knowledge is codified
 421 while the major portion comprises of tacit knowledge [12, 32, 82], making tacit knowledge the
 422 predominant knowledge type, reinforcing the need for a unified representation. Third, existing
 423 knowledge encompasses both tacit and explicit knowledge with the understanding that a
 424 transformation between these forms is a key characteristic of the conversion process [32, 33].
 425 Finally, modeling knowledge transfer through a single communication channel reduces model
 426 complexity while closely reflecting real-world organizational practices. Table 1 provides a
 427 summary of the four knowledge conversion processes along with an explanation of how each
 428 stakeholder contributes to knowledge conversion within the supply network. Knowledge

429 conversion in this study starts with the externalization phase considering that the sequence of
 430 the model can be adapted to meet organizational and cultural requirements [84, 3].

431
 432
 433

SECI Phase	Stakeholder	Knowledge Conversion
Externalization	Focal firm	The focal firm converts tacit knowledge about blockchain applications that it holds into explicit knowledge to enable unidirectional distribution with brokers
Combination	Brokers	Brokers categorize and integrate the received explicit knowledge into their communication flow and distribute it unidirectionally to the wine producers, predominantly through power hubs
Internalization	Wine producers	Within the wine producers, explicit knowledge diffuses bidirectionally, which enables the creation of new tacit knowledge through reciprocal sharing
Socialization	Wine producers	The tacit knowledge, that is built among the wine producers through interpersonal exchanges and experiences, has the potential to be converted into new tacit knowledge. At this phase, firms with high potential absorptive capacity are more likely to absorb and assimilate complex knowledge about the benefits of blockchain applications

434
 435 **Table 1.** SECI knowledge conversion (Source: Elaboration of the authors)

436
 437 The EKTM integrates SECI, dynamic capabilities, and the Barabási-Albert network model
 438 across dyadic, firm, and network levels, linked by trust-based dyadic relationships to explain
 439 knowledge flows in supply networks of the wine sector. At the dyadic level, SECI explains tacit
 440 and explicit knowledge transfer through trust and collaboration, supported by triadic closure
 441 and dynamic edge rewiring. At the firm level, dynamic capabilities enable firms to absorb and
 442 utilize knowledge from dyadic exchanges. At the network level, the Barabási-Albert model
 443 facilitates explicit knowledge transfer through power hubs, while triadic closure and edge
 444 rewiring enable tacit knowledge sharing within their respective hub ecosystems. This
 445 mechanism reflects knowledge transfer in the wine sector, where both explicit and tacit
 446 knowledge are critical for innovation. Dyadic relationships serve as the core linking
 447 mechanism, ensuring consistency and theoretical integrity across all levels.

448

449 **5. Results and discussion**

450 This chapter presents and discusses the findings related to the research question of how
451 knowledge about disruptive technologies evolves within vertically coordinated multi-tier
452 upstream wine supply networks. To answer this question, explicit and tacit knowledge types
453 were investigated, conceptualized as continuously oscillating within a single communication
454 channel within the SECI model, driven by potential absorptive and disseminative capacity as
455 well as trust. As highlighted in the theory section a comparative analysis of network models was
456 conducted to evaluate their applicability to vertically coordinated supply networks. Results are
457 presented in Table 2, revealing the limitations of established models. Building on this insight,
458 the Barabási-Albert network model was identified as a suitable network topology, which was
459 extended by a) incorporating two additional tiers to represent the three-tier supply network
460 architecture and b) integrating a tacit knowledge layer operationalized through dynamic edge
461 rewiring and triadic closure. In developing the EKTM, results from previous research such as
462 initial knowledge distribution, attitude type of firms, network structure, and power hubs were
463 integrated. These findings confirmed that the extended Barabási-Albert network appropriately
464 represents a vertically coordinated wine supply network, characterized as a decentralized
465 network of interacting wine producers connected to several brokers and a single focal entity.
466 Within this network each producer belongs to an environment characterized by scale-free
467 properties led by an influential node, the power hub. This decentralized network shows
468 properties of social networks. Results from the previous study further revealed that focal firms
469 predominantly distribute knowledge through explicit channels, such as newsletters, conferences,
470 and documents. While this reflects the externalization phase of the SECI model, which
471 transforms tacit knowledge into explicit knowledge [57], it lacks the consideration of tacit
472 knowledge exchange, particularly within power hub environments. The emphasis on explicit
473 knowledge transfer could be attributed to the fact that sharing explicit knowledge is easy when

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Table 2. Comparative analysis of complex network models (Source: Developed by the authors)

it must be done across large and geographically dispersed groups [50]. However, according to the interviews there were instances of tacit knowledge exchange, such as through messenger applications or personal meetings aligning with Polanyi’s theory [64], which states that not all knowledge can be codified, and that inter-personal knowledge is essential for innovation and competitive advantage. This also aligns with Cowan and Jonard [18], who experimented with

Attributes/Network Models	Evolutionary Knowledge Transfer	Barabási-Albert	Erdős-Rényi	Evolutionary Network	Holme and Kim	Watts-Strogatz
Supply Chain Governance Centralized coordination	Centralized through focal firm	Tendency to decentralization through hubs	Distributed coordination	Evolving, depends on initiating model	Tendency to decentralization through hubs	Between centralized and decentralized, but depending on rewiring
Hierarchical structure	Fully supported	Moderately supported, power hubs represent influential stakeholders	Lack of hierarchical structure	Depends on initiating model	Moderately supported, power hubs represent influential stakeholders	Moderate implementation, decentralization
Distribution of knowledge	Originates at focal firm, distributed to brokers, then diffused from power hubs	Directed, originate from power hubs	Random between nodes	Depends on initiating model and evolutionary dynamics	Directed, originate from power hubs	Random between nodes
Network Configuration and Dynamics Network topology	Scale free, "rich get richer" phenomenon, small world	Scale free, "rich get richer" phenomenon	Random graph	Depends on initiating model and evolutionary dynamics	Scale free, "rich get richer" phenomenon, small world	Small world
Network architecture	Centralized	Decentralized	Distributed	Can evolve over time	Decentralized	Decentralized
Node interactions	Uni-directional, bi-directional and preferential attachment, formation of power hubs, triads	Preferential attachment, formation of hubs	Random connections, homogeneous distribution	Following evolutionary dynamics	Preferential attachment, formation of hubs, triad formation	Based on a regular grid, random rewiring of nodes results in short path length
Power hubs	Yes, few highly connected nodes	Yes, few highly connected nodes	Not supported	Potential to emerge	Yes, few highly connected nodes	Not supported
Clustering coefficient	High to very high	Low to moderate	Very low to low	Flexible, adaptable	High	Moderate to high
Behavior after formation	Dynamic	Static	Static	Dynamic	Static	Static
Explicit Knowledge Compatibility	Strong	Strong	Moderate	Strong	Strong	Moderate
Tacit Knowledge Compatibility	Strong	Minor	Minor	Moderate	Moderate	Strong
Transfer Mode	Peer-to-peer based on reputation of power hubs	Static, hubs based, based on reputation of power hubs	Probabilistic, unstructured, random	Adaptable, dynamic	Centralized, peer-to-peer	Informal due to high clustering, peer-to-peer
Vertically Coordinated Supply Chain Suitability Strategic alignment	Good for centralized coordination and tendency to decentralization through power hubs	Good for networks with tendency to decentralized coordination	Not suitable for networks with hierarchic structure	Flexible; can be adapted to meet specific requirements	Good for networks with tendency to decentralized coordination (due to increased local interactions resulting from higher clustering)	Moderate for networks with tendency to decentralized coordination
Strategic network compatibility	High, multi-echelon supply chain characteristic can be represented	Moderate, influence of key stakeholders can be represented	Low, no representation of supply chains	Flexible; can be adapted to meet specific requirements	Moderate, influence of key stakeholders can be represented	Moderate, focus on local interactions between nodes
Representation of influential firms	Very good, as network creates dominating agents	Very good, as network creates dominating agents	Not applicable, focus is on random connection of nodes	Potential to emerge	Very good, as network creates dominating agents	Limited, as focus is on local connectivity
Intra-hub communication	Evolving edge characteristics	Static upon network formation	Not applicable	Can be modeled according to specific requirements	Static upon triad building	not applicable

483 random edge rewiring for tacit knowledge exchange. While learning about disruptive
484 technologies can be achieved through codified information by combining text and pictures [53],
485 effectively transferring and absorbing that knowledge requires the integration of both, explicit
486 and tacit knowledge [64, 55]. The cyclic and dynamic nature of explicit and tacit knowledge
487 conversion aligns with the findings of Plangger et al. [63] and Liu et al. [49]. Moreover, findings
488 align with Rogers' diffusion of innovations theory [67], who proposes that the adoption of novel
489 technologies follows a bell curve with early adopters, followed by majority and laggards.
490 Furthermore, it was found that the knowledge spiral of the supply network remains incomplete
491 as the knowledge conversion from producer firms back to the focal firm is absent. The slow
492 adoption rate in the wine industry may be attributed to that fact as well as to the complexity of
493 the technology, limited resources and the traditional character of the sector.

494 While alternative perspectives exist, they were not considered as the focus of the study is on
495 relational mechanisms and structured transfer processes. For instance, Innovation Diffusion
496 Theory [67] explains adoption patterns but underemphasizes structural mechanisms.
497 Organizational Learning Theory [4], while addressing internalization processes, lacks focus on
498 inter-organizational coordination. Resource-Based View [85] addresses networked knowledge
499 exchange. Social Capital Theory can be applied to both inner-firm and intra-firm networks as
500 the theory centers on nodes and relational ties linking them [41]. It emphasizes trust and
501 relational assets, constructs that are already considered within the proposed model within
502 knowledge management and strategic management. Consequently, it was not included as a core
503 theory due to conceptual overlap. However, selected key elements such as trust and strength of
504 ties could be integrated into an agent-based model (ABM) to enhance relational realism and to
505 better reflect the dynamics of explicit and dyadic knowledge flows within the context of a
506 simulation. While these theoretical alternatives may enrich the model, their inclusion risks
507 theoretical fragmentation and a dilution of analytical clarity.

508 This study advances theory by developing the Evolutionary Knowledge Transfer Model
509 (EKTm), which extends the Barabási-Albert network model to represent a multi-tier
510 architecture and integrates the tacit knowledge layer within the SECI framework. By combining
511 knowledge management, complex network, and strategic management theories, the EKTm
512 explains how explicit and tacit knowledge are transferred between firms in vertically
513 coordinated wine supply networks. The model advances theoretical understanding of inter-firm
514 knowledge transfer by highlighting the dominant role of tacit knowledge in disruptive
515 technology adoption and addressing the current lack of integration of dyadic, firm, and network

516 perspectives in knowledge transfer models. The study provides practical guidance to managers
517 particularly from focal firms planning to implement blockchain solutions by clarifying how
518 knowledge flows and capabilities interact across dyadic, firm, and network levels to enable
519 successful blockchain adoption and innovation management. For managers and wine producers,
520 the EKTM highlights the need to first strengthen dyadic relationships through trust building
521 measures and tacit knowledge sharing, e.g., regular meetings, training sessions, and mentorship
522 potentially enhancing trust through interpersonal exchange to enable effective knowledge
523 sharing and lower adoption barriers. These tacit exchanges create a culture of open learning and
524 innovation, which assist in the integration of external knowledge by stimulating collaboration
525 and knowledge sharing, which result in more efficient knowledge transfer and technology
526 adoption, aligning with Chesbrough [15] and Lezoche et al. [39]. Furthermore, structured
527 feedback loops between wine producers and focal firms should be established to align
528 blockchain knowledge with operational requirements. On the firm level managers should
529 develop absorptive and disseminative capacities through e.g., training programs and knowledge
530 sharing platform solutions to enable structured knowledge sharing. Supply chain stakeholders
531 can use these insights that a few influential hubs connect many nodes to facilitate tacit
532 knowledge flow and position themselves as influential knowledge hubs, while strengthening
533 connections with wine producers, brokers, and focal firms within the network to increase
534 adoption probability within their ecosystem. For policymakers, the EKTM highlights the
535 importance of supporting the formation of knowledge hubs and knowledge sharing initiatives
536 to strengthen knowledge flows. This can be achieved e.g., by stimulating collaborative learning
537 programs to reduce knowledge inequalities, creating an environment for efficient blockchain
538 adoption. Policies that encourage dyadic collaboration (e.g., funding partner projects) and firm
539 level capacity building (e.g., financing of training) has the potential to further accelerate
540 innovation diffusion across the wine supply chain.

541 Ultimately, findings demonstrate that strategic decision-making, technology investment, and
542 innovation management should follow a stepwise approach by building trust and collaboration
543 at the dyadic level, developing absorptive and disseminative capacities at the firm level, and
544 engaging in governance and standardization activities at the network level. This ensures that
545 resources are aligned with knowledge flows, capabilities are developed in consideration of
546 network structures, and innovation is managed as an ecosystem effort. While the EKTM offers
547 a robust framework, the static representation of knowledge flows and the complexity of
548 quantifying tacit knowledge remain a theoretical limitation. Future research could address this

549 gap by operationalizing the model through agent-based modeling, as this enables the simulation
550 of complex interactions and provides insights into how knowledge evolves over time.

551 While interpreting the results, limitations of the study should be considered. The Evolutionary
552 Knowledge Transfer Model (EKTM) is based on empirical insights from stakeholders in the
553 German wine industry. Although this strengthens the validity of the model, it limits its
554 generalizability beyond that specific sector. Future studies should therefore apply, test, and
555 refine the EKTM in other countries and agri-food sectors to assess its transferability. In
556 addition, the model focuses on a three-tier upstream supply network representing focal firm,
557 broker firms, and wine producers. While this structure reflects the vertically coordinated supply
558 network of the study, extending the model to include downstream stakeholders (e.g., logistics
559 providers, distributors, and retailers) would provide a more holistic understanding of interfirm
560 knowledge transfer and adoption processes. Furthermore, the study addresses knowledge
561 transfer about the perceived benefits of blockchain technology but does not observe the effects
562 of blockchain implementation within the supply network on knowledge transfer itself. The
563 model therefore addresses primarily the dynamics in the pre-adoption phase rather than post-
564 adoption knowledge transfer processes. Future research should investigate how blockchain
565 attributes such as transparency, immutability, decentralization, traceability, and smart-contract-
566 based coordination impact knowledge transfer. Finally, external factors such as market
567 dynamics, regulatory environments and the acceptance of knowledge sharing practices in the
568 wine sector could also play a role, suggesting a need to study how these conditions moderate
569 knowledge transfer. These factors have been considered less relevant in the study as external
570 influences are often mitigated by the power exerted by the focal firm and by efficient flow of
571 knowledge. However, future research could examine how external conditions moderate
572 knowledge transfer processes and whether the coordinating role of the focal firm mitigates,
573 amplifies, or redirects these influences.

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575 **6. Summary**

576 This study investigates the dynamic evolution of transferring knowledge about the perceived
577 benefits of disruptive digital technologies within strategic networks, addressing a critical
578 research gap in the field of inter-firm knowledge transfer. It contributes to the academic
579 discourse in supply chain management, knowledge management, business strategy, and
580 technology adoption behavior, while offering practical insights for managers integrating

581 blockchain-based solutions into their businesses. As disruptive digital technologies have the
582 potential to significantly impact the agri-food and wine sectors, efficient adoption can result in
583 substantial performance improvements. The proposed Evolutionary Knowledge Transfer
584 Model, which rests on the integration of dyadic, firm, and network perspectives, offers a novel
585 framework to facilitate effective knowledge exchange. While the wine industry provides the
586 empirical and conceptual base for model development, the insights are intended to be relevant
587 to other agri-food sectors characterized by vertical coordination and complex inter-firm
588 relationships. Findings support managers to improve knowledge management processes by
589 designing mechanisms that strengthen tacit and explicit knowledge flows to improve
590 technology adoption behavior.

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592 7. References

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