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FROM ENTREPRENEURIAL DISCOVERY PROCESSES TO DEPLOYMENT – GOVERNING CRITICAL TECHNOLOGIES IN INDUSTRIAL REGIONS

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Purpose: This research investigates the influence of regional governance mechanisms on the deployment of critical technologies in industrial regions, specifically addressing the persistent gap between entrepreneurial discovery processes (EDP) and practical implementation at the firm and value chain levels. The study seeks to develop and empirically test a diagnostic framework that elucidates the transition from EDP to deployment within the context of smart specialisation, employing academic language and analytical rigour throughout.
Design/methodology/approach: The study adopts a mixed-methods exploratory and explanatory design, developing three semiquantitative diagnostic indices: the Governance Coordination Index (GCI), the Adoption Readiness Index (ARI), and the Value Chain Resilience Index (VCRI). The framework is empirically validated through an in-depth case study of the Silesian Voivodeship, integrating documentary analysis of RIS3 strategies and EDP reports (2019-2024), quantitative assessments from innovation dashboards, and 12 semi-structured stakeholder interviews. Each index is calibrated on a 0-2 scale across multiple dimensions, with methodological triangulation employed to enhance validity.
Findings: The Silesian Voivodeship demonstrates strong institutional coordination (GCI: 8/10) but shows notable weaknesses in adoption readiness (ARI: 5/8) and value chain resilience (VCRI: 5/8). The analysis uncovers a "governance-implementation asymmetry" where formal coordination mechanisms are well-developed, yet EDP processes remain limited, TRL-IRL convergence is weak, and resilience varies across sectors. Advanced manufacturing and medical technologies display stronger adaptive capacity compared to energy-related value chains.
Research limitations/implications: The study is limited by its single-case design and reliance on semi-quantitative expert judgment; however, data triangulation mitigates these concerns. Future research should undertake comparative studies across regions with varying industrial profiles and employ longitudinal designs to track adoption trajectories during external shocks. Incorporating quantitative firm-level indicators would complement the existing approach.
Practical implications: Regional authorities should focus on three key areas: increasing SME and end-user participation in EDP processes, creating targeted adoption tools that address the TRL-IRL gap (including managerial training and innovation-focused procurement), and fostering systemic resilience through coordinated supply chain platforms. These findings

guide policy development for regions experiencing industrial transformation within the EU's critical technologies agenda.
Social implications: The research supports just transition policies in industrial regions by identifying bottlenecks in technology deployment that impact employment, competitiveness, and sustainable development. It offers guidance for strengthening regional innovation ecosystems' capacity to tackle societal challenges through effective governance of critical technologies in areas such as clean energy, healthcare, and digital transformation.
Originality/value: This study introduces a diagnostic framework that operationalises the EDP-to-deployment pathway using three integrated indices. It advances theoretical understanding of governance-implementation dynamics in regional development, and provides practitioners with practical tools for assessing and improving technology adoption readiness in industrial regions transforming.
Keywords: smart specialisation, entrepreneurial discovery process, critical technologies, regional governance.
Category of the paper: Research paper.

1. Introduction

Discussions on critical technologies highlight not only the importance of setting priorities but also the capacity of regional innovation systems to support the transition from entrepreneurial discovery to effective adoption within firms and value chains. Governance, in this context, is understood as the arrangement of roles, coordination mechanisms, and policy instruments that connect administration, business, science, and users within a smart specialisation framework (Foray, 2014; Flanagan et al., 2011; McCann, Ortega-Argilés, 2015). In industrial regions such as the Silesian Voivodeship, critical technologies are expected to strengthen economic resilience while speeding up structural change, thus requiring coherent policy combinations and integrated risk management across infrastructures and supply chains (Řehák et al., 2022; Guijarro et al., 2024).

Building upon this foundation, a governance framework, here referred to as the pathway from Entrepreneurial Discovery Process (EDP) to deployment, has been proposed to connect entrepreneurial discovery with concrete implementation. This framework consists of three interconnected dimensions: firstly, the coordination of actors and participatory decision-making processes from priority setting to resource allocation within RIS3; secondly, transition instruments that convert strategic priorities into firm-level adoption, including technology roadmapping, technological due diligence, and targeted capability building within clusters and SMEs (Phaal et al., 2004; Zahra, George, 2002); thirdly, system learning achieved through ongoing monitoring and adaptive adjustment of the policy mix, where demand-side tools act as supportive enablers rather than main drivers (Bogers et al., 2018; Gottinger et al., 2025). Effectiveness in this context is assessed not only through programme inputs and outputs but

also by the maturity of implementation levels and the resilience of the value chain within sectors considered crucial for regional development (Frank et al., 2019; Yin, 2022).

Existing research on innovation management and Industry 4.0 emphasises that the adoption of digital technologies improves transparency and responsiveness when integrated within suitable managerial practices and absorptive capacity at both firm and ecosystem levels (Zahra, George, 2002; Bogers et al., 2018). At a regional level, varied digitalisation patterns among SMEs and the structural composition of clusters influence adoption routes, highlighting the need for governance and capability-building efforts tailored to local industrial contexts (Delgado et al., 2016; Chiappinelli et al., 2025). Using Silesia as a case study of a mature industrial economy undergoing simultaneous energy and digital transitions, this analysis explores how effectively the proposed governance architecture bridges the gap - the "last mile" - between entrepreneurial discovery and implementation within firms and along value chains (Foray, 2014; McCann, Ortega-Argilés, 2015).

2. Conceptual framework

The reviewed literature on smart specialisation, regional innovation systems, and critical technologies consistently highlights a persistent gap between setting strategic priorities and their practical implementation at the level of firms and clusters. While the Entrepreneurial Discovery Process (EDP) has gained widespread acceptance as a participatory mechanism for identifying innovation areas, many authors point out that later stages, such as supporting adoption, coordinating policies, and monitoring, often remain fragmented or poorly developed (Foray, 2014; Flanagan et al., 2011; McCann, Ortega-Argilés, 2015; Aranguren et al., 2018). This issue becomes especially evident in regions with strong industrial histories, where institutional complexity and overlapping mandates weaken the connection between discovery and execution. Recent European policy frameworks emphasise the need to close this gap. For example, the 2023 Commission Recommendation on Critical Technologies and the 2024 STEP regulation both stress the importance of strong regional governance mechanisms to promote technology development and adoption across ecosystems, particularly in sectors considered strategically important.

In addressing these challenges, this article proposes a conceptual framework based on three mutually reinforcing pillars designed to transform identified priorities into concrete implementations. The first pillar emphasises coordination and participation, regarded as a meta-capability that identifies who is involved in strategic decision-making, assigns responsibilities, and involves implementation actors early on. In advanced industrial regions, these coordination functions are often housed within cluster organisations and innovation ecosystems, thus connecting public policy instruments with firm-level needs (Delgado et al., 2016; Foray,

2014). When such structures are well developed, implementation barriers are managed proactively, and projects more reliably align with broader regional development goals. Indicators of coordination maturity include (Flanagan et al., 2011; McCann, Ortega-Argilés, 2015; Bzhalava et al., 2022):

- clearly formalized governance roles,
- transparent criteria aligning RIS3 objectives with project selection,
- regular EDP cycles involving implementation stakeholders,
- joint fora facilitating cross-level strategic steering.

Together, these factors reduce transaction costs and uncertainty, making it more likely that strategic areas will become actionable investments.

However, strategic coordination alone rarely suffices to ensure that regional priorities turn into concrete deployments. Many innovation systems face operational challenges in bridging the gap between intent and action, particularly when navigating fragmented value chains and diverse firms. As Zahra and George (2002) argue, a firm's absorptive capacity, particularly within small and medium-sized enterprises (SMEs), depends not only on technological potential but also on organisational readiness and effective intermediation. To address this operational gap, the second pillar highlights transition tools - mechanisms that link the strategic outputs of the EDP with firm-level adoption processes. Technology roadmapping is particularly noteworthy among these tools as a planning instrument that converts long-term innovation ambitions into sequenced, time-bound investments. Phaal et al. (2004) show that when roadmaps are co-created with various stakeholders, they act as effective coordination devices across public policy, firms, and research organisations, especially in contexts where emerging technologies lack established pathways to commercialisation. Another crucial tool is technological due diligence, a structured method for assessing a project's technological maturity, implementation risks, and systemic importance. Starzyńska's (2019) analysis of Polish industrial policy reveals how such assessments expose bottlenecks in regional innovation support instruments, particularly when adoption necessitates cross-sectoral integration.

Furthermore, direct support for adoption is vital. Frank et al. (2019) emphasise that digital transformation efforts in manufacturing tend to yield better results when paired with organisational change support, rather than relying solely on equipment funding. Likewise, Chiappinelli et al. (2025) emphasise the importance of advisory services that enable firms to align their regional priorities with internal investment strategies. Public-private pilot projects also help reduce adoption risks by allowing technical and organisational validation in real-world conditions. Embedded within cluster frameworks or value-chain consortia, these pilots promote knowledge exchange and policy learning (Bogers et al., 2018). Overall, these tools form an intermediate governance layer that converts strategy into practice by supporting iterative, context-sensitive transitions instead of enforcing top-down mandates.

The third pillar emphasises the necessity for regional governance systems to pursue systemic learning, characterised by continuous monitoring of implementation outcomes, early identification of potential failures, and the adaptive adjustment of policy tools. Instead of viewing monitoring as just a compliance task, recent scholarship advocates a formative evaluation approach that integrates policy learning within iterative feedback loops (Haddad et al., 2022). It has been stressed that governance should go beyond project-specific performance metrics to include systemic indicators like value chain resilience, absorptive capacity, and sectoral spillovers. These metrics offer a more complete assessment of whether innovation policies truly transform systemic conditions, rather than merely supporting incremental improvements (Yin, 2022). This distinction is especially vital in regions undergoing structural change, where institutional inertia can obscure weak adoption dynamics. Supporting this view, Řehák et al. (2022) observe that traditional performance indicators often fail to measure progress from goal setting to market-ready solutions. As a result, governance structures are encouraged to incorporate adaptive cycles, where programme designs develop responsively based on implementation feedback. This aligns with broader trends towards mission-oriented innovation policies, which promote experimentation and incremental adjustments (Mazzucato, 2018).

From a practical perspective, effective systemic learning requires robust data infrastructures and incentives that promote shared accountability among relevant parties. Regions that invest in multi-level monitoring platforms, integrating public authorities, clusters, and companies, are better equipped to adjust funding allocations, scale successful pilot initiatives, or stop underperforming programmes. Such platforms improve reflexivity, allowing for a critical reassessment of policy assumptions in light of new evidence. Within this framework, adaptability becomes a fundamental design principle rather than an additional characteristic. Regional systems that demonstrate dynamic learning capabilities - driven by real-time action rather than solely by retrospective evaluations - are more likely to convert EDP outputs into sustained technological adoption and secure a strong strategic position within emerging markets (European Commission, 2023; Guijarro et al., 2024).

All three pillars (figure 1) - coordination and participation, transition tools, and systemic learning - form a governance framework that implements the pathway from entrepreneurial discovery to firm-level deployment. Each pillar focuses on a different stage of this process: setting the agenda and aligning stakeholders, turning strategic priorities into investment-ready projects, and adaptive implementation guided by ongoing feedback. Notably, this process is iterative rather than strictly linear. For example, roadmaps may be adjusted based on monitoring insights, while coordination platforms can broaden or narrow their scope in response to adoption experiences.

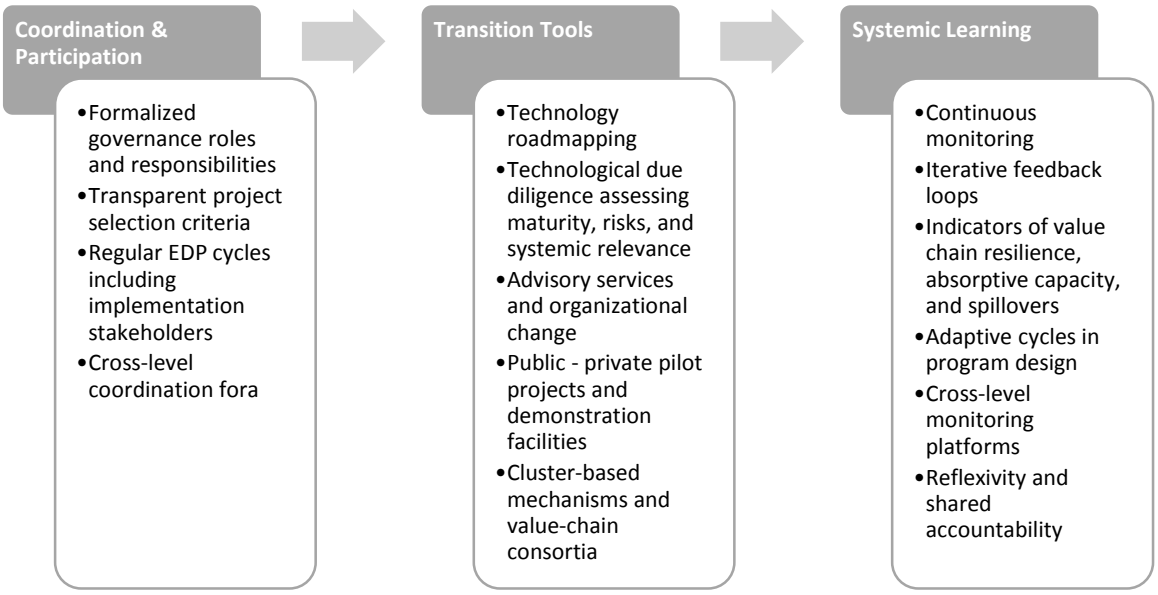

Figure 1. Conceptual Framework: Governance Architecture from Entrepreneurial Discovery Process to Technology Deployment.

Source: own study based on Foray, 2014; Flanagan et al., 2011; McCann, Ortega-Argilés, 2015; Aranguren et al., 2018.

Beyond serving as a normative model, this architecture also functions as an analytical tool to evaluate how prepared regional innovation systems are to deploy critical technologies effectively. By emphasising governance capabilities rather than specific technology or sector factors, it enables cross-regional comparisons among areas experiencing similar structural changes. It is essential to recognise that while conceptual models offer valuable frameworks for understanding innovation processes, the realities of implementing technology are often far more complex. Regional innovation systems are dynamic and diverse ecosystems where participants differ greatly in experience, resources, and motivations. This heterogeneity frequently leads to unforeseen challenges during deployment. Therefore, effective governance requires not only formal mechanisms but also flexibility and ongoing learning to adapt to local conditions and the specific needs of stakeholders.

Empirically, such a framework proves essential in contexts like the Silesian Voivodeship, where it can identify leverage points, uncover coordination gaps, and delineate barriers that obstruct implementation. It also enables the evaluation of alignment between RIS3 priorities, support instruments, and actual deployment outcomes within regional value chains. The following section applies this conceptual framework to a region undergoing industrial transition, illustrating how governance capabilities influence the real-world dynamics of critical technology adoption.

3. Methods and data

This study uses a mixed-methods approach, following an exploratory–explanatory sequence, to investigate how regional governance mechanisms affect the deployment of critical technologies in the Silesian Voivodeship. The methodological design is closely aligned with the conceptual model outlined earlier and centres on three diagnostic indices: the Governance Coordination Index (GCI), the Adoption Readiness Index (ARI), and the Value Chain Resilience Index (VCRI). These indices are designed not as universal measures, but as structured, context-sensitive tools that capture how institutional configurations turn innovation priorities into practical implementation (Creswell, 2014; Plano Clark, Ivankova, 2016).

These indices were developed drawing on recent research into innovation governance and systemic resilience. The Governance Coordination Index (GCI) expands on the work of McGregor et al. (2021), who stress the crucial role of coordination across various administrative levels in complex areas such as land use planning and risk management. Additionally, Geng and Huang (2022) have highlighted the importance of integrated coordination within multidimensional policy environments, proposing frameworks suitable for multi-faceted governance metrics. Markard and Truffer (2008) and Könnölä et al. (2021) offer further conceptual insight, examining the capacities for multi-level governance within innovation systems.

The Adoption Readiness Index (ARI) builds on research into institutional readiness and adoption capacity, drawing on insights from Ioannou and Serafeim (2019) on how governance legacies, socio-economic contexts, and organisational competencies jointly impact innovation diffusion (Cohen, Levinthal, 1990; Todorova, Durisin, 2007). The Value Chain Resilience Index (VCRI) incorporates recent findings on supply chain robustness and digitalisation, focusing particularly on the role of Industry 4.0 technologies in improving adaptability under turbulent conditions (Guijarro et al., 2024; Yin, 2022; Christopher, Peck, 2004; Ivanov, Dolgui, 2020).

Instead of replicating existing measurement models, each index has been customised to reflect the unique institutional and policy dynamics typical of the Silesian context. Their design adheres to a semi-quantitative evaluative framework commonly used in policy foresight and regional strategy appraisal, which combines structured expert judgement with administrative and project-level data (Teräs et al., 2020; Edler, Fagerberg, 2017). The structure and weighting of the indices were developed through a synthesis of theoretical foundations and empirical data gathered throughout the study. The credibility of this mixed-method approach is supported by expert elicitation and data triangulation methodologies, as recommended by Kelle et al. (2019) and Patton (2015).

The Governance Coordination Index assesses the extent to which institutional arrangements within the regional innovation system (RIS) are formal, participatory, and strategically aligned, from setting priorities to implementing policies. It assesses governance performance as the capacity to coordinate fragmented stakeholder input into effective action across government, academia, industry, and intermediaries. Five key dimensions underlie the GCI, drawing on previous studies of multi-level governance and innovation policy integration (McGregor et al., 2021; Geng, Huang, 2022):

1. Formalization of roles and responsibilities, assessed by the clarity and enforceability of governance documents such as RIS strategies and implementation roadmaps.
2. Frequency and inclusiveness of Entrepreneurial Discovery Process (EDP) cycles, operationalized via the number, composition, and documented feedback of participatory meetings (Foray et al., 2011; Grillitsch, Sotarauta, 2020).
3. Transparency in project selection criteria, measured by the accessibility and clarity of evaluation frameworks applied in allocating public resources.
4. Presence and quality of roadmaps, evaluated according to the existence of technology-specific or mission-oriented plans that incorporate milestones, key performance indicators, and responsible actors.
5. Institutionalized stakeholder coordination, determined by the establishment of multi-level coordination platforms, working groups, or innovation councils with formal mandates.

Each dimension was scored on a scale from 0 (absent or informal) to 2 (fully institutionalised and functional), based on a structured content analysis of RIS3 and EDP documents from 2019 to 2024, supplemented by 12 expert interviews with regional authorities, cluster coordinators, and innovation intermediaries. Experts were selected using purposive sampling to cover key components of the regional innovation system, ensuring representation of stakeholders directly engaged in RIS3 priority sectors and EDP processes. Scores were triangulated for validity and independently coded by two researchers. The GCI focuses on institutional coordination as a driver of implementation outcomes rather than an abstract measure of governance quality (Edquist, Hommen, 2008; Howlett, 2023).

The Adoption Readiness Index assesses the readiness of firms and intermediary institutions within the regional ecosystem to take on, implement, and spread crucial technologies. While the GCI focuses on governance architecture, ARI moves its attention to organisational and technical capabilities at the firm and cluster levels, mirroring the absorptive capacity concept (Zahra, George, 2002; Ioannou, Serafeim, 2019). ARI consists of four interconnected dimensions:

1. Convergence of Technology Readiness Levels (TRL) and Implementation Readiness Levels (IRL) within innovation projects (Mankins, 2009; ISO/IEC, 2012).
2. Firm-level implementation capabilities, gauged through involvement in adoption programs, evidence of pilot deployments, and internal investments in digital infrastructure.
3. Availability of cluster-based support mechanisms, such as dedicated innovation services, demonstration facilities, or specialised cluster initiatives targeting key technologies.
4. The technology deployment environment, including institutional facilitations like regional innovation hubs and market-facing mechanisms such as procurement pilots or testbeds.

Data sources included project documentation from regional development agencies, records from innovation intermediaries (e.g., technology parks, accelerators), and digital transformation metrics from public monitoring systems (e.g., SME digitalisation dashboards). Additional insights were gained from interviews with programme coordinators and project managers. Each ARI dimension was scored on a scale of 0 to 2, resulting in a maximum total score of 8. A representative sample of 45 innovation projects funded through the RIS3 strategy between 2020 and 2023 was analysed for TRL-IRL convergence. The index aims to identify systemic enablers and bottlenecks affecting the regional adoption trajectory rather than exhaustively measuring all innovation capacities.

The Value Chain Resilience Index measures the capacity of regional firms and industrial ecosystems to withstand, adapt to, and recover from technological, environmental, or market disruptions. This index complements the GCI and ARI by focusing on the operational resilience of interconnected business networks. Building on recent studies of industrial resilience during crises such as the COVID-19 pandemic and supply chain digitalisation (Guijarro et al., 2024; Yin, 2022; Hambali, Adhariani, 2024), the VCRI consists of four dimensions:

1. Supplier diversification, quantified by the number and geographic origin of active suppliers in critical RIS sectors (e.g., energy, materials, machinery).
2. Recovery time, measured as the estimated duration for restoring supply chain operations post-disruption, based on historical data and expert judgment.
3. Transparency and data sharing, reflected by the availability of digital platforms enabling end-to-end supply network visibility.
4. Crisis adaptation capabilities, encompassing redundancy mechanisms, reconfiguration potential, and documented experience managing disruptions.

Data were collected through structured interviews with business associations, cluster reports, supply chain mappings, and secondary sources, including digital transformation assessments of Polish SMEs. Special emphasis was placed on value chains identified as strategic in RIS3 and relevant national foresight documents. Each dimension was rated on a 0-2 scale, resulting in a maximum VCRI score of 8. Resilience is understood as an evolving

capacity shaped by exposure, responsiveness, and coordination, making the VCRI a proxy for "implementation maturity" in strategic sectors.

Together, the GCI, ARI, and VCRI enable a comprehensive, multidimensional assessment of the Silesian region's readiness to move from "EDP to deployment". The following section applies this diagnostic framework empirically, examining how institutional and economic structures support or hinder the adoption of critical technologies in practice.

4. Case Study: Silesian Voivodeship

Poland's Silesian Voivodeship is one of the country's most industrialised and historically rooted regions, with a development path closely tied to coal mining, metallurgy, and heavy industry. However, over the past 20 years, the region has faced dual pressures: the need for decarbonisation and industrial restructuring, and the imperative to adopt digital transformation in line with the European Industry 4.0 agenda. These pressures have made Silesia a key testing ground and focal point for national and EU-level strategies on just transition, technological upgrading, and innovation governance (Silesian Voivodeship, 2020, 2021, 2022; Resources for the Future, 2022). Within this context, the regional innovation system has evolved under the RIS3 framework, with Entrepreneurial Discovery Processes (EDP) promoted as key mechanisms for priority setting and stakeholder inclusion. Since 2014, the region has completed several EDP cycles, identifying strategic technological areas such as clean energy, medical technologies, the green economy, ICT, and advanced manufacturing, which align directly with European critical technology agendas in sustainability, renewable energy, digitalisation, and health resilience (Silesian Voivodeship, 2019).

Despite this ambitious approach, empirical evidence shows ongoing challenges in aligning institutional governance with firm-level adoption capacities. Interviews with regional stakeholders reveal significant coordination gaps between public authorities, cluster organisations, and companies, especially in turning formal strategies into practical support mechanisms. A common concern is the limited absorptive capacity of SMEs, which often lack sufficient managerial and financial resources to adopt advanced technologies in practice. This weakness is further exacerbated by the fragmented and sometimes overlapping nature of regional support instruments. The COVID-19 pandemic and the supply chain disruptions of 2022-2023 made these gaps more evident, exposing structural vulnerabilities in time-sensitive industries and emphasising the need for systemic adaptability in a region heavily dependent on industrial value chains.

Against this backdrop, the Silesian Voivodeship serves as a key example for applying the diagnostic framework developed in this study. The operationalisation of three indices - Governance Coordination, Adoption Readiness, and Value Chain Resilience - followed

a systematic approach that combined documentary evidence, statistical indicators, and qualitative insights. Strategic frameworks (RIS3 Strategies, the regional Technology Development Programme, and EDP reports) and project portfolios from 2019 to 2024 were systematically coded to identify the presence or absence of governance and adoption mechanisms. Complementary data from regional dashboards and Observatories provided measurable proxies, such as SME participation in innovation programmes or indicators of supplier diversification. Lastly, 12 semi-structured interviews were conducted with officials, cluster coordinators, entrepreneurs, and researchers to triangulate findings and validate ambiguous results, thereby enabling a more nuanced interpretation of both quantitative and documentary evidence.

Taken together (Table 1), the empirical results suggest that the Silesian Voivodeship combines institutional consolidation in governance with selective, cluster-based adoption capacity and asymmetric resilience across sectors. This configuration underscores the partial functional coupling of its innovation system, where well-developed institutional coordination mechanisms coexist with a weak capacity for systemic adoption and resilient transformation.

Table 1.
Diagnostic index results for the Silesian Voivodeship (2019-2024)

Index	Dimensions (0-2 scale)	Total score	Interpretation
Governance Coordination Index (GCI)	• Roles (2) • EDP inclusiveness (1) • Transparency (2) • Roadmaps (1) • Coordination (2)	8/10	Strong institutional frameworks, but inclusiveness and roadmap implementation remain weak
Adoption Readiness Index (ARI)	• TRL–IRL convergence (1) • Firm capabilities (1) • Cluster support (2) • Deployment environment (1)	5/8	Adoption concentrated in clusters, with systemic SME bottlenecks
Value Chain Resilience Index (VCRI)	• Supplier diversification (2) • Recovery time (1) • Transparency/data (1) • Crisis adaptation (1)	5/8	Uneven resilience: stronger in advanced manufacturing, weaker in energy-related chains

Source: own research.

With a score of 8/10, the Governance Coordination Index (GCI) highlighted both the institutional maturity of regional frameworks and ongoing systemic shortcomings. The score was boosted by the formalisation of mandates and responsibilities within bodies like the Regional Innovation Council, as well as the transparency of project selection criteria, which were widely seen as predictable and accessible. The coordination of stakeholders across regional, national, and EU levels was also assessed positively. However, inclusiveness remained an issue: while universities and cluster organisations regularly participated in EDP consultations, SME contributions were often marginal and viewed by entrepreneurs as symbolic. A similar structural weakness was found in relation to roadmapping exercises, which although present for sectors such as clean energy and health technologies, rarely led to concrete

operational milestones or budgetary commitments. These disparities reflect a governance-implementation imbalance (McCann, Ortega-Argilés, 2015): while procedural transparency and formalisation are well advanced, mechanisms ensuring substantive inclusiveness and practical follow-through remain weak.

According to the Adoption Readiness Index (ARI), which scored 5/8, Silesia has a significant adoption capacity in certain areas, but it hasn't yet been widely disseminated across the economy. Projects funded by RIS3 show that while technologies often reached mid-to-high Technology Readiness Levels (TRL 6-7), they didn't align with Implementation Readiness Levels as much. This gap between technology and organisational readiness reflects the limited financial and managerial skills of companies, as well as the limited spread of support mechanisms beyond leading clusters. A lack of investment in digital infrastructure and workforce training particularly limited small and medium-sized enterprises (SMEs) in metallurgy and traditional manufacturing. However, successful cluster-led initiatives, such as the Medical Technology Accelerator in Zabrze or pilot infrastructures in Gliwice, including labs at the Silesian University of Technology and innovation spaces supported by GAPR, demonstrate the potential for targeted interventions to lead to tangible improvements. Nevertheless, a structural limitation remains in the deployment environment: insufficient procurement pilots and underdeveloped testbed facilities hinder the translation of promising prototypes into market-ready solutions.

The Value Chain Resilience Index (VCRI) also scored 5/8, indicating that resilience remains unevenly distributed across sectors. While advanced manufacturing and medical technologies showed relatively strong supplier diversification and cross-border integration with Central European networks, energy-related value chains appeared more vulnerable, especially in recovery time after supply disruptions. The 2022 automotive shortages, which caused multi-month delays, highlighted these weaknesses. Transparency and information-sharing mechanisms were limited: large firms have mainly implemented ERP and SCM platforms, whereas SMEs continue to depend on informal communication, preventing systemic visibility. Efforts to integrate adaptive mechanisms, such as pilots in circular economy practices, remain highly fragmented and lack the necessary cross-sectoral coordination for scaling.

The case thus illustrates a broader pattern observed in industrial regions undergoing structural transition: while institutional maturity and transparent frameworks are established, the “last mile” of implementation, reflected in inclusiveness, firm-level capabilities, and resilience, remains insufficiently secured (Edler, Fagerberg, 2017; Foray et al., 2011). For policy and practice, this implies three critical needs: deepening the inclusiveness of EDP processes, particularly through SME and end-user engagement; enhancing adoption capacity through targeted managerial and financial instruments that bridge the TRL-IRL gap; and embedding resilience via integrative tools such as digital supply chain platforms and coordinated adaptation strategies. Addressing these bottlenecks is essential if the Silesian Voivodeship is to progress from an administratively consolidated innovation system to

a functionally resilient region capable of translating strategic priorities into sustained technological deployment in line with the EU's agenda for critical technologies and open strategic autonomy.

5. Discussion and Conclusions

The influence of regional governance mechanisms on the deployment of critical technologies was examined, with a particular focus on the Silesian Voivodeship as a case study. A mixed-methods approach was used, operationalising three diagnostic indices: the Governance Coordination Index (GCI), the Adoption Readiness Index (ARI), and the Value Chain Resilience Index (VCRI). These indices collectively provide a robust framework for assessing how institutional coordination, organisational readiness, and systemic resilience interact to determine the extent to which Entrepreneurial Discovery Processes (EDP) lead to concrete technological deployments within firms and across value chains.

The findings demonstrate that substantial progress has been achieved in establishing governance frameworks, enhancing transparency in resource distribution, and developing coordination platforms within the region. However, challenges remain. The inclusiveness of EDP cycles is still limited, a clear gap between technology readiness levels (TRL) and implementation readiness levels (IRL) is apparent in many projects, and resilience differs greatly across sectors. Notably, the real-world impacts of these governance arrangements intersect with broader phenomena seen in other industrial and post-industrial economies, where the deployment of advanced (particularly digital and AI-based) technologies introduces both new opportunities and complex societal challenges.

Recent international analyses highlight that the acceleration of generative artificial intelligence and automation is transforming skill requirements and reshaping regional employment landscapes far beyond traditional industrial settings. The OECD (2024) reports that generative AI increasingly distinguishes between urban and rural labour markets, potentially exacerbating digital divides and existing spatial inequalities – a trend also visible in Silesia, where reskilling needs are most acute among workers in declining industries and less connected localities. At the same time, the World Economic Forum (2025) identifies that nearly 60% of workers globally will need some form of upskilling by 2030, and that regions with accessible, well-coordinated retraining programmes are best positioned to navigate these transitions. Silesia's regional policy focus on reskilling, digital infrastructure, and support for SMEs thus aligns with emerging best practices but must continuously adapt to the shifting nature of technological change (OECD, 2024; World Economic Forum, 2025).

Three main theoretical contributions are identified. Firstly, the study demonstrates how semi-quantitative diagnostic indices can convert abstract governance concepts into measurable and comparable formats across various regional contexts — integrating multi-level governance literature (Markard, Truffer, 2008; Könnölä et al., 2021) with empirical coding. Secondly, the analysis broadens the discussion on absorptive capacity (Cohen, Levinthal, 1990; Zahra, George, 2002), suggesting that institutional consolidation primarily benefits larger, networked firms, while SMEs and peripheral communities often face cumulative disadvantages in reskilling and adaptation. Thirdly, sectoral fragmentation in resilience is evident: highly internationalised clusters display strong adaptive capacities, whereas energy-intensive and less diversified sectors remain more vulnerable, confirming trends emphasised by recent comparative studies (Yin, 2022; Ivanov, Dolgui, 2020).

This discussion also has practical implications. Regional policymakers should remember, based on both local evidence and international experience, that governance needs to go beyond merely following procedures. It should actively promote inclusiveness, flexibility, and cross-sector collaboration. This involves providing targeted support to SMEs, improving access to reskilling and training- especially outside cluster hubs- and establishing feedback systems to detect and address new inequalities. Implementing pilot facilities, demo testbeds, and cluster services is crucial for closing TRL-IRL gaps and achieving fairer labour market results. Lastly, building resilience, especially for vulnerable groups and peripheral regions, requires ongoing investment in digital and social infrastructure and forming partnerships that guarantee no worker or area is left behind during the technological transition (OECD, 2024; World Economic Forum, 2025).

The study's limitations are acknowledged, especially its focus on a single case with an industrial legacy and institutional context that may not apply to other areas, such as urban knowledge economies. The semi-quantitative indices and reliance on expert judgment introduce some subjectivity, though this is reduced through data triangulation. Additionally, the timeframe (2019-2024) restricts the ability to evaluate long-term policy effects. These constraints suggest avenues for future research, including comparative analyses to see if governance-implementation gaps are common across industrial transition regions or unique to Central and Eastern Europe. Long-term studies could also explore how adoption readiness and resilience evolve over time amid repeated shocks like energy crises or digital disruptions. Adding firm-level quantitative data on innovation could strengthen the semi-qualitative indices, allowing for more accurate benchmarking across different regions.

Overall, the Silesian case demonstrates both the potential and the limitations of regional innovation systems. While institutional maturity and transparency are essential foundations, they alone are not sufficient to guarantee successful deployment. To connect entrepreneurial discovery with implementation, governance must be inclusive, support systemic adoption, and enhance resilience across value chains. Placing these findings within the broader European discussion on critical technologies and strategic autonomy (European Commission, 2023), this study offers a framework that is both analytically sound and practically useful.

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Appendix

Coding Framework with Illustrative Quotes

Main Category	Subcategory / Code	Description	Illustrative Quote
Governance Coordination	Formalization of roles	Clarity of responsibilities in RIS3 and EDP governance	"Responsibilities are well described in the RIS3 strategy, but in practice overlaps still occur between regional agencies" (Regional authority)
	EDP inclusiveness	Degree of SME and end-user participation	"Most meetings involve universities and clusters – SMEs are usually informed, not actively engaged" (Cluster coordinator)
	Transparency	Visibility of project selection criteria	"We know in advance what evaluation criteria will be applied, which makes the process predictable" (Entrepreneur)
	Roadmapping	Existence and operationalization of technology roadmaps	"Energy sector roadmaps exist, but they lack milestones connected to funding" (Researcher)
	Coordination platforms	Multi-level collaboration mechanisms	"The Innovation Council works well as a forum, but decisions often remain at the discussion stage" (Regional policymaker)
Adoption Readiness	TRL-IRL convergence	Gap between technological maturity and implementation capacity	"Projects often reach TRL 6 or 7, but companies don't have resources to commercialize them" (SME manager)
	Firm-level capabilities	Organizational and financial readiness	"We lack skilled staff to operate new digital systems, even if the technology is available. (Entrepreneur)
	Cluster support	Availability of specialized services	"The medical technology accelerator in Zabrze really helps with pilots and mentoring" (Cluster coordinator)
	Deployment environment	Procurement pilots, testbeds, innovation hubs	"There are too few testbeds to validate prototypes under real conditions" (Program manager)
Value Chain Resilience	Supplier diversification	Extent of alternative sourcing	"Larger firms diversify suppliers abroad, SMEs usually rely on one domestic provider" (Business association)
	Recovery time	Ability to restore operations after disruptions	"The automotive shortage showed it takes months to stabilize production chains" (Entrepreneur)
	Transparency and data	Use of digital platforms for supply chain visibility	"Big players use ERP systems, but smaller suppliers still communicate via phone and email" (Cluster coordinator)
	Crisis adaptation	Redundancy and reconfiguration capacities	"We experimented with circular economy pilots, but without systemic support they remain isolated" (Innovation intermediary)