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THE PHILOSOPHY OF INCERTO AND POPPERIAN–CONTRARIAN METHODOLOGY OF DECISION-MAKING IN THE INNOVATION ECONOMY

Summary. The article develops a methodological framework for economic decision-making in the innovation economy under conditions of radical uncertainty, technological discontinuity, and information asymmetry. It substantiates the relevance of integrating the philosophy of Incerto with Popperian and contrarian approaches as an alternative to classical optimization models based on equilibrium, predictability, and known probabilities. The philosophy of Incerto, grounded in the recognition of fundamental epistemological limits and "unknown unknowns," shifts the focus of decision-making from maximizing expected returns to minimizing catastrophic losses and enhancing system resilience. Within this framework, the Popperian approach operationalizes decision-making by treating economic and innovation strategies as falsifiable hypotheses subject to continuous testing, revision, and learning through error. This logic enables adaptive governance, reduces dogmatic planning, and supports experimentation through real options, pilot projects, and iterative policy design. Complementarily, the contrarian approach addresses behavioral distortions and herd effects by encouraging decisions that deviate from dominant expectations when market consensus is systematically biased. The article demonstrates that the combined Popperian–contrarian methodology allows for the formalization of innovation-related decisions while accounting for uncertainty, nonlinear technological dynamics, and asymmetric payoffs. Special attention is given to its application within the National Innovation System (NIS), where innovation policy is interpreted as a set of hypotheses continuously tested in practice rather than a fixed strategic blueprint. The proposed methodological synthesis enhances the adaptability of innovation policy, mitigates inefficient investment risks, and contributes to the formation of long-term competitive advantages in the context of the innovation and emerging quantum economy.

Keywords: innovation economy, uncertainty, philosophy of Incerto, Popperian approach, contrarian strategy, decision-making, National Innovation System, quantum economy.

Introduction and problem statement. The contemporary innovation economy is characterized by high levels of technological uncertainty, shortened innovation cycles, asymmetric information, and nonlinear effects of technological change. Under such conditions, classical models of economic rationality and optimization – based on stable probabilities, equilibrium assumptions, and forecast-centered planning – prove increasingly inadequate. The problem lies in the lack of a coherent methodological framework that would allow economic agents and policymakers to make robust decisions under radical uncertainty while avoiding catastrophic losses and systemic errors. This necessitates the development of an alternative decision-making methodology capable of combining epistemological realism, adaptive learning, and resistance to behavioral distortions.

Analysis of recent research and publications. Recent economic research increasingly focuses on uncertainty, behavioral factors, and adaptive decision-making in innovation-driven environments. The philosophy of Incerto, developed primarily in the works of N. Taleb, has introduced the concept of antifragility and emphasized the limitations of predictive models in complex systems. Parallel to this, Popper's critical rationalism has been actively applied in management and policy studies as a foundation for experimental governance, hypothesis testing, and learning through error.

Behavioral economics and financial theory have further contributed to the development of contrarian approaches, highlighting systematic cognitive biases, herd behavior, and market inefficiencies. However, existing studies tend to analyze these approaches separately. The integration of Incerto, Popperian, and contrarian methodologies within a unified framework for innovation economics and national innovation systems remains insufficiently explored, particularly in the context of emerging quantum technologies and Industry 4.0.

The purpose of the article is to substantiate and develop an integrated methodological framework for economic decision-making in the innovation economy under conditions of radical uncertainty by combining the philosophy of Incerto with Popperian and contrarian approaches, and to demonstrate its applicability for analyzing innovation dynamics, investment behavior, and the adaptive development of national innovation systems in the context of technological disruptions and the emerging quantum economy.

Results of the study. Today, research on the innovation economy is conducted under conditions of high technological and market uncertainty, limited historical information, and significant knowledge asymmetry among participants in the innovation process. Under such conditions, classical optimization approaches oriented toward static equilibrium prove to be insufficient. In this regard, the article applies a combination of the philosophy of Incerto, Popperian, and contrarian approaches to economic decision-making as a methodological framework for analyzing innovation dynamics. It is demonstrated that the proposed Popperian–contrarian methodology makes it possible to formalize decision-making processes in the innovation economy while accounting for uncertainty, behavioral distortions, and technological dynamics. This is particularly important for enhancing the adaptability of national innovation policy, reducing the risks of inefficient investments, and forming long-term competitive advantages.

The philosophical concept of uncertainty known as Incerto has been comprehensively developed by N. Taleb in a series of works [1; 2; 3; 4] devoted to forecasting methodology, strategic management, and business decision-making practice. At present, it represents a modern epistemological paradigm based on the recognition of ***fundamental ontological uncertainty*** of future states in complex, nonlinear, and open economic systems. It constitutes an alternative to the classical "rational" decision-making model, which relies on assumptions of stable probabilities, predictability, and optimization. The key principles of the philosophy of Incerto include the following [4, pp. 33–87].

First, there is the fundamental uncertainty of economic knowledge, which has ***limited predictive capacity*** because: a) future events do not always follow known statistical regularities; b) "unknown unknowns" exist; and c) historical data do not guarantee the reproducibility of future outcomes. In decision-making systems, this implies abandoning the illusion of full control and precise economic or strategic forecasting.

Second, priority is given to negative knowledge (knowledge of what not to do), according to which knowledge grows not through confirmation but through identifying the ***boundaries of admissibility.*** In economic terms, this implies identifying strategies with catastrophic consequences, minimizing systemic risks, and avoiding decisions with asymmetrically negative outcomes. Decisions are evaluated not by expected gains but by potential harm under worst-case scenarios.

Third, information is unevenly and asymmetrically distributed, as it is ***fragmented***, localized, and context-dependent. This necessitates abandoning centralized "classical" management models in favor of decentralized and adaptive decision-making systems.

Fourth, truth and business decisions are contextual, as truth in complex economic systems is ***conditional and temporary.*** Decisions that are effective under certain conditions may become ineffective or dangerous under others. Consequently, optimal solutions are not universal, strategies must be dynamic, and the capacity for rapid adjustment is more important than initial optimality.

In general, within economic and strategic management practice, the epistemology of Incerto as a foundation for decision-making systems is transformed into the following cycle: "forecasting → optimization → antifragility → planning → experimentation → symmetric/asymmetric strategies" [5]. Its main characteristics are: 1) the objective of decisions is not maximizing expected value but increasing resilience to shocks and extreme uncertainty; 2) decisions are designed so that systems not only withstand uncertainty but benefit from volatility; 3) portfolio and iterative approaches are applied instead of rigid long-term plans (real options, pilot projects, A/B/n testing); and 4) preference is given to decisions with limited downside risk and potentially unlimited upside. In this context, comparing classical rationality with the philosophy of Incerto is particularly relevant (Table 1).

The epistemological foundations of Incerto are based on the recognition of fundamental informational limitations, an orientation toward minimizing catastrophic risks, and the construction of adaptive, decentralized systems of economic and strategic decision-making under uncertainty. These foundations are particularly relevant in the innovation economy characterized by a high level of technological uncertainty within VUCA (Volatility, Uncertainty, Complexity, Ambiguity) and BANI environments, as well as under the accelerated development of quantum technologies and artificial intelligence, which shape the modern Q-economy. In effect, a ***meta-rational decision-making model*** is emerging – one that both acknowledges the informational limits of knowledge and transforms uncertainty from a threat into a source of strategic advantage.

Indeed, within the innovation economy, classical rationality demonstrates limited effectiveness, as technological cycles are short and innovations produce exponential and uneven effects. In contrast,

Table 1

Comparison of Classical Rationality and the Philosophy of Incerto

Comparison criterion	Classical economic rationality	Philosophy of Incerto (innovation and quantum economy)
Epistemological basis	Positivism, determinism, completeness of knowledge	Radical uncertainty, limited knowledge, anti-determinism
Type of uncertainty	Risk with known probabilities	Uncertainty ("unknown unknowns")
Attitude to forecasting	Forecasting as the main tool	Forecasting is secondary; priority of experimentation
Goal of decision-making	Maximization of expected utility	Minimization of catastrophic losses
Model of agents' behavior	Fully rational, homogeneous	Boundedly rational, heterogeneous, adaptive
Logic of optimization	Static optimization	Dynamic adaptation and learning
Time horizon	Stable, predictable	Unstable, with constant "shifts"
Attitude to errors	Errors as deviations from the optimum	Errors as a source of learning (trial-and-error)
Institutional logic	Centralized planning	Decentralized, experimental ecosystems
Evaluation of innovations	Through NPV, IRR, expected returns	Through real options, gain/loss asymmetry
Attitude to radical innovations	Considered excessively risky	Treated as strategic options
Role of volatility	Undesirable, subject to smoothing	Beneficial as a source of antifragility
Thinking about the future	Linear extrapolation of the past	Nonlinear scenarios and persistent "shifts"

Source: compiled by the authors based on [3; 6]

the philosophy of Incerto emphasizes the preservation of strategic flexibility. In the quantum economy, the principles of Incerto acquire additional conceptual grounding through economic analogies: "superposition" as the parallel existence of multiple strategies; "quantum uncertainty" as the impossibility of precisely forecasting economic outcomes; and "entanglement" as deep interdependence among agents and markets [7]. Thus, in the context of innovation and quantum economies, the philosophy of Incerto forms a new type of economic rationality based not on predicting the future, but on the ability of economic systems to adapt to fundamentally uncertain and nonlinear changes.

In contemporary management systems, the inherent unpredictability of the future, the impossibility of accurately assessing probabilities in complex economic systems, and the asymmetry of decision outcomes – core propositions of the philosophy of Incerto – necessitate abandoning ***forecast-centric logic*** and transitioning toward governance through the minimization of catastrophic risks. While Incerto provides the epistemological foundation for modern decision-making under radical uncertainty, Popperian and contrarian approaches perform an operational and methodological function [2]. Their combination enables a shift from classical optimization models to adaptive, experimental, and antifragile decision-making systems.

Within the Incerto framework, economic or strategic decisions are not validated through extrapolation of past experience, but are treated as temporary ***hypotheses*** tested in real environments, equipped with clear stopping or adjustment criteria, and not claiming final optimality. The Popperian approach aligns directly with the philosophy of Incerto by providing a ***mechanism for disciplined experimentation*** under uncertainty and serving as a verification tool for economic and strategic decisions. The principle of "falsification instead of confirmation" corresponds to the "impossibility of full knowledge of the future"; "growth of knowledge through errors" corresponds to "learning through limited experiments"; and the "temporality of theories" corresponds to the principle of "contextuality of strategic decisions."

Decision-making analysis based on the Popperian approach, grounded in the concept of critical rationalism developed by K. Popper – particularly the principle of falsification – is associated with a core idea: decisions are not "final truths" but are continuously tested for potential error. This implies the following principles: a) the hypothetical nature of decisions, whereby each decision is treated as a temporary hypothesis rather than a final truth; b) falsification instead of confirmation, emphasizing the active search for conditions under which a decision may prove false; c) learning through errors, where mistakes are viewed as sources of knowledge rather than failures; and d) openness to revision, meaning that decisions are adjusted when new information emerges.

These principles are especially important when applied in strategic management, risk management, venture investment, and the implementation of national monetary and regulatory policies. It is well known that a company's investment strategy is considered acceptable until predefined risk or return thresholds are violated, after which it is revised. Accordingly, attention is focused on addressing the following questions: "How is a decision-hypothesis formulated?" "How is a decision made with built-in revision triggers?" "How is a decision cancelled or modified under critical business conditions?"

Thus, the Popperian approach ensures the adaptability of the research model and reduces the risk of dogmatic interpretation of analytical results by framing managerial and economic decisions as hypotheses and defining critical conditions under which these decisions are deemed ineffective. Equally important

is the mechanism for revising and adjusting decisions when new data emerge, as well as interpreting errors as sources of economic knowledge growth [8, pp. 96–117]. This approach is particularly relevant for economic research conducted under conditions of uncertainty, incomplete information, and dynamic changes in market environments.

Consequently, the Popperian approach provides a disciplined logic of learning through error, which is especially important in innovation and quantum economies, where most technological decisions cannot be fully verified prior to practical implementation. The combination of the philosophy of Incerto with Popperian logic minimizes systemic errors, reduces the scale of potential losses, and simultaneously preserves the capacity for strategic experimentation.

The contrarian decision-making system, understood as an approach in which decisions are made against dominant expectations, trends, or collective behavior – especially when mass opinion is erroneous under conditions of uncertainty and information "noise" – is based on two fundamental premises. First, it involves analyzing behavioral distortions, including herd behavior, excessive optimism, or panic. Second, it entails assessing fundamental value, whereby decisions are based not on trends but on intrinsic characteristics of the object. Originating from behavioral economics and financial market theory, the contrarian approach involves the deliberate adoption of decisions contrary to dominant market trends or mass expectations, provided there are well-founded reasons to believe that these expectations are systematically distorted.

The contrarian approach is an effective applied tool for strategic decision-making in environments where: a) collective expectations dominate and create an illusion of predictability, leading market participants and innovation ecosystems to overestimate future gains; b) information asymmetries and herd thinking prevail; and c) classical rationality fails due to incorrect probability assessments [9, pp. 31–44]. From the perspective of Incerto, market and innovation ecosystems systematically overestimate the predictability of the future, resulting in cycles of excessive optimism or panic. Contrarian strategies exploit these disproportions by forming asymmetric decisions with limited potential losses and significant possible gains. Moreover, the contrarian approach complements Popperian logic by orienting research toward critical analysis of dominant assumptions and scenarios rather than consensus-building. In innovation economics and quantum technologies, this creates conditions for investing in undervalued or prematurely rejected technological directions, forming strategic options, and developing antifragile business models.

Examples of its application include crisis management, corporate competitive strategies, and public economic policy. These approaches are not mutually exclusive: the Popperian approach answers the question "When should a decision be abandoned?", while the contrarian approach answers "When should one act against the majority?" The contrarian approach is based on the assumption that economic agents possess cognitive limitations and behavioral biases, causing market prices, strategic decisions, or policy orientations to deviate significantly from fundamentally justified values. Its application enhances analytical depth and reduces the influence of conjunctural factors by identifying overheating phases, analyzing alternative development scenarios, and substantiating medium- and long-term strategic decisions.

In complex economic systems, effective strategies are often formed contrarianly and implemented Popperianly, with continuous testing for error. Table 2 presents a comparative characterization of these approaches.

Thus, decision-making based on the Popperian approach treats managerial and economic decisions as falsifiable hypotheses, whereas the contrarian decision-making system is grounded in critical attitudes toward dominant expectations and resistance to collective cognitive distortions. Their combination as complementary elements forms an adaptive ***methodological model of economic choice*** that: a) operates effectively under high uncertainty, technological shifts, and structural economic changes; b) generates non-standard economic hypotheses and systematically tests their robustness; and c) minimizes the risk of long-term decision-making errors.

At the same time, the application of the Popperian–contrarian methodology enables the formalization of decision-making processes in the innovation economy while accounting for uncertainty, behavioral distortions, and technological dynamics. Its use enhances the adaptability of innovation policy, reduces the risks of inefficient investment, and supports the formation of long-term competitive advantages. In simple terms, Incerto answers the question "What can we know?", the Popperian approach addresses "How should decision effectiveness be tested?", and the contrarian approach

Table 2

Comparative Characteristics of the Popperian and Contrarian Approaches

Criterion	Popperian approach	Contrarian approach
Philosophical basis	Critical rationalism	Behavioral economics
Attitude to truth	Temporary hypothesis	Skepticism toward collective opinion
Key mechanism	Falsification	Counter-trend action
Risk focus	Erroneous decisions	Mass errors
Time horizon	Adaptive	Predominantly longer-term

Source: compiled by the authors based on [10]

clarifies "When and why should one act against dominant expectations?"

Within the Popperian methodology, innovation decisions – such as investments in R&D, the launch of new technologies, and the formation of innovation strategies – are treated as hypotheses subject to continuous testing and potential falsification, with threshold values defined by the strategic objectives of innovation actors. From a practical perspective, it is necessary to define: (a) the minimum acceptable level of technological readiness (TRL); (b) the minimum expected market size or growth rate; and (c) the maximum acceptable level of financial or technological risk. Accordingly, the Popperian approach provides a flexible and adaptive logic for innovation management oriented toward learning through controlled errors.

The contrarian approach in the innovation economy is used to analyze situations in which mass expectations regarding new technologies deviate significantly from their fundamental economic potential. A contrarian action signal is generated when aggregated market expectations and fundamental economic assessments exceed an acceptable deviation threshold. Typical contrarian situations in the innovation economy include: 1) excessive investment in low-TRL technologies; 2) overestimation of short-term effects of radical innovations; and 3) neglect of technologies with delayed but systemic effects [11, pp. 112–121]. In this way, the contrarian approach enables both the identification of innovation disproportions and the justification of deferred or alternative innovation strategies, while minimizing losses from herd investor behavior.

The integration of Popperian and contrarian approaches forms an integrated system of innovation decision-making in which the contrarian approach determines the direction of hypothesis formation, while the Popperian approach ensures its dynamic testing and adjustment. Accordingly, the integrated algorithm identifies dominant innovation expectations, formulates technological development hypotheses, defines formalized falsification criteria, supports implementation with built-in revision triggers, and enables correction or abandonment of decisions based on test results.

A three-level ***"Incerto–Popper–Contrarian" model*** (the decision-making triangle) makes it possible to determine the boundaries and types of uncertainty and agent behavior during phases of market imbalance, ensure verification and adjustment of decisions in the process of strategy formation, and guide market actors in avoiding catastrophic errors. In the innovation economy, Incerto explains the impossibility of accurately forecasting breakthrough technologies; the Popperian approach is implemented through MVPs, pilot projects, and real options; and the contrarian approach enables investment in undervalued technologies. In the quantum economy, Incerto correlates with the principle of quantum uncertainty, while Popperian and contrarian approaches correlate with iterative testing of quantum algorithms and asymmetric bets on radical technologies [12, pp. 98–108].

Regarding the alignment of the Popperian–contrarian approach with models of the ***national innovation system (NIS)***, it should be noted that NIS is generally understood as a set of interconnected institutions that generate, diffuse, and commercialize knowledge and technologies within a national economy. Classical NIS models (linear, interactive, triple helix, mission-oriented) assume gradual knowledge accumulation; however, under conditions of radical technological disruption (quantum technologies, Industry 4.0), these models require methodological supplementation.

In this context, the Popperian–contrarian approach functions as a ***meta-methodology*** that ensures dynamic adaptation of NIS to technological uncertainty. The state formulates falsification criteria for innovation policy; business tests commercialization hypotheses; science generates alternative (contrarian) technological trajectories; and financial institutions select innovations through portfolio experimentation. Thus, NIS innovation policy is interpreted as a system of hypotheses continuously tested in practice rather than a fixed, once-and-for-all strategy.

Within the Popperian framework, NIS development in high-tech sectors, quantum technologies, and Industry 4.0 is based on the principle of ***managed experimentation*** under a defined national innovation strategy. Policy choices are treated as hypotheses regarding the effectiveness of supporting specific technological fields (quantum computing, quantum cryptography, AIoT), their socio-economic returns, and the pace of technological progress. This approach helps avoid institutional inertia and reduces losses from supporting technologically unviable directions.

The contrarian approach within NIS aims to ***counteract innovation isomorphism***, whereby states replicate "fashionable" technological priorities without considering their own economic structures and technological competencies. At the NIS level, the contrarian criterion implies that global technological trends and national competencies must exceed a critical incompatibility threshold; otherwise, it is advisable to move away from global technology races and develop niche specializations.

Quantum technologies exemplify a domain characterized by immature market statistics, dominant strategic uncertainty, and high risks of technological overinvestment. Accordingly, from a Popperian perspective, quantum algorithms are treated as experimental hypotheses, while from a contrarian perspective they are viewed as undervalued assets when priority is given to infrastructure readiness rather than computational power alone. The emerging Q-economy is marked by deep convergence of digital, physical, and cognitive technologies. The Popperian–contrarian methodology helps avoid technological fragmentation and governance failures related to digitalization, innovation integration, and resilience to systemic risks of digital transformation.

Thus, the alignment of approaches forms an ***adaptive next-generation NIS model*** in which the state acts as the architect of an experimental space, the market serves

as a selection mechanism, and science becomes a source of contrarian innovation. This enables the formation of a quantum–industrial innovation ecosystem capable of simultaneously supporting technological breakthroughs and systemic resilience.

In conclusion, the integration of the philosophy of Incerto, the Popperian approach to hypothesis formation and testing, and contrarian decision-making logic provides, first, a methodological foundation for analyzing contemporary innovation processes, quantum technologies, and new business models in a post-VUCA environment. Second, it creates a coherent system of economic decision-making under conditions of high uncertainty, technological shifts, and nonlinear innovation dynamics. In this context, economic and business decisions cannot rely solely on expected values or averages, but must account for the risk of catastrophic losses and the potential for disproportionate gains. This necessitates abandoning deterministic strategic planning in favor of flexible, experimental, and option-based development models capable of functioning under rapid technological change and structural uncertainty.

The application of the Incerto philosophy, along with Popperian and contrarian approaches, in research methodology makes it possible to combine critical rigor, adaptability, and strategic depth in economic analysis. Popperian logic ensures continuous updating and revision of decisions, while the contrarian approach facilitates moving beyond established economic paradigms and dominant mass expectations. Whereas the contrarian approach determines the direction of decision formation in situations dominated by collective expectations, the Popperian approach provides the mechanism for their subsequent testing and adjustment. Taken together, this creates a robust methodological foundation for the study of complex economic processes. The integration of the Popperian–contrarian approach with models of the NIS provides a methodological framework for analyzing the development of the innovation economy, quantum technologies, and Industry 4.0. Such an approach makes it possible to account for uncertainty, information asymmetry, and behavioral effects, thereby shaping a flexible and adaptive innovation policy under conditions of evolving technological trends.

Conclusions. The article concludes that the integration of the philosophy of Incerto with Popperian and contrarian approaches forms a robust methodological basis for economic decision-making in the innovation and quantum economy. This synthesis enables a shift from deterministic planning toward adaptive, experimental, and option-based strategies. The Popperian approach ensures continuous testing and revision of decisions, while the contrarian approach counteracts collective cognitive distortions and identifies asymmetric opportunities. Applied within the NIS, this methodology enhances policy adaptability, reduces the risk of inefficient investments, and supports sustainable long-term competitiveness under conditions of radical uncertainty.

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ФІЛОСОФІЯ INCERTO І ПОППЕРІАНСЬКО-КОНТРАРІАНСЬКА МЕТОДОЛОГІЯ ПРИЙНЯТТЯ РІШЕНЬ В ІННОВАЦІЙНІЙ ЕКОНОМІЦІ

Анотація. У статті розроблено методологічні засади прийняття економічних рішень в інноваційній економіці за умов радикальної невизначеності, технологічних зсувів та асиметрії інформації. Обґрунтовано обмеженість класичних моделей економічної раціональності, орієнтованих на рівновагу, оптимізацію та прогнозування, і запропоновано інтеграцію філософії Incerto з попперівським та контрарним підходами як альтернативну методологічну основу аналізу інноваційних процесів. Філософія Incerto інтерпретується як епістемологічна парадигма, що визнає принципову обмеженість знань про майбутнє та зміщує фокус прийняття рішень із максимізації очікуваних вигод на мінімізацію катастрофічних втрат і підвищення стійкості економічних систем. Попперівський підхід забезпечує операціоналізацію цієї логіки шляхом трактування управлінських та інноваційних рішень як фальсифікованих гіпотез, що підлягають постійному тестуванню, коригуванню та навчанню через помилки. Контрарний підхід доповнює методологію,

дозволяючи протидіяти масовим когнітивним викривленням і формувати асиметричні стратегічні рішення. Показано, що поєднання попперівського та контрарного підходів створює адаптивну систему прийняття рішень в інноваційній та квантовій економіці, а також у межах національної інноваційної системи. Запропонована методологія сприяє підвищенню ефективності інноваційної політики, зменшенню інвестиційних ризиків та формуванню довгострокових конкурентних переваг в умовах технологічної невизначеності.

Ключові слова: інноваційна економіка, невизначеність, філософія Інцерто, попперівський підхід, контр-стратегія, прийняття рішень, Національна інноваційна система, квантова економіка.

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