SPHERITY RESEARCH | LONG ACADEMIC PAPER

Europe's Fundamental AI Opportunity

Trusted execution capital, industrial renewal and the economics of transformation speed

European Union focus with comparative international evidence

Bo Harald
Why-Advisory Oy

Carsten Stöcker
Spherity GmbH

Prepared: September 2026
Evidence cut-off: 30 August 2026

Except where otherwise noted, this work is licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). © 2026 Carsten Stöcker and Bo Harald.

Core proposition. Europe's strongest near-term AI opportunity is to build the world's most capable interoperable execution environment for AI acting across organisations, industries, public authorities and physical systems. This environment converts AI Governance, trustworthy system properties and machine-verifiable operational controls into trusted execution capital. Policy direction, implementation speed, complementary investment, corporate resource reallocation and open capability coalitions determine how quickly that capital raises authorised process coverage, productivity and resilience. Reusable authority, verifiable evidence, shared semantics, Trust Algorithms and runtime controls allow firms, public authorities and citizens to authorise more consequential digital and physical actions while containing systemic risk.

Suggested citation. Harald, B. and Stöcker, C. (2026). *Europe's Fundamental AI Opportunity: Trusted Execution Capital, Industrial Renewal and the Economics of Transformation Speed.* Spherity Research, co-author review draft.

Abstract

Europe's industrial core faces a coupled productivity, demographic, fiscal and security challenge. Artificial intelligence offers a material source of task productivity, process redesign, industrial automation and scientific acceleration. This paper's central proposition is that Europe's strongest near-term AI opportunity lies in building the world's most capable interoperable execution environment for AI acting across organisations, industries, public authorities and physical systems. Foundation models increasingly diffuse across borders. Economic value depends on implementation, complementary intangible investment, resource reallocation, institutional speed and the share of economically or physically consequential actions that organisations can authorise safely. Evidence ranges from a conservative macroeconomic estimate of roughly 0.06 percentage points of annual total-factor-productivity growth over a decade to central OECD scenarios of 0.5 to 1.0 percentage point of annual labour-productivity growth in major advanced economies. Firm-level and experimental studies document stronger

gains in bounded settings, while robotics meta-evidence advises caution about extrapolation. This variation motivates a scenario approach.

Bill Gates' recent essay frames AI as a simultaneous source of broad economic and social value and of structural risks to employment, community stability, security, equality and public trust [1]. This dual effect requires systemic and holistic leadership across government, industry and civil society, supported by international coordination. AI Governance, Trustworthy AI and Trusted AI form complementary parts of this response. AI Governance allocates legitimate purposes, duties, oversight and remedies. Trustworthy AI defines the socio-technical qualities a system should achieve. Trusted AI provides machine-verifiable claims and enforcement mechanisms for a specified actor, action, context and time; trusted execution is the resulting decision and action under those controls. Together these layers can reduce avoidable harm, support public confidence and widen authorised process coverage. Labour, education, fiscal, competition and social policy remain essential to the wider transition. The paper develops the Trusted Execution Transformation and Diffusion Model, TETDM. The model separates stakeholder deployment acceptance from authorised process depth, and adoption readiness from post-adoption effectiveness. It treats trusted execution capital as reusable authority, evidence, semantics, policy, assurance and runtime control that reduce verification cost, expected loss and the option value of waiting. Three scenarios are calibrated for 2026 to 2040. Median sensitivity runs produce a 2040 real-GDP uplift below one per cent in fragmented drift, around four per cent in coordinated acceleration and around ten per cent in trusted industrial leadership. Final-year AI contributions to annual growth are around 0.1, 0.5 and 1.0 percentage points. The results illustrate coherent transformation regimes; they carry no forecast status and identify no isolated causal coefficient for trust infrastructure.

The institutional contribution is a European federated transformation architecture. Capability anchors assemble the strongest complementary teams around measurable missions, deployment owners and procurement pathways. Open interfaces, transparent admission, time-limited mandates and independent assurance convert concentration of capability into contestable diffusion. Public bodies act as authoritative credential issuers, high-frequency verifiers, procurement customers, cross-border process owners and creators of dependable demand. The architecture aims to spread knowledge, reusable trust services and implementation routines from frontier firms and regions into the Mittelstand, smaller enterprises, public bodies and adjacent business domains. The final sections present a policy and leadership agenda centred on time-to-capability, core-process automation, Industrial and Physical AI, agentic commerce, public-sector demand and a common trust infrastructure.

Keywords. macroeconomics of AI; AI Governance; Trustworthy AI; Trusted AI; trusted execution; Trust Algorithms; European Business Wallets; Industrial AI; Physical AI; agentic commerce; productivity; diffusion; absorptive capacity; public-private transformation; Europe; Deutschland AG 2.0.

Contents

Research questions **6**

1 Europe's execution opportunity and strategic productivity window **6**

1.1 A coupled economic problem 6

1.2 Productivity is an implementation outcome 7

1.3 Direction, speed, trust and public legitimacy as economic variables 7

2 Scope, method and evidence boundary **9**

2.1 Analytical scope 9

2.2 Method 9

2.3 Evidence classification and legal status 10

3 Comparative position: a portfolio with a speed gap **10**

3.1 Global strategic position 10

3.2 The adoption gap inside Europe 11

4 Where AI creates economic value **13**

4.1 Business-process automation and the administrative economy 13

4.2 B2C agentic commerce 14

4.3 B2B agentic commerce 14

4.4 Industrial AI 14

4.5 Physical AI and autonomous science 15

4.6 B2G and G2G applications 16

5 Trusted execution capital and operational architecture **18**

5.1 From governance and trustworthy properties to execution capital 18

5.2 The authority-evidence-semantics-runtime architecture 18

5.3 Trust Algorithms and threshold-based security 19

5.4 Defensive infrastructure against fraud, misinformation and cyber conflict 19

5.5 Verifiably governed execution as a European proposition 20

6 The Trusted Execution Transformation and Diffusion Model **20**

6.1 Purpose and theoretical foundations 20

6.2 Adoption and diffusion 21

6.3 Corporate risk-taking and resource reassignment 21

6.4 Productivity, spillovers and fiscal capacity 22

6.5 Capability anchors and diffusion 22

6.6 Calibration . . . 23

7 Three scenarios for Europe's industrial core 24

7.1 Scenario A: fragmented drift . . . 24

7.2 Scenario B: coordinated acceleration . . . 24

7.3 Scenario C: trusted industrial leadership . . . 25

8 Model results 25

8.1 GDP paths . . . 25

8.2 Adoption, growth and fiscal capacity . . . 25

8.3 Sensitivity and permitted interpretation . . . 25

9 Corporate leadership, risk-taking and resource reassignment 28

9.1 A board-level transformation portfolio . . . 28

9.2 Risk appetite and bounded autonomy . . . 28

9.3 Partnership strategy . . . 28

9.4 Transformation velocity . . . 29

10 A European public-private transformation architecture 29

10.1 European direction and mission selection . . . 29

10.2 Capability anchors: strongest teams first . . . 30

10.3 Spillover and dissemination architecture . . . 30

10.4 Governance and safeguards . . . 31

11 Policy direction and implementation agenda 31

11.1 Six policy priorities . . . 31

11.2 Transformation scorecard . . . 32

11.3 Sequencing . . . 33

12 Limitations and research agenda 33

12.1 Evidence limitations . . . 33

12.2 Model limitations and research agenda . . . 34

13 Leadership and policy mandate 34

Declarations 35

13.1 Author contribution and responsibility . . . 35

13.2 Conflict of interest . . . 35

13.3 Funding . . . 35

13.4 Data, code and generative AI 35

A Model variables and interpretation **35**

B Model results table **36**

C Comparative scoring rubric **36**

Research questions

Table 1: Research questions and analytical responses.

ID	Research question	Analytical response
RQ1	Through which channels can AI affect productivity, income, fiscal capacity and Europe's industrial resilience?	A causal macroeconomic architecture and a scenario model linking adoption, complementarity, trust and diffusion.
RQ2	How do policy direction and implementation speed change corporate risk-taking, resource reallocation and transformation timing?	A risk-adjusted investment equation and a time-to-capability parameter that changes adoption and the value of waiting.
RQ3	How can Europe's strongest corporate, regional and research capabilities create wider spillovers?	Capability anchors, mission organisations, open interfaces, diffusion nodes and absorptive-capacity investment.
RQ4	Which trust capabilities allow AI agents and cyber-physical systems to act safely across organisational boundaries?	An authority-evidence-semantics-runtime architecture with Trust Algorithms for access, evidence fitness and action authorisation.
RQ5	Which transformation regime produces credible macroeconomic gains under the evidence range?	Three conditional scenarios with parameter sensitivity through 2040.

Source: authors' formulation.

1 Europe's execution opportunity and strategic productivity window

1.1 A coupled economic problem

Europe enters the agentic AI era with a valuable but time-sensitive asset combination: a large Single Market, globally significant manufacturing and engineering capabilities, strong public institutions, a deep standards tradition, leading research clusters and an established legal framework for digital identity, data protection, cybersecurity and AI governance. The same economy carries structural constraints. Productivity growth has weakened relative to the United States, investment needs have expanded, the working-age population is tightening and public budgets must finance ageing, defence, energy systems, climate adaptation and infrastructure renewal. These pressures interact. A smaller labour pool raises the economic value of automation; automation raises dependency on digital and cyber-physical systems; that dependency raises the value of trust, security and resilience.

The Draghi competitiveness report estimated additional annual investment needs of roughly EUR 750 to 800 billion by 2030, around five percentage points of EU GDP at the time of publication [2]. The figure aggregates energy, digitalisation, innovation and defence requirements and therefore serves as a measure of transformation scale rather than an AI budget. Eurostat

reported an EU old-age dependency ratio of 34.5 per cent at the beginning of 2025, with a rapid increase projected through 2050 [3]. The combination makes productivity a social-system variable. Durable gains in output per worker expand the income and contribution base from which pensions, health systems, care, security and public infrastructure can be financed.

This paper uses the phrase strategic productivity window to describe the period in which Europe can still shape the architecture through which AI is deployed across industry, services and government. Europe's opportunity is primarily an execution opportunity: to create an interoperable environment in which AI can perform accountable economic, administrative and physical work across organisational boundaries. Foundation models diffuse globally, while economic value remains embedded in local production systems, data, professional rules, machinery, distribution channels, worker knowledge and public processes. The causal chain is execution infrastructure, wider authorised process coverage, faster investment and diffusion, deeper process redesign, higher productivity and stronger fiscal and industrial capacity. Policy and corporate leadership therefore need to move within the technology cycle.

1.2 Productivity is an implementation outcome

General-purpose technologies generate productivity through complementary change. Bresnahan and Trajtenberg [4] emphasised the role of downstream co-invention. Brynjolfsson, Rock and Syverson [5] formalised a productivity J-curve in which intangible investments in skills, organisational redesign and new processes depress measured productivity before their benefits mature. AI follows this logic. Model access becomes cheaper, while deployment still requires clean data, redesigned workflows, evaluation, cybersecurity, integration, labour participation, new managerial routines and accountable decision rights.

The evidence range is wide because studies address different units and horizons. Acemoglu [6] estimates a cumulative total-factor-productivity effect below 0.66 per cent over ten years under task-based assumptions, equivalent to roughly 0.06 percentage points a year. The OECD's 2026 central scenarios place the annual labour-productivity contribution across the G7 at approximately 0.5 to 1.0 percentage point over the next decade, conditional on adoption and capability [7]. The ECB presents an electricity-like diffusion analogy of up to 1.3 percentage points and also cites a digital-boom analogue of around 0.8 percentage points [8]. These estimates support disciplined scenario calibration. They also establish a shared proposition: complementary investment and diffusion govern aggregate value.

Firm evidence sharpens the mechanism. Aldasoro et al. [9] analyse more than 12,000 European and US firms and report an approximately four per cent increase in the level of labour productivity associated with AI adoption using an instrumental-variable strategy. The gains operate largely through capital deepening and are strongest among medium-sized and large firms with software, data and training complements. Short-run employment remains broadly stable. The EIB's 2025 and 2026 investment work similarly associates AI adoption with firm productivity while documenting a European gap in the breadth of use across business functions. Diffusion into core processes therefore matters more than access to a general tool.

1.3 Direction, speed, trust and public legitimacy as economic variables

Policy direction coordinates expectations. Clear outcome missions, stable rules, credible procurement and infrastructure commitments increase the probability that complementary private investments arrive together. Implementation speed changes project economics through discounting, first-mover risk and the option value of waiting. A slow authorisation pathway can turn a technically valuable use case into a negative net-present-value project. A rapid pathway with

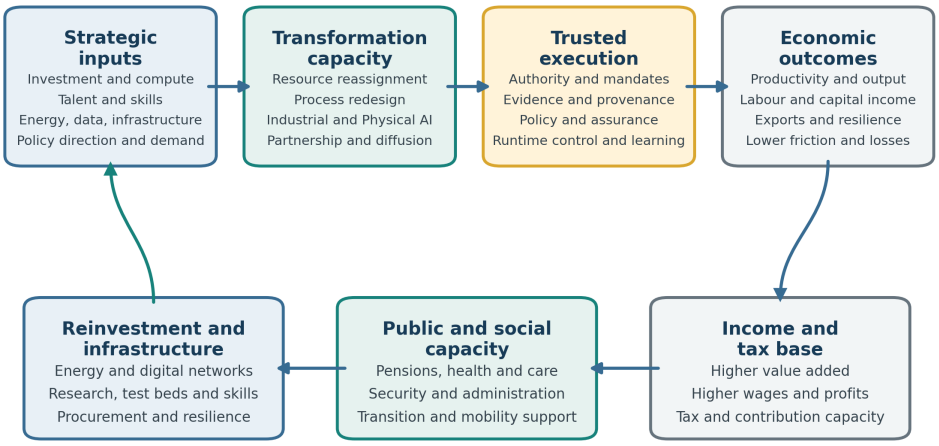

Figure 1: Macroeconomic levers, transformation mechanisms and public-capacity feedback.

Note: Authors' conceptual model. The fiscal channel uses capacity language because political allocation determines whether incremental revenue supports social systems, security, infrastructure, tax relief or debt reduction.

clear assurance gates lowers uncertainty while preserving safety and legal accountability.

Trust changes two separate margins. Stakeholder deployment acceptance affects whether boards, regulators, workers and counterparties support production use. Authorised process depth affects which actions a deployed system may perform. A firm may use an assistant to draft text with limited external consequence. The same firm requires stronger authority, evidence and control before an agent can submit a regulatory filing, release a payment, alter production parameters or negotiate across borders. Trusted execution capital can raise both margins through distinct mechanisms. It can also reduce expected incident loss, repeated verification and bilateral integration cost. The model keeps deployment acceptance and process depth separate to prevent one trust mechanism from carrying two meanings.

Gates [1] frames AI as a system transition in which opportunities and risks arrive together. Realised benefits, broad access and fair distribution can strengthen public trust and stakeholder acceptance. Visible displacement, concentrated gains, serious incidents and weak remedies can erode trust, increase resistance and delay implementation. Public legitimacy therefore enters the economic mechanism through stakeholder deployment acceptance, policy durability and the adoption ceiling. It remains conceptually distinct from authorised process depth.

Systemic and holistic thinking and execution mean coordinated outcomes and decision rights across industrial, labour, education, fiscal, security, health, competition and public-service policy. They require cross-ministry ownership, public-private implementation organisations, participation by workers, regions and affected communities, shared evidence and metrics, and feedback from realised benefits and harms into policy adjustment. European, national and international coordination should operate as one connected architecture rather than as separate programmes.

Public-sector participation can create the first dependable demand loop. Public bodies issue authoritative organisational, professional and regulatory claims, verify them in high-frequency processes, procure compliant services, own cross-border workflows and provide recurring demand. This combination addresses empty-wallet dynamics more directly than availability of wallet

software alone.

2 Scope, method and evidence boundary

2.1 Analytical scope

The unit of macroeconomic analysis is the EU economy. The term industrial core denotes EU manufacturing and infrastructure-intensive activities together with the business services, research, finance, software, skills and public systems required to operate them. Model results apply to the EU aggregate rather than to a selected group of countries. The comparative section includes the United States, China, India, Japan, South Korea, Türkiye, the United Arab Emirates, Saudi Arabia and Canada. The European country view covers Germany, France, Spain, Italy, Poland, the United Kingdom and the Nordic group. The time horizon runs from 2026 to 2040. Use cases cover business-process automation, B2C and B2B agentic commerce, Industrial AI, Physical AI and B2G or G2G processes.

The term Industrial AI refers to AI applied to industrial design, engineering, operations, maintenance, quality, energy and supply chains. Physical AI refers here to AI-enabled systems that perceive, reason and act in the physical world through robotics, machines, vehicles, laboratories or infrastructure. The concept includes embodied autonomy and agentic cyber-physical systems. It remains a working analytical term across a rapidly developing field.

AI Governance, Trustworthy AI and Trusted AI form cumulative layers. AI Governance allocates legitimate purposes, accountable actors, duties, oversight and remedies. Trustworthy AI describes the socio-technical qualities required across the lifecycle, including validity, reliability, safety, security, privacy, transparency, fairness and human oversight. Trusted AI is the narrower operational subdomain. It combines machine-verifiable identity, legal authority, provenance-bearing evidence, current status, enforceable policy, assurance state and runtime action records for a specified actor, action, context and time. Trusted execution is the outcome when those capabilities support justified reliance and effective enforcement at the moment of action [10].

The term Trusted AI therefore describes a capability layer rather than a blanket certificate for an AI model. The paper uses trusted execution when describing the operational outcome and trusted execution capital when describing the reusable stock of capabilities that makes this outcome scalable.

2.2 Method

The paper uses conceptual synthesis, secondary evidence review, institutional analysis, comparative scoring and scenario simulation. Macroeconomic studies establish an admissible range for productivity effects. Firm studies and task experiments identify mechanisms. Official EU, OECD, EIB, ECB, Eurostat, Stanford AI Index and International Federation of Robotics sources support adoption and comparative indicators. Peer-reviewed work on ecosystems, absorptive capacity, mission-oriented policy and network governance informs the institutional design. Current EU legal instruments and legislative proposals establish the trust-policy baseline. The three-layer terminology and the operational assurance chain align with the comparative capability analysis in Stöcker [10], while NIST Zero Trust Architecture supplies the specific Trust Algorithm concept used in Section 5.3.

The comparative portfolio matrix in Figure 2 is an authors' evidence-coded assessment rather than an official index. Five dimensions are scored from one, limited, to five, leading: frontier scale; adoption and skills; industrial and physical deployment; trust and coordination potential;

and capital mobilisation and execution speed. Scores synthesise Stanford AI Index and Global AI Vibrancy evidence, IFR robotics data, official adoption surveys and current institutional evidence. An EU score represents a distributed portfolio and therefore differs in kind from a national score. The figure supports strategic diagnosis rather than investment selection or causal ranking.

The macroeconomic model is a stylised conditional simulation. Parameters are calibrated to published ranges and to observed EU enterprise adoption. Monte Carlo sensitivity varies diffusion, implementation velocity, productivity intensity, trust maturity, complementarity and adoption ceilings. Results show 10th, median and 90th percentiles. The model excludes a complete sectoral input-output system, endogenous interest rates, trade retaliation, monetary responses and distributional heterogeneity. These exclusions appear again in Section 12.

2.3 Evidence classification and legal status

Table 2: Evidence classification and legal status at the evidence cut-off.

Element	Status at evidence cut-off	Permitted interpretation
EU AI Act	Enacted Regulation (EU) 2024/1689 with phased application	Legal framework for AI risk, governance and obligations; implementation details remain time-dependent.
European Digital Identity Framework	Enacted Regulation (EU) 2024/1183	Legal basis for EUDI Wallets and qualified trust services for natural persons and relying parties.
European Business Wallets	Commission proposal COM(2025) 838; Council negotiating position adopted 9 June 2026	Potential organisational execution infrastructure. Legislative content and timing remain subject to the EU procedure.
EBW benefit estimate	Commission ex ante analytical scenario	Approximately EUR 58.4 billion to EUR 169 billion of annual direct benefit across modelled conditions. Usage and process redesign determine realised value.
Trusted execution architecture	Authors' architectural proposition	A system model linking authority, evidence, semantics, Trust Algorithms, assurance and runtime execution across vendors and domains.
TETDM results	Authors' scenario model	Conditional comparisons of transformation regimes. They are scenarios rather than forecasts.

Sources: European Commission [11–14], Council of the European Union [15], authors' classification.

3 Comparative position: a portfolio with a speed gap

3.1 Global strategic position

Global AI leadership is multidimensional. The United States leads in private investment, frontier-model production, compute concentration and venture scaling. The 2025 Stanford AI Index

reported USD 109.1 billion in US private AI investment during 2024, compared with USD 9.3 billion in China, and forty notable US models compared with fifteen in China and three in Europe [16]. The 2026 edition shows continued concentration in US investment and data-centre capacity, while China leads publications, citations, patents and industrial robot installations [17]. China therefore combines frontier capability with manufacturing-scale deployment.

South Korea and Japan hold exceptional robotics density and industrial systems capability. IFR reported 2024 manufacturing robot densities of 1,220 units per 10,000 employees in South Korea, 567 in China, 449 in Germany and 446 in Japan [18]. India combines a large technical workforce and rising research performance with a lower current industrial automation base. The UAE and Saudi Arabia mobilise capital and policy direction rapidly, including substantial announced national initiatives. Canada combines research, talent and governance institutions with a smaller industrial scale. Türkiye retains manufacturing depth and a growing technology sector while current enterprise AI adoption and frontier infrastructure remain more limited.

Europe's portfolio is different. It combines the world's strongest cross-border regulatory and trust potential with industrial depth, a distributed network of innovation clusters and broad public-sector demand. WIPO's 2025 cluster analysis counted seven German clusters among the global top one hundred, while the wider European system includes major nodes in France, the Nordics, the Netherlands, Switzerland and the United Kingdom [19]. The constraint is conversion speed. Fragmented procurement, uneven public digital capacity, scale-up finance gaps, energy and compute constraints, and heterogeneous implementation reduce the rate at which distributed strength becomes common market capability.

3.2 The adoption gap inside Europe

Eurostat reported that 20.0 per cent of EU enterprises with at least ten employees used at least one AI technology in 2025. Adoption reached 55.0 per cent among large enterprises, 30.4 per cent among medium-sized enterprises and 17.0 per cent among small enterprises [22]. Sectoral dispersion is equally significant. Information and communication reached 62.5 per cent, professional and scientific services 40.4 per cent, electricity 33.6 per cent and manufacturing 17.3 per cent. Construction and transport remained near eleven per cent. The aggregate opportunity therefore lies in diffusion into smaller firms and core operating sectors.

Country variation reveals both leaders and transmission challenges. The Nordic economies recorded the strongest European adoption profile, with Denmark, Finland, Sweden and Norway producing an unweighted mean of 35.9 per cent. Germany reached 26.0 per cent, Spain 20.3 per cent, France 18.2 per cent, Italy 16.4 per cent and Poland 8.4 per cent. The ONS reported approximately 35 per cent [23] of UK firms with at least ten employees using AI in June 2026, although its later timing and survey design differ from Eurostat. IFR robot-installation evidence places Germany far ahead of other large European economies in annual factory deployment, with approximately 27,000 installations in 2024, followed among the selected countries by Italy, Spain, France and the United Kingdom [21]. Europe therefore contains several distinct capability profiles that require targeted rather than uniform policy.

A portfolio strategy should combine these profiles. Nordic adoption and digital public services can inform rapid diffusion and human-centred implementation. Germany supplies industrial engineering, equipment, automotive, chemical and enterprise integration assets. France contributes frontier research, models, aerospace, energy and state implementation capacity. Italy and Spain contribute advanced manufacturing, machinery, design, energy and fast-growing digital adoption. Poland contributes engineering talent, industrial capacity and a strategic Eastern European location. The United Kingdom contributes frontier research, finance, safety institutions and professional services. The European opportunity emerges from interoperability among these

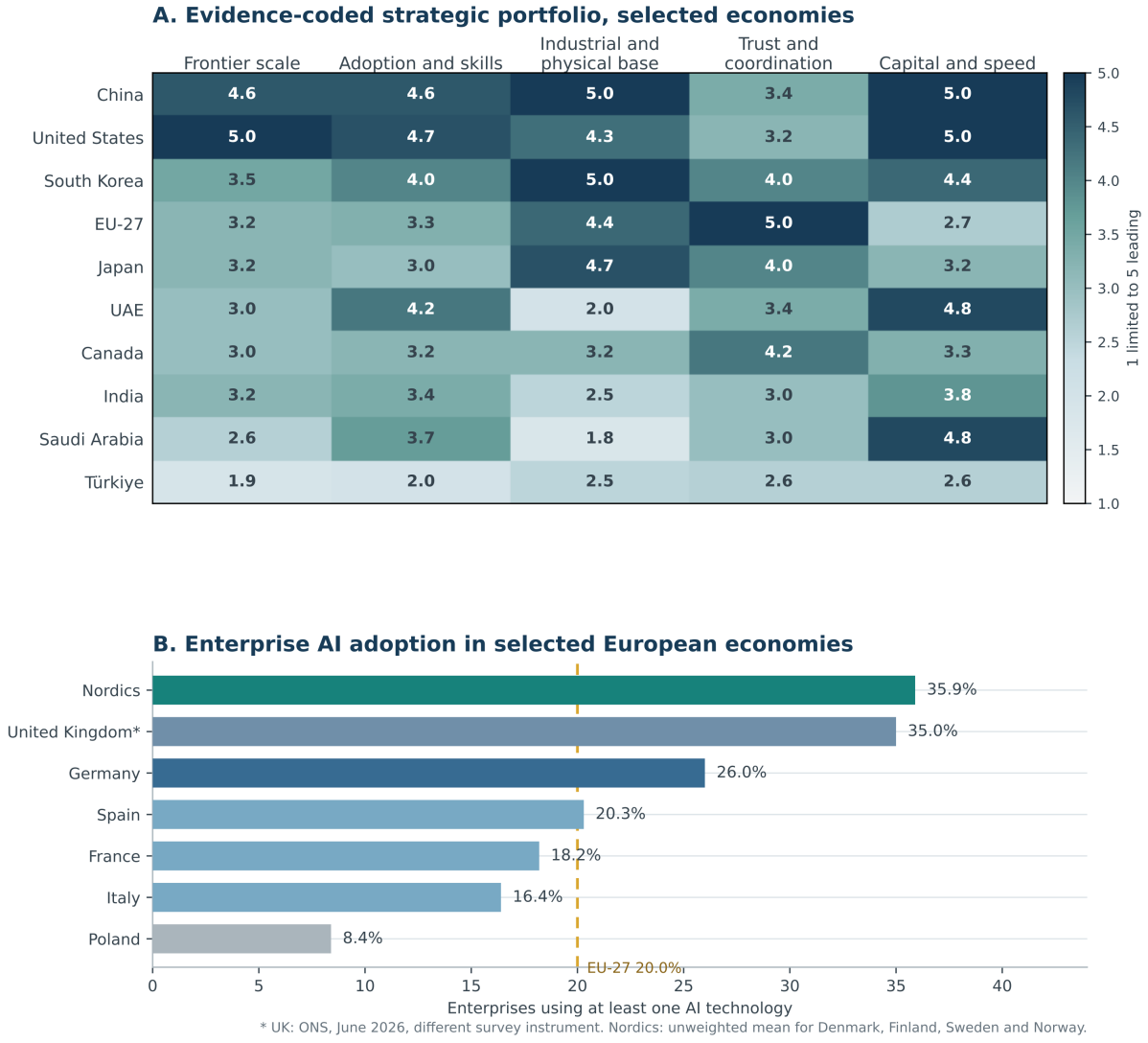

Figure 2: Europe's comparative AI position and selected European adoption rates.

Note: Panel A: authors' evidence-coded ordinal assessment using Stanford HAI [16, 17], Fattorini et al. [20], IFR [18, 21], Eurostat [22], ONS [23], WIPO [19] and institutional evidence. Panel B: Eurostat 2025 data, except UK ONS June 2026. Nordic value is the authors' unweighted mean for Denmark, Finland, Sweden and Norway. Cross-survey comparisons require caution.

strengths.

4 Where AI creates economic value

Gates [1] emphasises that the opportunity reaches beyond aggregate output. AI can accelerate scientific discovery, improve access to professional knowledge, strengthen public services and release time now absorbed by paperwork and search. For Europe, these benefits connect directly to industrial research, clean energy, healthcare, education, agriculture, SME capability and administrative modernisation. Their economic value depends on diffusion, process redesign, accessible services and a distribution of gains that strengthens public legitimacy.

4.1 Business-process automation and the administrative economy

Business processes offer the earliest broad diffusion pathway because they are repeated across sectors. Accounting, procurement, customer service, reporting, compliance, human resources, sales operations and supply-chain administration contain structured documents, recurring classifications and high verification loads. AI can raise output per professional while also improving cycle time and evidence quality. The economic value comes from redesigning the whole workflow, including data capture, exception handling, authorisation and audit, rather than adding a conversational layer to an unchanged process.

Experimental evidence illustrates bounded task gains. Noy and Zhang [24] found that generative AI reduced completion time for selected professional writing tasks by about 40 per cent and raised assessed quality by about 18 per cent. Brynjolfsson, Li and Raymond [25] studied 5,172 customer-support agents and found a 15 per cent increase in issues resolved per hour, with larger gains for newer and lower-performing workers. These studies concern assistive use in defined environments. They provide mechanism evidence for task productivity and knowledge diffusion while leaving economy-wide reorganisation effects open.

Accounting research provides a more operational view. Choi and Xie [26] examine 277 accountants serving 79 small and medium-sized enterprises across more than 200,000 transactions. A one-standard-deviation increase in AI use is associated with 19 per cent more weekly clients, an 8.5 per cent shift of time from data entry towards client communication and quality assurance, greater ledger granularity and a month-end close around 7.5 days faster. The field associations require causal caution. The study's task experiment adds a critical control insight: AI improved average classification accuracy, while unusual recommendations could mislead users. Trusted workflow design should therefore combine confidence thresholds, source evidence, exception routing and accountable professional review.

For Europe, the administrative economy intersects directly with trust infrastructure. A verified organisational attribute, licence, signing mandate, product status or tax registration can be reused across onboarding, reporting, procurement and compliance. AI agents can prepare and exchange evidence, while formal decision rights remain attributable to people and legal persons. This reduces repeated data entry and bilateral verification. It also raises the value of semantic interoperability because an automated workflow requires machine-readable meaning, provenance and status.

The human value channel deserves equal attention. Trusted automation can reduce repetitive verification, data entry, reconciliation and administrative anxiety. It can release time for judgement, care, design, customer work, quality assurance and other higher-value tasks. Worker participation and benefit-sharing support both legitimacy and adoption because employees hold essential process knowledge and bear transition costs.

4.2 B2C agentic commerce

B2C agentic commerce allows consumers to delegate search, comparison, negotiation, purchase, service changes, claims and returns within explicit constraints. Value arises from lower search cost, continuous market monitoring, personalised configuration and reduced friction across service providers. A travel agent could combine identity, age, payment authority, accessibility preferences, insurance coverage and loyalty status. An energy agent could compare tariffs, verify household eligibility and execute a switch. A care-support agent could coordinate appointments and entitlements while preserving sensitive data boundaries.

The trust requirement is substantial because an agent can bind a person economically. The system should verify the consumer's identity, the agent's mandate, spending and purpose limits, merchant identity, product claims, cancellation rights and transaction evidence. EUDI Wallets can provide person-held credentials, while payment and merchant systems provide complementary controls. Verifiable receipts and decision traces support complaints and redress. Europe can differentiate B2C agentic commerce through portability, informed delegation and enforceable accountability across borders.

4.3 B2B agentic commerce

B2B agentic commerce has a larger immediate transaction base in procurement, logistics, financing, compliance and industrial services. Agents can discover suppliers, request quotes, verify company status, negotiate within approved ranges, check product and sustainability evidence, place orders, trigger payments and monitor fulfilment. Each action depends on legal authority, counterpart identity, role, credit, product status, policy and audit evidence. Current enterprise integration reproduces these checks in bilateral interfaces. Reusable organisational credentials and machine-verifiable mandates can convert that fixed cost into shared infrastructure.

The proposed European Business Wallet framework is strategically relevant because it contemplates organisational identification, authentication, attestations and electronic mandates. The Commission proposal also anticipates future implementing specifications for agentic AI and asset identity [13]. The framework remained a legislative proposal at the evidence cut-off, and the Council adopted its negotiating position on 9 June 2026 [15]. An EBW is an access, custody, presentation and authority-management component. Authoritative sources, issuers, trust registries, status services, shared semantics, policy engines and relying-party verification complete the trust infrastructure. European policy should therefore prepare interoperable use cases and conformance regimes while the legal text evolves.

Commission supporting analysis modelled direct annual EBW benefits between approximately EUR 58.4 billion and EUR 169 billion across assumptions, with the high case using 75 per cent enterprise adoption and full public-sector adoption [14]. The estimate is ex ante and survey-dependent. Realised value arises from credential supply, counterparty readiness, verifier coverage, current status, semantic alignment, actual usage and process redesign. AI agents create an additional adoption engine because their transactions need reusable authority and evidence at machine speed.

4.4 Industrial AI

Industrial AI applies learning systems to engineering, planning, quality, energy, maintenance and supply networks. Europe possesses proprietary process knowledge, equipment expertise, installed machinery and regulated product domains that foundation-model benchmarks capture only partially. Industrial value therefore depends on combining general models with physics, domain

ontologies, sensor evidence, simulation, engineering constraints and operational accountability.

High-value applications include generative engineering, code and control assistance, predictive maintenance, process optimisation, quality inspection, demand and production planning, energy management, digital twins and root-cause analysis. Industrial agents can coordinate work orders, materials, documentation and service providers. Runtime authority must remain bounded. A planning agent may propose a schedule, while release to a machine or safety-critical process requires verified configuration, change control, role authority, risk gates and human escalation.

Historical robotics evidence indicates material but heterogeneous productivity effects. Graetz and Michaels [27] estimate that industrial robots contributed about 0.36 percentage points to annual labour-productivity growth across seventeen countries during 1993 to 2007, with no statistically significant aggregate employment effect in the period and a lower share of low-skilled employment. A quantitative meta-study of 1,847 estimates from 85 studies finds a small average productivity boost and evidence of positive publication bias [28]. The policy implication concerns system quality rather than robot count: capital, skills, work organisation and value-chain integration determine returns.

4.5 Physical AI and autonomous science

Physical AI connects perception, reasoning and action through industrial robots, autonomous vehicles, mobile machines, drones, laboratory equipment, warehouses, agriculture, construction, healthcare, homes, grids and critical infrastructure. The opportunity therefore extends far beyond humanoid robots. It can address labour scarcity, hazardous work, inspection, maintenance, logistics and high-mix manufacturing. The field also expands the impact boundary. An erroneous control action can damage equipment, interrupt a grid or injure people. Safety cases, verified configuration, environment limits, simulation, runtime monitoring, functional-safety controls and human takeover therefore belong to the economic architecture.

Commercial evidence signals rapid interest and a large implementation gap. Capgemini Research Institute reported in April 2026 that 79 per cent of surveyed organisations were engaging with Physical AI, while 27 per cent were deploying or scaling solutions and four per cent reported operation at scale [29]. IDC projects a global robotics market above USD 40 billion by 2029, and Counterpoint Research projects 145 million cumulative Physical AI device shipments across vehicles, robots and drones during 2025 to 2035 [30, 31]. These commercial forecasts describe market expectations and remain outside the TETDM calibration.

Platform competition is accelerating. NVIDIA is developing the Cosmos world-model family, Isaac simulation frameworks and GR00T robot models; Google DeepMind's Gemini Robotics 2 and ER 2 extend whole-body control, dexterity, tool orchestration and multi-robot collaboration [32–34]. Figure AI reported more than 16 million uploaded training videos and a commitment above USD 1 billion for data and compute during the following twelve months [35]. These are company-reported capability and investment signals rather than independent performance evidence.

Capital is moving across the wider stack. SoftBank entered a definitive agreement to acquire ABB's robotics business for USD 5.375 billion, with closing planned for mid-to-late 2026, and AWS and NVIDIA announced plans for two million additional GPUs during 2027 and 2028 for workloads including agentic and Physical AI [36, 37]. Reuters also reported discussions about a majority investment in OpenAI-backed 1X at an indicative USD 6 billion valuation; Reuters could not independently confirm the report, and terms remained subject to change [38]. The verified and reported signals together show a race across models, physical data, simulation, compute, industrial platforms, machines and deployment ecosystems.

Autonomous laboratories illustrate the innovation channel. Szymanski et al. [39] integrated

robotics, machine learning, active learning and literature-derived knowledge in an autonomous materials-synthesis laboratory. Such systems can increase experimental throughput and shorten the loop between hypothesis, synthesis, measurement and learning. European laboratories, chemical firms, materials companies, equipment makers and data infrastructures could form capability coalitions that extend beyond one institution. Provenance, calibration evidence and reproducibility become central assets because scientific automation magnifies both learning speed and error propagation.

Physical AI also creates an export opportunity for verifiably governed machinery and infrastructure. Europe can integrate product identity, lifecycle evidence, software bills of materials, machine credentials, operator mandates, Trust Algorithms and service records into industrial systems. The resulting proposition combines equipment, software, assurance and long-term service. It aligns with Europe's strength in regulated, safety-relevant and capital-intensive markets. European leadership therefore depends on complete system capability across data, models, simulation, semiconductors, edge compute, sensors, machines, cyber security, functional safety, authorisation and service operations.

4.6 B2G and G2G applications

Business-to-government and government-to-government processes provide high-leverage adoption because public bodies are both rule setters and major transaction counterparties. Candidate processes include company registration, licences, grants, tax and customs, procurement, environmental reporting, social-security administration, inspections, health-system coordination and cross-border evidence exchange. Public adoption can solve a platform coordination problem by creating reliable demand for credentials and verifiers.

Public bodies can accelerate the market in five linked roles: authoritative credential issuer, high-frequency verifier, procurement customer, cross-border process owner and creator of dependable demand. This role combination can turn isolated wallet and credential pilots into recurring economic infrastructure.

Public-sector automation should begin with authoritative sources and clear decision accountability. An agent can assemble evidence, detect inconsistencies, route cases and prepare decisions. Legal discretion remains with the authorised public body. Verifiable credentials allow the source institution to issue a reusable claim; evidence graphs preserve the provenance and relationships required for a decision; audit records support appeal and oversight. Shared infrastructure can reduce administrative burden while also improving fraud detection and policy implementation speed.

G2G value increases when credentials and evidence cross borders. Mutual recognition currently depends on document formats, national registries and bilateral arrangements. A common trust layer can support machine-verifiable organisational status, roles, licences and product information while preserving national competence. This is a practical route toward a more executable Single Market.

Table 3: AI value domains, trust objects and European deployment opportunities.

Domain	Primary value mechanism	Critical trust object	Leading European deployment opportunity
Breakthrough Science & Engineering	Accelerated hypothesis-to-validation cycles, multi-physics simulation, and generative design for complex systems	Real world evidence (RWE) provenance, simulation integrity, safety containment boundaries, and verified regulatory data	Quantum computing applications, nuclear fusion control, therapeutic cure discovery, and resilient food systems
Democratised Knowledge & Public Services	Scalable access to specialized expertise, administrative burden reduction, and improved delivery of health, legal, and educational services	Professional credentials, consent and privacy boundaries, evidence-based baselines, and transparent decision traces	Primary healthcare triage, SME regulatory and legal guidance, adaptive education platforms, and modernized civil services
Business-process automation	Task productivity, faster close, fewer handoffs, better evidence	Role, source, confidence, exception and approval	Accounting, reporting, procurement and compliance for SMEs and large firms
B2C agentic commerce	Search, comparison, personalisation and transaction convenience	Person mandate, merchant identity, spending and purpose limits	Portable consumer delegation with redress across the Single Market
B2B agentic commerce	Lower onboarding, verification, contracting and coordination cost	Organisation identity, signing mandate, product and compliance evidence	Machine-speed cross-border procurement and supply-chain finance
Industrial AI	Yield, quality, uptime, energy and engineering productivity	Asset identity, data provenance, configuration and release authority	Model-agnostic industrial execution across machines and suppliers
Physical AI	Labour augmentation, hazardous-work reduction and autonomous operation	Safety envelope, environment status, operator mandate and runtime evidence	Trusted robotics, autonomous laboratories and infrastructure operations
B2G and G2G	Administrative capacity, compliance reuse and faster public decisions	Authoritative source, legal competence, decision record and appeal	Wallet-enabled licences, procurement, reporting and cross-border public services

Source: authors' synthesis of the evidence reviewed in Section 4.

5 Trusted execution capital and operational architecture

5.1 From governance and trustworthy properties to execution capital

AI Governance, Trustworthy AI and Trusted AI perform different economic functions. Governance creates legitimate authority and accountability. Trustworthy AI engineering creates context-appropriate system qualities. Trusted AI makes selected claims and controls machine-verifiable at the point of action. A runtime perspective turns these layers into an innovation complement. Reusable identity lowers onboarding cost. Reusable mandates lower the cost of delegated action. Verifiable evidence reduces repeated due diligence. Shared semantics support automated interpretation. Machine-readable policy enables straight-through processing. Runtime monitoring, interruption and revocation reduce expected loss and incident duration. Together, these capabilities expand the range of activities that boards, insurers, regulators, workers and users will authorise.

The paper therefore defines trusted execution capital as the stock of reusable technical, legal and organisational capabilities that allow digital and physical actions to be attributed, constrained, evidenced, monitored and corrected. Like other intangible capital, it requires upfront investment and yields value through reuse. Its return rises with network adoption and process volume. Its depreciation arises from stale credentials, changing law, cryptographic weakness, model drift, semantic divergence and institutional failure. Empirical proxies can include reusable credentials, conformant mandates, verifier coverage, cross-border reuse, automated policy decisions, authorised process coverage, incident rates, interruption latency and recovery time.

5.2 The authority-evidence-semantics-runtime architecture

The operational chain asks six questions. Who or what is acting? Identity and attribution answer this question. For whom may it act? Mandate and delegation establish the chain of representation. Which facts support the action? Verifiable evidence and provenance provide the basis. What do those facts mean? Shared semantics and validation rules make them machine-interpretable. Is the action permitted now? Current status, dynamic policy and runtime authorisation decide. What happens if execution fails? Monitoring, interruption, recovery and accountability close the control loop. AI assurance evaluates model capability, data quality, robustness, uncertainty, safety cases and human-control design across this chain.

Four connected architectural elements make the chain operational. The authority and control plane manages identity, delegation, policy, current status, limits and revocation. The evidence plane manages claims, provenance, transformations, contradictions, uncertainty and fitness for purpose. A semantic layer supplies shared meanings and validation rules across both planes. The runtime execution layer enforces decisions, observes behaviour, interrupts unsafe action, supports recovery and produces accountable records. An EBW can hold or present organisational identity, mandates, licences, account credentials and asset evidence. Trust also depends on authoritative issuers, authentic sources, trust registries, status mechanisms, semantics, governance, policy engines and relying-party verification.

A credential establishes a verifiable claim; it does not by itself establish that a specific action remains authorised at the moment of execution. Current status, purpose, context, delegated limits, relying-party policy and runtime state determine actionability.

NIST uses data plane for the application and service communication flows established through the control plane. This paper's evidence plane is a separate epistemic concept. Raw data becomes evidence for a decision when its origin, meaning, integrity, status, transformation history, uncertainty and relevance to the decision have been established. Verifiable evidence

graphs preserve these relationships across complex industrial processes [40].

5.3 Trust Algorithms and threshold-based security

NIST SP 800-207 defines a Trust Algorithm, TA, as the process used by a policy engine to grant or deny access to a resource [41]. Its inputs include the access request, subject identity and attributes, asset state, resource requirements, historical behaviour and threat intelligence. NIST distinguishes criteria-based from score-based TAs and singular from contextual evaluation. A score-based TA compares a confidence score with a resource-specific threshold; a criteria-based TA requires all configured conditions to be met. The policy administrator then instructs policy enforcement points to establish, restrict, pause or terminate the connection.

Agentic, Industrial and Physical AI require two linked TA families. A control-plane TA decides whether an actor or workload may access data, a service, an AI model, a tool or an actuator, based on identity, mandate, status, workload or asset posture, threat intelligence and policy. An evidence-plane TA evaluates whether the decision basis is fit for purpose, using source authority, provenance, semantic validity, freshness, contradictions, uncertainty and decision risk. A final action-authorisation TA combines both results with model state, environmental context, safety envelope and legal limits before the system acts. Outputs can be permit, restrict, escalate or deny.

NIST does not define a separate construct named Threshold Security. This paper uses threshold-based security as an authors' extension of NIST's criteria and score thresholds. Every material action must clear context-specific thresholds for authority, evidence fitness, cyber-security posture, compliance, functional safety and recoverability. Thresholds should reflect consequence and reversibility: a data read, payment, regulatory filing, machine-parameter change and physical movement require different assurance. Falling below a threshold should reduce privilege, request stronger evidence, route to human review or interrupt execution.

This creates a second design centre for machine-to-machine systems. Human-centred design remains essential for legitimacy, usability, oversight and remedy. TA-centric design thinking complements it by designing the machine-verifiable inputs, evidence, semantics, thresholds, decision outcomes, enforcement points, action receipts and recovery paths before an autonomous workflow enters production. The trust decision becomes a first-class system artefact for cyber security, functional safety and compliance.

5.4 Defensive infrastructure against fraud, misinformation and cyber conflict

Generative AI increases the scale, speed and personalisation of social engineering. Europol's 2025 threat assessment describes the use of large language models to automate and improve criminal workflows. ENISA and the UK National Cyber Security Centre similarly expect AI to increase cyber-threat speed and reach. Deepfakes weaken the evidential value of voice, image and video. A defensive architecture should therefore verify authoritative claims, transaction mandates and source provenance rather than relying on content appearance.

Frontier models also create new technical attack surfaces. NIST's adversarial machine-learning taxonomy covers evasion, poisoning, privacy attacks, misuse and prompt injection, while emphasising the limits of available mitigations [42]. The International AI Safety Report [43] identifies higher risk when agents gain autonomy and direct access to tools, particularly when multi-agent systems propagate errors. European defence should combine model-level evaluation with system-level controls: least privilege, tool allow-lists, isolated execution, contextual Trust Algorithms, action thresholds, evidence validation, continuous monitoring, human takeover,

rapid revocation and cross-organisation incident exchange.

Cyber warfare raises the same requirement at national and industrial scale. Critical infrastructure connects software, operational technology, data and physical assets. An attacker may compromise a credential, a model, a supplier update or the evidence used by an automated decision. Defence in depth requires organisational and asset identity, signed software and configuration evidence, supply-chain provenance, network segmentation, behavioural monitoring, recovery plans and post-quantum migration. Trusted execution contributes through attribution, evidence-aware policy decisions and bounded action. It complements cybersecurity engineering, operational resilience and functional safety.

Gates [1] places employment, community stability and public trust alongside malicious use and security risk. Trusted AI can directly constrain operational risks when an action depends on verifiable identity, authority, evidence, policy, runtime state and enforceable limits. Systemic transition risks require a wider response. Employment displacement, regional decline, unequal income distribution, market concentration and loss of public trust also depend on labour, education, fiscal, competition and social policy. Trust infrastructure can improve attribution, evidence and accountability; it cannot substitute for these policies.

5.5 Verifiably governed execution as a European proposition

Europe's differentiator can be dependable deployment across regulated and cross-border markets. The Single Market contains many contexts in which identity, product status, professional authority, safety, sustainability and audit evidence already matter. Converting these requirements into interoperable technical services reduces friction for European firms and trusted external partners. The proposition is verifiably governed execution: organisations can deploy suitable models through a European execution layer that makes authority, evidence, semantics, policy and accountability portable.

This advantage requires technology neutrality and contestability. Firms should retain the ability to change model, cloud, wallet and assurance providers. Credentials and action evidence should remain portable. Conformance testing should focus on interoperable outcomes and policy-decision interfaces. Public procurement should reward proven integration, security, functional safety and operational value. Europe can then combine openness to global models with control over the institutional conditions of their use.

6 The Trusted Execution Transformation and Diffusion Model

6.1 Purpose and theoretical foundations

The Trusted Execution Transformation and Diffusion Model, TETDM, explains how policy and corporate choices translate AI capability into aggregate output. It combines five established mechanisms. General-purpose technology theory supplies complementarity and co-invention. The productivity J-curve supplies intangible investment and delay. Diffusion theory supplies adoption dynamics. Absorptive-capacity research supplies the ability to learn from external knowledge [44]. Ecosystem and network-governance research supplies multilateral alignment and accountable orchestration [45, 46]. Trusted execution capital is the paper's extension.

The model's unit of adoption is a firm or public organisation in sector i at time t. The system boundary covers investment, adoption readiness, stakeholder deployment acceptance, post-adoption effectiveness, authorised process depth, resource reallocation, inter-organisational spillovers, productivity, income and fiscal capacity. This separation addresses two possible sources

of double counting. Readiness to adopt differs from effectiveness after adoption. Stakeholder acceptance of deployment differs from the share of economically relevant actions authorised under runtime controls. The model separates reference growth from the incremental AI contribution, treats labour-market adjustment and early implementation effort as transition costs, and allows policy to change incentives, shared infrastructure and coordination while firms retain investment and operational decisions.

6.2 Adoption and diffusion

Let $A_{i,t}$ denote the share of organisations in sector i with production-grade AI use. The adoption equation is a bounded diffusion process:

$$A_{i,t+1} = A_{i,t} + V_t \left[p_i + q_i \sum_j w_{ij} A_{j,t} \right] \left[\bar{A}_i - A_{i,t} \right] C^A_{i,t} S_{i,t} \tag{1}$$

The innovation term p_i captures external availability and entrepreneurial entry. The imitation and spillover term q_i links adoption to the weighted network W of suppliers, customers, regions and adjacent domains. $\bar{A}_i$ is the adoption ceiling. V_t represents implementation velocity, including public decisions, infrastructure connection, procurement and internal programme speed. $C^A_{i,t}$ is adoption readiness in data, process, skills, compute and management. $S_{i,t}$ is stakeholder deployment acceptance among boards, regulators, workers, counterparties and affected publics. It includes public legitimacy and workforce acceptance as observed through support for production deployment. Realised benefits, fair access and effective remedies can strengthen S, while displacement, concentrated gains and serious incidents can weaken it. The current calibration treats S as scenario-conditioned rather than endogenous; future empirical versions should estimate this feedback. These variables govern readiness to adopt. They carry distinct meanings from post-adoption effectiveness and authorised process depth in the productivity equation.

6.3 Corporate risk-taking and resource reassignment

Corporate investment responds to expected risk-adjusted value. For project k in firm f, the decision variable is:

$$NPV^k_f = \sum_h \frac{B^k_{f,h} A_{f,h} C^P_{f,h} D_{f,h} - O^k_{f,h} - \mathbb{E}(L^k_{f,h})}{(1 + r_f + u_{f,h})^h} - F^k_f \tag{2}$$

B is gross operating benefit, O is operating and transition cost, E(L) is expected incident or compliance loss, r is the cost of capital, u is policy and implementation uncertainty, and F is fixed integration and organisational cost. C^P is post-adoption effectiveness and D is authorised process depth. Trusted execution capital can widen D through current authority, evidence and policy controls, while monitoring and recovery can reduce E(L). Stable policy direction and faster decisions reduce u and delay. Shared infrastructure lowers F. These changes cause marginal projects to cross the investment threshold and increase the willingness to reassign people, budget and management attention from legacy processes.

Resource reassignment contributes when capital and labour move towards higher-productivity firms, functions and sectors. Let R_t measure the share of transformation resources that can be reallocated within a relevant decision period. Leadership influences R through portfolio discipline, workforce transition agreements, internal capital markets, hiring and divestment.

Public policy influences R through competition, insolvency and scale-up finance, mobility support, procurement access and the treatment of incumbent structures. The model rewards productive reassignment and charges an early transition cost.

6.4 Productivity, spillovers and fiscal capacity

The incremental AI contribution to annual growth is:

$$g_t^{AI} = \sum_i \omega_i \theta_i A_{i,t} C_{i,t}^P D_{i,t} + \mu R_t + \nu \sum_i \sum_j w_{ij} A_{i,t} A_{j,t} - \chi_t \tag{3}$$

Sector weights ω_i aggregate direct productivity intensity θ_i. Its unit is percentage points of annual growth at full production-grade adoption, full post-adoption effectiveness and full authorised process depth. C^P captures the effectiveness of data, process, skills, compute, management and integration after adoption. D captures the share and consequence of actions permitted under current controls. The second term captures resource reallocation. The third captures network spillovers. Transition cost χ_t reflects implementation effort, duplication, displaced routines and training. The GDP level evolves as $Y_{t+1} = Y_t(1 + g_t^0 + g_t^{AI})$, where g^0 is the reference growth rate. The fiscal-capacity effect is measured mechanically as the tax-and-social-contribution ratio times incremental GDP:

$$\Delta F_t = \tau \left[Y_t - Y_t^0 \right] + \Delta S_t - I_t^P \tag{4}$$

τ is the aggregate tax-to-GDP ratio, ΔS captures separately modelled administrative or incident savings, and I^P is public investment and transition spending. The main figures report only the first term using the EU's 2024 ratio of 40.4 per cent [47]. This avoids assigning unverified savings and keeps the result transparent. Political choices determine allocation across social systems, infrastructure, security, tax relief and debt.

6.5 Capability anchors and diffusion

Europe should begin complex missions with the strongest complementary teams rather than spreading initial funding uniformly. A capability anchor is a coalition whose members jointly close the critical activity gaps in a value proposition: domain owner, technology, integration, data, equipment, security, assurance, finance, skills and deployment customer. Selection should use demonstrated capability, operational evidence and complementarity. The anchor receives a measurable mandate, a deployment environment and a pathway to recurring demand.

Concentration at the mission frontier requires designed diffusion. Open interfaces, published credential profiles, reference implementations, shared test facilities, supplier academies, portable training credentials, secondments, joint procurement and evidence from production reduce the fixed cost for followers. Regional and sector diffusion nodes adapt the common architecture to local value chains. Absorptive-capacity funding allows smaller firms to redesign processes and train staff. Time-limited mandates, transparent admission and independent competition review preserve contestability.

The spillover coefficient ν therefore depends on three conditions: relatedness between the frontier use case and adjacent domains; the absorptive capacity of receiving firms; and the portability of technical and organisational components. A successful accounting agent can spill into procurement and regulatory reporting through common evidence and approval patterns. An industrial inspection stack can spill into infrastructure maintenance through shared sensors,

provenance and safety controls. A wallet-enabled mandate can spill across commerce and public administration. Dissemination is an engineered activity rather than an automatic side effect.

6.6 Calibration

Table 4: Central scenario calibration for the TETDM.

Scenario	**Velocity V**	**Adoption ceiling**	S / D factors	C^A / C^P factors	**Reallocation R**	**Direct intensity** θ
Fragmented drift	0.45	45%	0.45 to 0.58	0.40 to 0.52	0.30	1.00
Coordinated acceleration	0.75	75%	0.68 to 0.84	0.55 to 0.76	0.62	1.10
Trusted industrial leadership	0.95	88%	0.80 to 0.95	0.68 to 0.90	0.82	1.20

Source: authors' calibration. S, D, C^A and C^P run from 0 to 1. The scenario trust range applies separately to S and D; the complementarity range applies separately to C^A and C^P. A direct intensity θ of 1.00 means 1.00 percentage point of annual growth at full effective adoption before spillover and transition terms. The current scenario design correlates these factors within each coherent regime and varies their endpoints in sensitivity analysis.

The reference path starts at an index of 100 in 2026 and grows by 0.5 per cent a year. It represents a low-growth EU industrial core under demographic pressure. Globally available digital technology and continuation of current productivity trends are embedded in that rate; the path assigns zero additional post-2026 growth to the transformation mechanisms modelled in TETDM. Fragmented drift is therefore the continuation scenario with modest incremental AI diffusion above the reference. Initial enterprise adoption is 20 per cent, aligned with Eurostat's 2025 EU observation. Eurostat's indicator covers use of at least one AI technology and therefore serves as a broad calibration proxy; recurring core-process adoption is likely lower. Direct productivity intensity and scenario endpoints are calibrated so that the fragmented case remains near conservative macro estimates, the coordinated case enters the OECD central range, and the leadership case reaches the upper part of that range by 2040 while remaining below the ECB's electricity-like analogy. Early transition costs decline by 2031.

The simulation uses 6,000 draws per scenario. Innovation, imitation, velocity, productivity intensity and spillovers vary around the central calibration. Stakeholder deployment acceptance S, authorised process depth D, adoption readiness C^A and post-adoption effectiveness C^P vary within bounded normal distributions, and adoption ceilings vary within scenario-specific ranges. Percentile bands show parameter sensitivity within each regime. They exclude structural surprises such as war, energy shortage, major model breakthroughs, systemic cyber incidents or sharp trade fragmentation. The scenarios bundle direction, speed, complementarity, acceptance, process depth and reallocation; they therefore estimate coherent transformation regimes rather than an isolated causal effect of trusted execution infrastructure.

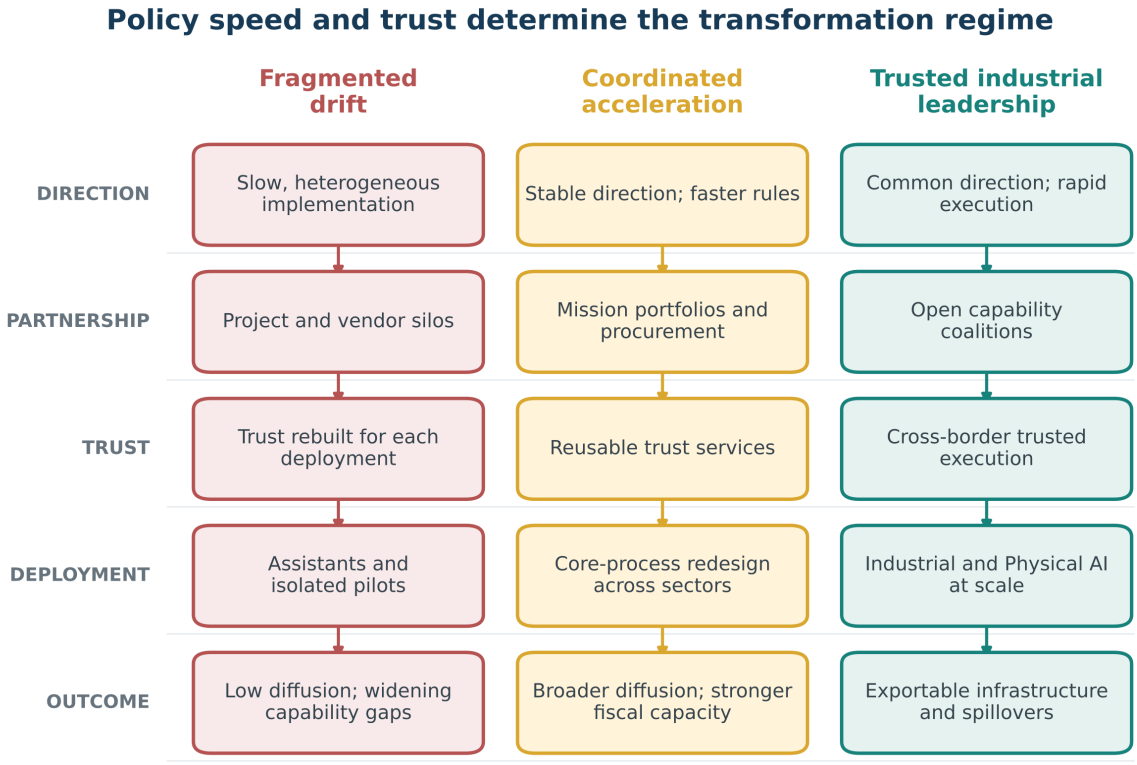

Figure 3: Three policy-speed and capability-diffusion scenarios.

Note: Authors' conceptual scenarios. Each scenario represents a coherent regime across policy, partnership, trust, deployment and spillover rather than a prediction about a specific government.

7 Three scenarios for Europe's industrial core

7.1 Scenario A: fragmented drift

Fragmented drift combines slow implementation, heterogeneous national rules, project-based funding, vendor silos and limited reuse of trust services. Firms adopt assistants and peripheral tools while core processes remain constrained by legacy data, uncertain accountability and long integration cycles. Large companies build proprietary solutions; smaller firms face high fixed costs and scarce expertise. Public bodies digitise unevenly. Industrial and Physical AI projects remain concentrated in pilots with limited procurement conversion.

Corporate leaders preserve option value by waiting. Resources remain tied to legacy systems because policy direction, demand and technical interfaces remain uncertain. Partnerships form around individual grants and dissolve after pilots. Trust controls are implemented separately in each sector and organisation. Spillovers stay weak, regional gaps widen and frontier firms recruit scarce talent away from followers. Europe retains industrial assets while capturing a modest share of the productivity opportunity.

7.2 Scenario B: coordinated acceleration

Coordinated acceleration establishes stable European direction, faster technical implementation, common procurement use cases and interoperable trust services. Member states create high-capability public-private implementation units. Firms redesign selected core processes and share reference architectures through sector missions. European Business Wallet and EUDI Wallet

use cases progress alongside evidence graphs, product passports and data spaces. Skills, data, cybersecurity and change programmes receive funding as complements to model access.

Corporate investment rises because common interfaces lower fixed cost and credible demand lowers uncertainty. Mission organisations manage dependencies across firms and public bodies. Regional diffusion nodes adapt successful methods for the Mittelstand and services. The regime remains heterogeneous across sectors, yet it produces material cross-border reuse and reaches the central macroeconomic evidence range.

7.3 Scenario C: trusted industrial leadership

Trusted industrial leadership treats execution infrastructure as a strategic European asset. Policy defines a limited portfolio of measurable missions, funds common digital and physical infrastructure and uses procurement to create deployment demand. Capability anchors combine Europe's strongest firms, start-ups, research institutions, equipment makers and public users. Technical architectures remain model-agnostic and modular. Identity, mandates, evidence, policy and runtime assurance work across borders and sectors.

Companies move rapidly from *assistant use to process and operating-model redesign.* Industrial AI connects engineering, machines, energy and supply chains. Physical AI scales through safety cases, trusted asset identity and shared test facilities. *Public bodies become authoritative credential issuers and high-frequency verifiers.* Successful mission components enter supplier networks, vocational programmes, managed services and adjacent domains. Independent assurance, open interfaces and sunset reviews limit capture. Europe develops an exportable proposition in trusted industrial and agentic systems.

8 Model results

8.1 GDP paths

8.2 Adoption, growth and fiscal capacity

8.3 Sensitivity and permitted interpretation

Productivity intensity, authorised process depth, post-adoption effectiveness and implementation velocity have the largest influence on the 2040 GDP level. Stakeholder deployment acceptance affects the adoption path. Adoption ceilings become decisive in the later period. Spillovers produce modest early effects and larger late effects because they depend on installed capability in connected organisations. Higher transition costs reduce early gains while leaving long-run potential intact when complementary capital becomes productive. A lower reference path increases the relative importance of AI without changing the model's absolute contribution.

The results quantify the value of a coherent regime under transparent assumptions. The model does not identify the isolated causal contribution of trust infrastructure; it estimates outcomes under regimes in which trusted execution is one necessary complement. It also carries no forecast status, predicts no market valuation and makes no allocation of gains among workers, firms and states. The upper scenario requires an exceptional level of institutional and corporate execution. The lower scenario remains plausible if Europe continues to combine strong capabilities slowly.

A reproducible release should report four specification checks alongside the headline scenarios: a model without S and D; S affecting adoption alone; D affecting process depth alone; and lower adoption ceilings. Exact medians belong in figures, tables and the repository. Executive-facing

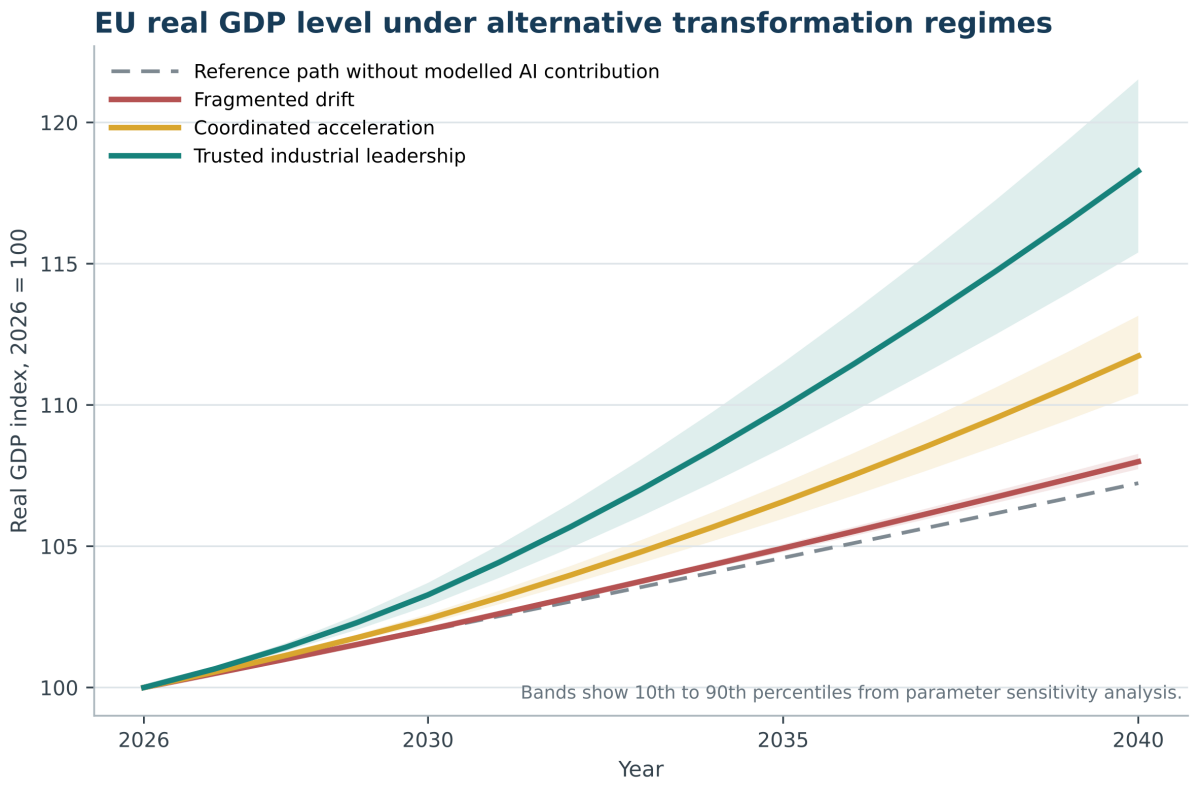

Figure 4: Modelled EU real-GDP level under alternative transformation regimes, 2026 to 2040.

Note: Authors' TETDM simulation. Index 2026 = 100. The reference path grows by 0.5 per cent annually. Lines are medians; bands show 10th to 90th percentiles from 6,000 parameter draws per scenario. Results are conditional scenarios rather than forecasts.

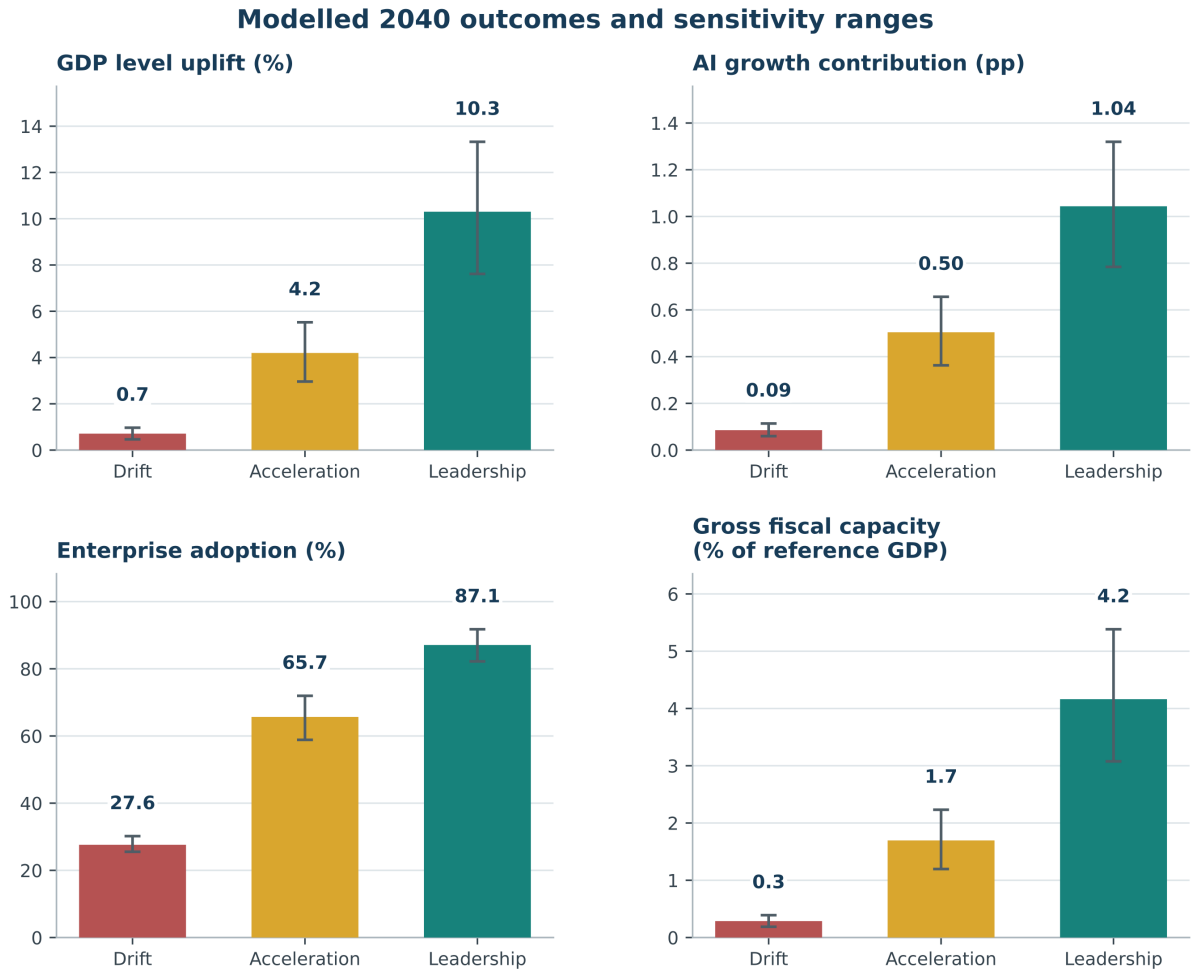

Figure 5: Modelled 2040 outcomes and sensitivity ranges.

Note: Authors' TETDM simulation. Error bars show 10th to 90th percentiles. Fiscal capacity applies Eurostat's 2024 EU tax-to-GDP ratio of 40.4 per cent to the incremental GDP level. It precedes transition spending, distributional choices and behavioural feedback.

text should use approximate ranges that match the uncertainty of the evidence.

9 Corporate leadership, risk-taking and resource reassignment

9.1 A board-level transformation portfolio

Corporate leaders should manage AI as a transformation portfolio with three horizons. The first horizon raises productivity in bounded tasks and builds data, evaluation and workforce capability. The second redesigns end-to-end core processes such as quote-to-cash, procure-to-pay, engineering change, maintenance and regulatory reporting. The third changes the business model through agentic commerce, autonomous operations, outcome-based services and ecosystem participation. Each horizon needs its own risk threshold, decision rights and value metric.

Boards should authorise resource reassignment explicitly. Funding an AI programme alongside every legacy process creates duplication and weakens the investment case. Leaders should identify processes that will be retired, simplified, consolidated or rebuilt. Workforce agreements should map tasks, skills and transition pathways. Finance should capitalise relevant intangible investment consistently where accounting permits and track the cost of delay. Cybersecurity, legal, operations and worker representatives should join design before production gates.

9.2 Risk appetite and bounded autonomy

Risk appetite should vary by action rather than by the label AI. A low-impact assistant can operate with broad human review. A procurement agent that commits funds requires verified mandate, counterparty checks, value limits and audit evidence. A physical agent requires safety constraints, environment monitoring and a tested fallback state. This action-based model allows organisations to expand automation safely as evidence accumulates.

A practical deployment gate asks six questions. Who or what is acting? For whom may it act? Which evidence supports the action? What does that evidence mean for this context? Is the action permitted now? Which monitoring, interruption and recovery controls remain active? A Trust Algorithm evaluates these inputs against the board-approved risk appetite and the applicable cyber-security, functional-safety and compliance thresholds. The result should be permit, restrict, escalate or deny. Weak evidence should route to exception handling rather than hidden model confidence.

9.3 Partnership strategy

The agentic stack spans capabilities held by model providers, cloud and compute operators, data owners, equipment makers, integrators, wallet and credential providers, cybersecurity firms, assurance bodies, finance providers and public authorities. Partnership strategy should begin with the value proposition and activity blueprint, following Adner's ecosystem-as-structure approach. It should identify the weakest required capability as carefully as the strongest participant.

Contracts and governance should preserve portability. Common interfaces, data rights, evidence ownership, liability allocation, incident reporting, intellectual-property rules and exit arrangements belong in the initial design. Partnerships should use staged commitments tied to operational milestones. Firms should share reusable non-differentiating infrastructure while competing on products, models, customer value and execution. This structure converts mutual assistance into productive capacity without recreating a closed corporate network.

9.4 Transformation velocity

Transformation speed should be measured as time-to-capability rather than announcement volume. Relevant intervals include idea to approved production case, source data to verified evidence, pilot to recurring procurement, model update to validated release, incident to containment, and successful deployment to first external reuse. A velocity scorecard should combine speed with safety, economic value and diffusion. Fast failure has value when evidence is preserved and resources move quickly to stronger approaches.

Leadership culture shapes these intervals. High-performance cooperative leadership aligns autonomous organisations around measurable missions while preserving accountability and competition [48]. Leaders state constraints, disclose capability gaps, decide with sufficient evidence, give partners operational credit and accept responsibility for outcomes. Mission organisations coordinate dependencies; line executives retain delivery accountability.

10 A European public-private transformation architecture

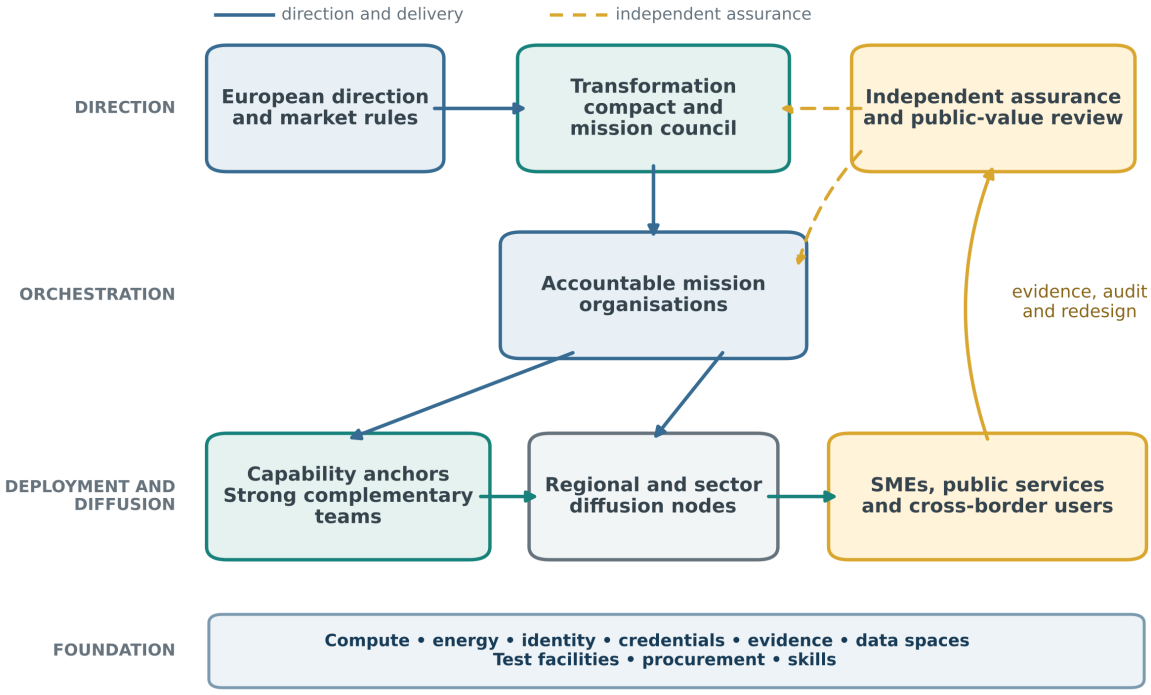

Figure 6: Federated public-private collaboration for capability formation and diffusion.

Note: Authors' adaptation of the Deutschland AG 2.0 federated transformation architecture [48]. Capability anchors concentrate complementary strength at the frontier; regional and sector nodes engineer spillovers; independent assurance protects public value and competition.

10.1 European direction and mission selection

European institutions should define a limited set of outcome missions that require cross-border and cross-sector coordination. A mission describes an operational result, deployment owner, budget, assurance boundary and path to scale. Examples include agentic manufacturing across supplier tiers, trusted cross-border procurement, autonomous inspection of energy infrastructure,

verifiable public reporting and rapid materials discovery for energy and defence. Technology choices remain contestable within each mission.

Gates' warning about fragmented bureaucratic responsibility reinforces the need for a horizontal transition architecture [1]. The coordinating council should align productivity and industrial transformation, labour and skills, security and critical infrastructure, public-service reform, competition and distribution, and public trust and democratic accountability. Mission organisations should translate that direction into delivery through explicit decision rights and measurable outcomes. Workers, regions and affected communities should contribute evidence on transition effects, while firms and public bodies report realised value, incidents, job redesign and distributional outcomes.

Policy direction should align regulation, standards, infrastructure, finance and procurement. The European level supplies Single Market rules, cross-border interoperability and strategic infrastructure. Member states supply authoritative sources, public services, skills systems and deployment capacity. Regions and sectors supply industrial context and local networks. Firms and research organisations supply technology and operational capability. The architecture is federated because these roles retain autonomy and accountability.

10.2 Capability anchors: strongest teams first

The strongest theme of the proposed model is capability complementarity. Europe should assemble the strongest available teams around the full activity system required for deployment. A frontier industrial mission may combine a leading manufacturer, specialised Mittelstand suppliers, a robotics or equipment firm, an AI company, a systems integrator, a trust-infrastructure provider, a university, a vocational network, an insurer and a public deployment customer. Selection evidence should include production performance, integration depth, security, workforce capability and willingness to publish interoperable components.

Public support should buy capability formation and diffusion. Anchor coalitions receive access to compute, test facilities, procurement, guarantees and regulatory coordination in exchange for open interfaces, conformance artefacts, supplier participation, measurable milestones and transfer plans. The mission organisation tracks dependency closure and can replace underperforming components. Independent assurance reviews competition, safety, security, sustainability and public value.

10.3 Spillover and dissemination architecture

Spillovers require receiving capacity. Regional and sector diffusion nodes should provide shared engineering, managed trust services, data preparation, evaluation, cybersecurity, training and change support. Supplier academies and secondments move tacit knowledge. Reference deployments and reusable credentials reduce uncertainty. Procurement frameworks create demand for conformant components. Portable skills credentials allow workers to move between declining and growing activities.

Diffusion should follow related business problems. A capability developed for automotive quality can transfer to machinery and aerospace. An energy asset-identity stack can transfer to buildings and logistics. Accounting evidence and mandates can transfer to tax, grants and procurement. Cross-domain reuse raises the model's network coefficient and lowers fixed cost. Mission reviews should therefore measure external reuse and supplier upgrading in addition to the performance of the original anchor.

10.4 Governance and safeguards

A dedicated mission organisation is appropriate when many autonomous actors must align and legitimate authority remains distributed. It should have a small executive team, public mandate, industrial and technical competence, defined decision rights, worker and societal participation, independent assurance, published metrics and a limited term. Continuation depends on operational evidence. This design follows network-governance research and adapts the Deutschland AG 2.0 mission model to Europe.

Safeguards address capture, bureaucracy and concentration. Admission criteria should be transparent. Interfaces and credential profiles should be published. Procurement should permit competing implementations. Data and intellectual-property rules should reward contribution while preserving switching. Funding milestones should include stopping conditions. Regional distribution should follow capabilities and transition needs, while access to common services remains broad. Competition authorities and independent experts should review systemic dependencies.

11 Policy direction and implementation agenda

11.1 Six policy priorities

Europe should manage opportunity creation and transition risk through one policy portfolio. The opportunity track covers adoption, skills, compute, data, procurement, Industrial and Physical AI and public-service transformation. The transition track covers workforce adjustment, regional concentration, cyber and information risk, competition, distribution and public trust. Shared governance, evidence and trusted execution infrastructure connect both tracks.

First, Europe should establish a Trusted Execution Infrastructure programme that aligns AI Governance, Trustworthy AI assurance, EUDI Wallets, the evolving European Business Wallet framework, organisational, workload and asset identity, verifiable credentials, product passports, evidence graphs, data spaces, Trust Algorithms and runtime policy enforcement. Wallets should serve as access, custody, presentation and authority-management components within this wider infrastructure. The programme should publish interoperable profiles for high-volume business and public processes.

Second, member states should establish high-capability public-private implementation units. Their mandate should focus on authoritative credential issuance, verifier readiness, public procurement conversion, semantic interoperability, conformance, Trust Algorithm profiles and cross-border problem resolution. Public bodies should be measured as issuers, high-frequency verifiers, procurement customers and cross-border process owners. Units should publish time-to-capability metrics and maintain direct executive escalation routes.

Third, AI investment policy should fund complements. Compute and models matter alongside data engineering, organisational redesign, cybersecurity, safety evaluation, skills, energy and integration. Financial instruments should include scale-up equity, guarantees, advance market commitments, project finance and corporate-customer commitments. Funding should follow deployment milestones and credible paths to recurring operation.

Fourth, Europe should launch a small portfolio of Industrial and Physical AI missions with strong capability anchors. Missions should connect manufacturing, energy, logistics, laboratories, infrastructure and defence-relevant dual-use capability. Shared test facilities and safety assurance should lower entry cost for smaller firms.

Fifth, public procurement should become an adoption engine. Authorities should select high-frequency processes in which reusable organisational, professional and product evidence can reduce burden. Procurement specifications should require portability, auditability, security and open conformance rather than a single vendor architecture.

Sixth, social transition should be designed into the productivity strategy. Trusted automation can shift work from repeated verification, data entry, reconciliation and administrative anxiety toward judgement, care, design, customer work and system stewardship. Portable training, occupational mobility, worker participation, benefit-sharing, income support and regional adjustment improve legitimacy, adoption and absorptive capacity. Higher productivity can support better work, wage growth, a broader tax base and stronger capacity to finance ageing societies when institutions distribute gains through skills, bargaining, competition and fiscal policy [49].

11.2 Transformation scorecard

Table 5: Transformation Velocity Scorecard.

Dimension	**Core metric**	**Suggested 36-month evidence**	**Escalation signal**
Direction	Share of mission funding tied to measurable deployment outcomes	Named owners, budgets, use environments and stop criteria	Portfolio dominated by general technology labels or disconnected pilots
Velocity	Median pilot-to-recurring-operation time	At least three cross-border production deployments per mission	Decision or procurement intervals exceed the underlying technology cycle
Core adoption	Share of AI use in core processes	Verified production use across large firms, SMEs and public bodies	Growth remains concentrated in peripheral assistants
Trust reuse	Reusable credentials, conformant mandates, verifier and Trust Algorithm coverage	Cross-border reuse, automated policy decisions, incident rates and recovery time	Credential presentation lacks current status, policy or runtime enforcement
Diffusion	External reusers and upgraded suppliers	Reference components, training, secondments and managed services	Anchor performance rises while follower capability stagnates
Economic value	Cycle time, quality, output and avoided loss	Audited baseline and post-deployment evidence	Value relies on activity counts or unverified estimates
Safety and resilience	Material incidents, recovery time and control coverage	Runtime monitoring, revocation, recovery tests and independent assurance	High-impact actions lack attributable authority or fallback

Source: authors' Transformation Velocity Scorecard, adapted from Stöcker [48]. Indicators require mission-specific thresholds and safeguards against gaming.

11.3 Sequencing

During the first twelve months, European and national leaders should select missions, appoint accountable organisations, publish the first cross-border credential and evidence profiles, identify deployment owners and establish baseline metrics. Firms should map core processes, action-level risk and resource reassignment. Public bodies should prioritise authoritative credential issuance and verifier readiness.

Between twelve and twenty-four months, mission coalitions should operate in production with real users, budgets and assurance. Procurement frameworks, shared test facilities, managed trust services and supplier training should open to followers. Evidence should cover cycle time, productivity, security, worker impact and cross-border reuse.

Between twenty-four and thirty-six months, weak approaches should stop or redesign, and strong ones should enter recurring procurement and private investment. Successful components should move into adjacent sectors and member states. Mission organisations should publish continuation decisions and dependency risks. European institutions should use the evidence to refine implementing acts, standards and finance.

12 Limitations and research agenda

12.1 Evidence limitations

The macroeconomic literature remains young and heterogeneous. Task experiments measure bounded activities, firm studies face selection and measurement challenges, and macro models depend on task exposure, substitution, demand and diffusion assumptions. Robotics research contains substantial variation and possible publication bias. Rapid capability changes can make even recent estimates stale. The paper therefore presents a range and calibrates scenarios rather than selecting one headline estimate.

Gates [1] provides a strategic systems perspective rather than empirical calibration. This paper uses the essay to frame institutional coordination, public legitimacy and transition risk. It does not use it to calibrate unemployment, robotics adoption, taxation or distributional outcomes. Proposals such as robot taxation or occupations reserved for humans require separate labour-market, fiscal and ethical analysis.

Cross-country indicators differ in definitions, timing and coverage. The global portfolio matrix combines national data with an EU aggregate and includes authors' judgement. The UK adoption figure uses a different 2026 survey instrument. Robot installations measure capital deployment rather than AI value. These indicators support strategic positioning and should not serve as a league table for capital allocation.

The EBW benefit range is an ex ante Commission scenario with adoption and use assumptions. Legislative text remains under negotiation. The Trusted AI taxonomy, trusted execution architecture, Trust Algorithm extension and proposed public-private architecture are normative designs. Empirical evidence should test whether reusable authority, evidence, semantics and runtime controls causally raise deployment acceptance, authorised process depth, reduce verification cost and improve incident outcomes.

12.2 Model limitations and research agenda

TETDM is a stylised aggregate model. It lacks sector-specific production functions, input-output propagation, endogenous wages, prices, interest rates, trade flows and public-debt dynamics. The fiscal calculation applies an average ratio and therefore abstracts from tax structure and behavioural response. Labour-income distribution is discussed qualitatively. Transition costs are simplified. Sensitivity ranges cover parameter uncertainty within each regime and exclude structural breaks. Before journal submission, the reproducibility package should report four pre-specified tests: removal of the trust factors, stakeholder acceptance acting only through adoption, authorised depth acting only through productivity, and lower adoption ceilings. These tests can reveal parameter dependence and protect the scenario results from false precision.

Priority empirical work includes a European firm-panel analysis of core-process AI adoption; matched studies of wallet-enabled and conventional verification; sectoral estimates of implementation delay and intangible investment; network analysis of capability anchors and supplier spillovers; labour-market studies of task reassignment, wages and mobility; controlled evaluations of runtime trust controls; and comparative research on mission organisations, procurement conversion and capture safeguards. An open model repository and claim-evidence register would support cumulative revision.

13 Leadership and policy mandate

Europe's strategic choice concerns the architecture and speed of deployment. The continent can remain a portfolio of strong but slowly connected capabilities, or it can build a *common execution layer* through which people, organisations, products, assets and AI agents transact with verifiable authority and evidence. The economic difference compounds through adoption, core-process depth, resource reassignment and spillovers.

Gates' message to leaders is direct: "You have a chance to act now" [1]. For Europe, acting now means connecting opportunity policy, transition policy, security policy and trusted execution infrastructure in one mission-led programme. Executive leaders should establish accountable ownership before displacement, incidents or declining public trust force institutions into crisis management.

The leadership mandate is to convert *complementarity into capability.* European institutions should provide direction and common market infrastructure. Member states should build implementation capacity and authoritative sources. Firms should reassign resources, *redesign core processes* and enter open capability coalitions. Research institutions should *connect discovery to deployment.* Labour organisations and skills systems should shape transition. Investors and public procurement should finance scale. Independent assurance should protect safety, competition and public value.

The operating principle is *disciplined acceleration*: connect the strongest complementary teams, give them measurable deployment missions, verify the conditions under which agents may act, disseminate reusable components into adjacent firms and domains, and scale operational evidence. *Trust becomes a source of speed when it is designed as infrastructure.* Speed becomes a source of productivity when it produces durable capability.

Declarations

13.1 Author contribution and responsibility

This co-author review draft synthesises Bo Harald's work on real-time economic processes, public-sector adoption and business wallets with Carsten Stöcker's work on organisational identity, trust infrastructures, evidence graphs, Industrial AI, Physical AI and federated transformation. The final allocation of author contributions will be confirmed during co-author review. The authors retain responsibility for all claims, judgements, models and recommendations in the approved manuscript.

13.2 Conflict of interest

Carsten Stöcker is founder and managing director of Spherity GmbH, which develops digital identity, credential and trust-infrastructure technologies relevant to the subject. Company research is identified as author-provided evidence and architectural proposition. Independent sources support the principal macroeconomic, legal and security claims.

Bo Harald acts as independent advisor through Why-Advisory Oy and as co-chair of the Wallet Interoperability Special Interest Group in Open Wallet Foundation.

13.3 Funding

No external research funding is declared in this review draft. The authors should confirm the final statement before publication.

13.4 Data, code and generative AI

The paper uses public sources and author-provided manuscripts. No original personal data were collected. The authors' scenario code, model inputs, robustness specifications, figure data and claim-evidence register should accompany the publication package after co-author validation. The register should label author-originated Spherity research separately from independent evidence. Generative AI supported research synthesis, drafting, coding and editorial quality checks under human direction. The authors are responsible for source verification and final content.

A Model variables and interpretation

Table 6: TETDM variables and interpretation.

Symbol	Meaning	Range or unit	Interpretation
$A_{i,t}$	Production-grade AI adoption share	0 to sector ceiling	Organisations using AI in recurring production processes
V_t	Implementation velocity	0 to 1 index	Speed of policy, infrastructure, procurement and internal execution
$C^A_{i,t}$ / $C^P_{i,t}$	Adoption readiness / post-adoption effectiveness	Two 0 to 1 indices	Readiness to deploy / effectiveness after deployment

Table 6. TETDM variables and interpretation. *(continued)*

Symbol	Meaning	Range or unit	Interpretation
$S_{i,t}$ / $D_{i,t}$	Stakeholder acceptance / authorised process depth	Two 0 to 1 indices	Acceptance of deployment / share of actions permitted under current controls
p_i	External innovation effect	Annual diffusion parameter	Model availability, entry and external knowledge
q_i, W	Network diffusion	Parameter and weight matrix	Learning through suppliers, customers, regions and adjacent domains
R_t	Resource reassignment	0 to 1 index	Ability to move capital, people and management attention toward higher-value uses
θ_i	Direct productivity intensity	Percentage points per year	Contribution at full adoption, effectiveness and authorised depth
ν	Spillover coefficient	Annual growth effect	Value from reusable components and cross-domain learning
χ_t	Transition cost	Share of annual output	Implementation, training, duplication and displaced routines
τ	Tax and contribution ratio	40.4% calibration	Mechanical mapping from incremental GDP to gross fiscal capacity

Source: authors' TETDM model. Indices require empirical operationalisation before econometric use.

B Model results table

Table 7: TETDM model results: 10th, median and 90th percentiles for 2040.

Scenario	GDP uplift (%)	AI growth contribution (pp)	Adoption (%)	Gross fiscal capacity (% reference GDP)
Fragmented drift	0.46/0.71/0.97	0.06/0.09/0.11	25.53/27.61/30.19	0.19/0.29/0.39
Coordinated acceleration	2.96/4.20/5.52	0.36/0.50/0.66	58.85/65.68/71.96	1.20/1.70/2.23
Trusted industrial leadership	7.62/10.30/13.33	0.78/1.04/1.32	82.21/87.09/91.77	3.08/4.16/5.38

Values show 10th/median/90th percentile from 6,000 draws. Rounding can create small differences from figures.

C Comparative scoring rubric

The global strategic portfolio uses a five-point ordinal scale. A score of one indicates limited capability relative to the selected group; three indicates material capability with visible constraints;

five indicates leading scale or institutional potential. Frontier scale covers model production, research, investment and compute. Adoption and skills cover business use, workforce and diffusion. Industrial and physical base covers robotics, manufacturing, equipment and deployment assets. Trust and coordination cover legal infrastructure, governance capacity and cross-market interoperability. Capital and speed cover mobilisation, procurement and implementation. Equal visual weight supports diagnosis; the paper avoids a statistically spurious composite league table.

The EU score represents the Union's distributed portfolio. It therefore captures collective industrial and legal capacity alongside implementation fragmentation. Country scores would change with alternative weights, new data or different definitions. The matrix should be refreshed annually and accompanied by observable indicators in any policy dashboard.

References

[1] Gates, B. (2026). The Turbulent AI Era Is Here. The Choices We Make Now Are Critical. Gates Notes. . https://www.gatesnotes.com/a-turbulent-ai-era-and-critical-choices-to-make

[2] Draghi, M. (2024). The Future of European Competitiveness. European Commission. https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

[3] Eurostat (2025a). Population structure and ageing. Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_structure_and_ageing

[4] Bresnahan, T. F. and Trajtenberg, M. (1995). General purpose technologies: engines of growth? Journal of Econometrics, 65(1), 83-108. https://doi.org/10.1016/0304-4076(94)01598-T

[5] Brynjolfsson, E., Rock, D. and Syverson, C. (2021). The Productivity J-Curve: How Intangibles Complement General Purpose Technologies. American Economic Journal: Macroeconomics, 13(1), 333-372. https://doi.org/10.1257/mac.20180386 https://www.aeaweb.org/articles?id=10.1257/mac.20180386

[6] Acemoglu, D. (2024). The Simple Macroeconomics of AI. NBER Working Paper 32487. https://doi.org/10.3386/w32487 https://www.nber.org/papers/w32487

[7] OECD (2026). Foundations for Growth and Competitiveness 2026. OECD Publishing. https://www.oecd-ilibrary.org/en/publications/foundations-for-growth-and-competitiveness-2026_40a7532f-en.html

[8] European Central Bank (2025b). The transformative power of AI. Speech, 24 November. https://www.ecb.europa.eu/press/key/date/2025/html/ecb.sp251124_1~c239fb4a7f.en.html

[9] Aldasoro, I., Gambacorta, L., Korinek, A., Rees, D. and Stein, M. (2026). AI adoption, productivity and employment: evidence from European and US firms. BIS Working Papers No. 1325. https://www.bis.org/publ/work1325.htm

[10] Stöcker, C. (2026e). From Trustworthy AI to Trusted, Operational Agentic Systems: A Comparative Capability and Assurance Framework Analysis for China, the European Union and the United States. Spherity Research, version 1.0, 26 August.

[11] European Commission (2024a). Regulation (EU) 2024/1183 establishing the European Digital Identity Framework. https://eur-lex.europa.eu/eli/reg/2024/1183/oj

[12] European Commission (2024b). Regulation (EU) 2024/1689 laying down harmonised rules on artificial intelligence. https://eur-lex.europa.eu/eli/reg/2024/1689/oj

[13] European Commission (2025a). Proposal for a Regulation establishing European Business Wallets, COM(2025) 838 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2025:838:FIN

[14] European Commission (2025b). Analytical supporting document for the European Business Wallet proposal, SWD(2025) 837 final. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2025)837&lang=en

[15] Council of the European Union (2026). European Business Wallets: Council adopts negotiating position. 9 June. https://www.consilium.europa.eu/en/press/press-releases/2026/06/09/european-business-wallets-council-adopts-negotiating-position/

[16] Stanford Institute for Human-Centered AI (2025). AI Index Report 2025. https://hai.stanford.edu/ai-index/2025-ai-index-report

[17] Stanford Institute for Human-Centered AI (2026). AI Index Report 2026. https://hai.stanford.edu/ai-index/2026-ai-index-report

[18] International Federation of Robotics (2025b). Automation is a cornerstone of modern manufacturing: robot density 2024. https://ifr.org/post/automation-is-a-cornerstone-of-modern-manufacturing

[19] WIPO (2025). Global Innovation Index 2025. World Intellectual Property Organization. https://www.wipo.int/web-publications/global-innovation-index-2025/en/index.html

[20] Fattorini, L., Maslej, N., Perrault, R., Parli, V., Etchemendy, J. and Shoham, Y. (2025). The Global AI Vibrancy Tool 2025. Stanford Institute for Human-Centered AI. https://hai.stanford.edu/research/the-global-ai-vibrancy-tool-2024

[21] International Federation of Robotics (2025a). Global robot demand in factories doubles over ten years. https://ifr.org/ifr-press-releases/news/global-robot-demand-in-factories-doubles-over-10-years

[22] Eurostat (2026). Digitalisation in Europe, 2026 edition. Publications Office of the European Union. https://doi.org/10.2785/9221093 https://ec.europa.eu/eurostat/documents/7870049/23260410/KS-01-26-009-EN-N.pdf

[23] Office for National Statistics (2026). Artificial intelligence in UK businesses, 2023 to 2026. https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/articles/artificialintelligenceinukbusinesses/2023to2026

[24] Noy, S. and Zhang, W. (2023). Experimental evidence on the productivity effects of generative artificial intelligence. Science, 381(6654), 187-192. https://doi.org/10.1126/science.adh2586 https://www.science.org/doi/10.1126/science.adh2586

[25] Brynjolfsson, E., Li, D. and Raymond, L. R. (2025). Generative AI at Work. Quarterly Journal of Economics, 140(2), 889-942. https://doi.org/10.1093/qje/qjae044 https://academic.oup.com/qje/article/140/2/889/7990658

[26] Choi, J. H. and Xie, C. (2026). Generative AI and the Accounting Profession. Journal of Accounting Research. https://doi.org/10.1111/1475-679X.70052 https://onlinelibrary.wiley.com/doi/10.1111/1475-679x.70052

[27] Graetz, G. and Michaels, G. (2018). Robots at Work. Review of Economics and Statistics, 100(5), 753-768. https://doi.org/10.1162/rest_a_00754

[28] Schneider, F. (2026). Do robots boost productivity? A quantitative meta-study. Journal of Economic Surveys, 40(3), 1531-1571. https://doi.org/10.1111/joes.70042 https://onlinelibrary.wiley.com/doi/full/10.1111/joes.70042

[29] Capgemini Research Institute (2026). Physical AI: Taking Human-Robot Collaboration to the Next Level. 16 April. https://www.capgemini.com/news/press-releases/two-thirds-of-organizations-rate-physical-ai-as-a-high-priority-for-the-next-three-to-five-years/

[30] IDC (2026). Physical AI Is a USD 40B+ Market by 2029. Physical AI and Robotics Research Hub. https://www.idc.com/resource-center/blog/resource-region/3_328/page/2/

[31] Counterpoint Research (2026). Cumulative Physical AI Device Shipments to Reach 145 Million Units by 2035. 8 April. https://counterpointresearch.com/en/insights/cumulative-physical-ai-device-shipments-to-reach-145-million-units-by-2025

[32] NVIDIA (2026a). NVIDIA and Global Robotics Leaders Take Physical AI to the Real World. 16 March. https://nvidianews.nvidia.com/news/nvidia-and-global-robotics-leaders-take-physical-ai-to-the-real-world

[33] Google DeepMind (2026a). Gemini Robotics 2 Brings Whole Body Intelligence to Robots. 30 July. https://deepmind.google/blog/gemini-robotics-2-brings-whole-body-intelligence-to-robots/

[34] Google DeepMind (2026b). Introducing Gemini Robotics ER 2. 30 July. https://deepmind.google/blog/gemini-robotics-er-2-powering-robotics-with-video-understanding-task-orchestration-and-multi-robot-collaboration/

[35] Figure AI (2026). Introducing Index: Building the World's Largest and Most Diverse Physical Dataset. 25 August. https://www.figure.ai/news/introducing-index

[36] SoftBank Group (2025). Acquisition of ABB Ltd's Robotics Business. 8 October. https://group.softbank/en/news/press/20251008

[37] NVIDIA (2026b). AWS and NVIDIA to Deliver 2 Million Additional GPUs and Next-Generation Infrastructure for Agentic and Physical AI. 26 August. https://nvidianews.nvidia.com/news/aws-and-nvidia-to-deliver-2-million-additional-gpus-and-next-generation-infrastructure-for-agentic-and-physical-ai

[38] Reuters (2026). SoftBank in Talks to Buy Stake in 1X at USD 6 Billion Valuation, The Information Reports. 27 August. https://www.reuters.com/legal/transactional/softbank-talks-buy-stake-1x-6-billion-valuation-information-reports-2026-08-27/

[39] Szymanski, N. J. et al. (2023). An autonomous laboratory for the accelerated synthesis of novel materials. Nature, 624, 86-91. https://doi.org/10.1038/s41586-023-06734-w https://www.nature.com/articles/s41586-023-06734-w

[40] Stöcker, C. (2026b). Evidence Graphs for Industrial AI Data Plane Architectures. Spherity Research.

[41] NIST (2020). Zero Trust Architecture. NIST Special Publication 800-207. https://doi.org/10.6028/NIST.SP.800-207

[42] NIST (2025). Adversarial Machine Learning: A Taxonomy and Terminology of Attacks and Mitigations. NIST AI 100-2e2025. https://doi.org/10.6028/NIST.AI.100-2e2025 https://csrc.nist.gov/pubs/ai/100/2/e2025/final

[43] International AI Safety Report (2026). International AI Safety Report 2026. https://internationalaisafetyreport.org/publication/international-ai-safety-report-2026

[44] Cohen, W. M. and Levinthal, D. A. (1990). Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128-152. https://doi.org/10.2307/2393553 https://www.jstor.org/stable/2393553

[45] Adner, R. (2017). Ecosystem as structure: an actionable construct for strategy. Journal of Management, 43(1), 39-58. https://doi.org/10.1177/0149206316678451 https://journals.sagepub.com/doi/10.1177/0149206316678451

[46] Provan, K. G. and Kenis, P. (2008). Modes of network governance: structure, management, and effectiveness. Journal of Public Administration Research and Theory, 18(2), 229-252. https://doi.org/10.1093/jopart/mum015 https://academic.oup.com/jpart/article/18/2/229/935895

[47] Eurostat (2025b). Tax revenue statistics: EU tax-to-GDP ratio in 2024. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tax_revenue_statistics

[48] Stöcker, C. (2026). Deutschland AG 2.0: A Federated Transformation Architecture for Industrial AI, Sustainability, Security and Resilience. Unpublished journal review draft, 16 August.

[49] Brollo, F., Dabla-Norris, E., de Mooij, R., Garcia-Macia, D., Hanappi, T., Liu, L. and Nguyen, A. D. M. (2024). Broadening the Gains from Generative AI: The Role of Fiscal Policies. IMF Staff Discussion Note 2024/002. https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2024/06/17/Broadening-the-Gains-from-Generative-AI-The-Role-of-Fiscal-Policies-549639

[50] Ansell, C. and Gash, A. (2008). Collaborative governance in theory and practice. Journal of Public Administration Research and Theory, 18(4), 543-571. https://doi.org/10.1093/jopart/mum032 https://academic.oup.com/jpart/article/18/4/543/1090370

[51] Cazzaniga, M., Jaumotte, F., Li, L., Melina, G., Panton, A. J., Pizzinelli, C., Rockall, E. and Tavares, M. M. (2024). Gen-AI: Artificial Intelligence and the Future of Work. IMF Staff Discussion Note 2024/001. https://www.imf.org/en/publications/staff-discussion-notes/issues/2024/01/14/gen-ai-artificial-intelligence-and-the-future-of-work-542379

[52] European Central Bank (2025a). AI can boost productivity if firms use it. ECB Blog, 28 March. https://www.ecb.europa.eu/press/blog/date/2025/html/ecb.blog20250328~60c0a587f7.en.html

[53] European Central Bank (2026a). Artificial intelligence and the euro area economy. Speech, 23 March. https://www.ecb.europa.eu/press/key/date/2026/html/ecb.sp260323_1~1e06784a89.en.html

[54] European Central Bank (2026b). How European firms are using AI in core business processes. ECB Blog, 24 June. https://www.ecb.europa.eu/press/blog/date/2026/html/ecb.blog20260624~44f70da110.en.html

[55] European Central Bank (2026c). Firm-level AI adoption in the euro area. ECB Occasional Paper 395. https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op395.en.pdf

[56] European Commission (2025c). European Business Wallets: policy overview. https://digital-strategy.ec.europa.eu/en/policies/business-wallets

[57] European Investment Bank (2025a). Investment Report 2024/2025: Innovation, Integration and Simplification in Europe. https://www.eib.org/en/publications/20240354-investment-report-2024

[58] European Investment Bank (2025b). EIB Investment Survey 2025: European Union overview. https://www.eib.org/en/publications/20250216-econ-eibis-2025-eu

[59] European Investment Bank (2026). Investment Report 2025/2026. https://www.eib.org/en/publications/20250379-investment-report-2025

[60] Europol (2022). Facing Reality? Law Enforcement and the Challenge of Deepfakes. https://www.europol.europa.eu/publications-events/publications/facing-reality-law-enforcement-and-challenge-of-deepfakes

[61] Europol (2025). Internet Organised Crime Threat Assessment 2025. https://www.europol.europa.eu/cms/sites/default/files/documents/Steal-deal-repeat-IOCTA_2025.pdf

[62] ENISA (2025). ENISA Threat Landscape 2025. https://www.enisa.europa.eu/publications/enisa-threat-landscape-2025

[63] Filippucci, F., Gal, P., Jona-Lasinio, C., Leandro, A. and Nicoletti, G. (2024). The impact of artificial intelligence on productivity, distribution and growth. OECD Artificial Intelligence Papers No. 15. https://doi.org/10.1787/8d900037-en https://www.oecd.org/en/publications/the-impact-of-artificial-intelligence-on-productivity-distribution-and-growth_8d900037-en.html

[64] Kattel, R. and Mazzucato, M. (2018). Mission-oriented innovation policy and dynamic capabilities in the public sector. Industrial and Corporate Change, 27(5), 787-801. https://doi.org/10.1093/icc/dty032 https://academic.oup.com/icc/article/27/5/787/5089909

[65] Mazzucato, M. (2018). Mission-oriented innovation policies: challenges and opportunities. Industrial and Corporate Change, 27(5), 803-815. https://doi.org/10.1093/icc/dty034 https://academic.oup.com/icc/article/27/5/803/5127692

[66] NIST (2023). A Zero Trust Architecture Model for Access Control in Cloud-Native Applications in Multi-Cloud Environments. NIST Special Publication 800-207A. https://doi.org/10.6028/NIST.SP.800-207A

[67] OECD (2025). OECD Economic Surveys: Germany 2025. OECD Publishing. https://www.oecd.org/en/publications/oecd-economic-surveys-germany-2025_39d62aed-en.html

[68] Stöcker, C. (2026a). European Business Wallets as the Legal Control Plane for Zero Trust AI Agents. Spherity Research.

[69] Stöcker, C. (2026c). Verifiable Access-Controlled Digital Product Passports. Spherity Research.

[70] Stöcker, C. (2026d). Quantum-Resilient Organisational Identity. Spherity Research.

[71] UK National Cyber Security Centre (2025). The near-term impact of AI on the cyber threat. https://www.ncsc.gov.uk/report/impact-ai-cyber-threat-now-2027