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The Artificial Intelligence Value Chain: Autonomy Strategies for Spain

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Abstract:

In the age of artificial intelligence (AI), the technological and economic power of nations is increasingly tied to their control over digital value chains. AI is not an isolated product, but the result of a complex integration of inputs and processes that span from mining to the deployment of services in the hands of end users. This AI supply chain – or AI stack – consists of several interdependent layers: physical components (minerals and chips), digital infrastructure, intangibles inputs (datasets, human capital), and applications that permeate the socioeconomic fabric. Each layer could be affected by bottlenecks, creating vulnerabilities for the rest of the world. In particular, examining Spain's position at each stage allows for the identification of exploitable strengths as well as dependencies.

Keywords:

Artificial intelligence (AI), Digital value chain, Semiconductors, Data, Human capital

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The concept of the artificial intelligence supply chain describes the set of interdependent layers that enable its operation, from the extraction of mineral resources to end applications. This structure includes six levels (raw materials, semiconductors, computing and energy infrastructure, data, human capital and technology adoption) that make up an integrated system in which each stage depends on the previous one, so that a blockage in any of them can disrupt the entire value chain[1] . To strengthen the most vulnerable links, the European Union has deployed a far-reaching regulatory and industrial framework. The European Chips Act provides for an investment of €43 billion with the aim of doubling Europe's share of global semiconductor production to 20% by 2030, thereby strengthening European strategic autonomy[2] .

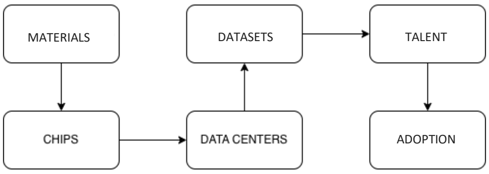

Figure 1: AI chain (own elaboration)

In line with this initiative, in 2022 Spain launched the *PERTE for Microelectronics and Semiconductors*, with a budget of €12.25 billion until 2027, aimed at developing industrial and training capacities throughout the chip chain[3] . Additionally, the Critical Raw Materials Act seeks to guarantee the supply of minerals essential for the digital and green transition through production, setting refining and supplier diversification targets, and reducing structural dependence on China, which dominates more than 90% of rare earth refining[4] . Finally, the National Artificial Intelligence Strategy and the creation of the Spanish AI Supervisory Agency complete the institutional framework for governance, talent and data, consolidating a comprehensive vision in which technological sovereignty and digital resilience depend on an integrated chain connecting the subsoil with the cloud, materials with software, and innovation with society[5] .

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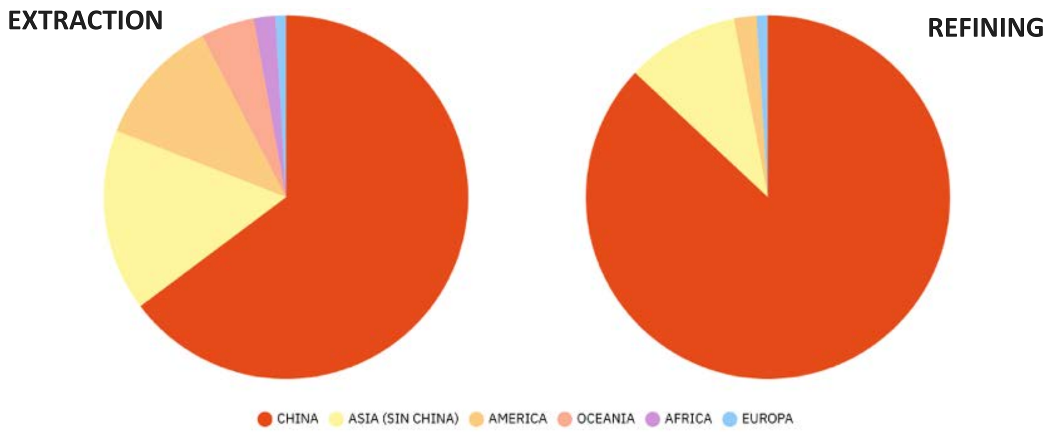
[1] *European Commission. Regulation (EU) 2023/1781 – European Chips Act. Brussels, 2023.*
[2] *European Commission. Critical Raw Materials Act – Proposal. Brussels, 2023.*
[3] *Government of Spain. PERTE for Microelectronics and Semiconductors. Madrid, 2022.*
[4] *Government of Spain. National telitelligence Strategy. Madrid, 2020.*
[5] *Government of Spain. Royal Decree creating the Spanish Agency for the Supervision of Artificial Intelligence (AESIA). Madrid, 2022.*

Raw materials: the mineral basis of AI

Artificial intelligence technologies are often perceived as a purely digital field, but their beginning is related to geology. The chips that make up the material infrastructure of AI depend on a small set of critical minerals: ultra-pure silicon, gallium, germanium, rare earths, copper, lithium, cobalt and graphite. Without them, the technological chain that sustains the digital economy cannot exist.

The case of rare earths sums up the magnitude of the challenge. In 2024, China produced around 270,000 tonnes of rare earth oxides (almost seven out of every ten tonnes extracted worldwide) and maintains even greater control over the refining and separation stages. In recent years, Beijing has strengthened its control policy by establishing licences for gallium, germanium and graphite products, demonstrating how minerals have become instruments of geo-economic influence[6].

Figure 2: Extraction and refining of rare earths (own elaboration)



This concentration is not only national but also territorial: a large part of the world's supply comes from a single district, Bayan Obo, in Inner Mongolia. For decades, this iron, niobium and rare earth deposit has financed the extraction of these minerals as a by-product of iron. Historically, up to half of the global supply came from this enclave, a clear case of a "single point of failure". Technical stoppages, environmental

[6] *World Trade Organisation (WTO). China – Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum (DS431/DS432/DS433). Geneva, 2014.*

tensions or local restrictions can immediately disrupt the global chain, a risk that is replicated in other critical materials[7] .

The pattern repeats itself in the case of high-purity silicon, which is essential for silicon wafers and crucibles used in microelectronics. In 2024, Hurricane Helene temporarily halted production in Spruce Pine (North Carolina), the world's leading supplier. This reminds us that the resilience of the technological fabric can be broken by natural events unrelated to the sector[8] .

The economic value of these materials does not reflect their true strategic importance. The global market for rare earths is small (Chinese exports reached only $489 million in 2024[9]), but their strategic value is disproportionate, as they influence high value-added industrial chains.

Faced with this fragility, the United States and the European Union have adopted converging strategies to reduce their dependence on China by diversifying suppliers, creating strategic reserves, recycling and searching for substitute materials. However, the room for manoeuvre is limited: developing a mine from discovery to commercial production takes 16 years, making it difficult to correct imbalances in the short term.

Spain remains highly dependent on foreign sources for the first link in the artificial intelligence chain, with no active rare earth mining operations. The national strategic framework seeks to reduce this vulnerability through domestic exploration, waste reuse and processing development within the EU [10] [11]. Projects such as Matamulas, which was rejected on environmental grounds, or those in Barruecopardo and Valtreixal, focused on tin-tungsten, together with the San Cibrao refinery, show both the potential and the limitations of an industrial policy that is still in its infancy [12] [13] [14]. Ultimately, the mineral base of AI remains the invisible but decisive foundation of the

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[7] NASA Earth Observatory. Rare Earth in Bayan Obo. Washington D.C., 2012.
[8] Associated Press (AP). Hurricane Helene Disrupts Quartz Production in North Carolina. New York, 2024.
[9] Reuters. China's rare earth exports in 2024 climb as home demand limited. Beijing, 2025.
[10] Ministry for Ecological Transition and Demographic Challenge (MITECO). First Action Plan 2025–2029 for the Sustainable Management of Mineral Raw Materials (Draft). Madrid, 2025.
[11] EUR-Lex. Regulation (EU) 2024/1252 on Critical Raw Materials. Brussels, 2024.
[12] Regional Government of Castilla-La Mancha. Report on the Environmental Impact Statement for the Matamulas Project. Toledo, 2017.
[13] Saloro S. L. U. Barruecopardo – MRE JORC Technical Report 2023. Salamanca, 2023.
[14] Regional Government of Castilla y León. Valtreixal Mining Project (Tin and Tungsten). Valladolid, n.d.

entire technological chain and a factor of geo-economic power that will determine the autonomy and pace of the algorithmic revolution.

Semiconductors: a concentrated domain

The second layer of the chain consists of semiconductors, the components that enable data centres to function. In practice, they constitute the "physical brain" of AI. Since 2023, demand for chips, particularly AI accelerators such as GPUs, has skyrocketed, leading to supply shortages, delivery delays and widespread price increases. This phenomenon, centred on NVIDIA products and underpinned by a monopoly on CUDA computing software, has revealed the extreme sensitivity of the AI ecosystem [15] [16] .

The chip chain is one of the most complex and interdependent in the global technology system. In the design phase, the most advanced electronic design automation (EDA) tools are dominated by suppliers based in the United States and the European Union, which has allowed Washington to turn that position into an instrument of export control. The leading designers concentrate leadership in AI acceleration architectures, consolidating Silicon Valley's design hegemony and reinforcing the dependence of the entire global ecosystem on US rules.

However, the most critical link is in advanced manufacturing. Most production below 7 nanometres (especially 5 and 3 nm) is concentrated in Taiwan (TSMC) and South Korea (Samsung). It is estimated that nearly 90% of global capacity is located in Taiwan. A geopolitical crisis, trade blockade or even a natural disaster could paralyse the supply of state-of-the-art chips and thus slow down the progress of global AI[17] .

[15] *Semiconductor Industry Association. Strengthening Global Semiconductor Supply Chain. Washington, D.C., 2021.*

[16] *Government Accountability Office. Implementation of October 2022 Rules on Semiconductors. Washington, D.C., 2024.*

[17] *Council on Foreign Relations (CFR). Onshoring Semiconductor Production: National Security vs. Economic Efficiency. New York, 2024.*

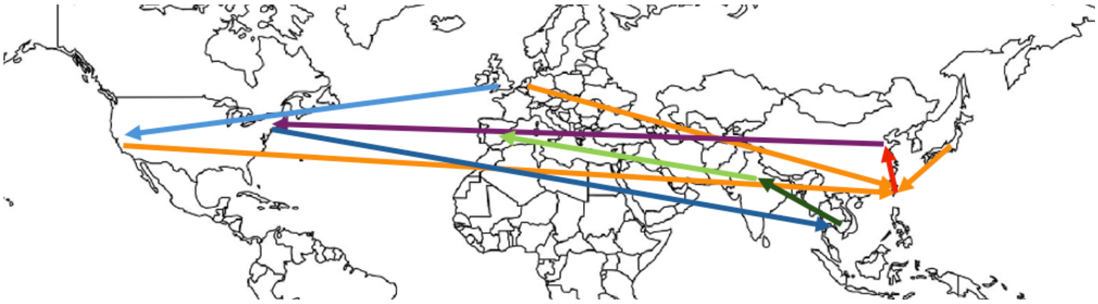

Figure 3: Apple's M2 chip journey (own elaboration)

Production also depends on ultra-precise equipment and materials with very small markets. Extreme ultraviolet lithography (EUV), which is essential for manufacturing chips below 7 nm, is practically monopolised by the Dutch company ASML, which is subject to control regimes that restrict exports to China[18] .

Encapsulation and testing (the final stage of the process) add another geographical dependency. Companies such as ASE (Taiwan), Amkor (US) and JCET (China) account for most of the assembly capacity. The most advanced packaging techniques are also anchored in that region, which means that most Western chips travel to Asia for completion and then return integrated into final products[19] .

The lessons learned from the pandemic continue to shape industrial strategy. Factory shutdowns, the rise of remote working and increased demand for consumer electronics led to unprecedented shortages. Sectors such as the automotive industry lost up to 9 million vehicles and more than £200 billion in revenue, demonstrating that without strategic reserves or long-term contracts, production priority falls to customers with greater purchasing power: large technology companies[20] .

In the wake of these tensions, industrial policies have been reactivated. In the USA, the *CHIPS and Science Act* allocates £52.7 billion to reindustrialise semiconductor production, reanchor factories and attract investment from TSMC, Samsung and Intel. In the European Union, the *European Chips Act* (Regulation 2023/1781) sets a target of achieving 20% of global manufacturing by 2030 [1] [21] .

[18] *ASML. Annual Report 2025. Veldhoven, 2025.*
[19] *BIS. Advanced Packaging and Assembly Trends in Asia. Washington, D.C., 2023.*
[20] *S&P Global Mobility. The Semiconductor Shortage Is (Mostly) Over for the Auto Industry. London, 2023.*
[21] *White House (US). Fact Sheet: CHIPS and Science Act of 2022. Washington, D.C., 2022.*

Spain lags behind in the semiconductor value chain, with no industrial-scale wafer factories and a heavy dependence on imports for its technology and defence industries. The PERTE Chip, with €12.25 billion until 2027, seeks to reverse this situation by promoting design, training and encapsulation, although the cancellation of the Broadcom plant in 2025 was a symbolic setback [3]. Factors such as scientific talent, competitive renewable energy and good logistics offer potential, but the lack of a national "driving force" and intermediate capabilities limits its autonomy.

Computing and energy infrastructure: the digital foundation

The third layer of the artificial intelligence *stack* is made up of the computing infrastructure, the physical and energy network that supports the operation of AI systems. If semiconductors are the "brain," the infrastructure represents the "body" that houses them and the energy "blood" that keeps them active. This layer encompasses data centres, communication networks, electrical availability, and computing capabilities [22] [23].

Over the past decade, companies have taken the lead in cloud computing, which today forms the material basis of commercial AI. AWS, Microsoft Azure, and Google Cloud account for nearly two-thirds of the global *cloud* services market, providing computing capacity used by corporations, governments, and research centres alike. This oligopoly creates a technological and strategic concentration: few organisations outside these companies can build comparable infrastructures [24].

Electricity is another critical issue. AI is energy-intensive, and it is estimated that data centres already consume around 2% of the world's electricity. Training a large-scale model can require hundreds of megawatt-hours, so areas with cheap, stable and, preferably, renewable energy are becoming destinations for new facilities. At the same time, environmental pressure and network constraints have led governments such as those of Ireland and the Netherlands to curb the expansion of data centres

[22] *World Economic Forum. AI Infrastructure and Global Cloud Report. Geneva, 2024*
[23] *Spanish Institute for Strategic Studies. Artificial intelligence in geopolitics and conflicts. Strategy Notebooks No.*
226, Ministry of Defence, 2024
[24] *European Union. State of the Digital Decade Report 2024. Brussels, 2024*

due to their impact on electricity demand and water consumption for cooling [25].

Connectivity completes this layer: fibre optic networks and submarine cables that carry data are the arteries of the system. A handful of companies, the same ones that dominate the cloud, also finance and own much of the transoceanic cables, reinforcing their vertical control of the infrastructure. Digital inequality in connectivity, therefore, translates directly into inequality of access to artificial intelligence[26] .

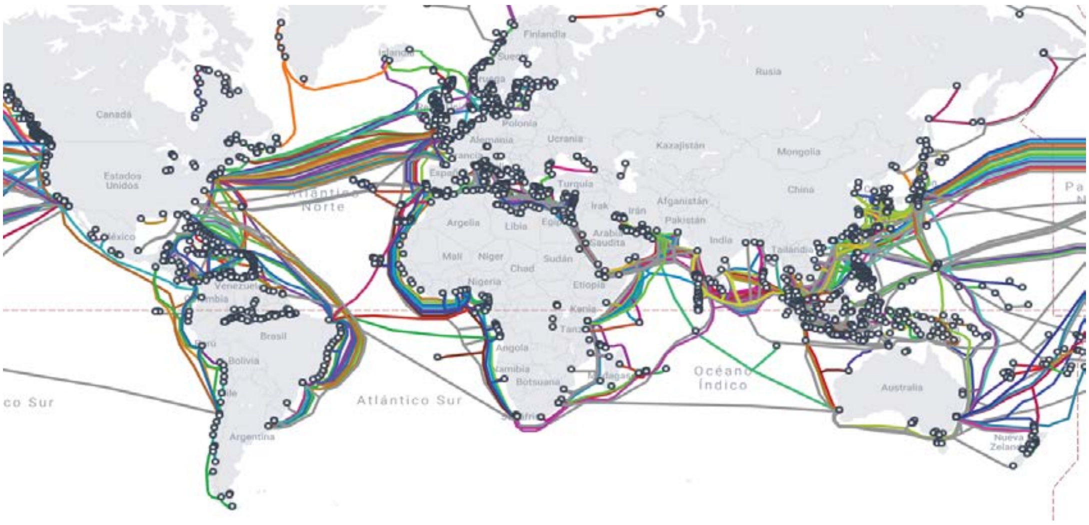

Figure 4: Submarine cables (updated October 2025) (Source: https://www.submarinecablemap.com/)

Spain occupies an intermediate but strategic position in the computational and energy infrastructure layer for artificial intelligence: although it is technologically dependent on foreign suppliers, it has managed to attract significant investment from the world's major *cloud* players. AWS opened its region in Aragon in 2022, while Microsoft Azure and Google Cloud are establishing centres in Madrid, reinforcing local connectivity and national processing capacity, albeit under foreign ownership. In the field of European supercomputing, cutting-edge infrastructures such as JUPITER, LUMI and LEONARDO stand out as among the most powerful in the world. In this context, Spain is consolidating its role as a benchmark thanks to the Barcelona Supercomputing Centre and its MareNostrum 5 system, located on national territory and also ranked among the fifteen most powerful supercomputers on the planet. In terms of energy, the country has an increasingly renewable energy matrix that favours the deployment of sustainable data centres, although challenges remain in terms of cooling and water

[25] *International Energy Agency. Data Centres and Energy Demand Outlook 2024. Paris, 2024*
[26] *TeleGeography. Global Submarine Cable Map 2024. Washington D.C., 2024*

availability in some regions. Its geographical position reinforces this advantage: the MAREA, Grace Hopper, 2Africa and EllaLink submarine cables turn the Iberian Peninsula into a digital hub between Europe, America and Africa, expanding its potential as a data transit and storage node. Overall, Spain combines strengths such as clean energy, good connectivity and cutting-edge supercomputing with weaknesses such as foreign ownership and technological dependence, which means it could consolidate its position as a European green computing hub, capable of attracting investment without sacrificing its digital autonomy [23].

Data: the value of information

The fourth layer, data, is the element that feeds models and algorithms, the real "fuel" of AI. Its relevance lies in the availability, accessibility and quality of large volumes of information. The United States and China dominate this sphere through conglomerates that act as veritable information oligopolies: Google, Meta, Amazon, Microsoft and Apple, together with their Chinese counterparts Alibaba, Tencent, Baidu and ByteDance, accumulate and control most of the data generated by users around the world. These companies concentrate information on searches, consumption, social interactions and biometrics, building a closed ecosystem where private data feeds their own AI models, inaccessible to other players [27] [28] .

Regional asymmetry accentuates this gap. The United States and China have the largest digital populations, enabling them to generate massive and varied data sets. Europe, on the other hand, although it has a considerable user base, is hampered by linguistic and regulatory fragmentation, as well as a lack of its own global platforms. At the same time, the United States and China have taken advantage of regulatory gaps to consolidate their data ecosystems and train models in predominant languages, thus generating a structural advantage and a linguistic bias in AI, which is more accurate in English or Chinese than in less represented others languages [27].

However, in recent years there has been a re-commodification of access to data. Platforms that previously offered open interfaces, such as Twitter or Reddit, have

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[27] *World Economic Forum. Global Data Platforms and AI Value Chains Report. Geneva, 2024*

[28] *European Parliament. Regulation (EU) 2016/679 – General Data Protection Regulation (GDPR). Brussels, 2018*

restricted or monetised their use, transforming data that was previously considered digital commons into commercial assets. This closure responds to the economic value that AI extracts from user-generated content, reinforcing the strategic nature of control over information. In short, the data layer reflects the unstable balance between protection and exploitation, between sovereignty and concentration: while the technological powers consolidate their dominance through accumulation, Europe is committed to regulated and cooperative governance that seeks to preserve autonomy without sacrificing digital rights.

Spain reflects the European Union's general position in the data layer and digital platforms: it depends on foreign infrastructure and services. It lacks large national technology platforms, so user and company data tend to reside on foreign servers, although its language is a strategic strength: Spanish, with more than 500 million speakers, is useful for positioning the country as a benchmark in AI in Spanish[29] .

Research, algorithms and talent: intellectual capital

The fifth step, that of knowledge and innovation capacity, constitutes the intellectual and scientific core of the entire ecosystem. It includes research into algorithms, model development, the generation of intellectual property (patents and software) and, above all, specialised human capital. This level defines which actors create the next generation of technology and with what degree of autonomy. Its intangible nature does not make it any less strategic: it concentrates structural power, since whoever dominates innovation dictates the standards and pace of progress[30] .

The United States has maintained its historical primacy in AI development since the Dartmouth Conference (1956). Institutions such as MIT, Stanford, Berkeley and Carnegie Mellon, together with corporate laboratories (IBM, Google, OpenAI, Microsoft), have marked the progress. China, however, has risen rapidly: in 2020, it already surpassed the US in the number of annual scientific publications on AI,

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[29] *Bank of Spain. Adoption of Artificial Intelligence in Spanish Firms: An Initial Analysis. Economic Bulletin, 25/Q2, 2025*

[30] *European Commission. White Paper on Artificial Intelligence: A European approach to excellence and trust. Brussels, 2020*

although its impact as measured by citations remained lower [31,32] . Meanwhile,

Europe retains a solid academic base, but with less capacity for industrial transfer. *Brain drain* patterns to the United States and the United Kingdom persist, this study examines where researchers find more competitive funding (in public or private sources) and under what conditions.

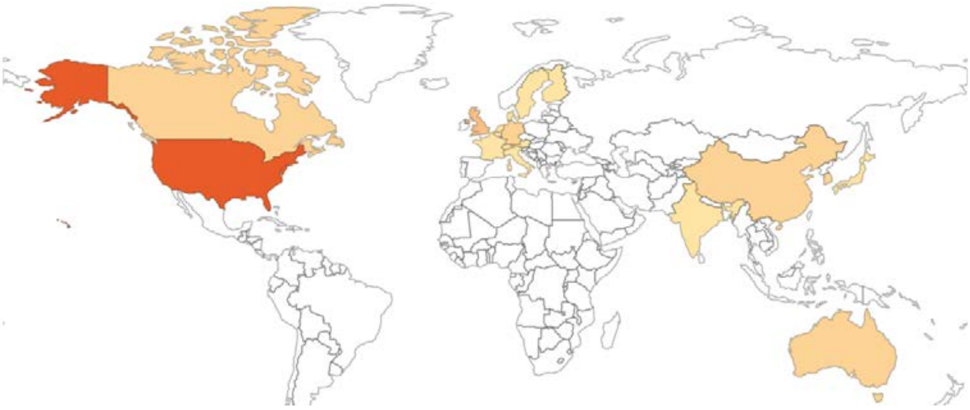

Figure 5: Countries with universities in the Top 100 in AI (own elaboration)

Another point of asymmetry is the financial dimension. In 2023, AI *start-ups* in the US raised nearly $68 billion, compared to $8 billion across the European Union[33] . This imbalance prevents European companies from scaling up quickly and results in early acquisitions by US conglomerates, with notable examples being *DeepMind* (United Kingdom, acquired by Google in 2014) and Vision Factory (Spain, acquired by Apple).

The most qualified specialists are grouped around large corporations with abundant computational resources and the ability to offer high salaries. Google AI, Microsoft Research, Meta AI, Amazon AI, OpenAI, DeepMind and NVIDIA Research monopolise the leading PhDs in AI, displacing universities as hubs of innovation[34] .

The race for AI patents has intensified over the last decade, dominated by American and Chinese corporations. While the scientific publishing paradigm has favoured the rapid dissemination of innovations, the trend towards patenting optimisation algorithms or proprietary architectures could lead to a "legal enclosure" of knowledge.

[31] *Carnegie Endowment for International Peace. The EU's AI Power Play: Between Deregulation and Innovation. Washington D.C., 2025.*
[32] *European Union. State of the Digital Decade Report 2024. Brussels: EU, 2024.*
[33] *Reuters. AI startup investment data 2023: Global distribution. London, 2024.*
[34] *OpenAI. Model access policy change announcement. San Francisco, 2023*

Aware of this, the European Union promotes open standards and free licences as a strategy for technological sovereignty[35] .

Spain occupies an intermediate position in the field of artificial intelligence research and talent. It has a solid academic base, with leading groups at universities such as the Polytechnic University of Catalonia, Carlos III University in Madrid and Pompeu Fabra University in Barcelona, which account for around 5% of European publications on AI[23]. However, its overall scientific impact is limited, and the brain drain to international hubs reduces its critical mass: around 10% of AI master's degree graduates work abroad[28]. At the business level, Spain has a dynamic ecosystem of *start-ups* (such as Sherpa.ai and Satlantis), but few scale globally due to limited domestic venture capital funding [36][37] . Looking ahead, the country needs to increase investment, retain talent and specialise in areas where it has competitive advantages, such as AI in Spanish or applications for tourism and smart cities, in order to move from being a follower with potential to a true generator of technology.

Adoption and market: from the laboratory to the user

The spread of artificial intelligence constitutes the stage of socio-economic impact. Here, the issue is not so much having digital infrastructure, but rather achieving its effective integration into businesses, public administrations and everyday life. In Europe, although the trend is upward, structural gaps persist that reflect differences in business size, productive fabric and human capabilities[38] .

China and the United States lead the way in business adoption (58% and 50% of companies respectively), while Europe remains at around 30%, with greater progress in the Nordic countries than in the south[32]. Spain, despite its digitisation programmes, lags behind in human capital and the intensive use of AI by SMEs.

By sector, information technology and finance lead the way in adoption. In contrast, construction, agriculture and small businesses are progressing slowly, widening the

[35] *World Intellectual Property Organisation (WIPO). AI Patents Landscape Report 2024. Geneva, 2024*
[36] *Datos.gob.es. The State of Innovation and Digital Transformation in Spain. Secretariat of State for Digitalisation and Artificial Intelligence, 2024.*
[37] *European Commission. Use of Artificial Intelligence in Enterprises – Statistics Explained. Luxembourg, 2025.*
[38] *European Union. State of the Digital Decade Report 2024. Brussels: EU, 2024*

internal digital divide[32][39] . In the public sphere, implementation varies between countries and areas, combining advances in digital services with regulatory caution in the face of ethical and transparency risks [40] [41] .

At the citizen level, the emergence of generative AI in 2023 (with ChatGPT and its equivalents) marked a milestone in direct interaction between people and intelligent systems, expanding the educational, creative and work-related use of the technology. However, it also increased social concern about bias, privacy and reliability. At this point, digital literacy and ethical governance emerge as requirements for consolidating public acceptance and maximising the economic and social return on AI [24.]

Conclusions

Artificial intelligence has become one of the most transformative forces in the world. The major technological powers are competing to dominate it, aware that whoever controls the links of its value chain will gain economic, military, and political advantage. Within this context, Spain occupies a particular position: it is integrated into the European and Western economy, yet remains dependent on third parties for several key segments of the AI value chain. However, such dependency is not a fatality. Spain possesses resources, talent, and a favorable political environment that can serve as the foundation for strengthening its technological autonomy.

The first weak link lies in critical raw materials. Globally, China dominates the market for the minerals needed to manufacture technological components—from rare earth elements to gallium and cobalt. The USA and the European Union are trying to reduce that dependence by diversifying supply sources and building strategic reserves. In Spain's case, the situation is delicate: the country does not produce these materials at scale, but it does possess potential resources that could be developed under appropriate environmental criteria. A national strategy for critical raw materials, aligned with the European framework, would make it possible to identify domestic

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[39] European Commission. Artificial Intelligence Act – Proposal. Brussels, 2023
[40] Carnegie Endowment for International Peace. The EU's AI Power Play: Between Deregulation and Innovation. Washington, D.C., 2025
[41] Ministry of Economic Affairs and Digital Transformation. National Artificial Intelligence Strategy. Government of Spain, 2020

deposits, facilitate extraction projects, and promote the recycling of strategic metals. Beyond reducing vulnerability, such a policy would generate employment and reactivate industrial sectors linked to the energy transition.

The second link—semiconductors—reveals intense global competition. Chip manufacturing is concentrated in Asia, mainly in Taiwan and South Korea, which makes Europe a dependent continent. The European Union seeks to correct this imbalance through its "European Chips Act," yet the process will be long. Spain, which lacks large-scale manufacturing facilities, must focus on areas where it can be competitive. The ongoing PERTE Chip project should be complemented by policies that attract foreign investment, create national design centers, and support firms that design chips domestically even if production occurs abroad.

In the field of technological infrastructure, the global race for computing power and energy is equally strategic. Large data centers and supercomputing facilities are essential to train artificial intelligence systems, and their operation demands enormous electricity consumption. Here, Spain holds a notable advantage: it has abundant renewable energy resources, a modern network of interconnections, and internationally recognized supercomputing centers, such as the Barcelona Supercomputing Center. Leveraging this position requires maintaining affordable energy and ensuring sovereignty over critical infrastructures—meaning that data and the systems operating them remain under national control.

Another crucial front in global competition is data control and use. The major technology platforms of the United States and China accumulate vast quantities of information, enabling them to train advanced AI models, while Europe seeks a more balanced and ethical governance model. Sharing data securely and efficiently among companies, universities, and public administrations would make it possible to develop AI solutions tailored to national needs. Promoting open data and clarifying the rules on data collection and reuse would further encourage innovation without fear of sanctions.

Ultimately, the development of knowledge and talent determines who leads the AI revolution. Around the world, major powers are investing heavily to attract the best scientists. Although Spain has high-quality research centers, its innovation ecosystem needs strengthening. Increasing research funding and launching programs to bring back emigratted Spanish talent are essential steps. Encouraging collaboration among universities, businesses, and government, while offering attractive conditions for researchers, would help curb brain drain. Spain can also capitalize on its comparative advantages—such as its high quality of life, climate, and cultural appeal—to retain and attract talent.

The final link in this chain is the widespread adoption of technology. In many countries, AI has been integrated into small and medium-sized enterprises and public administration, boosting productivity and improving services. In Spain, this process remains uneven. Facilitating SME digitalization through guidance, incentives, and training is vital to ensure that AI's benefits do not remain confined to large corporations. Programs for worker reskilling, support for automation, and public procurement clauses rewarding responsible AI adoption would foster diffusion. Additionally, an observatory assessing AI's impact on employment would help adapt labor policies to new technological realities.

Taken together, the challenges Spain faces mirror a global trend: the transition from an economy dependent on imported technology to one that seeks to produce, control, and adapt it to its own needs. Technological autonomy does not mean isolation; it means the ability to choose partners and define the terms of cooperation. Spain must harness its European integration, energy potential, and human capital to turn its current weaknesses into opportunities for long-term strategic development.

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