

# Dependencies and Power in the Digital Economy: A Deep Dive into the Global Technology Value Chain

## The Foundations of Control: Raw Materials, Refining, and the Chinese Dominance

The digital economy's immense value is built upon a foundation of physical materials, whose extraction and processing are fraught with geopolitical risks and economic concentration. China has masterfully constructed a vertically integrated monopoly over this foundational layer, creating a strategic choke point that gives it outsized influence over the entire technology supply chain. This dominance extends from raw mineral extraction to the complex chemical refinement processes required for advanced semiconductors, effectively placing the control levers for modern electronics in the hands of a single nation.

China's control is most pronounced in the realm of rare earth elements (REEs), a group of 17 chemically similar metallic elements critical for magnets, batteries, and other electronic components. As of 2024-2025, China controlled approximately 69-70% of global REE mine production, with its state-planned quotas accounting for 270,000 metric tons of rare earth oxide (REO) equivalent<sup>19 20</sup>. While the United States was the second-largest producer at 11.5%, it produced only 45,000 metric tons<sup>20 21</sup>. More critically, China dominates the downstream processing, refining between 85% and 90% of the world's total REEs<sup>19 23</sup>. This near-total control over both mining and processing means that even when Western nations like the U.S. successfully extract these minerals, they often lack the domestic capacity to refine them, forcing them to export the raw ore to China for processing<sup>23</sup>. In 2024, China imported 129,500 metric tons of REEs, primarily from Burma (Myanmar) and Malaysia, before exporting finished products like magnets back to the West<sup>20</sup>.

This strategic advantage is not limited to rare earths. China also controls an estimated 70% of global rare earth magnet production and 90% of the capacity to process them<sup>19</sup>. These magnets are essential for electric motors in EVs and wind turbines, as well as for hard disk drives. In 2024, China exported nearly 6,000 metric tons of REOs and a massive 58,142 metric tons of rare earth magnets, with Germany, the U.S., South Korea, and Vietnam being top importers<sup>20</sup>. This complete end-to-end control allows China to dictate prices, manage supply, and leverage its position geopolitically. It has demonstrated this power through new export controls on certain medium and heavy REEs effective April 4, 2025, which disrupted global supply chains and halted production at major companies like Ford and Suzuki<sup>20</sup>. Further, a new policy effective December 1, 2025, requires foreign firms to get licenses to export products containing Chinese-sourced minerals or made with Chinese technology, tightening China's grip even further<sup>19</sup>.

While China reigns supreme in minerals, other countries and regions hold significant sway in different material categories. For instance, Japan and South Korea are key players in the chemical refinement of ores and gases used in semiconductor manufacturing. Companies like Sumitomo, Mitsubishi Materials, Shin-Etsu, and Wacker Chemie dominate this space, with Japan and Germany serving as major hubs for this critical intermediate stage<sup>56</sup>. However, China's overall dominance in the upstream supply chain creates a systemic dependency; without access to refined materials, even advanced equipment and fabrication capabilities are rendered useless. The capital intensity and technical complexity of building non-Chinese processing capacity are enormous, with experts estimating it will take 10 to 15 years for the U.S. and its allies to build a self-sufficient supply chain despite recent policy actions and funding pledges<sup>19 23</sup>. This reality underscores how control at the raw material level translates directly into strategic power across the entire digital economy. The table below summarizes the market share and control dynamics for key raw materials and their processing.

Material Category	Key Country/ Region	Market Share / Control Level (Latest Data)	Key Companies Mentioned	Citations
Rare Earth Elements (REE) - Mining	China	~69-70% of global production	China Rare Earth Group, China Northern Rare Earth Group	19 20
Rare Earth Elements (REE) - Processing	China	~85-90% of global capacity	State-owned enterprises under MIIT, MNR, NDRC	19 23
Silicon Metal	China	Dominant producer	Not Available in Provided Sources	6
Graphite	China	Major producer and processor	Not Available in Provided Sources	6
Lithium, Cobalt, Nickel	DRC, Chile, Australia, Indonesia	Significant reserves and production	Glencore, Albemarle, SQM, CMOC	6
Refining & Chemical Processing	Japan, South Korea, Germany	Specialized, high-value processing	Sumitomo, Mitsubishi Materials, Shin-Etsu, Wacker	56

## The Engine of Innovation: Semiconductor Equipment and the Dutch Monopoly

Beneath the surface of the semiconductor industry lies a fiercely competitive and highly concentrated market for the tools and machines that make advanced chips possible. This "Equipment & Materials for Semiconductors" stage is the engine of innovation, where technological breakthroughs in lithography and materials science enable the relentless pace of Moore's Law. At the apex of this engine stands ASML Holding N.V., a Netherlands-based company that holds a near-monopoly on

the most critical component of all: Extreme Ultraviolet (EUV) lithography systems. This singular choke point grants ASML extraordinary strategic power, making it one of the most important companies in the world, regardless of its small geographic footprint.

ASML commands an estimated 90% of the global lithography equipment market, a figure that highlights its overwhelming dominance<sup>42</sup>. Its EUV machines are not just another piece of factory equipment; they are the indispensable tool for producing the most advanced chips that power everything from AI accelerators to smartphones. Foundries like TSMC, Samsung, and Intel rely on ASML's technology to etch circuits at the nanometer scale, a feat impossible with older Deep Ultraviolet (DUV) methods alone<sup>39</sup>. This dependency is so profound that there is a historically strong correlation (+0.85) between TSMC's capital expenditures and ASML's revenue, with a six-quarter lag, demonstrating how investment decisions at the world's leading foundry directly fuel ASML's growth<sup>39</sup>. With plans to install thousands of these machines by 2030 to meet surging demand for AI hardware, ASML's importance is set to grow exponentially<sup>42</sup>.

ASML's financial performance reflects its dominant market position. The company reported Q3 2025 net sales of €7.5 billion, a gross margin of 51.6%, and a net income of €2.1 billion, showcasing exceptional profitability<sup>2 40</sup>. Analysts have projected long-term growth, forecasting annual sales to reach between €44 billion and €60 billion by 2030, a significant increase from the projected €32.5 billion for 2025<sup>9 41 42</sup>. This outlook is supported by robust order books, with net bookings reaching €5.4 billion in Q3 2025<sup>40</sup>. However, ASML is not immune to geopolitical risk. U.S. and Dutch export controls severely restrict sales of its most advanced EUV systems to customers in China, a market that had accounted for up to 15% of its sales in previous years<sup>9 41</sup>. The company now anticipates a significant decline in demand from China in 2026, which could impact its revenue streams<sup>2 40</sup>.

ASML's monopoly is sustained by astronomical R&D investments and a decades-long head start. The development of EUV technology required solving immense scientific and engineering challenges, including the creation of a powerful plasma light source and specialized mirrors (in partnership with Carl Zeiss)<sup>43</sup>. This has erected a formidable barrier to entry, leaving competitors far behind. While the U.S. companies Applied Materials and Lam Research, and the Japanese firm Tokyo Electron, are also leaders in the broader semiconductor equipment sector, none possess a comparable monopoly on a single, irreplaceable technology<sup>13</sup>. Tokyo Electron, for example, holds a 90% global market share in photoresist coater/developer systems, another crucial but less monopolistic segment<sup>7</sup>. The concentration in this stage is therefore characterized by a clear leader (ASML) who sets the pace of technological advancement for the entire industry, while others compete in adjacent, albeit vital, areas. This structure makes ASML a primary target for industrial policies aimed at reshoring advanced manufacturing capability, such as those in the U.S. CHIPS Act and the EU Chips Act, as replicating its technology is considered impossible<sup>5</sup>.

# Fabrication Frenzy: The Taiwanese Foundry and the Race for Process Leadership

The semiconductor foundry market represents the physical heart of the digital economy, where the intricate designs created by fabless chip companies are transformed into tangible silicon wafers. This stage has become a hyper-competitive arena dominated by a handful of colossal players, led by Taiwan Semiconductor Manufacturing Company (TSMC). TSMC's stranglehold on the market for advanced, leading-edge chips is not just a matter of market share; it constitutes a critical geopolitical choke point, giving the island nation and its premier foundry immense strategic leverage over the global tech ecosystem. The race for process leadership—manufacturing chips on smaller and more efficient nodes—is the central narrative defining this competitive landscape.

TSMC's dominance is staggering. As of 2024, the company held 62% of the global pure-foundry market share, a figure that grew to 63% in Q1 2024 and 71% in Q2 2025<sup>10 11</sup>. Another analysis covering the broader "Foundry 2.0" market, which includes packaging and photomasks, showed TSMC with a 35% share in Q1 2025<sup>37</sup>. This concentration means that a vast majority of the world's most powerful processors, including GPUs from NVIDIA and AMD, are manufactured exclusively at TSMC's fabs in Taiwan. The company's founder, Morris Chang, has stated that TSMC has no real competitors, noting that nearly all global AI chip customers are under its control<sup>15</sup>. This leadership is driven by its early and aggressive investment in cutting-edge technologies. TSMC's 3nm process reached full capacity in 2024, and its 2nm process is on track for mass production in 2025, offering significant performance and power-efficiency gains over its rivals' offerings<sup>10</sup>. Its key clients, accounting for over 70% of its revenue, include U.S.-based firms like NVIDIA, Apple, Broadcom, and Amazon, cementing a deep economic interdependence<sup>15</sup>.

The competition for this leadership is intense, yet fragmented. Samsung Electronics, traditionally a formidable rival, has seen its share slip to 10% in 2024 and is projected to fall below 10% by 2025 due to technical yield issues and a perceived lack of strategy<sup>10 15</sup>. The company does produce a competitive 3nm process, but it lags TSMC in adoption and volume<sup>10</sup>. The third-place contender, SMIC of China, faces severe constraints due to U.S. sanctions that limit its access to advanced equipment and technology. Despite this, it reportedly produces Huawei's 5nm Kirin X90 chip using 193nm immersion lithography, a remarkable feat of engineering under duress, though with low yields<sup>34</sup>. Other players like GlobalFoundries, UMC, and Vanguard maintain smaller shares, primarily focused on mature processes or niche markets<sup>11 34</sup>. The table below details the market share and key developments among the top foundries.

Foundry	2024 Market Share (%)	Key Developments & Strategy	Top Customers	Citations
TSMC	62% (Pure-Foundry) / 71% (Foundry 2.0)	Leading node: 2nm process for mass production in 2025. Expanding capacity in Taiwan	NVIDIA, Apple, Broadcom,	10 15 18

Foundry	2024 Market Share (%)	Key Developments & Strategy	Top Customers	Citations
		and the U.S. Strongest customer relationships in AI.	Amazon, Google, Meta	
Samsung	10% (Pure-Foundry) / 7.2% (Q2 2025 Foundry 2.0)	3nm process shipping since 2022. Developing 2nm process with MBCFET technology. Faces yield challenges.	Not specified in sources	<a href="#">10 33 37</a>
SMIC	6% (Q2 2025 Pure-Foundry)	Advanced process (5nm) in pilot production with low yields. Heavily sanctioned by the U.S. Producing Huawei's 5nm chip via workaround.	Huawei (domestic focus)	<a href="#">11 34 36</a>
GlobalFoundries	5% (Q1 2024 Pure-Foundry)	Investing \$16B in U.S. fabs and packaging. Focus on specialty and mature processes.	Not specified in sources	<a href="#">14 34</a>
UMC	5% (Q1 2024 Pure-Foundry)	New Singapore fab for 22nm/28nm will begin volume production in 2026.	Not specified in sources	<a href="#">11 34</a>

This intense competition is mirrored in the market capitalization of these firms. TSMC's valuation of \$1.496 trillion makes it the world's most valuable semiconductor company <sup>17 35</sup>. Samsung (\$413B), Nvidia (\$4.558T), and ASML (\$389B) are also among the top global semiconductor firms by market cap, underscoring the immense wealth generated by leadership in this field <sup>17 35</sup>. However, the true measure of power lies in controlling the future of chip manufacturing. Here, TSMC's lead is unassailable, making the stability and security of Taiwan a paramount concern for the entire global digital economy.

## The Vertical Integration of Power: From Design to Advanced Packaging

The digital technology value chain is characterized by a complex web of specialization and vertical integration, where power is distributed unevenly across design, fabrication, and assembly stages. A critical trend shaping this dynamic is the increasing vertical integration by the leading foundry, TSMC. By controlling not just the core fabrication process but also the final assembly, testing, and packaging (ATMP) of chips, TSMC is capturing more layers of the value chain, solidifying its market dominance and creating a formidable barrier to entry for competitors. This move transforms the foundry model from a simple service provider into a comprehensive manufacturing powerhouse, exerting influence over the entire lifecycle of a digital product.

The design and intellectual property (IP) stage is largely a fabless operation, with companies like NVIDIA, AMD, Qualcomm, and Apple designing cutting-edge chips that are then manufactured by

foundries<sup>13 16</sup>. These fabless giants capture significant value through their innovative designs and software ecosystems, but they remain dependent on the manufacturing prowess of others. NVIDIA, for example, generates massive data center revenue, powering most generative AI models, yet relies entirely on TSMC for the production of its GPUs<sup>14 16</sup>. This creates a symbiotic but asymmetrical relationship: the designer needs the fabricator, but the fabricator can increasingly serve multiple designers, consolidating its power.

The true shift in power dynamics is occurring in the ATMP stage. Traditionally, this work was handled by independent specialists like ASE, Amkor, and JCET, particularly for consumer electronics<sup>1</sup>. However, TSMC has aggressively expanded its own ATMP capabilities, most notably through its CoWoS (Chip-on-Wafer-on-Substrate) advanced packaging technology. CoWoS is a critical solution for integrating multiple chiplets—smaller, specialized chips—into a single package, which is essential for creating powerful, multi-chip AI accelerators. TSMC has committed to doubling its CoWoS capacity from 330,000 wafers in 2024 to 660,000 wafers in 2025, driven almost entirely by demand from NVIDIA, AMD, AWS, and other cloud providers<sup>18</sup>. This strategic expansion allows TSMC to capture the high-margin profits associated with this sophisticated technology, directly competing with and putting pressure on dedicated ATMP firms. In fact, constrained advanced packaging capacity has allowed some ATMP players like ASE and UMC to gain ground, but TSMC's vertical integration is a clear threat to their long-term viability<sup>37</sup>.

This vertical integration strategy is a calculated move to secure its customers and deepen its moat. By offering a one-stop-shop for everything from wafer fabrication to final packaging, TSMC reduces the incentive for its key clients, like NVIDIA, to diversify their manufacturing base or invest heavily in developing their own packaging solutions. It effectively internalizes a crucial part of the value chain, capturing profits that would otherwise go to specialized partners. This is further evidenced by TSMC's ownership of the world's largest photomask manufacturer, another critical and high-cost component in the fabrication process<sup>37</sup>. The result is a vertically integrated giant that controls a larger portion of the end-to-end manufacturing process than any of its competitors. This consolidation of power from design through packaging is a fundamental structural change in the industry, concentrating more economic and strategic control within a single entity and making the global reliance on TSMC for advanced technology even more acute.

## The Cloud and AI Arms Race: Capturing Value in Software and Infrastructure

At the pinnacle of the digital technology value chain lie the software and infrastructure layers, where immense computational power is harnessed to create transformative applications like artificial intelligence. This stage is defined by a fierce arms race between a handful of colossal cloud providers and AI developers, who are engaged in a bid to out-invest and out-innovate one another. The battle is not just about creating better models but about securing the underlying compute resources—the servers, data centers, and networking fabrics—that make them run. This has led to unprecedented levels of investment and a dramatic shift in how value is captured, moving away from traditional software licensing towards a capital-intensive model centered on hardware procurement and energy consumption.



The primary battleground is the AI chip market, where NVIDIA has achieved an astonishing 80% market share, supplying the GPUs that form the backbone of nearly all modern AI training and inference <sup>51</sup>. This positions NVIDIA as a critical supplier to the entire AI ecosystem, with major cloud providers like Microsoft, Google, and Amazon accounting for half of its data center revenue <sup>51</sup>. In response to explosive demand, these companies are engaging in a massive build-out of data centers. McKinsey forecasts that \$6.7 trillion will be spent globally on data centers by 2030, with 60% of that allocated to chips and computing hardware <sup>42</sup>. OpenAI, for instance, has announced a plan to spend \$500 billion over four years on AI infrastructure in the U.S., while Meta and Google are building out fleets of H100 GPUs to power their models <sup>49 59</sup>. This capital expenditure is financed by a combination of internal funds and commitments from partners like NVIDIA, which has pledged up to \$100 billion in investment <sup>51 56</sup>.

The cloud infrastructure providers—Amazon Web Services (AWS), Microsoft Azure, and Google Cloud—are the ultimate enablers of this revolution, providing the scalable compute platforms on which AI models and other digital services are built. Their combined revenue dwarfs that of any individual semiconductor company. The table below shows the revenue of key players, highlighting the immense scale of the cloud and AI leaders.

Company	Revenue (Annualized Run Rate or Fiscal Year End)	Key Context	Citations
OpenAI	\$13B (Projected 2025 Run Rate)	Projected to be the first AI developer to reach \$100B in revenue by 2028.	<sup>48 51</sup>
Google	\$29.2B (Q2 2025)	Revenue from Google Cloud and other ads/services.	<sup>57</sup>
Microsoft	\$22.5B (Q2 2025)	Driven by Azure cloud platform and enterprise software.	<sup>57</sup>
Alibaba Cloud	\$11.2B (Q2 2025)	Revenue from cloud computing and related services.	<sup>57</sup>
Meta Platforms	\$35.2B (Q2 2025)	Revenue from social media advertising and VR hardware.	<sup>47</sup>
TSMC	\$23.53B (Q3 2024)	Revenue from chip manufacturing services.	<sup>10</sup>
AMD	\$12.7B (2024 Revenue)	Revenue from CPU, GPU, and server chip sales.	<sup>53</sup>

However, this race for computational supremacy comes at a steep cost. The electricity consumption of fabs is expected to reach 237 TWh globally by 2030, while data center consumption alone is projected to exceed 1,000 TWh by 2026 <sup>14</sup>. This has led to a new kind of strategic constraint: power availability. Microsoft CEO Satya Nadella has publicly stated that his company faces power, not chip, constraints for scaling its AI workloads <sup>14</sup>. This shifts the locus of power from silicon to energy grids,

creating a new potential choke point where geopolitical control over energy infrastructure becomes as critical as control over chip fabs. Furthermore, the business models of the leading AI developers are paradoxical. OpenAI, despite its projected \$13 billion in 2025 revenue, reported a net loss of \$13.5 billion in the first half of 2025 and is projected for cumulative losses of \$44-\$92 billion through 2028<sup>49 53 54</sup>. Anthropic, valued at \$183 billion after a massive funding round, earns significantly higher API revenue per token than its competitors but is also priced as a premium, safety-focused service<sup>58 60</sup>. This indicates that value capture in this stage is not yet fully realized through profit but is instead channeled into securing market share, attracting talent, and accumulating assets for the next phase of the AI arms race.

## Geopolitical Levers: Industrial Policy and the Shifting Balance of Power

The intricate dependencies woven into the digital technology value chain have made it a central theater of geopolitical competition. Nations are no longer content to let market forces determine the balance of power; instead, they are deploying industrial policies, subsidies, and regulations as active levers to reshape the global landscape in their favor. This strategic intervention is clearest in the race to re-shore and strengthen semiconductor manufacturing, with the United States, European Union, and China pursuing ambitious, state-supported strategies that are fundamentally altering the structure of global supply chains and creating new blocs of technological rivalry.

The United States has been the most aggressive actor in this domain, launching the most significant industrial policy initiative in the sector's history with the CHIPS and Science Act of 2022. This legislation authorized \$52.7 billion in incentives, with \$39 billion targeted at boosting domestic chip manufacturing and R&D<sup>5</sup>. The direct financial impact is substantial: Micron secured over \$6 billion in CHIPS Act funding for new fabs, Texas Instruments received \$4.6 billion in grants and loans, and Intel received \$19.5 billion in grants and loans, plus a 10% equity stake in the U.S. government<sup>13</sup>. This influx of public capital is intended to spur over \$600 billion in private investment and increase U.S. manufacturing capacity from 10% of the global total in 2025 to 14% by 2032<sup>5 13</sup>. The act also includes provisions for grants for semiconductor machinery and supply chain improvements, directly targeting the U.S.'s vulnerability to export tariffs and its dependence on foreign equipment suppliers<sup>5</sup>.

In parallel, the European Union is implementing its own strategy with the EU Chips Act, which aims to boost Europe's share of global chip manufacturing to 20% by 2030. A cornerstone of this effort is the Critical Raw Materials Act, which seeks to have 40% of the bloc's annual rare earth processing occur within the EU by 2030, reducing reliance on China<sup>19</sup>. This policy push is reflected in corporate activity, such as Solvay launching a new rare earth magnet production line in France and the opening of Europe's first such facility in Estonia<sup>19</sup>. These initiatives signal a clear European intent to build a more resilient and sovereign technology base.

On the other side of the Pacific, China is pursuing a classic industrial policy under its "Made in China 2025" strategy, which explicitly targets dominance in advanced manufacturing, including semiconductors. The government provides massive subsidies and support to domestic champions



like SMIC, aiming to close the technology gap with global leaders<sup>13</sup>. China's goal is to increase its share of advanced process manufacturing from 6% in 2023 to 8% by 2027, while continuing to dominate the mature process market with a projected 40% share<sup>38</sup>. This state-led approach is complemented by China's use of export controls, which it implemented in 2025 on dual-use items and later on REEs, demonstrating its willingness to weaponize its supply chain strengths<sup>20</sup>.

These national strategies are fostering the formation of new alliances and blocs. The most prominent is the emerging U.S.-led coalition with its democratic partners, particularly the Netherlands (home of ASML) and Japan (a key materials and equipment supplier), to coordinate export controls and ensure that advanced technology does not flow to China<sup>41 45</sup>. A \$8.5 billion pact signed between the U.S. and Australia in October 2025 to jointly invest in rare earth projects exemplifies this cooperative approach<sup>19</sup>. Conversely, China is strengthening its own network of resource partnerships, particularly with countries in Africa and Latin America, to secure the raw materials needed for its ambitions. The result is a bifurcation of the global technology ecosystem, where economic efficiency is increasingly subordinated to strategic imperatives of security and sovereignty, locking nations into competing, partially overlapping supply chains.

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