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GUY WARD-JACKSON
KEEGAN MCBRIDE



Technological Chokepoints: How to Balance Resilience and Leverage in a Weaponised Economy

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Contributors: Mathew Sim, Tom Smith, Jeegar Kakkad

Executive Summary

It is not possible for leaders to opt out of the technological revolution. Innovation, scientific advancements and the development and diffusion of frontier technologies are the fundamental building blocks of prosperity and power. Yet, as well as a source of growth, technology is also an arena for competition and conflict. Technological “chokepoints”,¹ meaning key frontier technologies or nodes in broader supply chains, can be disrupted or exploited.

There is therefore a paradox: being part of this interdependent technological economy is necessary for competitiveness, security and building state capacity but, for precisely that reason, it is also an unequivocal source of vulnerability that must be grappled with.

Although chokepoints are not a new concept, decades of extensive globalisation have made technological interdependence permanent. The rapid rise of dual-use technologies such as artificial intelligence impacting competitiveness and national security, along with the resurgence of great-power rivalry over the past decade centred on technology, have enhanced the significance of this interdependence.

For middle powers, developing the agency required to navigate this technological interdependence is critical to enhancing economic prosperity and ensuring national security. To do this, leaders will be required to balance three competing priorities:

- **Resilience:** Individual countries must ensure that their economy, government and security are resilient in the face of potential disruption when trying to access key frontier technologies, regardless of the cause.

- **Leverage:** Securing a place at the global table means developing a strategy, leveraging comparative advantages and actively working to develop key points of influence in the global supply chains of both frontier and basic foundational digital technologies.
- **Openness:** The catch is that technological security cannot be achieved without economic competitiveness. Attempts to attain full-stack technological self-sufficiency might boost resilience, but they also limit opportunities to build genuine influence. Therefore, middle powers should develop strategies to increase resilience and leverage in specific areas while remaining committed to free markets and integration.

The main challenge for leaders of middle powers is therefore one of prioritisation. They must understand where they can develop leverage within the broader global supply chain, where they need to rely on external providers and where to build resilience and optionality – all while remaining embedded in global supply chains and ensuring access to frontier technologies.

The TBI Chokepoints Framework

This report introduces the TBI Chokepoints Framework, which is intended to assist leaders in facing this challenge. It is a means for policymakers to determine which areas of technological security and leverage to prioritise, where to intervene and, just as importantly, where not to – thereby balancing security with competitiveness.

The framework consists of three main measures:

- **Exposure:** How structurally dependent a country is on a given technological component or layer, and how difficult substitution would be in the event of disruption.
- **Strategic importance:** The national-security relevance, systemic economic impact and importance to long-term innovation trajectories if access to a technology is lost.

- **Feasibility:** Can a country realistically build domestic capacity, utilise supply-chain leverage or meaningfully diversify and influence the market through procurement or standards?

By applying the framework to various technologies, policymakers can prioritise and de-prioritise intervention areas – and develop strategic positions for different technological chokepoints. These strategic postures include:

- **Managed dependence:** High exposure and high importance, but little room for manoeuvre. Avoid sovereign replication and focus instead on reducing lock-in and ringfencing the most sensitive uses.
- **Targeted intervention:** High exposure and high importance, with practical levers in place. Act selectively on key nodes using procurement, standards and allied coordination, rather than pursuing full self-sufficiency.
- **Pre-emptive shaping:** High importance but market structure still fluid. Intervene early to anchor capability before path dependencies set in.
- **Avoid securitisation:** High exposure but low strategic importance. Restraint is the rational choice; not every chokepoint is existential.
- **No strategic action:** Low exposure and low importance. Normal trade and competition policy are sufficient.
- **Leverage as deterrence:** When others are exposed to a chokepoint that a leader's country controls, that leader should preserve leverage within allied coalitions and use it as deterrence, not a routinely deployed weapon.

Ultimately, technological security depends on economic competitiveness in the long term. In a hard-power world, the need to build resilience and leverage should be taken seriously. But without a clear strategy, leaders risk over-securitising technologies, distorting markets and investing in areas where meaningful leverage and resilience cannot be built. Only a clear strategy and prioritisation can enable leaders to build resilience in today's interdependent technological economy, while preserving the openness and competitiveness on which long-term security depends.

01

Technology and Weaponised Interdependence

Power and influence matter. And in today's world, how powerful a country is is hugely dependent on the strength of its science and technology innovation ecosystem, whether that means actively adopting frontier technologies or building a stake in global supply chains.

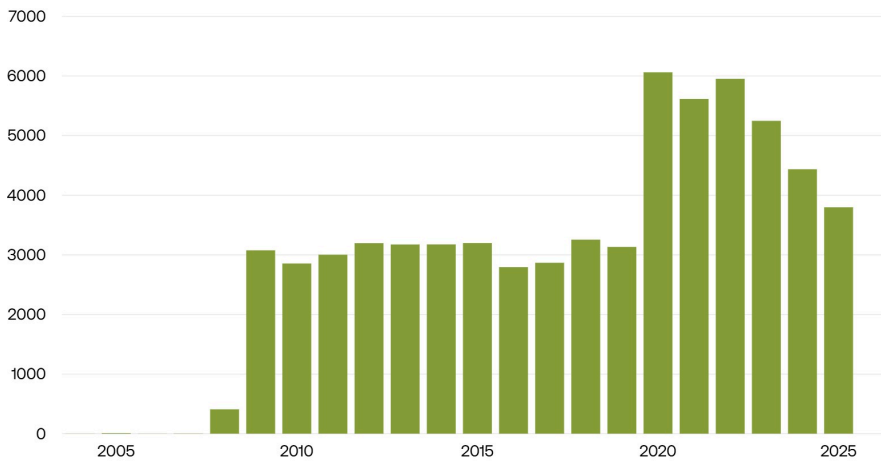
Of course, interdependence, geopolitical rivalry and the use of “chokepoints” are nothing new; the 1970s oil shocks, for example, demonstrated how control over a critical resource could be turned into a geopolitical weapon, forcing a fundamental rethink of energy security.² However, the situation today is more extreme. Advanced technologies are (and will become even more) integrated into every layer of the modern economy, from how governments deliver services to how militaries carry out operations. The network effects that result from advanced technologies create dependencies far more complex than those of traditional commodities – and are much harder to dismantle. The pace of change is accelerating, with new systems appearing faster than policymakers can respond; this narrows the window of opportunity to build resilience and leverage.

That, in turn, creates a fundamental tension: the widespread adoption of advanced technologies is essential for economic growth and state capacity, but also introduces new forms of vulnerability. Events over the past decade have made this clear: the 2018 Huawei debate forced governments to confront the security implications of foreign-built digital infrastructure; the Covid-19 pandemic exposed the fragility of global supply chains, from semiconductors to pharmaceuticals. More recently the rapid emergence of generative AI has triggered a new phase of technological competition, accompanied by tighter controls on advanced chips and AI systems. This means that the boundaries between technology, economics and national security have become increasingly blurred.

This is reflected in the data: since the 2000s, harmful trade interventions have increased by more than two orders of magnitude³ and more than half of the high-tech exports between major countries are now subject to some form of export restriction.⁴ This technology-focused economic statecraft is concentrated around the US and China.

FIGURE 1

Globally, the number of harmful trade interventions has increased significantly since 2005

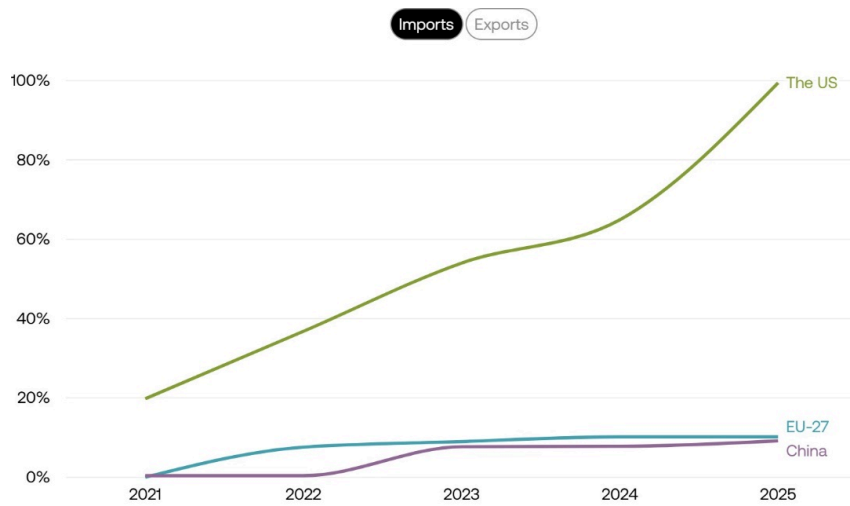


Source: Global Trade Alert

Canadian Prime Minister Mark Carney captured the moment as part of his Davos address in early 2026.⁵ “Great powers,” he argued, “have begun using economic integration as weapons, tariffs as leverage, financial infrastructure as coercion, supply chains as vulnerabilities to be exploited.” However, while this diagnosis is increasingly accepted, no strategy has emerged.⁶

FIGURE 2

More and more imports are covered by policies that are motivated by national security or geopolitical concerns, particularly in the US

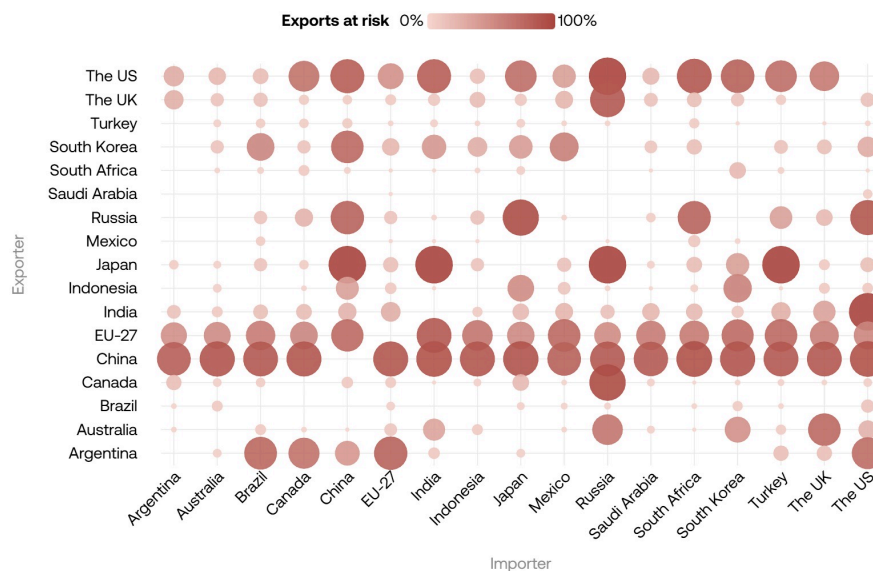


Source: Global Trade Alert

This is not a “rupture”, in that technology has always determined power – and power has always shaped the international order. Still, it has reignited a shared recognition that in the current technological revolution, countries must do more.

FIGURE 3

A large share of global high-tech trade is now at risk of export restrictions



Source: Global Trade Alert

There is a growing tendency to treat technologies as matters of national security, without a clear framework for distinguishing which dependencies are truly consequential, which are manageable and which should be left to markets. This risks countries underreacting *and* overcorrecting: failing to address real vulnerabilities while simultaneously distorting markets or investing in areas where meaningful influence cannot be established.

This challenge is particularly acute for middle powers, which cannot eliminate technological dependence entirely. As outlined in [Sovereignty in the Age of AI: Strategic Choices, Structural Dependencies and the Long Game Ahead](#), replicating entire technology stacks domestically is economically infeasible. In addition, overbearing state intervention can stifle competitiveness and the opportunity costs mean that public money put towards pursuing frontier technological capability could be better spent: on schools, health care and defence, for example.

Perhaps most importantly, to retreat into protectionism is to misunderstand the dynamics of power. Technological interdependence, when deliberately managed, is not a weakness but the means by which leverage and resilience can truly be built – within, not outside, the global economic system.⁷

02

The TBI Chokepoints Framework

Effectively navigating the trade-offs between sovereignty and mutual reliance requires leaders to understand where dependencies are most consequential, where they can realistically shape outcomes and where restraint is the more effective strategy.

To assist leaders with these challenges, from this point on our report doubles as a framework that addresses a core challenge that does not feature in contemporary debates on technological sovereignty and security: prioritisation. How can countries prevent every dependency from being treated as existential, while still acting decisively where risks are genuinely consequential and the dial can be turned? The framework facilitates qualitative assessment, evidence-based risk scoring and subjective judgement to aid leaders' high-level decision-making (the [annex](#) at the end of this paper includes the full methodology).

FIGURE 4

TBI Chokepoints Framework: risk scoring

Indicator	Risk score (1-5)
Exposure	
Substitutability	1 = Many global alternatives 5 = No viable substitutes
Time to replace	1 = Weeks/months 5 = Multi-year/infeasible
Supplier concentration	1 = Diversified supply 5 = Monopoly/chokepoint
Switching costs	1 = Low friction 5 = Prohibitively costly
Strategic importance	
Dual-use significance	1 = No security relevance 5 = Core national security use
Political alignment of suppliers	1 = Closely aligned allies 5 = Adversarial states
Systemic impact	1 = Limited sectors 5 = Economy-wide disruption
Innovation trajectory	1 = Marginal relevance 5 = Foundational to future competitiveness
Feasibility	
Domestic-build feasibility	1 = Cheap and fast 5 = Infeasible
Allied diversification	1 = Easy via allies 5 = No viable partners
Market-shaping feasibility	1 = Strong market power 5 = No market power
Cross-supply-chain leverage	1 = Reciprocal leverage 5 = One-way dependence

Source: TBI

We also show how this framework can be applied. It does not exist to produce a definitive ranking of technologies, predict supply-chain shocks or act as a substitute for detailed quantitative sectoral modelling. It is designed to support an adaptable way of thinking over time, rather than being a one-and-done model. It evaluates technology domains and dependencies across three axes: exposure, strategic importance and feasibility of intervention. Together, these axes are intended to capture both the nature of the risk and the practicality of a policy response.

- **Exposure:** This captures the extent to which a country is structurally dependent on a given technology domain and how fragile that dependency would be if disrupted (based on factors such as concentration of supply, substitutability, switching costs and time to replace). It describes the structure of dependence itself, not the

consequences of disruption. A high level of exposure does not automatically justify intervention: it depends on what is at stake and whether the dependency can realistically be mitigated.

- **Strategic importance:** Reflects how critical any given technology is to national objectives. This includes its economic role, relevance to national security and the number of sectors or critical services that depend on it. Some technologies are strategically important not because of their current footprint, but because they could underpin future innovation.
- **Feasibility:** Assesses whether governments can realistically do anything to change the risk profile of a dependency. This depends on the policy tools available, the presence of domestic or allied capabilities, and whether intervention would be effective, futile or distortive.

The point is to force explicit trade-offs. The value of the framework lies in the fact that it can help with the creation of a method for making these distinctions explicit and consistent; this raises the standards for what constitutes a genuine chokepoint and makes it more difficult for ineffective interventions to go unchallenged.

Crucially, the framework is designed to be flexible. This is because dependencies are likely to change and governments need to be proactive if they are to seize early advantages or build pre-emptive resilience; analysis that focuses on *current* technologies and chokepoints will be limited. Rather than freezing policy around static sector lists or fixed technology stacks, the framework enables governments to reassess priorities as technologies, supply chains and geopolitical conditions evolve. It is also critical that leaders do not solely seek to change dependencies that have already set in; being future-facing about opportunities for resilience and leverage is key.

From Assessment to Policy Direction

Leaders rarely face a simple choice between intervention and inaction. The decision should not be between fully fledged industrial policy or nothing at all, but rather a spectrum of postures. To account for this, the TBI Chokepoints Framework demonstrates how different combinations of

exposure, strategic importance and feasibility lead to different policy directions. The table below sets out the most common configurations and the responses they are likely to necessitate.

FIGURE 5

Decisions about policy direction must account for several factors

Strategic posture	Exposure	Importance	Feasibility constraints	Policy direction
Managed dependence	High	High	High	Structural dependence but low room to manoeuvre. Avoid sovereign replication; reduce lock-in and protect critical uses.
Targeted intervention	High	High	Low/medium	Act selectively where levers exist. Focus on key nodes; use procurement, standards and allied coordination.
Avoid securitisation	High	Low	Any	Do not inflate the threat. Monitor commercially and avoid unnecessary industrial-policy escalation.
Pre-emptive shaping	Low/medium	High	Low	Window still open. Intervene early to anchor capability and prevent future lock-in.
Preserve integration	Low	High	High	Maintain diversified access and trusted partnerships. Avoid distortion where influence is limited.
No strategic action	Low	Low	Any	Normal trade, competition and innovation policy are sufficient.
Leverage as deterrence (framework flipped)	Others highly exposed	High (for them)	Low	Preserve and embed leverage within aligned coalitions. Avoid overuse that accelerates substitution or weakens competitiveness.

While this framework is primarily analytical, executing decisions with the intention of increasing resilience and leverage will require governments to have real and permanent state capacity. While the setup will vary, the institutional capacity needed to map technological resilience demands four core attributes:

1. **Centralisation:** State capacity must sit at the core of executive power, not dispersed across trade, security and industrial departments that each have only partial visibility and no authority to enforce trade-offs.

2. **Forward orientation:** The dependencies that will matter most (and where governments have the most agency) are those that are not yet fully formed. Capacity that only maps existing vulnerabilities has, to some extent, already failed its purpose. The function must be explicitly anticipatory.
3. **Prioritisation as a primary mandate:** The role is not to catalogue every vulnerability, but to make solid judgements about which dependencies genuinely require intervention and which do not. The ability to say no – and resist sustained pressure from well-funded stakeholders seeking to frame commercial interests as national security imperatives – is as operationally important as the ability to act.
4. **Structured engagement with the private sector:** Firms operating within critical supply chains will typically have earlier and deeper insight into where vulnerabilities or points of strategic advantage are emerging. Governments need formal, ongoing mechanisms to surface that intelligence, rather than relying on ad hoc consultation. They should be institutional channels that give industry a stake in sharing what it knows.

03

Applying the Framework: How Countries Build Agency in an Interdependent World

This chapter applies the framework to a set of case studies that focus on specific countries and example technologies, which are either dependencies or points of leverage for the countries in question. This highlights how different instances lead to different strategic outcomes: managed dependence, targeted intervention, pre-emptive shaping and leverage as deterrence.

Managed Dependence: The UK and Hyperscale-Cloud Infrastructure

BACKGROUND

Hyperscale-cloud infrastructure underpins much of the United Kingdom's digital economy and public sector, from health care and finance to government services and AI development. Yet while cloud is economically foundational, the UK has limited capacity to alter a highly concentrated market – which makes this a clear-cut case of accepting and managing dependency.

ANALYSIS

Exposure

The UK cloud-infrastructure market is dominated by two firms: Amazon Web Services (AWS) and Microsoft. Together they account for about 70 to 80 per cent of revenue,⁸ and all other providers together account for less than 5 per cent of market share.

The UK's exposure to hyperscale cloud is therefore structurally high; while alternatives exist in principle, there are no real substitutes that offer comparable scale. Even if competitors were to emerge, switching providers is challenging: fewer than one per cent of customers switch each year, and 59 per cent of organisations cite the difficulty and expense of switching as their top concern regarding the cloud-infrastructure market.⁹

Strategic Importance

Hyperscale cloud underpins multiple critical sectors, including finance, health care, telecommunications, core government digital services, and AI development and deployment. Disruption would not be limited to a single industry, but would cascade across essential systems and create national-scale effects.

In addition, cloud infrastructure has clear dual-use characteristics. While not a weapons system itself, it is foundational to state capacity in the digital era. The UK's designation of data centres as critical national infrastructure (CNI), coupled with the National Cyber Security Centre's warning of an "enduring and significant" threat environment for CNI, reflect this reality.¹⁰

Feasibility of Intervention

The most important insight from the framework is where intervention is – and is not – feasible.

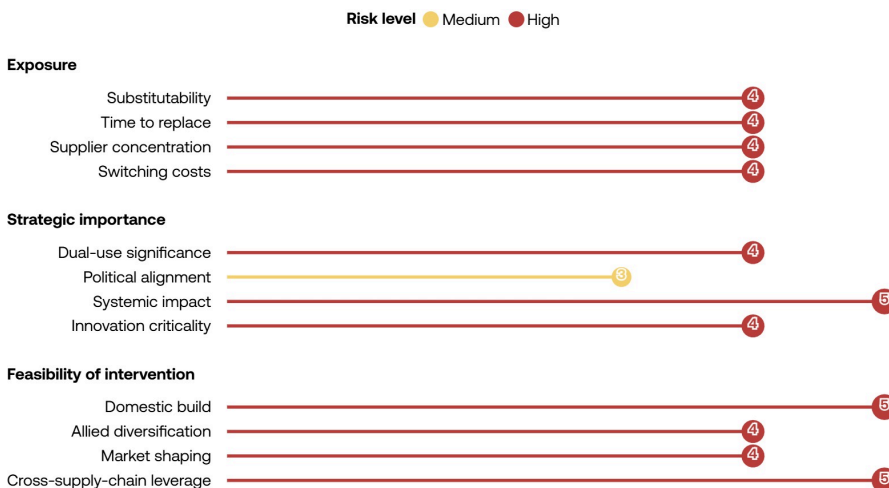
In this instance, building a national or even regional hyperscale cloud, or backing domestic champions to compete directly with global providers, would not be a credible route to resilience. The collapse of UKCloud, despite UK ownership, has illustrated the limits of sovereign substitution in a sector defined by extreme economies of scale, capital intensity and energy demands.¹¹ Similar challenges have plagued European efforts to build full-stack alternatives, such as Gaia-X.¹²

Meanwhile, allied diversification offers only partial relief. European and other allied providers exist, such as France’s OVH, but their combined market share has declined over time from about 26 per cent in 2017 to 10 per cent today.¹³ Diversification may be feasible for specific workloads, especially high-sensitivity areas, but not as a wholesale substitute.

Even demand-side leverage should not be overstated. Interoperability standards and procurement reform can reduce some forms of contractual lock-in, but at the platform-services layer, dependence is often architectural rather than contractual: it can still exist even without direct procurement from a cloud provider. The UK’s share of global cloud demand – about 3 per cent¹⁴ – also limits its unilateral market-shaping power.

FIGURE 6

Hyperscale-cloud infrastructure represents a high-dependence, high-risk and mostly low-leverage area for the UK



Source: TBI

STRATEGIC POSTURE: MANAGED DEPENDENCE

Bottom line: *In an area of limited agency, the focus should be on standards and interoperability, not direct industrial policy.*

Hyperscale cloud represents a high-exposure, high-importance dependency for the UK that cannot be credibly eliminated through domestic build-out or large-scale diversification. The economics of hyperscale infrastructure mean that attempts to recreate national cloud stacks or back domestic champions would be costly, slow and very unlikely to work.

There is some role for policy, but its scope is limited. Standards such as interoperability, data portability and procurement can mitigate some types of lock-in, but only at certain layers of the stack; that is to say, not at the deeply embedded platform-services layer where dependence is structural.¹⁵ The UK might also attempt to better aggregate demand-side leverage, and work with like-minded partners such as the European Union to build interoperable standards. An approach like this might build some level of “collective resilience” through purchasing power.¹⁶ However, given the lack of realistic provider alternatives, even this has limitations.

Ultimately, opportunity costs mean that the UK’s attention is better directed towards technologies where real advantage can still be created.

Targeted Intervention: Singapore and Frontier Generative-AI Models

BACKGROUND

Large general-purpose AI models are advancing rapidly and are foundational drivers of economic growth and state capacity.¹⁷ However, frontier model development is concentrated in a handful of firms, making replication infeasible for middle powers such as Singapore given the capital, energy and R&D intensity required.¹⁸ Unlike hyperscale cloud, however, this

dependency contains greater scope for exercising agency. While complete control is out of reach, Singapore can still shape how models are adopted and adapted within its economy and build resilience along the way.

ANALYSIS

Exposure

At the AI frontier, concentration is structurally high. By 2025, the United States had produced 40 leading AI models, compared to China's 15 and Europe's three. Compute-training requirements roughly double every five months, and frontier systems demand tens of billions of petaFLOPs (units of compute power equal to quadrillions of calculations per second). These levels are effectively inaccessible to smaller organisations and states.¹⁹

However, at the model-access and application layer (where users can build on existing AI models), exposure is more moderate. For example, middleware (software that connects applications to underlying services) makes it easier to substitute models and switch between them; platforms such as OpenRouter and AWS Bedrock enable switching between models through unified application programming interfaces (APIs).²⁰ At the same time smaller high-performing models are increasingly viable substitutes for specific tasks, lowering the barriers to deployment for small and medium-sized enterprises and researchers.²¹ In addition, open-source models give Singapore flexibility since they can be fine-tuned, and their access cannot be retracted once released.²²

In short, there is extremely high exposure at the frontier training and chip layer, but only moderate exposure at the deployment layer due to interoperability and open ecosystems. Singapore does not have many options for *building* frontier models from scratch, but it does have options for *using* them.

Strategic Importance

Large general-purpose AI models are crucial to economic growth, government capacity and national security. Any disruption could ripple across multiple sectors, not just technology. Even leaving aside direct military use, frontier models are therefore of the highest strategic and security importance.

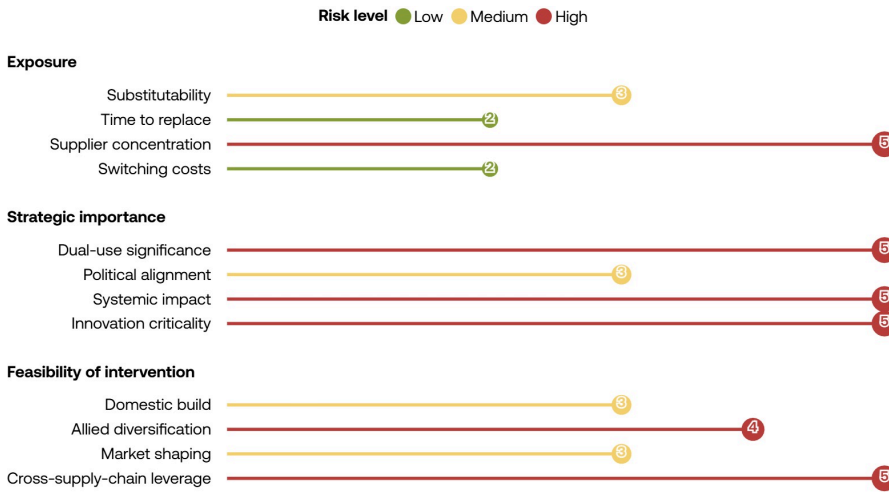
Feasibility of Intervention

Building frontier AI models from scratch, even with allied cooperation, is not feasible. However, Singapore retains meaningful options for building resilience, interoperability and partial leverage. These fall broadly into three areas:

1. **Economic value capture and open source:** As outlined in our paper, [*Open Source: How Middle Powers Can Build Influence in AI*](#), capturing the economic value of AI is a key component of building agency – and open source is a key lever for doing so. Singapore has already made headway here: by increasing trust, programs such as AI Verify make it easier for firms to integrate AI into finance, logistics and public services at scale.²³
2. **Agency through interoperability:** Government procurement and standards can preserve the interoperability of models; Singapore can prevent inflexible model lock-in through open APIs and data-portability requirements.
3. **Distilled, fine-tuned models:** “Distilling” means turning large foundation models into smaller, more efficient ones that are suited to specific purposes. Singapore has already demonstrated this pathway through the SEA-LION project: a distilled model based on Qwen and Llama, adapted for regional languages and context.²⁴ This represents meaningful training and adaptation capacity: foundation models might have been trained in the US and China, but they can be adapted for a region’s cultural and economic context. Furthermore, second-order effects of building the domestic talent needed to understand and adapt models is itself a core part of sovereign AI capability.

FIGURE 7

While full domestic capability is unrealistic, Singapore retains meaningful agency via other means



Source: TBI

STRATEGIC POSTURE: TARGETED INTERVENTION

Bottom line: *Preserve openness and access to frontier capabilities, build resilience and dynamism at the application layer to capture economic value, and cultivate resilience and optionality through the use of open-source models and adaptation.*

Exposure is high for Singapore, but with room for flexibility at the deployment layer – and strategic importance is very high. Yet the feasibility of intervention sits in the middle: frontier replication is impossible, but targeted action through open source, interoperability and domestic talent-building offers credible resilience and national capability. The strategic route for Singapore is not to try and build a model from scratch, but to build a dynamic ecosystem that captures the value of AI.

Pre-Emptive Shaping: The EU and Quantum Computing

BACKGROUND

Quantum computing is set to become a foundational upstream technology with major implications for economic competitiveness and national security. It could underpin defence, cryptography, pharmaceuticals, energy systems and advanced manufacturing, with estimated economy-wide productivity gains of up to 7 per cent by the mid-2040s – worth hundreds of billions in added value.²⁵ However, unlike cloud infrastructure and frontier AI, structural dependence is far from formed: large-scale fault-tolerant systems are unlikely before 2030, no single technical route dominates and key supply-chain nodes are dispersed across multiple countries. Quantum computing is therefore of very high strategic importance, with early industrial intervention (pre-emptive shaping) remaining possible and potentially decisive.

ANALYSIS

Exposure

The EU does not currently have many leading, pure-play quantum-computing companies. Moreover, the market is in its early stages but consolidating rapidly, given the sector's capital and R&D intensity. In 2024, global private investment doubled to about \$2.5 billion but across about half as many companies as in the previous year, indicating capital concentrating in fewer, more mature firms.²⁶

Despite this, the quantum market will continue to depend on highly complex and specialised supply chains, which make full consolidation unlikely. The EU has strong capabilities in upstream components, including cryogenics (Finland), photonics (Germany) and semiconductors (the Netherlands). These positions provide the EU with economic value and potential chokepoints.

Furthermore, the market remains marked by genuine technological diversity, with five hardware modalities (superconducting, trapped ions, neutral atoms, photonic and silicon-spin systems) still in active competition, with no clear favourite. This favours pre-emptive intervention.

Strategic Importance

Quantum computing is of high strategic importance because of its economic spillovers, importance to future innovation and dual-use characteristics. It will also likely catalyse other technologies, such as driving hardware breakthroughs that make AI training and inference far more efficient.

Quantum capabilities also intersect directly with national security. Applications in cryptography, secure communications, defence simulation and advanced sensing create both offensive and defensive implications.²⁷ As with AI, early leadership may shape long-term technological standards, supply-chain structures and geopolitical influence.

Feasibility of Intervention

Quantum computing is still in an early enough maturity phase (both in terms of the technology itself and the broader supply chain) for EU intervention to meaningfully shape outcomes. This is because of the following factors.

- **The EU already has comparative advantage in the broader quantum supply-chain:** Even though there are not many frontier quantum-computing companies in EU countries, the sector depends on a complex set of supply chains – and Europe has a strong track record of producing component- and process-level nodes, such as advanced cryogenics, lasers, packaging facilities and nanofabrication equipment. These underpin high-growth industries and represent potential chokepoints within the global quantum supply chain.
- **The EU has a strong R&D base to leverage:** In particular, countries such as Finland and Germany have capable engineering pipelines (the VTT Finnish Technical Research Centre and Fraunhofer Institutes, for example).

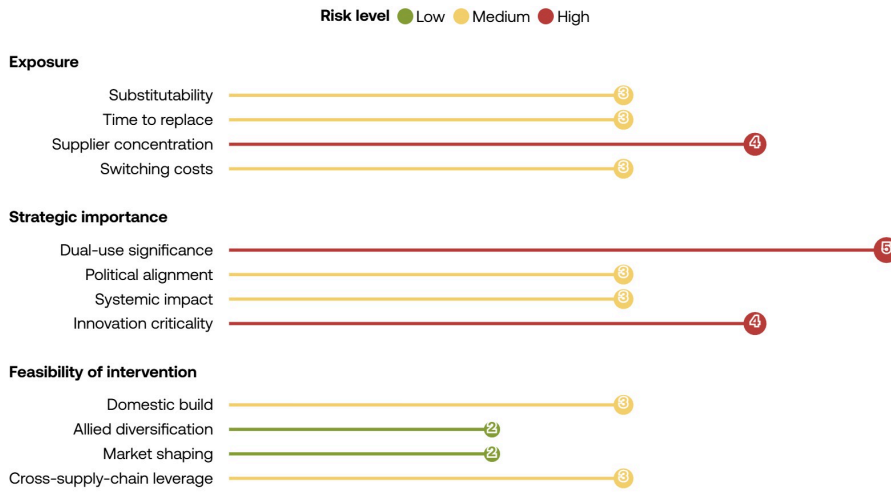
Given that the key breakthroughs required for fully scaled quantum systems depend primarily on solving engineering-related problems, this is a core advantage to build on.

- **Allied cooperation and diversification is highly feasible:** A significant number of leading quantum and component companies can be found in the EU, UK, US, Canada, Australia, Japan and South Korea; this creates opportunities for cooperation among allies, which increases collective resilience. Specifically, the Netherlands excels in advanced semiconductor processes and precision engineering; Finland specialises in cryogenic systems; Germany leads in photonics, lasers and industrial scaling; the UK focuses on quantum software, algorithms and system integration; and Canada, Japan, South Korea and Australia possess complementary strengths in hardware, materials and research. Instead of trying to replicate the entire quantum stack, the EU can foster asymmetric interdependence with trusted allies, maintaining access to essential inputs and frontier capabilities.²⁸
- **The ability to shape markets through demand-side policy is high:** EU countries do not need to rely on national champions to build defensible advantages in quantum technologies. Evidence from peer countries suggests that large, mission-driven procurement contracts materially shape firm trajectories, anchor companies domestically and crowd in private capital. For example, Germany's defence ministry procured a €67 million quantum system from Universal Quantum, a UK company, and secured control over the end-product intellectual property, demonstrating that procurement can generate leverage without full domestic ownership.²⁹

Full sovereignty over the most advanced quantum systems is unlikely, but it is also unnecessary. The EU's advantages across the supply chain mean that the more important ambition is to embed itself strategically across key inputs, developing its own upstream chokepoints.

FIGURE 8

For the EU, quantum is a highly strategic, medium-exposure upstream technology with strong scope for public policy intervention



Source: TBI

STRATEGIC POSTURE: PRE-EMPTIVE SHAPING

Bottom line: *There is a rare window whereby targeted industrial policy can still shape market structure in the quantum industry, before dependencies hardens.*

For the EU, quantum computing is a high-importance, medium-exposure domain where leverage and optionality remain high: market consolidation is underway but not yet complete; technological pathways remain plural; and upstream supply-chain strengths provide meaningful agency. The EU is already developing a quantum strategy, but for it to be effective it must not ape a full-stack approach, which would be inefficient and ineffective. Instead, it should incorporate the following actions.

- Double down on existing areas of comparative strength in upstream components and engineering-intensive domains to build durable leverage within global supply chains. The point is not that the EU should hawkishly squeeze these chokepoints, but that their existence would help ensure that agency and economic deterrence exist even in instances where other countries are relied upon to provide the final product.³⁰
- Use mission-driven procurement and advanced market commitments to anchor firms, attract private capital and maintain multiple technical pathways in parallel while uncertainty persists.
- Collaborate with trusted allies to fill supply-chain gaps and secure access to frontier systems.

Leverage as Deterrence: The Netherlands and ASML

Where a country occupies a structurally significant position in a value chain, that position can serve as a bargaining chip, a means of shaping outcomes, or a form of economic deterrence; in other words, leverage.³¹ The framework can account for this too: instead of identifying its exposure, a country can assess where others are highly exposed to nodes under its control. This section applies that flipped lens – and then tests how far such leverage can realistically be exercised by a middle power.

BACKGROUND

Advanced logic chips – which underpin AI, data centres, smartphones and much of the modern economy – rely on a highly complex global supply chain. One of the cornerstones of this supply chain is photolithography: the process of printing nanoscale circuits onto silicon wafers.³² At the frontier, extreme ultraviolet (EUV) lithography is indispensable: it is technically fragile, capital intensive and built on decades of tightly integrated innovation. Production of advanced EUV tools is effectively monopolised by ASML in the Netherlands: only around 40 of the most advanced systems are sold annually,³³ each machine starts at roughly \$220 million and no commercially credible second supplier exists, with rivals such as Nikon and Canon having exited the race.

For the Netherlands, this makes EUV lithography an instructive example of structural leverage in a crucial technological supply chain.

ANALYSIS

Exposure

For countries seeking to manufacture leading-edge logic chips, exposure to EUV supply is extreme, as there is no commercially viable alternative pathway for high-volume production at the frontier. It would take years to create a replacement source, requiring large-scale R&D, capital investment and the recreation of tacit engineering capabilities accumulated over decades. The result is a textbook asymmetric chokepoint.³⁴

Strategic Importance

For the major importing economies – the US, China, Taiwan and South Korea – access to EUV is not a preference but a condition. It determines whether they can produce chips at the frontier, and therefore whether they can sustain industrial competitiveness, defence capability and long-term technological position.

EUV is not just important to its buyers: it is a load-bearing node in the advanced-technology supply chain as a whole. Semiconductor scaling is not possible without it, and progress in AI, defence systems, aerospace and next-generation communications depends on that scaling. Chokepoint leverage here ramifies across the entire technological stack.

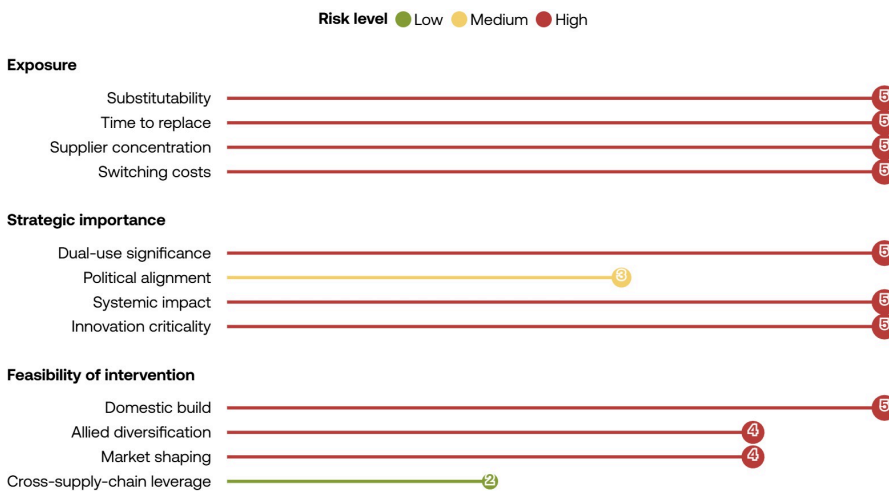
Feasibility of Intervention

Substitution feasibility remains low in the near to medium term. Replicating EUV capability would mean reconstructing a complex ecosystem spanning high-power lasers, precision optics, ultra-high-vacuum systems and advanced mechatronics, all under conditions of near-perfect reliability in high-volume production. China's progress in advanced deep-ultraviolet tools demonstrates that sustained state backing can narrow the gap, but EUV remains a qualitatively higher technical and organisational barrier – and it will

take some time before even China can build domestic capacity.³⁵ Allied diversification is also constrained: no alternative supplier currently produces EUV scanners at commercial scale.

FIGURE 9

For import-dependent countries, ASML is a monopoly with a niche position within a supply chain that is upstream of most critical technologies



Source: TBI

STRATEGIC POSTURE: LEVERAGE AS DETERRENCE (WITH LIMITS)

The framework developed in this report does not just have to be defensive. While it is primarily designed to diagnose vulnerability and guide resilience-building, it can also be applied in reverse to identify where asymmetric interdependence generates leverage. Indeed, many in Europe are calling for a more aggressive approach to economic security, via the leveraging of chokepoints to assert influence.³⁶

However, this posture is not without trade-offs. Even when a country like the Netherlands can lay claim to a structural chokepoint, translating that position into reliable strategic leverage is difficult – constraints are imposed by the messy reality of diplomacy and politics, as outlined below.³⁷

- **No chokepoint exists in a silo:** Pressure from major powers and the extent of interdependence shapes decision-making. The Netherlands' experience with semiconductor export controls illustrates this dynamic: Dutch decisions on the sale of advanced lithography tools have been closely coordinated with (and at times shaped by) US national security policy.³⁸ In this case, owning a chokepoint does not necessarily mean the Netherlands can act unilaterally.
- **Fully exploiting a chokepoint can be self-defeating:** ASML's products have a very small number of major frontier customers; its technological edge depends on sustained collaboration with leading labs and specialised upstream suppliers, and relies on data feedback loops. In extremis, cutting off one of its only key markets would likely lead to company collapse; squeezing a chokepoint can come at the cost of losing competitiveness.
- **The coercive threat of leverage accelerates substitution incentives:** For example, China's intensified efforts to develop domestic chip-making capacity has been partly driven by US export controls.³⁹ Overuse of leverage may therefore narrow the window during which asymmetry exists.
- **Leverage is embedded in wider interdependence:** The Netherlands, for example, depends on the US for security guarantees and the global financial system (which is essentially controlled by the US).⁴⁰ Structural leverage in one node can risk being overwhelmed by interdependence in other spheres, potentially creating imbalanced cost-benefit when it comes to aggressive action. In this sense, technological leverage can become overshadowed by horizontal or vertical "escalation dominance".
- **The state-private sector relationship is problematic:** No playbook has been created for how free-market economies such as the Netherlands can persuade their national private companies to play a global game of economic-security chess. Furthermore, even if the Netherlands was

successful in convincing its private champions to factor in geopolitical considerations, it might deter the founding and scaling of future companies, due to concerns that protectionist policies would be imposed.

So, even where structural chokepoints exist, translating them into diplomatic influence is no easy task. The question of how to achieve this on the world stage is critical – and beyond the scope of this report. The broad lesson is to not weaponise chokepoints indiscriminately, but to embed them within aligned coalitions and preserve the durability of the leverage.

04

Conclusion

The world has not suddenly become geopolitical – it has simply stopped pretending not to be. In this environment, middle powers cannot rely on nostalgia for a frictionless rules-based order, nor can they afford the illusion of self-sufficiency.

A clear strategy is needed, but this involves tough trade-offs and prioritisation. Not every dependency poses a threat, not every strategic technology can or should be copied and not every point of leverage can or should be exploited. Only through precise prioritisation and adaptation within specific technological contexts can resilience be established without harming competitiveness, and leverage be developed without abandoning globalisation.

The core point of this paper and our TBI Chokepoints Framework is this: without prioritisation, and in some cases restraint, there is a risk that everything becomes a technological priority. But technological security is not about doing more *everywhere*; it is about intervening where leverage or agency can be built, accepting limits where it cannot and preserving openness and integration everywhere else. Different contexts will demand different responses – but the thinking process must remain consistent.

Ultimately, technological security is downstream of economic competitiveness. The ultimate challenge is to create economic competitiveness and dynamism, and for countries to scale their own “national winners” that can themselves become nodes in future technology supply chains. In the meantime, new technological dependencies and security risks will have to be navigated – but middle powers must recognise that competitiveness is the central long-term objective.

05

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06

Annex: Framework Methodology

1. Purpose and Methodological Stance

The TBI Chokepoints Framework provides a repeatable and updatable qualitative method for assessing strategic technological dependencies within global supply chains. Its purpose is to support prioritisation and structured judgement about where government intervention might be warranted, rather than provide a definitive list of supply-chain vulnerabilities or a quantitative risk ranking.

The framework is explicitly designed to remain flexible over time. Rather than freezing policy around static sector lists or fixed technology stacks, it enables governments to reassess priorities as technologies, supply chains and geopolitical conditions evolve. Any fixed list of “strategic technologies” would rapidly become outdated.

Methodologically, the framework relies on structured expert judgement rather than comprehensive quantitative modelling. Many of the most important variables shaping technological dependencies – such as coercion risk, switching costs, tacit knowledge and innovation criticality – are not meaningfully quantifiable in a stable or comparable way. Attempting to impose false precision would increase analytical error rather than reduce it.

Reproducibility in this context refers to reproducibility of process rather than identical numerical outcomes. Another analyst following the same steps should be able to understand, replicate and contest the reasoning underlying each score.

1.2. THEORETICAL CONTEXT

This paper is grounded in a growing body of scholarship that reframes globalisation not as a source of mutual vulnerability, but as a terrain of strategic power.^{41,42,43} Work on weaponised interdependence has shown how states can exercise coercion by exploiting their position within global

networks, particularly where financial systems, technology standards or supply chains exhibit high centralisation. Rather than autonomy or self-sufficiency, power in these systems derives from control over key nodes and chokepoints – points where the flow of capital, goods and information can be monitored and constrained.

Related analyses of contemporary geoeconomics, including work on chokepoints and the emergence of an “underground empire” of informal influence and asymmetric dependencies, reinforce this insight. They highlight how modern economic power is increasingly applied through indirect leverage rather than overt ownership, and how states – particularly middle powers – are embedded in dense webs of dependency that they neither fully control nor can easily exit. Together, this literature converges on a central conclusion: interdependence is not disappearing, but its strategic consequences are intensifying. The key policy challenge is not how to eliminate dependence, but how to navigate, shape and selectively rebalance it.

However, much of this literature remains either descriptive or retrospective. It explains how coercion and leverage operate once dependencies are exploited, but offers limited guidance on how governments should prioritise risks *ex ante*, distinguish manageable from unmanageable vulnerabilities, or decide where intervention is actually warranted. That gap between theory and decision-making is where this framework is situated.

1.3. METHODOLOGICAL CONTEXT

This framework builds on a set of applied approaches that use structured judgement to prioritise risk in conditions of uncertainty. The most widely cited precedent is the Kraljic Matrix, which segments procurement items at the company level, based on supply risk and strategic importance to guide differentiated strategies. Its enduring value lies not in analytical precision, but in its ability to impose more disciplined judgement by forcing decision-makers to confront trade-offs explicitly, rather than treating all dependencies as equally strategic.

At the public-policy level, governments and international institutions have developed more comprehensive supply-chain risk frameworks. The US's Quadrennial Supply Chain Review⁴⁴ and Organisation for Economic Co-operation and Development resilience work assess exposure, concentration, and economic or security impact across sectors,⁴⁵ while defence-sector frameworks such as the United States Department of Defense's Supply Chain Risk Management model apply structured, multi-criteria judgement to mission-critical systems.⁴⁶ These approaches establish an important precedent: qualitative scoring, anchored criteria and expert judgement can be both rigorous and policy-relevant, particularly where false precision would obscure rather than clarify risk.

At the same time, these frameworks tend to be either highly resource-intensive, sector-specific or oriented toward execution and mitigation once a priority has already been identified. They often collapse diagnosis and response, implicitly assuming that if something is critical, intervention is feasible. This assumption does not hold for many technologically advanced, capital-intensive or geopolitically constrained domains.

1.4. THIS FRAMEWORK

Our deliberately lightweight and adaptable decision framework is designed to sit upstream of detailed sectoral analysis and quantitative modelling. Rather than producing a definitive catalogue of chokepoints or a ranked list of strategic technologies, it provides a structured way of thinking about where attention, political capital and policy effort should be focused. It separates three analytically distinct considerations: how exposed a dependency is, how much it matters and whether meaningful intervention is realistically possible. Treating these dimensions independently avoids the common failure mode of conflating importance with feasibility, or vulnerability with urgency.

The framework is intentionally focused on leadership and decision-making. It is designed to guide judgement, not to be a substitute for detailed cost-benefit analysis, industrial modelling or programme design. In cases where intervention appears justified, deeper quantitative analysis and sector-specific expertise will still be required to design effective policy responses.

Conversely, where feasibility is low, the framework helps clarify when resilience, diplomacy or acceptance of dependence may be the best available option.

The framework is also built to evolve. By operating at the level of components, capabilities and functions rather than fixed sector lists, it allows governments to reassess priorities as technologies, markets and geopolitical conditions change. In this sense, it operationalises insights from interdependence literature into a practical tool for middle-power governments: not a strategy of autonomy, but a structured approach to exercising agency within an interdependent system.

2. Unit of Analysis and Assessment Boundaries

Each assessment applies to:

- a specific technological component, layer, or functional capability
- areas where disruption could plausibly generate systemic economic or national-security effects

Explicit exclusions:

- whole sectors or entire technology stacks, which obscure where vulnerabilities actually arise
- firm-level contingency planning or crisis-management capacity

Analytical boundaries:

- exposure is assessed independently of national response capacity
- strategic importance is assessed independently of feasibility
- feasibility of intervention is assessed only after exposure and strategic importance have been scored

3. Conceptual Structure of the Matrix

The Chokepoints Matrix evaluates dependencies along three analytically distinct axes:

- Exposure: How easily a dependency could harm national functions if disrupted.
- Strategic importance: How much it would matter if access were lost.
- Feasibility of intervention: Whether a country can realistically reshape, mitigate or leverage the dependency, acting alone or with allies.

These correspond to three core questions:

- Are we exposed?
- Does it matter?
- Can we do anything about it?

Each axis is assessed separately to avoid collapsing diagnosis into a single notion of “risk”.

4. Indicators

Each axis is operationalised through four indicators, for a total of 12.

A. Exposure indicators

- Substitutability (global availability): Availability of alternative suppliers, standards or technologies in the global market.
 - Justification: Assesses whether functionally equivalent alternatives exist at comparable performance levels, reliability and scale. It focuses on the existence of alternatives, not the time, cost or difficulty of transitioning to them. A dependency may be highly concentrated but still substitutable, or diversified but effectively non-substitutable due to technical or standards lock-in.

- Time to replace: Time required to restore equivalent capability at scale if access were lost.
 - Justification: Measures how long it would take to restore equivalent capability following a disruption, assuming sufficient resources were available. It captures physical lead times, qualification cycles and scale-up constraints, rather than financial or organisational barriers. This distinguishes temporal exposure from switching costs, which may be high even when replacement timelines are short.
- Supplier concentration: Degree of global supply concentration, including geographic clustering and single-point-of-failure risks.
 - Justification: High supplier or geographic concentration increases vulnerability by creating single points of failure and amplifying exposure to shocks, export controls and political interference. This anchor captures the structure of global supply, not whether alternatives are viable or how costly switching might be. Concentration can therefore be high even where substitutes exist or replacement is fast, making it analytically distinct from other exposure measures.
- Switching costs: Economic, technical, contractual and organisational barriers to shifting away from the incumbent.
 - Justification: This captures the financial, contractual, regulatory and organisational burdens associated with moving away from an existing supplier or technology. These costs can lock in dependence even where substitutes exist and replacement timelines are manageable. By focusing on economic and institutional friction rather than feasibility in principle or speed, this anchor isolates a distinct source of persistence in dependency.

B. Strategic-importance indicators

- Dual-use significance: Degree to which the technology has military, intelligence or strategic-security relevance.

- Justification: This anchor captures the extent to which a dependency underpins military, intelligence or critical national-security functions. It focuses on the consequences of loss of access for security outcomes, rather than the likelihood of disruption or the structure of supply. A dependency can therefore be strategically critical even if it is currently diversified or politically low risk.
- Political alignment of key suppliers: Likelihood that the dependency could become coercive based on supplier geopolitics.
 - Justification: Assesses the likelihood that access could be intentionally restricted or leveraged for geopolitical purposes. It focuses on probability of denial rather than the severity of consequences, which are captured elsewhere. A dependency may therefore be highly strategically important but politically low risk, or politically high risk despite limited economic impact.
- Systemic impact (downstream dependence): Breadth of sectors, infrastructures or critical services affected by loss of access.
 - Justification: Assesses the breadth of downstream disruption that would result from loss of access across sectors, services and populations. It captures present-day macroeconomic and societal effects rather than future growth potential or security relevance. This keeps it distinct from innovation trajectory considerations, which are forward-looking by design.
- Criticality to innovation trajectory: Importance to future productivity growth, scientific capability and long-term strategic competitiveness.
 - Justification: This anchor captures whether a dependency shapes future productivity, technological leadership or the direction of innovation, even if its current economic footprint is limited. It reflects path-dependence and the cumulative advantages associated with early control over foundational inputs. By focusing on future competitiveness rather than immediate disruption, it avoids overlap with systemic impact.

C. Feasibility-of-intervention indicators

- Domestic-build feasibility: Practicality of developing domestic capability, considering cost, capital intensity, timescale, talent, tacit knowledge and regulatory hurdles.
 - Justification: Assesses whether it is realistic to develop or scale production within national borders, given capital requirements, skills, infrastructure and time horizons.
- Allied diversification feasibility: Likelihood of securing alternative supply from trusted partners given capacity, alignment and willingness to prioritise.
 - Justification: Captures the feasibility of securing supply from trusted partners that already possess, or can credibly scale, relevant capabilities. It is concerned with reallocating or expanding existing supply, not creating it from scratch. This keeps it analytically distinct from domestic build and avoids conflating diversification with speculative market creation.
- Market-shaping feasibility: Ability to influence global supply through procurement, standards-setting, pooled demand, partnerships and diplomatic convening.
 - Justification: Captures the ability to shape market architectures through standards, certification regimes or interoperability requirements, such that suppliers must adapt to participate. It influences who can supply and on what terms, without presupposing domestic production or allied substitution. By focusing on structural rule-setting rather than procurement or demand volume, it remains distinct from other feasibility pathways.
- Cross-supply-chain leverage feasibility: Ability to use strengths or chokepoints in other value chains as bargaining leverage to secure access indirectly.

- Justification: This anchor captures the ability to deter coercion or negotiate access through control over adjacent chokepoints or reciprocal dependencies. It focuses on strategic interaction rather than production capacity or market design. Leverage can exist even where a country lacks domestic capability or alternative suppliers.

5. Scoring Scale and Anchor Descriptions

Each indicator is scored on a 1–5 ordinal risk scale:

- 1 = very low risk
- 5 = very high risk

Scores must be assigned by matching the assessed dependency to the anchor descriptions below. Analysts may not redefine these anchors on a case-by-case basis.

A. Exposure anchor descriptions

1. Substitutability (global availability)

- 1: Many alternative global suppliers or technologies; switching is straightforward.
- 2: Several alternatives exist but require mild integration or short adjustment.
- 3: Limited alternatives; switching possible but costly or performance-reducing.
- 4: Only one or two substitutes; major quality trade-offs or long switching time.
- 5: No viable substitutes; replacement requires multi-year R&D or retooling.

2. Time to replace

- 1: Capability can be restored within weeks.

- 2: Replacement within a few months with manageable delay.
- 3: Replacement takes 6–12 months and disrupts operations.
- 4: 1–3 years needed to restore capability.
- 5: Multi-year, uncertain or technically infeasible replacement timeline.

3. Supplier concentration

- 1: Highly diversified supply; no dominant actors.
- 2: Some concentration but multiple competitive firms.
- 3: Market moderately concentrated; a few key players dominate.
- 4: One or two firms control global supply; major single-point dependencies.
- 5: A monopoly or tightly clustered geographic chokepoint.

4. Switching costs

- 1: Minimal cost, time and/or organisational disruption.
- 2: Minor contractual and/or technical barriers.
- 3: Noticeable one-off costs, retraining and/or system changes.
- 4: Significant financial, technical and/or organisational restructuring required.
- 5: Switching is prohibitively expensive and/or operationally destabilising.

B. Strategic-importance anchor descriptions

5. Dual-use significance

- 1: Little or no military, intelligence and/or strategic relevance.
- 2: Minor or indirect security implications.
- 3: Relevant to some defence, cyber and/or intelligence functions.
- 4: Significant strategic and/or military dependence.
- 5: Critical to core national-security missions and/or strategic deterrence.

6. Political alignment of suppliers

- 1: Suppliers in closely aligned allied states with shared strategic interests.
- 2: Suppliers in friendly or neutral states with stable relations.
- 3: Mixed or shifting geopolitical alignment.
- 4: Suppliers in states with diverging interests and/or coercive potential.
- 5: Suppliers in adversarial states with explicit coercive intent.

7. Systemic impact (downstream dependence)

- 1: Limited impact; affects few sectors.
- 2: Impacts a small number of industries; disruptions containable.
- 3: Affects multiple industrial sectors and/or public services.
- 4: Broad disruption across many critical sectors and/or infrastructures.
- 5: Cascading national-scale disruption across essential systems.

8. Criticality to innovation trajectory

- 1: Marginal relevance to future productivity or innovation.
- 2: Useful but not foundational to growth sectors.
- 3: Important for selected emerging industries.
- 4: Enables wide-ranging future technologies and R&D pathways.
- 5: Foundational general-purpose technology central to long-term competitiveness.

C. Feasibility anchor descriptions

9. Domestic build feasibility

- 1: Capability can be built quickly and cheaply; talent available.
- 2: Achievable with moderate investment and reasonable timelines.
- 3: Possible but slow, costly and/or talent-constrained.

- 4: Difficult; requires major capital, tacit knowledge and/or regulatory reform.
- 5: Essentially infeasible domestically due to cost, time and/or lack of know-how.

10. Allied diversification feasibility (reversed: high feasibility = low risk)

- 1: Trusted allies have capacity and strong alignment; easy to shift supply.
- 2: Partners available but require negotiation and/or integration work.
- 3: Diversification possible but constrained by capacity and/or interest.
- 4: Very few aligned partners; difficult to transition.
- 5: No allied alternatives or politically unviable.

11. Market-shaping feasibility

- 1: Government can materially influence supply via procurement or standards.
- 2: Some ability to shape markets with moderate investment.
- 3: Influence possible but indirect or limited.
- 4: Minimal ability to shift supply-chain structure.
- 5: No leverage; market forces or major powers dominate.

12. Cross-supply-chain leverage feasibility

- 1: Strong bargaining chips in adjacent value chains.
- 2: Some leverage through reciprocal dependencies.
- 3: Limited leverage but could be developed.
- 4: Very weak leverage; dependencies mostly one-way.
- 5: No leverage or counter-dependence; fully exposed to coercion.

6. Scoring Protocol (Structured Judgement)

For each indicator, analysts follow the same steps:

- Restate the indicator as a concrete analytical question.
- Identify the single dominant structural constraint shaping the answer (for example, capital intensity, tacit knowledge, regulatory barriers, standards lock-in, monopoly power, geopolitical alignment).
- Match the case to the closest anchor description (default to the lower score if between anchors, unless clear justification exists to do otherwise).
- Write a 1–2 sentence justification naming the constraint and causal mechanism.
- Assign a confidence level (high/medium/low) reflecting evidence strength and stability.

Sequencing rule:

- Score all Exposure indicators first.
- Strategic Importance next.
- Feasibility last.

7. Evidence standards

For each assessed component, analysts compile a minimal evidence pack covering:

- supply structure and concentration
- substitutability and technical constraints
- switching costs and lock-in
- downstream dependencies
- realistic intervention levers

Evidence may draw on:

- industry and market reports
- government and regulator publications
- academic and policy research
- targeted expert interviews

Endnotes

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