

Asymmetric Strategic Interdependence: A Repeated-Game Analysis of U.S.–China Bilateralism in Chips and Critical Minerals, with Implications for the European Union

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Abstract

This paper analyzes U.S.–China geoeconomic rivalry in advanced semiconductors and critical minerals through the lens of asymmetric strategic interdependence. We conceptualize the relationship as a bilateral monopoly in which the United States dominates high-end chip design and export-controlled technologies, while China dominates the mining and processing of critical minerals. We formalize this structure as an infinite-horizon repeated game in which each side can either sustain cooperation by maintaining cross-border flows or weaponize its chokepoints through export controls and sanctions. Using a discount factor $\delta = 1/(1 + R)$, where R is the interest rate or opportunity cost, we derive conditions under which cooperation can be sustained via grim trigger strategies and show that asymmetry in temptation payoffs creates a region of strategic instability. We then extend the model to incorporate the European Union (EU) as a third actor with strategic options to align with the United States, balance between both powers, or hedge toward China. The analysis demonstrates that the EU's optimal strategy depends on the intensity of U.S.–China rivalry and the structure of global supply chains, and that European Open Strategic Autonomy can reshape the overall payoff structure. The paper concludes by discussing implications for global economic stability, industrial policy, and future research on strategic interdependence.

Keywords: Bilateralism, Game Theory, Geoeconomics, USA, China, EU.

1. Introduction

The strategic relationship between the United States and China is defined by a paradox: deep economic interdependence coexists with intensifying geoeconomic rivalry. Nowhere is this tension more visible than in the domains of advanced semiconductors and critical minerals. The United States dominates high-end chip design, electronic design automation (EDA), and export-controlled semiconductor technologies. China, by contrast, dominates the mining, refining, and processing of critical minerals essential for semiconductor manufacturing, renewable energy, and defense applications.

This asymmetric structure creates a bilateral vulnerability: China depends on U.S. chips, while the United States depends on Chinese minerals.

The concept of asymmetric interdependence originates in the work of Keohane and Nye (1977), who argue that states with greater control over economic linkages can convert interdependence into political leverage. Their framework distinguishes between sensitivity (exposure to shocks) and vulnerability (the cost of adjusting to

shocks). In the context of U.S.–China relations, the United States exhibits low vulnerability but high sensitivity in minerals, while China exhibits high vulnerability in advanced semiconductors. Building on this tradition, scholars such as Hirschman (1945), Baldwin (1980), and Farrell et al. (2020), Luttwak (1990) and Oatley (2019) emphasize how states weaponize interdependence through export controls, sanctions, and chokepoints. The semiconductor supply chain is a textbook example of a “weaponizable network,” where control over key nodes—such as EDA tools or lithography—creates strategic leverage.

A growing body of work examines the geoeconomics of semiconductors. Scholars such as Bown (2020), Miller (2022), Fuller (2016), and Liu (2013) highlight the extreme concentration of advanced chip design and manufacturing capabilities in a handful of firms and countries. The United States dominates chip design and EDA tools, while Taiwan and South Korea dominate advanced fabrication. Recent U.S. export controls on high-end GPUs and lithography equipment, analyzed by BIS (2022), CSIS (2023), and SIA (2023), underscore the strategic logic of restricting China’s access to leading-edge technologies but U.S. defection may impose severe costs on China.

The literature on critical minerals highlights China’s overwhelming dominance in mining and processing. Reports by USGS (2023), IEA (2021), OECD (2023), and the European Commission (2023) document China’s control of 60–90% of global processing capacity for rare earths, gallium, germanium, and other inputs essential for semiconductor manufacturing. Scholars such as Klinger (2017), Mancheri (2015), and Leung (2022) argue that China’s mineral dominance is not accidental but the result of decades of industrial policy. This dominance gives China a credible threat to weaponize mineral exports.

The EU’s position between the United States and China has been analyzed through the lenses of hedging theory, strategic autonomy, and geoeconomic statecraft. Scholars such as Meunier et al. (2019), Leonard (2021), Borrell (2020), and Tocci (2021) argue that the EU, European Commission (2020), faces a structural dilemma: it is economically intertwined with China but strategically aligned with the United States.

In this paper, we focus on the intersection of international political economy, game theory, and geoeconomic strategy by formalizing asymmetric interdependence using a repeated-game model. Interdependencies are modeled as a repeated game between the United States and China in which each side chooses whether to cooperate (maintain flows) or defect (weaponize), with a discount factor $\delta = 1/(1 + R)$ capturing how much each state values the future relative to the present. We show how asymmetry in payoffs destabilizes cooperation. The model is then extended to include the European Union (EU) as a third actor. By integrating the EU as a strategic player, we demonstrate how hedging, alignment, and autonomy emerge endogenously from the structure of U.S.–China rivalry.

2. An asymmetric U.S.–China game

The United States has strong leverage in downstream chip technology. U.S. firms control a dominant share of global EDA software; U.S. companies account for a large share of global fabless chip design revenue; China imports a substantial volume of semiconductors annually; China produces none of the world's leading-edge (sub-10 nm) chips; and U.S. export controls restrict China's access to advanced GPUs and lithography tools. China, by contrast, has strong leverage in upstream mineral supply. It controls a large share of rare earth mining and processing, produces a significant portion of global gallium and germanium, supplies a substantial share of the EU's rare earths and a large share of U.S. imports of several minerals, and has already imposed export controls on gallium and germanium.

We model this as an asymmetric U.S.–China game in which each player chooses between two strategies:

- **C**: Cooperate (keep exports flowing)
- **W**: Weaponize (use export controls or sanctions)

The United States (controlling chips) plays rows; China (controlling minerals) plays columns. A hypothetical payoff matrix reflecting these points is:

		China	
		C	W
US	C	3, 3	0, 5
	W	4, 0	1, 1

- **(C, C) → (3,3)**: Stable interdependence; minerals and chips flow.
- **(C, W) → (0,5)**: China weaponizes minerals while the United States stays open. The United States suffers large immediate damage (0); China gains large short-term leverage (5).
- **(W, C) → (4,0)**: The United States weaponizes chips while China stays open. China suffers serious strategic damage (0) to its technological trajectory; the United States gains a large but slightly smaller short-term payoff (4) than China's minerals move.
- **(W, W) → (1,1)**: Mutual weaponization, decoupling, and low but non-zero payoffs.

Each side has a short-term incentive to weaponize: **W** strictly dominates **C** in the one-shot game. The unique stage-game Nash equilibrium is **(W, W)** with low payoffs (1,1). Yet **(C, C)** is Pareto superior with payoffs (3,3). The structure is thus a

Prisoner's Dilemma, but with asymmetric temptation: the U.S. temptation payoff is 4, while China's is 5.

The use of repeated games to model international cooperation dates back to Axelrod's (1984) work on the evolution of cooperation and to Fudenberg and Maskin's (1986) theory of repeated games, which shows that cooperation can be sustained through trigger strategies even in the absence of centralized enforcement. In asymmetric games, however, cooperation thresholds differ across players. Powell (1991), Snidal (1985), and Fearon (1998) show that asymmetry in payoffs or discount factors can destabilize cooperation, especially when one actor has a higher short-term gain from defection.

Consider a multi-period infinite-horizon repeated game. The stage game is repeated every period $t = 1, 2, 3, \dots$ with discount factor $\delta = 1/(1 + R)$, where R is the interest rate or opportunity cost.

To sustain cooperation, define a grim trigger strategy for both players: start by playing C ; continue playing C as long as the other has always played C in the past; if the other ever plays W , switch to W forever.

The natural question is: when is (C, C) sustainable as a subgame-perfect equilibrium?

2.1. U.S. incentives

If the United States cooperates forever, its present value (PV) from cooperation is:

$$PV_{US}^C = 3(1 + R)^0 + 3(1 + R)^{-1} + 3(1 + R)^{-2} + \dots \approx \frac{3(1 + R)}{R}.$$

If the United States deviates once (plays W when China plays C), its present value is:

$$PV_{US}^W = 4(1 + R)^0 + 1(1 + R)^{-1} + 1(1 + R)^{-2} + \dots \approx 4 + \frac{1(1 + R)}{R}.$$

The United States is indifferent between cooperation and defection when:

$$PV_{US}^C = PV_{US}^W.$$

It prefers to cooperate when $PV_{US}^C > PV_{US}^W$ and to defect when $PV_{US}^C < PV_{US}^W$.

Solving $PV_{US}^C = PV_{US}^W$ yields $R = 2$ as the point of indifference. Therefore, when $R < 2$, the United States has an incentive to cooperate because $PV_{US}^C > PV_{US}^W$; when $R > 2$, it has an incentive to defect because $PV_{US}^C < PV_{US}^W$.

2.2. China's incentives

If China cooperates forever, its present value from cooperation is:

$$PV_{\text{China}}^C = 3(1 + R)^0 + 3(1 + R)^{-1} + 3(1 + R)^{-2} + \dots \approx \frac{3(1 + R)}{R}.$$

If China deviates once (plays W when the United States plays C), its present value is:

$$PV_{\text{China}}^W = 5(1 + R)^0 + 1(1 + R)^{-1} + 1(1 + R)^{-2} + \dots \approx 5 + \frac{1(1 + R)}{R}.$$

China is indifferent between cooperation and defection when:

$$PV_{\text{China}}^C = PV_{\text{China}}^W.$$

It prefers to cooperate when $PV_{\text{China}}^C > PV_{\text{China}}^W$ and to defect when $PV_{\text{China}}^C < PV_{\text{China}}^W$.

Solving $PV_{\text{China}}^C = PV_{\text{China}}^W$ yields $R = 1$ as the point of indifference. Therefore, when $R < 1$, China has an incentive to cooperate because $PV_{\text{China}}^C > PV_{\text{China}}^W$; when $R > 1$, it has an incentive to defect because $PV_{\text{China}}^C < PV_{\text{China}}^W$.

2.3. Joint outcomes

Combining these results, we obtain:

- When $R < 1$: both the United States and China prefer to cooperate.
- When $R > 2$: both prefer to defect.
- When $1 < R < 2$: China prefers to defect earlier than the United States, creating a region of asymmetric tension and strategic uncertainty.

This asymmetry means both sides can, in principle, sustain cooperation (C,C) in an infinite-horizon game—but only if they care enough about the future [high enough $\delta = 1/(1 + R)$, or low enough R]. China needs a higher discount factor to resist the temptation to weaponize minerals, because its short-term gain from weaponizing (5) is larger. That reflects the strategic value of minerals for China's long-term ambitions, making it more tempted to use minerals aggressively. The United States is also tempted to use chip controls aggressively, but slightly less in this stylized setup. If either side becomes more short-termist—for example, due to political cycles, crises, or nationalism— δ effectively falls, and cooperation becomes harder to sustain.

3. The European union as a third actor

The European Union today finds itself deeply economically intertwined with both China and the United States yet strategically aligned only with Washington. On the economic front, Europe's trade and investment flows reveal strong interdependence with both powers: China is a critical supplier of manufactured goods, rare earths, and green-technology components, while the United States remains the EU's largest partner in services, foreign direct investment, and financial markets. This dual

economic reliance reflects the EU's position as an open, globally integrated economy whose prosperity depends on access to diversified markets and supply chains. Strategically, however, the EU's alignment is overwhelmingly transatlantic. Europe's security architecture is anchored in NATO, where U.S. military capabilities, intelligence networks, and nuclear deterrence form the backbone of European defense. No comparable security partnership exists with China, whose political system, global ambitions, and governance model place it at odds with Europe's strategic identity.

This divergence between economic and strategic relationships has become more pronounced as geoeconomic tensions intensify. The EU's economic ties with China have grown rapidly over the past two decades, driven by European demand for affordable manufactured goods and China's appetite for high-end machinery, luxury products, and industrial technology. German automakers, for example, rely heavily on the Chinese market for sales and profits, while European renewable-energy industries depend on Chinese supply chains for solar panels, batteries, and critical minerals. At the same time, the transatlantic economy remains the largest and most integrated economic relationship in the world, with dense investment flows, shared regulatory frameworks, and deep financial interdependence. Europe's economic future is therefore tied not to one major power but to both.

Yet when it comes to security, the EU's dependence is asymmetrical. The United States provides essential military capabilities that Europe cannot currently supply for itself, including strategic airlift, missile defense, advanced intelligence, and nuclear deterrence. The Russian invasion of Ukraine reinforced this reality: U.S. support—military, financial, and logistical—proved indispensable to European security. China, by contrast, is viewed by the EU not as a strategic partner but as a *systemic rival*, particularly in areas such as technology governance, human rights, and global influence. European concerns over Chinese involvement in critical infrastructure, such as 5G networks and port acquisitions, further underscore the lack of strategic trust.

This combination of economic openness and strategic dependence creates a structural dilemma for the EU. On one hand, Europe benefits from economic engagement with both China and the United States; on the other, it relies on Washington for its security and shares with the United States a political and normative worldview that China does not. The result is a geopolitical posture in which the EU must navigate a complex triangle: economically interdependent with two great powers but strategically aligned with only one. This tension lies at the heart of contemporary debates about Europe's Open Strategic Autonomy (OSA), see Baroncelli (2025), as the EU seeks to reduce vulnerabilities without abandoning the openness that underpins its prosperity.

OSA is the European Union's approach to balancing two goals: first, being able to act independently when necessary; and second, remaining open to global trade, cooperation, and partnerships. In other words, the EU aims to reduce harmful

dependencies without becoming protectionist or isolated. Key elements of OSA include:

1. *Ability to make independent choices.* The EU seeks the capacity to act according to its own strategic interests and values, especially in trade, technology, energy, and security.
2. *Reducing external dependencies.* The pandemic revealed that Europe relied too heavily on other countries for essential goods such as medical supplies, semiconductors, and energy. OSA aims to diversify supply chains and strengthen domestic capabilities.
3. *Staying open to global cooperation.* The “open” component is crucial: the EU continues to support global trade, multilateralism, and international partnerships. It is not seeking isolation.
4. *Linking competitiveness with security.* Recent EU policy connects industrial competitiveness with sovereignty and security concerns, especially in a world where trade and technology are increasingly “weaponized.”

The EU’s OSA agenda, which focuses on reducing vulnerability to both China and the United States, effectively turns the two-player game into a true three-player game in which the EU is no longer a passive recipient of U.S.–China choices but an actor with its own strategy. While the United States and China choose C or W, the EU may consider three strategic options:

- *Align with the United States*
- *Balance between both*
- *Hedge or lean toward China*

To see clearly how the EU’s choice reshapes payoffs, it is useful to consider one matrix per EU strategy, where the first two payoffs (for the United States and China) are identical to those above, while the third represents hypothetical EU payoffs.

I. Align with the United States

The EU is politically and strategically close to the United States and more distant from China. The EU benefits when the United States cooperates and suffers when China weaponizes. If the United States weaponizes, the EU shares the cost.

		China	
		C	W
US	C	3, 3, 3	0, 5, 2
	W	4, 0, 1	1, 1, 1

In this case, the EU’s payoff is highest when both the United States and China cooperate, moderate when the United States cooperates but China weaponizes (the

EU is partially protected by the United States), and low when the United States weaponizes (the EU shares the cost of escalation).

II. Balance

The EU tries to stay equidistant from both powers, maintaining economic ties and avoiding hard alignment.

		China	
		C	W
US	C	3, 3, 3	0, 5, 1
	W	4, 0, 1	1, 1, 0

In this case, the EU does best when both cooperate, is squeezed in mixed cases, and suffers most when both weaponize. This corresponds to a “status quo Europe”: open, exposed, and dependent.

III. Hedge or Lean Toward China

The EU deepens economic ties with China, becomes more dependent on Chinese supply chains, and distances itself from U.S. security preferences.

		China	
		C	W
US	C	3, 3, 3	0, 5, 0
	W	4, 0, 2	1, 1, 1

In this case, the EU’s payoff is higher when China cooperates, and the United States weaponizes (the EU is partially insulated by China) and lower when China weaponizes (the EU is exposed). The EU’s payoff in (W,W) is slightly better than in the balanced case because China is now the “anchor partner.”

In general, this three-player structure implies that:

(a) *The EU’s strategies reshape the entire U.S.–China game.* If the EU aligns with the United States, China is more isolated; if the EU hedges toward China, the United States loses leverage; and if the EU balances, both powers compete for influence.

(b) **The EU's payoffs are not fixed—they are political choices.** The EU can raise its payoffs in conflict scenarios by building autonomy; tilt its payoffs by aligning with one side; or lower its payoffs by remaining dependent and exposed.

(c) **The EU can change the equilibrium.** For example, if the EU aligns with the United States, the U.S.–China equilibrium may shift toward (W,W) because China feels encircled; if the EU hedges toward China, the United States may escalate to restore leverage; and if the EU balances, both powers may have incentives to cooperate to win European favor.

This is why the EU's Open Strategic Autonomy matters: it is an attempt to change the payoff structure of the entire system. Subject to OSA, EU member states should not act as spectators but as strategic players.

4. Conclusion and directions for future research

This paper demonstrates that U.S.–China interdependence in chips and critical minerals creates a structurally asymmetric bilateral relationship in which each side controls a distinct chokepoint. Using an infinite-horizon game with discount factor $\delta = 1/(1 + R)$, where R is the interest rate or opportunity cost, we find that cooperation is sustainable only when both states are sufficiently patient. Asymmetry in temptation payoffs creates a region of intermediate interest rates in which China is more tempted to defect earlier than the United States, generating strategic instability. Even small shocks—political cycles, crises, or technological breakthroughs—can push the system from a cooperative equilibrium into a low-payoff equilibrium of mutual weaponization and partial decoupling.

Extending the model to include the European Union transforms the bilateral structure into a genuine three-player strategic environment. The EU's position—economically intertwined with both China and the United States yet strategically aligned only with Washington—creates a distinctive set of incentives. By formalizing the EU's strategic options as alignment, balancing, or hedging, we show that Europe's payoff structure is not exogenous but endogenous to its own choices. The EU can raise its resilience by pursuing Open Strategic Autonomy, tilt the game by aligning with one side, or expose itself to greater vulnerability by remaining dependent on both. Crucially, the EU's strategy feeds back into the U.S.–China game: alignment may push China toward defection, hedging may induce U.S. escalation, and balancing may increase the likelihood of cooperation as both powers compete for European favour.

Taken together, these findings highlight the fragility of cooperation in asymmetric interdependence and the strategic importance of third-party actors. The EU is not merely a passive observer but a consequential player whose choices can stabilize or destabilize the broader system. Long-term planning, diversification of supply chains, and investment in technological capabilities are therefore essential not only for Europe's autonomy but also for global economic stability.

Several promising avenues for future research emerge from this analysis:

1. *Endogenizing the EU's payoff structure.* Future work could derive EU payoffs from underlying economic variables such as import dependence, supply-chain concentration, and security commitments. This would allow Open Strategic Autonomy to be modelled as a continuous variable rather than a discrete choice.
2. *Modelling dynamic investment in chokepoints.* Both the United States and China are actively investing in reshoring, friend-shoring, and technological substitution. A dynamic investment game could show how today's weaponization incentives shape tomorrow's industrial structure.
3. *Introducing uncertainty or incomplete information.* A Bayesian repeated game could capture misperceptions about discount factors, resolve signalling dynamics, and explain accidental escalation.
4. *Incorporating exogenous shocks.* Stochastic shocks—pandemics, wars, natural disasters, or technological breakthroughs—could temporarily alter payoffs or discount factors, making cooperation harder to sustain and potentially triggering transitions between equilibria.
5. *Modelling the EU as a first mover.* A Stackelberg extension in which the EU chooses alignment, balancing, or hedging before the United States and China move could reveal whether Europe can shape the equilibrium and under what conditions its choices deter or encourage weaponization.
6. *Extending to a network of chokepoints.* The logic of asymmetric interdependence applies beyond chips and minerals to cloud computing, AI compute, biotechnology, maritime shipping, and financial networks. A multi-chokepoint model could capture spillovers across domains and the possibility of cross-issue linkage.
7. *Empirical calibration.* Calibrating the model using trade flows, concentration ratios, export-control data, and supply-chain dependency metrics would make the framework testable and attractive to political-economy and international-relations journals.

By combining formal modelling with the empirical realities of chokepoint control, this paper, by and large, underscores how asymmetric interdependence can both enable and undermine cooperation—and how third-party actors such as the EU can reshape the strategic landscape rather than merely endure it.

References

- Axelrod, R. (1984). *The evolution of cooperation*. Basic Books.
- Baldwin, D. A. (1980). Interdependence and power: A conceptual analysis. *International Organization*, 34(4), 471–506.
- Baroncelli, E. (2025). The EU's Open Strategic Autonomy and the challenge of competitiveness in the era of geo-politicized interdependence. *Global Governance*, 27 August issue.
- BIS - U.S. Bureau of Industry and Security. (2022). *Export controls on advanced computing and semiconductor manufacturing items*. U.S. Department of Commerce.
- Borrell, J. (2020). *The EU's geopolitical awakening*. European External Action Service.
- Bown, C. P. (2020). *How the United States marched the semiconductor industry into its trade war with China*. Peterson Institute for International Economics Working Paper.

- CSIS - Center for Strategic and International Studies. (2023). *U.S. export controls and China's semiconductor ambitions*.
- European Commission. (2020). *A new industrial strategy for Europe*.
- European Commission. (2023). *Critical Raw Materials Act: Ensuring secure and sustainable supply chains*.
- Farrell, H., & Newman, A. L. (2019). Weaponized interdependence: How global economic networks shape state coercion. *International Security*, 44(1), 42–79.
- Farrell, H., & Newman, A. L. (2020). Chained to globalization: Why global production networks will survive COVID-19. *Foreign Affairs*, 99(1), 70–80.
- Fearon, J. D. (1998). Bargaining, enforcement, and international cooperation. *International Organization*, 52(2), 269–305.
- Fudenberg, D., & Maskin, E. (1986). The folk theorem in repeated games with discounting or with incomplete information. *Econometrica*, 54(3), 533–554.
- Fuller, D. B. (2016). *Paper tigers, hidden dragons: Firms and the political economy of China's technological development*. Oxford University Press.
- Hirschman, A. O. (1945). *National power and the structure of foreign trade*. University of California Press.
- IEA - International Energy Agency. (2021). *The role of critical minerals in clean energy transitions*.
- Keohane, R. O., & Nye, J. S. (1977). *Power and interdependence: World politics in transition*. Little, Brown.
- Klinger, J. M. (2017). *Rare earth frontiers: From terrestrial subsoils to lunar landscapes*. Cornell University Press.
- Leonard, M. (2021). *The age of unpeace: How connectivity causes conflict*. Bantam Press.
- Leung, G. C. (2022). China's critical mineral strategy. *Energy Policy*, 165, 112–129.
- Liu, J. (2023). The geopolitics of semiconductor supply chains. *Journal of Strategic Trade Studies*, 5(2), 45–72.
- Luttwak, E. (1990). From geopolitics to geoeconomics: Logic of conflict, grammar of commerce. *The National Interest*, 20, 17–23.
- Mancheri, N. A. (2015). World trade in rare earths, Chinese export restrictions, and implications. *Resources Policy*, 46, 262–271.
- Meunier, S., & Nicolaïdis, K. (2019). The geopoliticization of European trade and investment policy. *Journal of Common Market Studies*, 57(S1), 103–113.
- Miller, C. (2022). *Chip war: The fight for the world's most critical technology*. Scribner.
- Oatley, T. (2019). *The political economy of American hegemony*. Cambridge University Press.
- OECD - Organization for Economic Co-operation and Development. (2023). *Critical raw materials for the green transition*.
- Powell, R. (1991). Absolute and relative gains in international relations theory. *American Political Science Review*, 85(4), 1303–1320.
- SIC - Semiconductor Industry Association. (2023). *State of the U.S. semiconductor industry*.
- Snidal, D. (1985). Coordination versus prisoners' dilemma: Implications for international cooperation and regimes. *American Political Science Review*, 79(4), 923–942.
- Tocci, N. (2021). *European strategic autonomy: What it is, why we need it, how to achieve it*. Istituto Affari Internazionali Working Paper.
- USGS - U.S. Geological Survey. (2023). *Mineral commodity summaries*.