A Model of the Chip War: How Sanctions on Supply Chains Can Backfire

Kyungtae Park*

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Abstract

The purpose of this article is to examine the effect of sanctions that exploit choke points in supply chains on interstate and interfirm relations. I develop an original model that illustrates how a domestic government's choke-point sanction causes long-term backfiring in the market. When a home government imposes a sanction to rein in the target country's industrial growth, less productive firms are encouraged to enter the market as a result. Without almost full cooperation of the existing and the newly entering firms, the sanction fails to achieve its goal and backfire by benefiting foreign firms and harming domestic firms. I argue that the securitization of economic issues is driven not just by ideological or policy differences but by the complexity of supply chains. Given that the required level of cooperation is proportional to the degree of production fragmentation, my model implies that the U.S.-China rivalry will end up in hyper-securitization due to the highly intertwined supply chains in which both countries operate.

Keywords: supply chains, technology, semiconductors, weaponized interdependence, formal model

*Seoul National University, Department of Political Science and International Relations

1 Introduction

Semiconductors are at the center of the crossfire between the world's two biggest economies (Bown 2020). As China has grown into a behemoth of the industry with enormous economic, strategic and military values, the U.S. is trying to cut off the economic ties with extraordinarily strong measures in hope of defending its technological supremacy. The ongoing chip war warrants academic attentions not only for its practical implications. A group of scholars have recently studied how states weaponize interdependence as a coercive diplomacy in wide areas ranging from security to trade to finance to energy (Drezner, Farrell and Newman 2021; Farrell and Newman 2019). The modern semiconductor industry makes a strong test case of their theories since, unlike the last chip war between the U.S. and Japan (Friedberg 1991), no other industries have been involved in the trade network as complex and American firms are not welcoming trade restrictions. How far will states be able to push trade restrictions as they wish in opposition of business interests?

Scholars mostly view the strategic competition between the U.S. and China from economic statecraft theories (Aggarwal and Reddie 2021; Weiss 2021), according to which the economic dimension is less important to the success of sanctions than the political configuration of states such as the international regime and the political signal they convey (Baldwin 2020; Drezner 1999). Focusing on the role of states' guidance, however, they fail to fully appreciate a great change in the political economic context between past examples of market intervention and the ongoing war. Firms can sidestep states' restrictive efforts with strategic investment when production is fragmented (Beazer and Blake 2018; Betz and Pond 2019), and trade measures will be futile if they end up in benefiting the target as a result. Japan banned exports of crucial chipmaking materials to South Korea in 2019 that it had monopolized, resulting in helping Korean firms acquire materials via newly entered firms and undermining its monopoly. This demonstrates that even states can fatally misjudge the economic outcome of their own measures due to the overgrown interdependence. I introduce the firm-level approach of political economy to studies of economic warfare for a more balanced view of trade restrictions.[1]

[1]This paper relates to several strands of the most recent political economy literature. Studies on the U.S.-China trade war (Fajgelbaum and Khandelwal 2021; Kim and Margalit 2021) and the public backlash

This paper shows that firms can thwart states' trade restrictions that exploit choke points in supply chains (henceforth *choke-point sanctions*) and bring the opposite of the intended outcome. Any state actions in economic wars take effect through behavioral changes of the market players. Two problems are out there. First, states and firms have divergent interests. Firms are only interested in maximizing their own profits while states in strategic competition are also interested in increasing the profit gap between home and foreign firms. Second, the trade network is more flexible than the state network. Nodes can be newly introduced (market entry) or converge (collusion) with ease, so extreme shocks like sanctions can cause a seismic shift of the status quo. This violates the fundamental assumption of weaponized interdependence theories that networks are embedded in a contained system (Farrell and Newman 2019). The resulting shift in the trade network may be difficult to reverse even after the sanctions are lifted because, having paid adjustment costs that deterred the shift so far, the target firm has no incentives to revert to the original trade partner unless offered a price competitive enough. Therefore, if states make a wrong move with sanctions, supply chains lock in their mistake and prolong any costs incurred to a longer term.

I present a political economy model inspired by the trade row of 2019 between South Korea and Japan to support my arguments. In the model, a home government bans a home firm from trading with an entirely dependent foreign firm. The target firm in turn seeks alternative suppliers for imperfect substitutes at a lower price with some initial investment costs incurred to both firms. I found that choke-point sanctions encourage less productive firms to enter the market and strengthen the market competition, and as a result the home firm earns less and its trade partners earn more than what each earned before. If this is the case, sanctions are shooting oneself in the foot for the home government and a blessing in

against the liberal international order (Lake, Martin and Risse 2021; Mansfield, Milner and Rudra 2021) provide the starting point for our discussion, from which this paper points to one of the directions those phenomena are leading to. Theories on technology and politics (Milner and Solstad 2021) and security and trade (Davis and Pratt 2021) can be tested with the unfolding of the semiconductor war this paper suggests. Our study overlaps with: Cory, Lerner and Osgood (2021) and Malesky and Milner (2021) in that both study supply chains and politics, but they examine the political outcomes of economic change while we examine the economic consequences of political change; Cohen and Rogers (2021) and Wu (2021) in that both study supply chains and trade restrictions, but they examine their legal development while we examine their distributional outcome; Lim and Ferguson (Forthcoming) in that both study the outcome of trade restrictions, but their main explanatory variable is formality of the measures while ours is trade restriction in general.

disguise for the target firm. The home country can block the competitors' market entry with its own firm striking a collusive negotiation with potential competitors – through partnership or mergers – or the home government persuading other governments to join the sanctions. It has to block *all* firms that can potentially enter for an effective sanction either way. The government might prefer containment to market monopoly. However, it is a triply costly strategy; it inflicts on the home country (1) the deadweight loss from market intervention, (2) side payments for countries that relinquish profit opportunities and join the sanction, and (3) the overly escalated political tension.

The model has theoretical and practical implications. Theoretically, it delimits the extent to which states can weaponize economic interdependence. States have to take into account strategic responses by both domestic and foreign firms to ensure the sanction exerts pressure on another state as intended. When things go awry, they not only suffer long-term economic and political losses but also permanently lose the opportunity to weaponize the same economic ties. States motivated by security concerns could be willing to tolerate losing some money for their political goals, but the economic costs will not be negligible since they need to sell the idea of sanctions to the very countries that are most likely to reap economic benefits by trading with the target. It also does not help sanction-seeking states that firms predicate their responses much on private information that states cannot easily come by, *e.g.* their detailed investment plans and the availability of alternative trade partners. The combination of market forces and the information asymmetry renders choke-point sanctions increasingly limited as policy tools, so the ongoing chip war is an exception, not an indicator of a paradigm shift. These results can be extended to all products whose production requires high technology and flexible supply chains, especially batteries and pharmaceutics, the two products specially noted by the White House (2021).

Practically, the results easily relate back to the ongoing chip war. The collusive solution against China by the private sector is unlikely because of the rapid technological development and the fierce market competition. Instead, the U.S. is trying to multilateralize sanctions against China by doling out side payments and constructing supply chains centered around its allies. My model indicates that it must keep China contained until it secures alternative chipmakers free from Chinese influence in order to attain dual goals of curbing China's industrial growth and maintaining its industrial power. However, due to the porous nature of the trade network, purely economic enticement might not be enough to restrain all other countries from trading with China. This suggests that the securitization of economic issues can be driven not just by ideological or policy differences but by the complexity of supply chains. Given that the level of cooperation required to effectively implement a choke-point sanction is proportional to the degree of supply chain fragmentation, the U.S.-China rivalry will end up in hyper-securitization at the level well above what the U.S. would have initially liked.

This paper is organized as follows: Section 2 presents the formal specification of the model and the equilibrium analysis. Section 3 concludes the paper with discussion.

2 Model

2.1 Settings

Let us first define the scope of analysis. A trade restriction is *strategic* when it is imposed to exert pressure on another state, usually out of political motives such as security and election. Some restrictions are imposed for domestic purposes as in those on medical equipment during the pandemic. These are beyond the interest of this paper for their low relevance to strategic competition between states. All trade restrictions are assumed strategic from now unless noted otherwise.

Trade restrictions can be explained with three sets of players at the most general level. In case of an export restriction, these are upstream producers and downstream producers – the immediate sellers and buyers of the restricted goods – and a consumer who represents even more downstream producers down to the final consumers.[2] Usual trade models only include firms that are currently participating in trade. In order to fully capture the ramifications of trade restriction, however, we need to consider latent players who have a potential to enter the market once restriction is enacted but are yet to. These potential competitors often produce similar or related products whose technological content is not sophisticated so

[2]Those located even more upstream do not need consideration since strategic export restrictions exploit market power of the exporters and therefore their cost optimization will be hardly questioned.

much as the incumbent players. In general, more advanced technology better suits producers. Firms both on the exporting side and on the importing side can invest and improve their technology in order to produce better intermediate goods to accommodate production lines to those better inputs. Firms targeted by the restriction may trade with the newly entered competitors upon restriction, and decide to continue the relationship or revert to the original partners when the restriction is lifted.

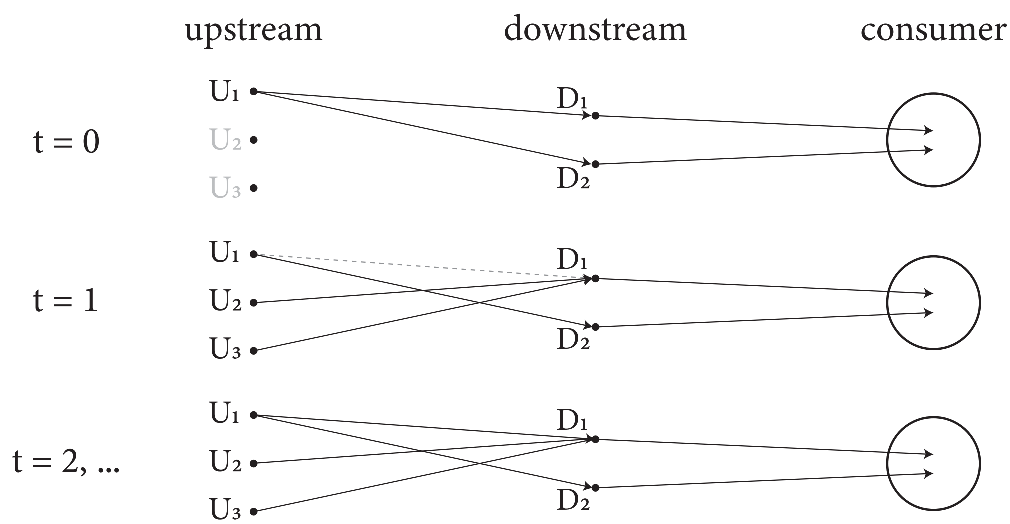

Figure 1: An example of a change in the trade network under a choke-point sanction: U_1 is a choke-point exporter and D_1 and D_2 are its customers. When U_1's government imposes export restriction on D_1 at $t = 1$, the removal of the restriction at $t = 2$ does not ensure that D_1 reverts to the exclusive relationship with U_1.

Figure 1 illustrates one example of a choke-point export sanction model. U_is and D_js are upstream and downstream producers. U_1 is the only supplier at $t = 0$ who successfully fends off latent competitors U_2 and U_3 with its advanced technology. U_1's government abruptly imposes a sanction on D_1 at $t = 1$ as depicted in the severed tie between them. D_1 has an incentive to invite one of U_2 and U_3 into the market in order not to forfeit the entire profit during the sanction. Although not depicted in the figure, U_1 might also seek alternative downstream producers who bid at lower prices than D_1 but would bring in some profits anyway. The sanction lasts for one period in the model – the value of the time discount β will be adjusted accordingly to its actual duration.

It takes a massive effort to construct an overarching micro model that accounts for all the individual differences in the model structure. I instead conduct a Nash equilibrium analysis in a model that specifically caters to the South Korea-Japan trade row of 2019, whose insights are nevertheless generalizable. The model basically follows that in Figure 1 but with several more simplifying assumptions. We impose symmetry between the downstream producers (D_1 and D_2) and between the latent competitors (U_2 and U_3). Investment is made only at the beginning of $t = 1$ and takes effect immediately. Technology only has an intrinsic value and is unidimensional.[3] Most importantly, the upstream producer U_1 faces zero production cost so it does not look for alternative downstream producers upon the sanction.[4]

Each player's goal at $t = 0$ is as follows. Suppose U_1 produces at technology level $s_1 = \bar{s}$ and latent competitors U_2 and U_3 are currently able to produce at level $s_i = \underline{s}$. U_2 and U_3 have incentives to upgrade their products up to level $s \in (\underline{s}, \bar{s})$ through negotiation with any of the downstream producers and opportunistically enter the upstream market. I assume the investment cost functions of upstream and downstream producers $R_U(s)$ and $R_D(s)$ satisfy $R'_U > 0$ and $R'_D < 0$, and $R''_U > 0$ and $R''_D > 0$ to ensure that firms pay less as the agreed technology level is closer to their original level and that radical changes are less probable. Note that R_D is decreasing in s since downstream producers need additional investment to accommodate to lower-quality inputs by improving their production line or strengthening quality control. I also assume that upstream producers can perfectly price discriminate downstream producers. Let p_{ij} and q_{ij} denote the price and the quantity that U_i sells at to D_j. The objective of U_i is to maximize $\sum_j p_{ij} q_{ij}$ subject to downstream producers' optimization problem.

The downstream market is monopolistically competitive where two similar downstream producers D_1 and D_2 vie for the same customer. They optimize their production according to the Cobb-Douglas production function $y = AL^\alpha \times \left(\overline{k(s)}K\right)^{1-\alpha}$ where an increasing function $k(s)$ denotes productivity determined by the technology content of the input, and $\overline{k(s)}$ denotes the average productivity weighted by the amount of inputs from each upstream

[3]If technology has an intrinsic value, it facilitates the production process of downstream producers but does not directly add values to consumers. Purer industrial materials, for example, would allow cost reduction by boosting production yields but consumers would feel indifferent if a producer chose a tighter quality control over purer materials. Conversely, if it has an extrinsic value, it directly speaks to consumers. Higher-performing chips in the computer better appeal to consumers and command higher value addition.

[4]Although U_1's costs will be negligible compared to its revenues, this is a nontrivial big assumption. I will discuss how adding costs to the model affects the results in the discussion section.

producer in case it has sourced from multiple firms. Formally, $\overline{k(s)} = \big(\sum_i q_{ij}\big)^{-1} \sum_i q_{ij} k(s_i)$. Defining p_{dj} and q_{dj} as the price and the quantity D_j sells at to consumers, the objective of D_j is to maximize $\sum_j p_{dj} q_{dj}$ subject to the consumer optimization problem.

The consumer consists of diverse economic agents ranging from downstream customers of D_js to the final consumers. Borrowing from Melitz and Ottaviano (2008), we summarize their aggregate demand into a single utility function

$$U_C = \eta(q_{d1} + q_{d2}) - \frac{1}{2}\big({q_{d1}}^2 + {q_{d2}}^2 + 2\sigma q_{d1} q_{d2}\big) \tag{1}$$

subject to the budget constraint E. $\sigma \in [0, 1]$ and η are parameters of product heterogeneity and the overall consumption level of the downstream market. Higher σ indicates products of D_1 and D_2 are more interchangeable so that an increase in demand for one leads to a decrease in demand for the other. Higher η implies an increase in demand for both items.

At the beginning of period 0, U_1 proposes p_{1j} to each of D_js. If D_j accepts this proposal, D_j sources only from U_1 and decides q_{1j}. D_j then sets p_{dj} and the consumer decides q_{dj}. But if D_j rejects this proposal, D_j negotiate with U_2 and U_3 over the technology level. They pay $R_D(s)$ and $R_U(s)$ respectively to upgrade their production facilities. The rest is the same; U_i sets p_{ij} and D_j decides q_{ij}. In turn, D_j sets p_{dj} and the consumer decides q_{dj}. We will see below that U_1 is better off by offering p_{1j} that deters entry of U_2 and U_3 at equilibrium.

When U_1 becomes unable to sell to D_1 at the beginning of period 1, U_2 and U_3 make decisions on whether to enter the upstream market through a negotiation with D_1. When the sanction is lifted at $t = 2$, the situation is not the same as with $t = 0$ if either of them has entered a period earlier, whom U_1 has to drive out through market competition if it wishes to restore its monopoly. Once the sanction is imposed, firms reorient themselves by maximizing their profit from $t = 1$ to $t = \infty$ minus the investment cost at $t = 1$ if incurred, with all future profits discounted by $\beta \in [0, 1]$ for each period.

2.2 Equilibrium Analysis

I first present the case where upstream producers are in full competition. The leading firm can extract sizable rents from its monopoly status at $t = 0$ that the potential competitors are keen to share. Due to this sharp conflict of interests, a strong coalition between the leading firm and the rest is unlikely if it were not for any external intervention. We say the potential competitors are *viable* if their current technology level $\underline{s}$ is high enough for downstream producers to be able to make profits by investing and trading with. Suppose that the competitors are viable if and only if $\underline{s} > s^v$. Proposition 1 states the pre-sanction Nash equilibrium at $t = 0$.

Proposition 1. *When upstream producers are competitive, before the sanction,*

1. *There exists s' such that D_1 gains by threatening U_1 with defection if $\underline{s} > s'$. D_1's gain and U_1's loss decrease in $R_U + R_D$ and increase in β.*

2. *D_1's gain is always bigger than U_1's loss if the threat works. In other words, decline of U_1's monopoly results in greater social efficiency.*

Proof of proposition 1. We first solve the consumer optimization problem. Consumers buy goods from downstream producers until their marginal utility equals the price. Therefore, $p_{dj} = \eta - q_{dj} - \sigma q_{d(3-j)}$ for $j \in \{1, 2\}$.

Next, we solve the optimization problem of the downstream producers. If wage is externally and competitively determined, the marginal return of labor should equal its cost:

$$\frac{\partial y}{\partial L} = \alpha A \left(\frac{\overline{k(s)}K}{L} \right)^{1-\alpha} = w \;\; \Rightarrow \;\; q_{dj} = \left(\frac{w}{\alpha A} \right)^{\frac{\alpha}{1-\alpha}} \times \overline{k(s)}K \equiv \frac{1}{\gamma} \times \overline{k(s)}K$$

Total cost is given as $wL_0 + \overline{p_{.j}}K_0$ where L_0 and K_0 denote the amount of each input at equilibrium. Note that $wL_0 = \alpha L^\alpha \left(\overline{k(s)}K \right)^{1-\alpha} = \alpha q_{dj}$ and $\overline{p_{.j}}K_0 = \sum_i p_{ij} q_{ij}$. D_j determines q_{dj} where its profit is maximized, so for all i such that $q_{ij} > 0$,

$$\frac{\partial \Pi_j}{\partial q_{ij}} = \frac{\partial}{\partial q_{ij}} \left[q_{dj} \left(p_{dj} - \alpha \right) - \sum_k p_{kj} q_{kj} \right] = \frac{k(s_i)}{\gamma} \left(p_{dj} - \alpha - q_{dj} \right) - p_{ij} = 0.$$

We learn from above that the effective price $\frac{p_{ij}}{k(s_i)}$ is the same across all inputs if D_j sources from multiple upstream firms. Under symmetry between D_1 and D_2,

$$q_{dj} = \frac{\eta - \alpha - \gamma c_j}{2 + \sigma}, \;\; p_{dj} = \eta - (1 + \sigma) q_{dj}, \; \Pi_j = (q_{dj})^2. \tag{2}$$

Without the symmetry,

$$q_{dj} = \frac{(2-\sigma)(\eta-\alpha) - 2\gamma c_j + \sigma\gamma c_{3-j}}{4-\sigma^2},\ p_{dj} = \eta - q_{dj} - \sigma q_{d(3-j)},\ \Pi_j = (q_{dj})^2. \tag{3}$$

If U_1 is the only viable supplier for downstream suppliers, U_1 maximizes its profit by choosing p_1 that maximizes $p_1 q_1$ according to (2). Therefore,

$$p_{11}^m = \frac{k(\bar{s})(\eta-\alpha)}{2\gamma},\ q_{d1}^m = \frac{\eta-\alpha}{2(2+\sigma)}$$

in which the superscript m signifies the monopoly equilibrium where U_1 is the only viable supplier.

When U_2 and U_3 are viable, D_1 can threaten U_1 to lower price or it will defect and acquire inputs from the competitors at a lower price. U_1 should lower the price, but how much? Suppose that U_2 and U_3 have reached an agreement with D_1 at the technology level $s^o \in (\underline{s}, \bar{s})$ without necessarily prohibiting provision from U_1. Let p_{i1}^o and q_{i1}^o be the price and the quantity determined at equilibrium. Their entry is easily deterred by the proposal of U_1 made *before entry* to provide D_1 with $q_{11}^o + q_{21}^o + q_{31}^o$ units of the goods at $p_{11}^o q_{11}^o + \frac{k(s^o)}{k(\bar{s})}\left(p_{21}^o q_{21}^o + p_{31}^o q_{31}^o\right)$. This proposal is always accepted since U_1 earns more by $\frac{k(s^o)}{k(\bar{s})}\left(p_{21}^o q_{21}^o + p_{31}^o q_{31}^o\right)$ and D_1 is supplied with higher-quality goods of the same amount at a lower cost. Also, it satisfies D_1's optimization problem (3) as the proposal preserves the effective price c_1 that D_1 pays for each unit of input. This implies that whatever U_2 and U_3 offer D_1, there is at least one proposal that is more efficient to both U_1 and D_1 among many pre-entry proposals that U_1 can make to D_1, hence U_1's dominance always guaranteed.

U_1 then maximizes its profit while guaranteeing D_1 at least the profit it could have earned by trading with U_2 and U_3. Imagine U_2 and U_3 try to enter the market. The competition between the two will lead their profit to zero, and the price will be determined at the level that barely recovers their initial investment cost $R_U(s)$ through infinite periods. However, U_1 can always undercut their price so they will never be able to recover the investment cost unless they set the price at zero. Knowing this, the only way D_1 can keep the defection threat credible is to fully assume U_2 and U_3's investment cost. D_1 does not need to invest for both firms. We posit $p_{21} = 0$, $q_{21} > 0$ and $q_{31} = 0$. Then,

$$q^o_{d1} = \frac{(2-\sigma)(\eta-\alpha) + \sigma\gamma\frac{p^m_{11}}{k(\bar{s})}}{4-\sigma^2} = \frac{(4-\sigma)(\eta-\alpha)}{2(4-\sigma^2)}.$$

D_1's final payoff becomes $v_1(s) = \frac{\Pi_1}{1-\beta} - R_D(s) = \frac{(q^o_{d1})^2}{1-\beta} - R_U(s) - R_D(s)$, based on which D_1 solely decides s^o as U_2's payoff is always zero. Viability of U_2 and U_3 is equivalent to $\max_s v_1(s) > 0$. Returning to the negotiation between U_1 and D_1, U_1 makes a proposal that maximizes $p_{11}q_{11} = \frac{p_{11}q_{d1}}{k(\bar{s})}$ under the constraint

$$(q_{d1})^2 \geq \max\left[\max_s(1-\beta)v_1(s),\ (q^m_{d1})^2\right]. \tag{4}$$

We know that $p_{11}q_{d1}$ decreases in q_{d1} from (3), so the quantity under the defection threat q^d_{d1} attains equality in (4).

1. Payoff is proportional to the profit in each period. Threat works when $\max_s(1-\beta)v_1(s)$ is greater than $(q^m_{d1})^2$. $\max_s(1-\beta)v_1(s)$ increases in $\underline{s}$ and therefore in R_U, suggesting the existence of the lower cutoff s'. D_1 gains since q_{11} is proportional to q_{d1}, and U_1 loses since $p^m_{11}q^m_{11} > p^d_{11}q^d_{11}$ from (3). Decrease in $R_U + R_D$ and increase in β lead to a higher q^d_{d1}.
2. It is enough to show $\Delta(q_{d1})^2 - \Delta(p_{11}q_{11}) > 0$ when $\Delta q_{d1} > 0$. Using $\Delta x^2 = 2x\Delta x + (\Delta x)^2$, a simple manipulation leads to

$$\left(3 - \frac{\sigma^2}{2}\right)\Delta q_{d1}\left(\Delta q_{d1} + \frac{(\eta-\alpha)(4-\sigma^2-2\sigma)}{2(2+\sigma)(6-\sigma^2)}\right) > 0,$$

which is always true as long as $\Delta q_{d1} > 0$. ■

Proposition 1 shows that D_1 can undermine U_1's monopoly by leveraging the existence of its competitors. The results are intuitive. D_1 has a choice to stay, or to defect and get supplied from one of U_2 and U_3 at a lower cost. U_1 would have tolerated their market entry rather than lowering the price. It instead finds it better to guarantee D_1 at least the profit D_1 could have earned by contracting with other suppliers and to maintain its monopoly. This is because U_1 is capable to offer at whatever price and quantity U_2 and U_3 offer *before* their entry and preempt their profits. However, for such a threat to be credible, D_1 should assume all investment costs of the competitors; otherwise, U_1 will undercut their pricing to secure even a bit of profit and the competitors will never be able to recover the investment costs. Decline in U_1's profit never exceeds growth in D_1's profit since monopoly is socially inefficient. In a special case where the upgrade costs R_U and R_S are zero, U_1 faces perfect competition with the potential competitors who are ready to supply at no cost and loses all profits coming from D_1, while D_1 experience four to nine times profit growth depending on the value of σ.

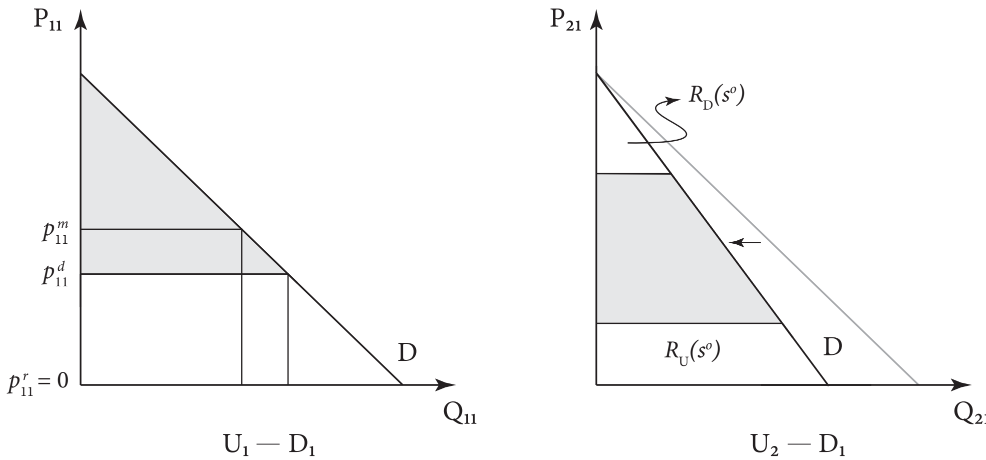

Figure 2: Price determination in the competitive upstream market: each panel represents D_1's demand function for the current supplier U_1 and the potential supplier U_2. The shaded region on the right denotes the surplus D_1 enjoys when it defects to D_2. U_1 has to then drive down its price from p_{11}^m to p_{11}^d that ensures D_1 as much surplus.

Figure 2 visualizes the above proposition. Suppose that the equilibrium price is formed at p_{11}^m under U_1's pure monopoly. When D_1 defects to U_2, the price competition between U_1 and U_2 will drive down the price to zero. U_2 will not enter the market unless D_1 assumes its investment cost. Let s^o denote the agreed technology level between the two. D_1 enjoys the surplus represented by the shaded region on the right which equals to the area of the entire triangle minus its own investment cost $R_D(s^o)$ – the area of the upper triangle –and U_2's investment cost $R_U(s^o)$ – the area of the trapezoid. However, U_2 never beats U_1 if U_1 ensures D_1 as much surplus by driving down the price from p_{11}^m to p_{11}^d, the point where the areas of the two shaded regions become equal. p_{11}^d is always feasible since D_1 always prefers inputs from U_1 over those from U_2 when they ask the same price so D_1's demand curve for

U_2 is inside that for U_1.

The result implies that the mere presence of a sanction lurking might be detrimental to the exporter if firms are risk-averse. D_1 would have always liked to bypass U_1's monopoly, but defecting from its already well-proven trade partner entails risks and uncertainty. The anticipation of a sanction may trigger its greater business strategy by nudging it to look for alternatives and take those risks. However, this will never amount to an actual source diversification until the tension develops into an actual crisis since U_1 is willing to tolerate a lower price when D_1 exploits it as a bargaining chip in the price negotiation.

I now consider the equilibrium at $t = 1$. The sanction renders U_1 no longer able to make a counterproposal and deter the competitors' entry. Proposition 2 describes the permanent equilibrium shift that occurs from this one-time shock.

Proposition 2. *When upstream producers are competitive, after the sanction,*

1. *Viable competitors enter the market. U_1 loses all profits from D_1 and some of the profits from D_2 as a result of the stronger market competition. D_1 and D_2 make modest gains.*
2. *As the sanction protracts, the competitors who were not viable might turn viable and D_1 less assumes their investment costs. U_1 suffers a loss but the effect on D_1 is ambiguous.*

Proof of proposition 2. At $t = 2$, all suppliers set the price at zero and $q_{d1} = q^o_{d1}$. Then, equilibrium at $t = 1$ occurs where D_1's margin is maximized under the constraint that U_2 and U_3's payoffs are non-negative. Without loss of generality we set $q_{31} = 0$, $p_{21} = \frac{R_U(s)}{q_{21}} = \frac{k(s)R_U(s)}{q_{d1}}$. Let q^r_{d1} be the quantity under the sanction. q^r_{d1} is the bigger solution of the following equation:

$$q^r_{d1} + \frac{2\gamma R_U(s)}{4-\sigma^2}\frac{1}{q^r_{d1}} = \frac{(4-\sigma)(\eta-\alpha)}{2(4-\sigma^2)}. \tag{5}$$

D_1's payoff is given as $(q^r_{d1})^2 + \frac{\beta(q^o_{d1})^2}{1-\beta} - R_D(s)$. $R_U(s)$ is implied in q^r_{d1} here, and partly in $R_D(s)$ if D_1 and U_2 arrange cost transfer.

1. If D_1 fails at securing alternative sources, D_1 does not produce any goods and resumes production after the sanction is lifted. If D_1 manages, U_1 cannot make profits from D_1 even

after the sanction is lifted. Notice that D_1's payoff is the same as before if D_1 and U_2 agree to transfer all investment costs to D_1 again. However, D_1 does not need to do so now. The payoff is concave in $R_U(s)$ and

$$\frac{\partial}{\partial R_U(s)}\left[(q^r_{d1})^2 + \frac{\beta(q^o_{d1})^2}{1-\beta} - R_D(s)\right]_{R_U(s)=0} = 1 - \frac{4\gamma}{4-\sigma^2}$$

if D_1 can freely allocate between $R_U(s)$ and $R_D(s)$ under the sum constraint. The investment cost is shifted towards U_2 if the derivative at $R_U(s) = 0$ is positive.

2. η and β are affected as the sanction protracts. D_1's decision on sourcing diversification depends on its payoff differential $(q^r_{d1})^2 - R_D(s) + \frac{\beta}{1-\beta}\big((q^o_{d1})^2 - (q^d_{d1})^2\big)$. This value is increasingly decided by the first two terms as β decreases. Increase in η leads to increase in q^r_{d1}, so D_1 is more likely to source from U_2. The investment cost allocation problem is defined as

$$\frac{\partial}{\partial R_U(s)}\big((q^r_{d1})^2 + R_U(s) - (R_U(s) + R_D(s))\big) = 0,$$

or equivalently, $\psi q(\eta) = q^r_{d1}$ where $q(\eta) \equiv \frac{(4-\sigma)(\eta-\alpha)}{2(4-\sigma^2)}$ and ψ is a constant independent of η. Plugging this in (5), we obtain $R_U(s) \propto (q(\eta))^2$, so the investment cost is shifted more towards U_2 at every level of s as η increases. Meanwhile, D_1's payoff depends on the relationship between the two parameters. Lengthening the sanction has two conflicting effects. U_2 can recover the investment cost for a longer time but fruits of full competition are delayed as much. ■

Proposition 2 states that U_1 always loses from the sanction and D_1 gains if the competitors were viable before the sanction. U_1 has no way to increase its revenue by cutting off economic ties with D_1. If U_2 enters the market, U_1 loses the remaining profits from D_1 plus some of the profits from D_2 who now exploits U_2's enhanced technology in lowering the input price. On the other hand, D_1 can not only implement what it threatened U_1 to do at $t = 0$ but shift some of the investment costs to U_2 as U_2 now can afford a non-zero price while the sanction takes place. This allows D_1 to secure alternative sources even when it is unwilling or unable to fully bear the competitors' investment cost.

What happens when the sanction lengthens? The common wisdom is that longer sanctions are more effective. Proposition 2 says it is not always the case. Adjustment costs of downstream producers (investment cost of U_2 and D_1 here) can be recovered through a longer period, so U_2 might be able to enter the market even if it was not viable before the sanction. Moreover, since U_2 can raise revenue just as much to offset the fixed investment cost during the sanction, the input price will get cheaper with $\underline{s}$ held constant. D_1 weighs additional profits it will earn during and after the sanction against the investment costs, so β governs the entire process. We assume that β is small enough for D_1 not to exaggerate the post-sanction profit increments.[5] As the sanction protracts, D_1 faces a better chance to run profits well above the initial investment costs, and is more likely better off by curtailing the massive transfer from U_2 and instead tolerating a rise in the input price.

Can a choke-point sanction discipline downstream producers and their countries? Not always, and there is even a great possibility of backfiring when D_1 is a global giant. It makes sense for U_1's country to impose a sanction only when it brings immediate external benefits that outweigh the economic loss and D_1 is unable to partly close the technological gap and harness lesser players in the upstream market. However, for the sanction to exert enough pressure against the country, the target firm has to be economically and politically sizable, who are ironically better able to undertake investment costs of the potential competitors. This model shows how sanctions are unlikely to settle in as a new mode of economic warfare between advanced countries. If the sanction is brief, the firm will wait out. If it lasts long, the firm will find a way around, demolish the monopoly of their previous supplier and permanently enjoy higher profits.

I now consider the case where upstream producers are collusive. Although the leading firm and the potential competitors had no common interest prior to the sanction, the leading firm might be interested in a profit-sharing arrangement from the sanction on. The competitors also favor such a proposal since they are unable to run any profits otherwise in this model. It can be realized in the form of foreign investment, takeover and partnership at the

[5] There are three reasons for this. First, global corporations are expected to show good numbers to investors every quarter. Second, both governments will not easily back down and defuse the tension too early, conscious of their own citizens. Third, alternative suppliers in reality will be driven out from the upstream market in the end due to the technological and cost advantage of the market leader. D_1 will therefore not be able to enjoy fruits of full competition after a few periods past the sanction even if β is large enough.

firm level, or a coalition through side payments at the state level.[6] Suppose that U_1 takes $\theta \in (0,1)$ of the total payoff they raise since $t = 1$, and U_2 and U_3 keep half of the rest each. Proposition 3 illustrates the post-sanction collusive equilibrium.

Proposition 3. *When upstream producers are collusive,*

1. *D_1 always loses all profits during the sanction, while U_1 experiences a moderate loss if the competitors were viable.*

2. *D_1 is indifferent whomever it sources from, and earns the same profit as before when the sanction is lifted.*

Proof of proposition 3. If the competitors do not enter the market at $t = 1$, the equilibrium at $t = 2$ is the same as at $t = 0$. Suppose otherwise and the competitors produce at the level s. For upstream producers to maximize their aggregate payoff, only one of U_2 and U_3 enters the market. Assuming U_2 entered at $t = 1$, the producers maximize $p_{11}q_{11} + p_{21}q_{21} = c_1 q_{d1}$ at $t = 2$. Their optimization problem is reduced to deciding c_1, which is equivalent to the problem at $t = 0$. As long as the level of c_1 is the same as $t = 0$, they are indifferent to who supplies to D_1 how much, and so is D_1. D_1's profit is also the same as before.

Returning to at $t = 1$, upstream producers' decision at this point does not affect their later payoffs. They will therefore make D_1 pay as much investment cost as possible, and the agreed level of technology level is decided where $(q^m_{d1})^2 - R_D(s) = 0$ if there is no cost transfer from U_2 to D_1, in the opposite direction of what was in Proposition 1. D_1 loses all profit for one period and the upstream producers collectively bear R_U. U_1's payoff is given $\theta\big(\frac{p^m_{11}q^m_{11}}{1-\beta} - R_U(s)\big)$. ■

According to Proposition 3, U_1 still exerts a power tantamount to monopoly via lesser players even when barred from direct export to D_1, whereas the target firm loses whatever profits it had enjoyed before during the sanction. Since the upstream producers will ask D_1 to pay for the investment cost as much as it can afford at $t = 1$, the whole consumer surplus of D_1 is consigned to the upstream producers. Time is also on their side in this

[6] The upstream coalition will continue to trade with D_1 via either U_1 or one of the competitors if the coalition is mainly driven by economic interests. However, if the coalition is mainly driven by security concerns, it severs economic ties with D_1 just as the U.S. is currently pursuing regarding sensitive products.

case as it helps D_1 make bigger investment at the benefit of U_js. The market returns to the pre-sanction equilibrium after the sanction is lifted, besides that the competitors sell their products at the same effective price with U_1 so their entry does not contribute any to D_1's welfare. Upstream producers' aggregate revenue is constant throughout these periods. Therefore, we can consider as if U_1 converges with U_2 and U_3 in the trade network upon the collusive negotiation and the new U_1 solely decides whether to continue to trade with D_1 or not, ignoring its internal dynamics. The political implication is the opposite here: the more capable downstream producers are, the more likely sanctions are. The target firms would try to address the external causes that triggered the sanction rather than seek solutions within the market, and their government would more seriously consider bending to the attacker.

3 Discussion

Since D_1 gains upon a sanction if there are at least two viable alternative supplier in the upstream market, the home country has to block almost all competitors for an effective sanction.[7] However, from the perspective of the competitors, there is no reason for them to reject the collusive proposal of the market leader as they cannot run any profits even if they enter the market under full competition. I discuss how this concern can be addressed by relaxing two main assumptions.

First, U_2 and U_3 may be asymmetric. Suppose that U_2 has more advanced technology than U_3. The total surplus when D_1 trades with U_2 will be greater than that when it trades with U_3 due to the lower investment cost required at equilibrium. U_2 and U_3 will compete to the point where U_3 loses all of its surplus. Then, U_2 can take the difference of two total surpluses, at least as much as which U_1 must pay if it wishes to maintain its monopoly.

Second, upstream producers can face nontrivial production costs. Adding costs can affect the model in different ways. U_1 did not look for alternative trade partners upon a sanction above since it has indefinite production capacity and would already have been trading with

[7] I did not explicitly deal with the case where there is only one viable competitor U_2 in the market, but then the problem basically reduces to the divide-the-dollar game – the equilibrium price can be determined anywhere between two extremes depending on the negotiation power of U_2 and D_1. D_1 still can gain in theory.

every firm willing to buy its products. Under positive costs, U_1 becomes less vulnerable to the sanction as it too can seek alternative trade partners. The lock-in logic can be applied for upstream producers. On the other hand, introduction of costs can be detrimental to U_1 if producers face economies of scale as in the semiconductor industry. Since the quantity is crucial in economies of scale, the potential competitors cannot enter as long as the market leader can take away their orders by means of a counterproposal as we have seen it in Proposition 1. D_1 cannot defect unless it assumes all of their enormous investment costs, which makes D_1's defection threat less effective. When U_1 is partly excluded from the market, however, not only does U_2 have enough time to take order to realize economies of scale but D_1 need not assume as much costs to have U_2 enter the market. The lock-in logic here operates against the home firm's benefit.

I plan to extend this model further in various directions. Incorporating the weight the home government puts between economic power and strategic competition will support my arguments of hyper-securitization. The more weight it puts on strategic competition, the more likely it would prefer containing D_1, which is expressed as the collusive equilibrium with no trade with D_1 in the model. I expect a non-linear relationship between the weight parameter and the optimal size of containment cooperation. Building a dynamic model where firms make investment decisions each period will help examine the role of technology advancement in the outcome of choke-point sanctions. I expect faster technology advancement makes it harder for potential competitors to enter, but at the same time strengthens the lock-in effect. Finally, modeling a multi-level trade network will help identify how choke-point sanctions affect the entire structure of the network and change the distribution of choke points.

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