Flexibility Value of Reshoring Capacity under Policy Uncertainty and Domestic Competition [1]

Panos Kouvelis
Olin Business School, Washington University in St. Louis, kouvelis@wustl.edu

Xiao Tan
East China University of Science and Technology, xiaotan@ecust.edu.cn

Sammi Tang
Herbert Business School, University of Miami, ytang@miami.edu

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Abstract

Problem definition: Companies operating global supply chains face growing policy uncertainties that affect the costs of importing raw materials (RM) and finished goods (FG) from low-cost to developed countries, as well as the relative profitability of production in different countries. This has prompted the need for diversified global supply chains often involving the addition of onshore production alongside existing offshore facilities. Motivated by recent developments in the U.S. clean energy sector, this paper adopts a game-theoretic model to analyze a global firm's reshoring capacity decision and output quantity competition with a domestic manufacturer under policy uncertainty. We examine the effects of these policies on operational decisions and profitability for both firms.

Methodology/results: We show that the impact of FG tariffs depends on two opposite effects: an output quantity effect that leads to reduction of reshoring investment as the expected unit cost in serving the market increases, and an overflow demand effect that encourages more reshoring investment to minimize the overflow of unsatisfied production to offshore locations. RM tariffs do not affect overflow production, and the output quantity effect will always dampen reshoring investment. Since consumer tax credits directly influence market demand, when firms' output decisions are made after demand and therefore policy realization, the output quantity effect is absent. The overflow demand effect and stimulated higher demand will incentivize higher reshoring investment. Furthermore, we show that higher tariffs hurt the global firm's profit as tariffs increase its average output cost, whereas generous tax credits can benefit the firm. Although both policies are intended to protect domestic firms, they may negatively affect their profit when the global firm's reshoring capacity is high, intensifying competition between them. Finally, the existence of domestic competition will reduce reshoring investment when domestic manufacturing is efficient. However, when global firms have significant cost advantage, the presence of domestic competition may encourage aggressive reshoring investment.

Managerial implications: For global firms, investing in reshoring capacity creates a "real option" in production allocation in serving the market, and the provided operational flexibility enhances competitiveness in an uncertain environment. For policymakers, it is crucial to carefully consider the tariff level, which stage of a supply chain to execute trade restrictions on, and tax credit amounts to be used. Very high tariffs on moderate size markets may have unexpected

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effect on reshoring. Trade and industrial policies should be carefully analyzed for their effectiveness, accounting for cost disadvantages of domestic competitors and market demand strength.

Keywords: global supply chain; reshoring; cost uncertainty; competition; industrial policy

1. Introduction

Over the last decade, Western countries have established ambitious targets for transitioning toward renewable energy sources. At the same time, China has emerged as a dominant producer for clean energy products such as solar panels and energy storage batteries, crucial for Western countries to meet their objectives. This creates much geopolitical tension between them and China.

To protect U.S. manufacturers, the Obama administration imposed high tariffs on solar panels (Bradsher & Cardwell, 2012). Later, the Trump administration increased tariffs on imported solar cells as part of a broader trade action. The tariffs started at 30% in 2018 and gradually decreased to 15% (Eckhouse *et al.*, 2018). However, in a greater effort to address climate change, the Biden administration temporarily eased the solar tariffs to help domestic energy developers get access to cheap overseas supplies (Renshaw & Groom, 2022). But there is no intention to end the tariffs. In fact, the Biden administration further increased the tariff on Chinese solar cells to 50% over concerned about China's excess capacity and the threat of flooding global markets (Tankersley & Rappeport, 2024). Domestic solar manufacturers also urge the U.S. to expand tariffs to other Asian countries, which might be serving as transshipment hubs of Chinese producers, as solar module prices from those countries plummet to record lows (Rappeport, 2024). The U.S. administration faces conflicting goals in setting tariff policy. On the one hand, its ambitious climate goals argue for reduced tariffs and relying on the vast Chinese supply chains. On the other hand, concerns about overreliance on China argue for growing the domestic supply chain through protective tariffs. This dilemma is behind the significant uncertainty about future U.S. tariff policies, what tariff rate will be imposed, and which stage will be targeted. Will tariffs continue to apply at the finished goods level (e.g., panels), or will they extend to the component level (solar wafers), as what the Trump tariffs did in other industries?

In addition to tariffs, recent industrial policies such as the Inflation Reduction Act (IRA) also aim to bolster domestic manufacturing through subsidization. The solar energy credit enables homeowners and business owners to claim a 26-30% tax credit for solar PV systems installed since 2020 (US Department of Energy, 2024). Similarly, for electric vehicle (EV) manufacturers utilizing battery minerals sourced from the U.S., and with battery components manufactured and final assembly done in the U.S., the IRA provides a \$7,500 tax credit for consumers purchasing these EVs. Moreover, the investment tax credit and production tax credit directly subsidize manufacturers for constructing new production facilities and making clean energy components in the U.S. (IRS, 2022). Will such tax credit policies be effective in reshoring supply chains?

These trade and industrial policies have a significant impact on companies' sourcing cost structures and the profitability of producing in different locations. The unpredictability of geopolitics often triggers frequent revisions of tariff policies, making these sourcing cost shocks hard to predict. Although many companies have advanced their demand planning skills to manage market demand uncertainty, now they have to deal with supply cost uncertainty, often requiring rapid responses. In such a turbulent environment, many multinational manufacturers realize the need to have diversified global supply chains—being global and local at the same time.[2] Local production capabilities enable firms to mitigate risks such as country-specific tariffs that disrupt supply to end markets. The recent tax policies and further increased tariffs have made such reshoring investments even more appealing. Global solar manufacturers like Enel and Maxeon, and even some from China (e.g., Longi), have initiated the construction of solar panel factories in the U.S., signaling a shift toward localized production (Dvorak, 2022, 2024). In response to IRA incentives, the South Korean manufacturer Hyundai Motors, which imports most of its EVs from its home country for sale in US, has rushed to build a factory in Savannah, Georgia (Amy, 2023).

However, both global and domestic manufacturers face challenges. For global companies, despite the generous tax credits, the cost of establishing new facilities and ramping up production is still quite significant. The costs of labor, supply, and energy tend to be higher in developed nations (Davis, 2024). Therefore, how much capacity to invest in these markets is probably a more urgent question to answer than whether they should invest or not. For domestic companies, although the high tariffs and tax incentives are intended to shield them from fierce competition from low-cost countries with excess capacity, the competition landscape shifts as competitors relocate some production onshore. This transition raises uncertainties regarding whether domestic companies can ultimately reap benefits from trade protectionism.

Motivated by these industry observations and the above raised questions, in this paper we develop a game-theoretic model to study global firms' reshoring investment decision and global production network configuration, as well as the impact on quantity competition in the domestic market. The domestic capacity, if installed, provides sourcing and production flexibility for the global firm. The firm may meet the output target by sourcing and producing in the existing offshore location or producing in the domestic facility using either locally or imported input. We aim to provide answers to the following research questions: How do trade and industrial policies

[2] Alfaro & Chor (2023) shows a sharp rise in the use of the phrase "reshoring" in earnings conference calls conducted by listed firms from mid-2017 to mid-2020. The study also shows that starting in 2022, there has been another increase in discussions about reshoring, reflecting the Biden administration's continued use of tariffs and its public turn toward industrial policy.

affect the global firm's investment and profitability in serving the domestic market? What are the differences among these policies? What is the differential impact of imposing tariffs at RM level versus FG level on reshoring investments? What is the role of competition in the domestic market on reshoring investments? Do trade and industrial policies always achieve the government objective of protecting domestic manufacturers and increasing total production output in the domestic market?

We will model reshoring decisions of the global firm under tariff and tax credit policies differently. The main consideration reflected in our modeling choice is that tax credit policies seriously impact consumer demand (Rivero, 2024), and companies' production planning decisions lag behind the implementation of such policies. Changes in tariff policies, especially in the last few years, are more frequent and easier to implement. With production plans made ahead of them, the only contingency plan is how to adjust assembly locations based on tariff costs (Sachs, 2024). Therefore, we formulate a three-stage tariff model reflecting firms' operational decisions in different phases: the global firm's long-term decision on how much reshoring capacity to install; the competing firms' output decisions based on observed market demand; and finally, the global firm's sourcing and production allocation decision based on realized tariffs. Recognizing the direct impact of tax credit policies on market demand, we formulate a two-stage tax credit model to reflect the dependency of demand on policy parameters. After both policy and demand uncertainties are resolved, competing firms make their output and production decisions accordingly.

Through the analysis of these models, we show that the effects of tariff and tax credit policies depend critically on two defined costs: the expected offshoring cost (when exclusively sourcing and producing in the low-cost country to serve the domestic market) and the expected global optimal cost (when the sourcing and production decisions optimize the use of the global supply chain). We identify two opposite effects associated with these costs. On the one hand, an increased global optimal cost means a higher average unit cost of serving the market, which leads to a lower output quantity and less need for reshoring capacity. We refer to this effect as the *output quantity effect*. However, when demand is high relative to planned reshored capacity, the global firm has to overflow excess production to the offshore location. An increased offshoring cost makes offshore production more expensive and thus encourages more reshoring investment. This effect is referred to as the *overflow demand effect*. Our analysis will point out that the effect of FG tariffs depends on which of the above two effects dominates. Specifically, when the output quantity effect dominates, raising the FG tariff may discourage reshoring investment. Furthermore, we show that imposing RM tariff will always dampen the incentives for reshoring, as such tariffs do not affect offshoring costs, but lead to an increased global optimal cost (when reshoring capacity uses imported raw materials). In the absence of overflow demand effect, the output quantity effect always reduces the reshoring capacity.

When firms' output and production decisions are made after policy and demand realization, as in the tax credit model, the policy only affects the global firm's reshoring investment decision via the overflow demand effect. Domestic capacity only matters when the domestic production cost is lower than the offshoring cost, but domestic production cost is not affected by the tax credit policy. Therefore, the policies will always lead to increased reshoring investment and higher domestic production.

We also show that the tariff policy always hurts the global firm's profit because tariffs increase its average cost in serving the market. Although the tariff policy has no direct impact on the domestic firm's cost, it will have an indirect effect on the domestic firm's profitability through market competition. The domestic firm can benefit from imposed tariffs when the global firm's reshoring investment is low or when the output quantity effect dominates. However, when the global firm aggressively increases its reshoring investment, the domestic competitor's profit may decrease. On the other hand, the tax credit policy can benefit both firms by stimulating demand and subsidizing domestic production. Nevertheless, like tariff policy, such subsidization may sometimes negatively impact the domestic firm's profit when the global firm's reshoring capacity is high, leading to intensified competition between them.

Our analysis offers insights on the role of domestic competition on the global firm's reshoring investments. In the presence of a domestic competitor with rather low production costs, reshoring is less attractive to the global firm as it leads to intense competition with an efficient domestic competitor. However, domestic competition may encourage more reshoring investment when the domestic production cost is relatively high. The increased reshoring capacity not only mitigates cost uncertainty but also enables the global firm to more effectively compete with the domestic firm in the presence of strong domestic demand.

2. Related Literature

Our paper relates and contributes to the global supply chain configuration literature. An important aspect of companies' global supply chain strategy is where to locate production/warehouse facilities and whether to source products from a foreign country or a domestic location in an uncertain environment. For example, Lu & Van Mieghem (2009) consider a single-firm, two-stage production system in which RM may be produced in either domestic or foreign locations, and the final assembly of FG localizes to every market. The modeled uncertainty is demand uncertainty in every market, with prices ex ante set. Along with a similar modeling approach, Dong *et al.* (2010) endogenize prices in a responsive pricing Newsvendor network under both demand and exchange rate uncertainties. One could interpret the results in these studies as follows: An increase in the "inbound transshipment cost" to the domestic market favors market-focused network configuration and the reshoring of material sourcing activities. Our paper accounts for uncertainties in both demand and costs of RM and FG, and for competition in the domestic market. We model the created "real option" for a global firm in serving the domestic market via the reshored capacity. The flexibility of such an added option in the presence of uncertain trade and industrial policies offers newly discovered insights on how tariffs and tax credits and their implementation uncertainty affect reshoring investment and competing firms' profits.

Several studies in the global supply chain literature do capture supply uncertainties in the form of random yield (Jung, 2020), production cost uncertainty (Shao *et al.*, 2020), or exchange rate uncertainty (Huchzermeier & Cohen, 1996; Dong *et al.*, 2010). These studies consider cost uncertainty at either the RM or FG level and without considering competition. The explicit modeling of cost uncertainty at both the RM and FG level and the explicit modeling of industrial policies behind the uncertainty as well as their differential impact on competing firms differentiate our work from those studies. Trade policies, for instance, as considered in our paper, affect the cost of both imported RM and FG, and the import cost increases may be different for RM and FG. For companies that have production facilities in different countries and must decide where to source RM and where to conduct FG production, it is important to consider the relevant costs at both RM and FG levels.

Our research also contributes to the literature on effectiveness of tax and tariff policies. The economics literature that studies the latest tariff policies mainly focuses on the impact of tariffs on macroeconomic indicators such as prices, quantities of imports and exports, and welfare (Amiti *et al.*, 2019; Fajgelbaum *et al.*, 2020; Handley *et al.*, 2020). The recent papers by Charoenwong *et al.* (2023) and Rogers *et al.* (2024) empirically examine the impact of trade policy uncertainty on the supply chain networks of American firms. Operational details such as capacity investment and production allocation are not explicitly modeled. Complementary to the economics literature are operations management (OM) studies that assess international tax policy implications at the firm level, including works on global firms' supply chain strategies under local content tariff rules (Li *et al.*, 2007), implications of supply chain structure and procurement strategy under China's export-oriented tax rules (Hsu & Zhu, 2011; Xu *et al.*, 2018), and capacity, sourcing, and pricing strategies when tax rates are different across operating countries (Shunko *et al.*, 2014; Hsu *et al.*, 2019). Two recent papers in this literature compare reshoring and offshoring under tariffs. Assuming deterministic demand and tariffs, Yang *et al.* (2021) analyze Cournot competition between a domestic firm and a multinational firm that can produce onshore or offshore. Their results are in support of the government policy of imposing high tariffs to induce reshoring. In a monopolistic model with demand uncertainty, Chen & Hu (2017) compare offshore and reshore of FG production with offshore-sourced components. They find that reshoring becomes less appealing when customs duties for components increase or those for FG decrease. These studies assume unlimited reshoring capacity and deterministic tariff rates. A recent global field study among leading manufacturers (Cohen *et al.*, 2018; Cohen & Lee, 2020) indicates that uncertainty around trade and industrial policies have gained more weight in influencing companies' global supply chain strategies. As part of a thought-leading piece on the impact of tariffs on the global supply chain, Dong & Kouvelis (2020) use simple models to highlight—but not analyze in detail—the implication of tariff policy uncertainty, product portfolio flexibility, and competition for firms' global supply chain design decisions. However, the current literature lacks a comprehensive model that captures critical operational details on reshoring capacity investment in the presence of tariff uncertainty and demand influencing tax credit policies with explicit consideration of domestic competition. Our paper is motivated by the effort to close this gap.

3. The Tariff Policy Model

This section introduces a stochastic programming problem to study the tariff policy impact. Consider a global firm that currently serves the "domestic market" (the market protected by the tariffs) in country U through offshore production in a low-cost country C. Without loss of generality, producing one unit of FG requires one unit of input. We denote the baseline FG cost as w_C per unit, which includes the current sourcing and production cost in country C. We normalize the current unit production cost in country C to 0, thus w_C is effectively the material cost. Due to the imposed tariffs on imported finished products, the total landed cost of imported FG will become $w_C(1+t_F)$, where $t_F > 0$ represents the ad valorem FG-level tariff rate. Assume t_F has a support on $[0, \bar{t}]$[3], and its *pdf* and mean are denoted as $f_1(\cdot)$ and μ_F, respectively.

To hedge against the increasing FG cost, the global firm has the option of installing capacity in country U and sourcing and/or producing locally. Denote the unit capacity installment cost as C_U (which includes the amortized variable cost for installing capacity) and the capacity to be installed as K_U. When RM is sourced from country C, as for FG, the imported RM may be subject to a tariff. In line with our previous assumption, the total landed cost of RM is $w_C(1+t_R)$, where $t_R > 0$ represents the ad valorem RM-level tariff rate. Assume t_R has a support on $[0, \bar{t}]$, and its *pdf* and mean are denoted as $f_2(\cdot)$ and μ_R, respectively. RM can also be sourced locally from country U, with cost w_U. We assume $w_U > w_C$ to reflect the reality that country C used to be a low-cost country for both production and materials. When FG is produced locally in country U, the firm

[3] We only assume the existence of a finite upper bound on both FG and RM tariffs. It can be a very large number. The existence of this upper bound will serve to support the case that the offshoring option is unattractive when the upper bound tariff rate is applied.

incurs a higher unit production cost than in country C (which is normalized to 0). The production cost difference is denoted as δ ($\delta > 0$).

Using an example from the global solar energy industry, Shanghai-based Trina Solar is among the biggest manufacturers in the world and also supplies the U.S. market. While Chinese companies can make solar panels for 16-19 cents per watt of generating capacity, American companies like First Solar cost 28 cents per watt (Bradsher, 2024a). In our model, Trina represents the global firm with main production facilities in China and is considering building assembly plants in the U.S. to avoid tariffs (and tap into subsidies offered by IRA). To summarize, with production facilities in both countries, the global firm has the following three sourcing and production options (Chen & Hu, 2017, consider similar reshoring structures):

- Offshore sourcing and production: that is, produce FG in country C and import to country U; the total landed cost of FG is $w_C(1 + t_F)$.
- Offshore sourcing and onshore production: that is, source RM from country C and produce FG in country U; the cost of FG is $w_C(1 + t_R) + \delta$.
- Onshore sourcing and production: that is, source and produce locally in country U; the cost of FG is $w_U + \delta$ (for convenience, we define $w'_U := w_U + \delta$).

In country U, a domestic manufacturer like US-based First Solar, referred to as firm L, produces locally and sells to the same market. Like the global firm, firm L incurs the total unit cost w'_U. We consider a Cournot competition between the two firms. Assuming that the products of the two firms are perfect substitutes, we define the market price by a linear inverse demand function $p = \epsilon - (Q + Q_L)$, where ϵ denotes the random market size, and Q and Q_L denote the output quantity of the global firm and firm L, respectively. Assume that ϵ is distributed according to *pdf* $g(\cdot)$ and *cdf* $G(\cdot)$. To focus on the global firm's reshoring capacity decision, we assume that both firms do not face any capacity constraints in their current facilities—that is, the global firm's offshore facility and firm L's domestic facility. The assumption implies that historically the firms have successfully supplied their markets, and these capacity investments are sunk. This assumption is also supported by the anecdotal evidence that solar manufacturers from China have rapidly developed with generous government support. Not only have they come to dominate the global solar industry, but they have to address their overcapacity issue (Bradsher, 2024b). Meanwhile, solar manufacturing facilities in the U.S. and Europe have been underutilized because of their cost disadvantage (Bradsher, 2024a).

We consider the operational decisions for the two firms in the following three stages. First, the global firm needs to decide how much domestic capacity to invest in. Capacity investments are long-term, irreversible nature decisions made ex-ante to demand and trade policy uncertainties

(Dixit & Pindyck, 1994). Then, the market uncertainty gets resolved, and both firms make medium-term planning decisions in setting output quantities (and the price) for the market. Such planning allows firms to put in place needed auxiliary assets (e.g., advertising, sales planning, logistics, etc.). Finally, after the trade policy uncertainty is resolved in the short term, the global firm optimizes the efficiency of its delivery to the market, deciding how to deploy its global facility network. In the clean energy sector we consider, manufacturers usually do not deviate from the planned volume because their buyers, mostly solar developers, expect to receive the contracted volume based on projected development plan for their own production or project. Deviations could lead to delayed projects for developers who have to make penalty payments to their customers such as utility companies and other business owners (Balaraman, 2022). In the case of EV, Stellantis announced sales and operations plans in Europe ahead of the tariff announcement. The company created cost thresholds that dictate the production location in executing its sales plans, and when facing newly imposed tariffs, the company has decided on ways to shift some production away from China to European factories (Sachs, 2024).

The three-stage game is formulated as follows and illustrated in Figure 1:

- Stage 1: The global firm decides on the domestic capacity size K_U to maximize its expected profit: $\Pi = \max_{K_U \geq 0} \; R(K_U) - C_U K_U$, where $R(K_U) = E_\epsilon[\pi(\epsilon, K_U)]$ denotes the global firm's long-term average profit over all possible market conditions ϵ, and $\pi(\epsilon, K_U)$ is the realized profit for a given ϵ (defined below).

- Stage 2: After demand realization, the global firm and firm L set the output quantity Q and Q_L simultaneously.[4] For a given ϵ, firm L solves the profit maximization problem: $\max_{Q_L \geq 0}[(\epsilon - (Q + Q_L)) - w'_U]Q_L$. The global firm maximizes its expected operating profit: $\pi(\epsilon, K_U) = \max_{Q \geq 0} \; (\epsilon - (Q + Q_L))Q - EC(Q, K_U)$, where $EC(Q, K_U) = E_{t_F, t_R} TC(Q, K_U, t_F, t_R)$ denotes the expected cost of deliverying the output quantity Q to the market.

- Stage 3: After the tariff policy realization, the global firm decides on the production quantities q_C, q_{UC}, and q_{UU}, where q_C denotes the sourcing and production quantity in country C. q_{UC} denotes the quantity produced in country U using imported RM from country C. q_{UU} denotes the quantity produced in country U using locally sourced RM. The global firm solves the

[4] We assume that K_U is public information. In the clean energy industry, companies often make public announcements about plans for new capacity or capacity expansion in the form of company press release and news release. Also, capacity decisions are usually long-term, and multi-year contracts to key suppliers are awarded with clearly stated sales expectations. From such information, capacity is often inferred.

following cost minimization problem:[5]

$$
\begin{aligned}
TC(Q, K_U, t_F, t_R) = \min_{q_C, q_{UC}, q_{UU} \geq 0} & \; w_C(1+t_F)q_C + [w_C(1+t_R)+\delta]q_{UC} + w'_U q_{UU} \\
\text{s.t.} \quad & q_{UC} + q_{UU} \leq K_U, \; q_C + q_{UC} + q_{UU} = Q
\end{aligned} \tag{1}
$$

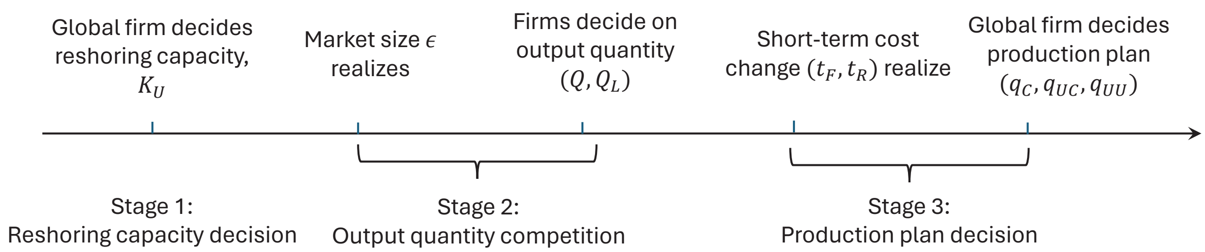


Figure 1: Sequence of events for the tariff policy model

To avoid uninteresting cases, we assume that $w_C < w'_U < w_C(1+\bar{t})$. It reflects the reality that in the absence of tariffs, offshore sourcing and production is cheaper than onshore. However, when the tariffs are too high, moving those activities to country U may save on costs (otherwise, the global firm has no incentive to reshore, and the problem is trivial).

3.1 Model analysis

We analyze the three-stage game using the standard backward approach. Starting from stage 3, we see that problem (1) is a linear program. The optimal sourcing and production decisions depend on the comparison among the three costs, $w_C(1+t_F)$, $w_C(1+t_R)+\delta$, and w'_U. Lemma 1 characterizes the optimality region for each production option.

Lemma 1: *For given $K_U, Q, \epsilon, t_R, t_F$, the optimal sourcing and production decisions are given in Figure 2:*

In region Ω_1, t_F is relatively small; offshore sourcing and production provides the lowest cost. Similarly, in region Ω_2, t_R is relatively small while t_F is relatively large; it is optimal to produce in country U using imported RM from country C. If the output quantity Q is larger than the available capacity K_U, the remaining quantity will be satisfied by the production in country C. Finally, in region Ω_3, when imported costs for both RM and FG turn out to be high, domestic sourcing and production becomes the preferred choice. Again, production in country C will satisfy any quantity beyond the domestic capacity. This result reflects the global firm's *sourcing and*

[5] More precisely, the stage 3 problem may be formulated with the constraint that $q_C + q_{UC} + q_{UU} \leq Q$ and incorporating a penalty term $l \cdot (Q - q_C - q_{UC} - q_{UU})$ in the objective function. When l is sufficiently high, the above constraint must be binding. This is the case for solar manufacturers in support of major customers' solar development plans.

Regions	$(q_C^*, q_{UC}^*, q_{UU}^*)$
Ω_1: $t_R \in (0, \bar{t})$ and $t_F \in \left(0, \min\left\{t_R + \frac{\delta}{w_C}, \frac{w_U' - w_C}{w_C}\right\}\right)$	$(Q, 0, 0)$
Ω_2: $t_R \in \left(0, \frac{w_U - w_C}{w_C}\right)$ and $t_F \in \left(t_R + \frac{\delta}{w_C}, \bar{t}\right)$	$((Q - K_U)^+, \min\{Q, K_U\}, 0)$
Ω_3: $t_R \in \left(\frac{w_U - w_C}{w_C}, \bar{t}\right)$ and $t_F \in \left(\frac{w_U' - w_C}{w_C}, \bar{t}\right)$	$\left((Q - K_U)^+, 0, \min\{Q, K_U\}\right)$

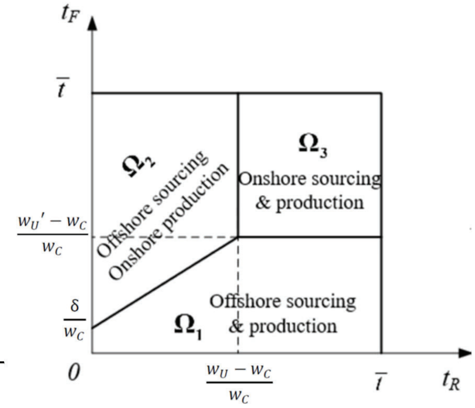


Figure 2: Tariff policy model: Optimal sourcing and production decision

production flexibility when operating a global production network with production capabilities in different locations. Such a network enables the global firm to optimally respond to cost changes. Using Lemma 1, we can express the global firm's expected cost of producing an output quantity Q as follows:

$$EC(Q, K_U) = E_{t_F, t_R} TC(Q, K_U, t_F, t_R) = \begin{cases} m_A \cdot Q, & \text{if } 0 \leq Q \leq K_U \\ m_A \cdot K_U + m_B \cdot (Q - K_U), & \text{if } Q > K_U, \end{cases} \tag{2}$$

where $m_A = E_{t_F, t_R}[\min\{w_C(1+t_F), w_C(1+t_R)+\delta, w_U'\}]$ represents the expected unit cost of serving the market when optimally utilizing the global production network, referred to as the (expected) *global optimal cost* in short hereafter, and $m_B = E_{t_F}[w_C(1+t_F)]$ represents the expected unit cost when always producing in the offshoring country C, referred to as the (expected) *offshoring cost*.[6] Clearly, we have $m_A < m_B$.

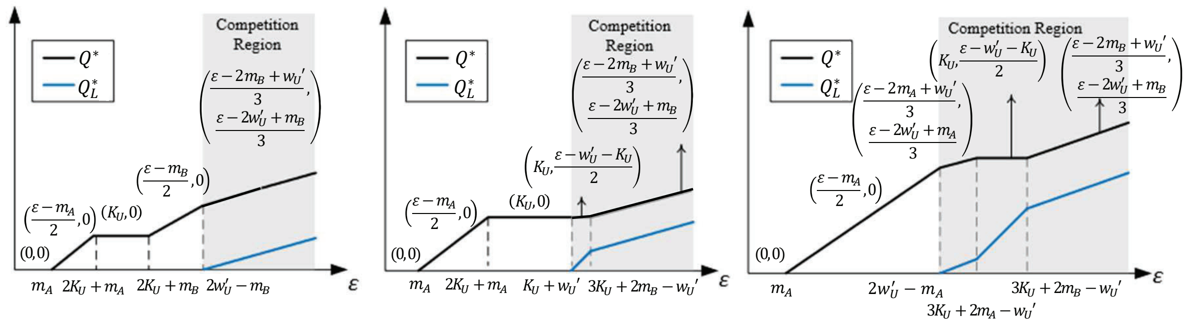
Next, we derive the equilibrium of stage-2 Cournot competition. Firm L solves the profit maximization problem: $\max_{Q_L \geq 0} (\epsilon - (Q + Q_L)) Q_L - w_U' Q_L$. The best response function is $Q_L(Q) = \frac{\epsilon - Q - w_U'}{2}$. The global firm solves the profit maximization problem: $\max_{Q \geq 0} (\epsilon - (Q + Q_L)) Q - EC(Q, K_U)$. The best response function can be derived as the following:

$$Q(Q_L) = \begin{cases} \frac{\epsilon - m_A - Q_L}{2}, & \text{if } \frac{\epsilon - m_A - Q_L}{2} < K_U, \\ K_U, & \text{if } \frac{\epsilon - m_B - Q_L}{2} \leq K_U \leq \frac{\epsilon - m_A - Q_L}{2}, \\ \frac{\epsilon - m_B - Q_L}{2}, & \text{if } \frac{\epsilon - m_B - Q_L}{2} > K_U. \end{cases} \tag{3}$$

The equilibrium of the Cournot competition can be derived from the intersection of the two best response functions.

[6]For brevity, when not confusing, we drop "expected" when referring to these costs hereafter.

Proposition 1: *Figure 3 characterizes the equilibrium output quantities (Q^*, Q_L^*) in stage 2. Q^* and Q_L^* are represented by the solid black and blue lines, respectively; the quantities are shown in parentheses.*



(i) $K_U \leq w_U' - m_B$ (ii) $w_U' - m_B < K_U \leq w_U' - m_A$ (iii) $K_U > w_U' - m_A$

Figure 3: Tariff policy model: Output quantity equilibrium in Cournot competition

The equilibrium result indicates that both firms will not find production profitable when the market size is too small. However, the two firms differ in their sourcing and production flexibility: The global firm can flexibly utilize the cheaper production site upon tariff realization, while firm L has no such flexibility. Therefore, the global firm is more competitive with a lower average output cost than its domestic competitor. This is reflected in the equilibrium in that for certain market size, only the global firm finds production profitable, and firm L stays out of the market. The two firms actively engage in quantity competition only in the competition region (shaded area) shown in Figure 3. In particular, when w_U' is much higher than the global firm's costs m_A or m_B, the domestic firm cannot effectively compete in the market (with a shrinking competition region). This seems to be the case for the solar industry in recent years,[7] and explains the need for tariffs to reduce the gap between w_U' and m_A as well as m_B in order to help domestic manufacturers survive.

Furthermore, for a range of demand realizations, the global firm's output quantity exhibits *inertia* in meeting the demand. This is caused by the limited reshoring capacity and cost discrepancy between offshore and onshore production. For example, in Figure 3(i), the global firm's domestic capacity K_U can fully satisfy its production needs when $m_A \leq \epsilon < m_A + 2K_U$. But as the market size increases, the global firm reaches its domestic capacity and any remaining output must be fulfilled by the capacity in country C. Since the offshoring cost is higher than the global optimal cost, meeting excess domestic demand through offshoring does not prove profitable if the extra fulfilled demand does not justify the extra cost. The output remains at K_U. However, for sufficiently high demand ($\epsilon > m_B + 2K_U$), the penalty for shorting demand gets too high, and the firm will increase its output by overflowing excess production to the offshore location. In the next

[7]In a recent article (Halper, 2024), the CEO of First Solar mentioned "a significant collapse in cell and module pricing threatening the viability of many manufacturers who may never be able to get off the ground."

section, we will see that this *overflow* behavior plays an important role in the reshoring capacity decision.

Equipped with the stage 3 and stage 2 solutions, we next analyze the global firm's stage 1 capacity decision. We can verify that the global firm's stage 1 objective function is concave when $g(\cdot)$ is non-increasing and the condition $w'_U < 2m_B - m_A$ holds. The latter condition implies that the onshore sourcing and production cost w'_U is not too high and reshoring is still attractive to global firms. The concavity of the objective function guarantees that the optimal reshoring capacity decision can be characterized by the first-order condition that depends on which stage-2 equilibria is achieved. Reshoring is profitable only when the capacity investment cost is below a certain threshold (C_0^m or C_0^d).

Proposition 2: *The optimal capacity K_U^* satisfies the following characterizing equation (the thresholds $C_0^m, C_0^d, C_1^d, C_2^d$ and first-order conditions FOC^m, FOC_1^d, FOC_2^d are defined in the proof):*

$w'_U \leq m_B$	$w'_U > m_B$
$\begin{cases} FOC_1^d, & \text{if } C_U \in [0, C_2^d) \\ FOC_2^d, & \text{if } C_U \in [C_2^d, C_0^d) \\ 0, & \text{if } C_U \in [C_0^d, \infty) \end{cases}$	$\begin{cases} FOC_1^d, & \text{if } C_U \in [0, C_2^d) \\ FOC_2^d, & \text{if } C_U \in [C_2^d, C_1^d) \\ FOC^m, & \text{if } C_U \in [C_1^d, C_0^m) \\ 0, & \text{if } C_U \in [C_0^m, \infty) \end{cases}$

In today's solar industry, the manufacturing cost for solar panels is still significantly cheaper in China than in other countries (Bradsher, 2024a). In this case, the reshoring feasibility region is determined by the threshold $C_0^m = \int_{m_A}^{m_B} (\epsilon - m_A) dG(\epsilon) + \int_{m_B}^{\infty} (m_B - m_A) dG(\epsilon)$. Clearly, the feasibility region is larger when the manufacturing cost in country U, w'_U, reduces. But as the manufacturing cost in country C fell sharply in recent years, the gap between w'_U and w_C widened. We observe that as $w_C(1+\bar{t})$ approaches w'_U, the reshoring threshold C_0^m approaches zero,[8] which will threaten the feasibility of reshoring. This explains the sharp increase in tariffs by the Biden administration in 2024 when the cost of Chinese solar panels dropped by more than 40% to a record low (Tankersley & Rappeport, 2024).

4. The Effects of Tariff Policies

In this section, we examine how tariff policies that change frequently in the short term would affect the global firm's reshoring investment and profitability in serving the domestic market, as well as the output quantity and profit of the domestic competitor. To facilitate analysis and gain clear

[8]When w_C is significantly lower than w'_U such that $w_C(1+\bar{t}) \gtrapprox w'_U$, the two costs are approximately equal, i.e., $m_A \approx m_B$. Therefore, $C_0^m \approx 0$.

insights, we assume that ϵ follows a uniform distribution on $[0, M]$ and the distributions for t_R and t_F are independent. As we will show later in §4.4, the insights largely hold in the correlation case.

We adopt the concept of deterministic (specifically, linear) transformation of a random variable (Meyer & Ormiston, 1989) to model the change in the magnitude of uncertain tariff rate. We say t'_i $(i = R, F)$ is an increasing deterministic transformation of t_i if t'_i is obtained by transforming every realization of t_i by an increasing amount (for simplicity, we assume the same positive amount hereafter). Therefore, the marginal *pdf* satisfies $f'_i(t_i + a) = f_i(t_i)$, $a > 0$. It is straightforward that t'_i has a larger mean than t_i. It also implies that t'_i first-order stochastically dominates t_i.

4.1 Impact on reshoring capacity

The next proposition shows that tariffs that impose on different stages of a supply chain may have different effects on reshoring investment. While a higher FG tariff can encourage more reshoring investment under certain conditions, imposing tariffs at the RM level will always dampen the reshoring incentive.

Proposition 3:

(i). When t_F undergoes an increasing deterministic transformation, there exists a threshold Θ_{K_U} (defined in the proof) such that $\frac{\partial K_U^*}{\partial \mu_F} > 0$ if $\frac{\partial m_A/\partial \mu_F}{\partial m_B/\partial \mu_F} < \Theta_{K_U}$, and $\frac{\partial K_U^*}{\partial \mu_F} < 0$ otherwise.

(ii). When t_R undergoes an increasing deterministic transformation, the global firm's optimal reshoring capacity decreases, i.e., $\frac{\partial K_U^*}{\partial \mu_R} < 0$.

Proposition 3(i) states that the FG tariff effect depends on how it affects the two costs m_A and m_B. On the one hand, an increased FG tariff makes the offshore production option more expensive and may even motivate the global firm to switch to onshore production. The consequence is a higher unit cost of producing for the market, reflected by an increased m_A. Recall from (2) that when $Q > K_U$, the total production cost is $m_A K_U + m_B(Q - K_U)$. Since a higher m_A will increase the unit cost of serving the market, the firm will have incentives to set a lower output quantity and therefore has less need for reshoring capacity. We refer to this effect associated with m_A as the *output quantity effect*. On the other hand, when demand is above the inertia region and the firm cannot fully satisfy the demand with the onshore capacity (when onshore production is favored), it must overflow part of its production to the offshore facility. The overflowed quantity is produced at the higher offshoring cost m_B (recall that $m_B > m_A$). Therefore, a higher m_B would incentivize the global firm to invest in a larger domestic capacity, allowing it to overflow less production to country C. We refer to this effect associated with m_B as the *overflow demand effect*.

When demand is high, and therefore, overflow possibility is also high, the overflow demand effect associated with m_B is more profound than the output quantity effect associated with m_A, and an increased FG tariff will lead to more reshoring investment. This outcome is what the U.S. and European governments intend to achieve with their trade policies for renewable energy related products such as solar panels, batteries, and EVs. The imposed high tariffs serve two purposes: One, they make producing in the domestic country cheaper. Second, given reshoring is feasible, the strong demand in the domestic market would lead to higher overflow production if reshored capacity is undersized. In this case high tariffs penalize overflow production, and thus incentivize higher reshored capacity. However, our analysis suggests that such trade policies have limitations. When the output quantity effect dominates, as might be the case for moderate domestic demand, raising tariffs will no longer be effective (see Figure 6 for an example). This possible limitation of tariff policy partially explains other policy needs (such as government subsidies) besides trade protectionism for these industries in the U.S.

We can explain Proposition 3(ii) using the same effects. An increased RM tariff does not have the overflow demand effect because m_B is independent of t_R. RM tariff does increase the global optimal cost m_A, especially when utilizing the reshoring capacity using imported raw materials (when the optimal stage 3 decision is in Ω_2). Due to the output quantity effect associated with m_A, the global firm's reshoring investment reduces when RM tariff rises in magnitude. This explains the current minimal tariffs on imported upstream products such as silicon, ingots, and wafers for solar panels. The U.S. has just started developing its domestic solar supply chain and is still relying on China for these materials. Extending tariffs beyond the panel level to these materials will only hinder the overall development of the domestic solar industry. Anecdotal evidence from other industries with raw materials and components mostly affected by the Trump tariffs also supports this result. For example, there was a slowdown in reshoring for U.S. bicycle manufacturers due to increased component-level tariffs (Behsudi & Bermingham, 2019).

4.2 Impact on expected output

Next, we examine how tariffs affect firms' expected output targets as well as total domestic production when domestic production is preferred. Define Θ_Q, Θ_{Q_L}, and Θ_{Dom} as the thresholds for the global firm, firm L, and the total domestic production, respectively (the thresholds are defined in the proof).

Proposition 4:

(i). When t_R undergoes an increasing deterministic transformation, we have $\frac{\partial E(Q^*)}{\partial \mu_R} < 0$, $\frac{\partial E(Q_L^*)}{\partial \mu_R} > 0$, and $\frac{\partial E_{\Omega_2+\Omega_3}(q_{UC}^*+q_{UU}^*+Q_L^*)}{\partial \mu_R} < 0$.

(ii). When t_F undergoes an increasing deterministic transformation, we have: (1) $\frac{\partial E(Q^*)}{\partial \mu_F} > 0$ *iff* $\frac{\partial m_A/\partial \mu_F}{\partial m_B/\partial \mu_F} < \Theta_Q$*; (2)* $\frac{\partial E(Q_L^*)}{\partial \mu_F} < 0$ *iff* $\frac{\partial m_A/\partial \mu_F}{\partial m_B/\partial \mu_F} < \Theta_{Q_L}$*; and (3)* $\frac{\partial E_{\Omega_2+\Omega_3}(q_{UC}^*+q_{UU}^*+Q_L^*)}{\partial \mu_F} > 0$ *if* $\frac{\partial m_A/\partial \mu_F}{\partial m_B/\partial \mu_F} < \Theta_{Dom}$.

First, as explained earlier, a higher RM tariff increases the global firm's unit cost of producing for the market. As a result, it will lower its output quantity. Proposition 4(i) formally confirms this result. Although the tariff does not directly affect the domestic competitor, it indirectly benefits it through market competition. Firm L can take advantage of the global firm's lower market output and increase its own output. The total domestic production, however, is lower due to a lower total output quantity of both firms ($Q + Q_L$) and a lower probability of producing domestically. Figure 4 illustrates the effect of an increased RM tariff.[9] This result is in line with the empirical findings for the Trump tariffs. A recent study conducted by the United States International Trade Commission (USITC, 2023) shows that the section 232 tariffs on imported steel and aluminum had negatively impacted downstream industries that depend on these raw materials. According to the study, domestic production in the most affected industries decreased by 0.6% per year on average, with the largest annual decrease of 3.2% in 2018 in the cutlery and hand tool manufacturing industry.

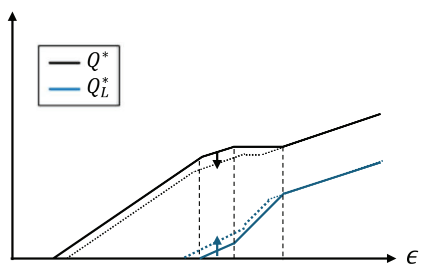


Figure 4: Effect of increased RM tariff on firms' output

Proposition 4(ii) shows that FG tariffs can have either a positive or negative impact on expected outputs depending on the output quantity and overflow demand effects. It can be shown that the thresholds for the reshoring capacity and output quantities of the two firms follow the relationship that $\Theta_Q < \Theta_{Q_L} < \Theta_{K_U}$, as illustrated in Figure 5(i). We make the following observations. First, when the output quantity effect associated with m_A is relatively strong and FG tariff has a negative effect on the reshoring capacity, FG tariff will lead to a lower output for the global firm and a higher output for firm L, similar to the RM tariff effect; see Figure 5(iii) for an illustration. However, when the overflow demand effect associated with m_B becomes dominant and FG tariff has a positive effect on the reshoring capacity, the tariff can affect firms' expected output in different ways, as shown in Figure 5(i) and illustrated in (ii). The increased reshoring capacity helps the global firm meet more demand using onshore production for intermediate demand realization; however, a higher

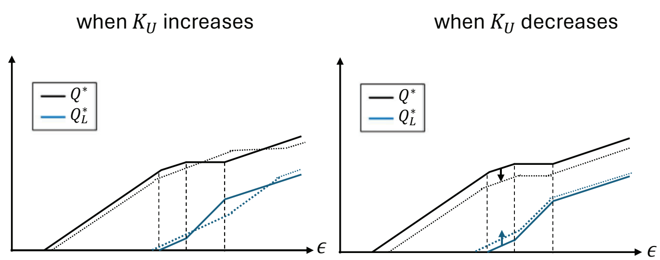
[9]We use Figure 3 (iii) for the illustration. The other two cases of Figure 3 can be analyzed in the same way.

FG tariff makes the global firm reduce its output when demand realization is either low or very high. Therefore, the global firm's expected output can either increase or decrease. Specifically, we observe that when the overflow demand effect becomes much stronger than the output quantity effect, the global firm's expected output can increase in the FG tariff, while the local competitor's expected output decreases. The increase in the global firm's output can dominate the decrease in the competitor's and lead to a higher total domestic production. The recent USITC (2023) study provides support for this result. For the industries with the highest value of imports covered by the section 301 tariffs (targeting finished goods), the value of total U.S. production rose between 1.2% and 7.5% in 2021 as a result of the tariffs.[10]

$\Theta_Q \quad \Theta_{Q_L} \quad \Theta_{K_U} \quad \rightarrow \frac{\partial m_A/\partial \mu_F}{\partial m_B/\partial \mu_F}$

$\frac{\partial K_U}{\partial \mu_F}$	+	+	+	−
$\frac{\partial E(Q)}{\partial \mu_F}$	+	−	−	−
$\frac{\partial E(Q_L)}{\partial \mu_F}$	−	−	+	+

(i)



(ii) (iii)

Figure 5: Effect of increased FG tariff on firms' output

4.3 Impact on profit

Proposition 5:

(i). When t_R undergoes an increasing deterministic transformation, the global firm's expected profit decreases in μ_R, and the local competitor's expected profit increases in μ_R.

(ii). When t_F undergoes an increasing deterministic transformation, the global firm's expected profit decreases in μ_F; the local competitor's expected profit may either increase or decrease.

Recall from Propositions 3 and 4 that an increased RM tariff results in a lower reshoring capacity and expected output for the global firm. The global firm's profit decreases as a result of increased average unit output cost and lower reshoring capacity to mitigate cost changes. This, in turn, benefits the local competitor who is immune from the tariffs and whose competitiveness strengthens as the global firm reduces its reshoring capacity investment and output.

Regarding the impact of FG tariff, we find that an increased FG tariff always harms the global firm. The previously cost-effective offshore production now becomes less attractive under the increased cost. Consequently, the global firm pivots toward onshore production, a previously

[10]A recent study, Alfaro & Chor (2023), also finds that in some mostly impacted industries such as electronics and semiconductors, the U.S. manufacturing jobs increase by 2.9-4.1% between 2017 and 2022.

more expensive option. Although the global firm may increase its investment in reshoring capacity to respond to cost increases, the net effect of increased FG tariff is a higher cost for the global firm, which hurts its profit. As previously noted, although the domestic competitor's cost is not directly affected by tariffs, tariffs can have an indirect effect through market competition. When the global firm invests minimally or not at all in reshoring capacity, e.g., as in Figure 3(i), it cannot effectively mitigate cost surge. This situation plays to the advantage of the domestic firm, as increased costs for the global firm translate into a competitive edge for the domestic competitor. Also, when the output quantity effect dominates and the global firm has to decrease its reshoring capacity, it is clear from Figure 5(iii) that the domestic competitor can output more and make more profit when the tariff increases. However, when the global firm invests in a high level of reshoring capacity and the overflow effect dominates, the firm will benefit from increased onshore capacity. This intensifies market competition, as the global firm gains access to substantial onshore capacity, enabling it to produce at the same cost as the domestic competitor. As Figure 5(ii) illustrates, the domestic competitor may become worse off when the region in which it has to lower its output widens.[11] These effects are illustrated in an example (Figure 6) in the next section.

4.4 Correlated tariffs

So far, we have assumed that t_R and t_F are independent. Here, we briefly discuss the case where the two tariffs are positively correlated (negative correlation is rare in practice). To facilitate the analysis, we consider the perfect positive correlation case and a simplified tariff distribution. Denote $t_R = t$ and $t_F = \alpha t$ ($\alpha > 1$). Assume that t follows a discrete distribution: $Pr(t = \mu - a) = Pr(t = \mu) = Pr(t = \mu + a) = \frac{1}{3}$. The mean μ has a support on $[\underline{\mu}, \bar{\mu}]$ ($\frac{\delta}{(\alpha-1)w_C} < \underline{\mu} < \bar{\mu} < \frac{w_U - w_C}{w_C}$) and the spread a satisfies $a > \max\{\bar{\mu} - \frac{\delta}{(\alpha-1)w_C}, \frac{w_U - w_C}{w_C} - \underline{\mu}\}$. These assumptions cover the most general case where any of the three sourcing and production options can be optimal based on the tariff realization. The global optimal cost m_A can be expressed explicitly as $m_A = \frac{w_U + 2\delta + w_C[2 - a\alpha + (1+\alpha)\mu]}{3}$, and the offshoring cost is $m_B = w_C(1 + \alpha\mu)$.

In the next result, we state the impact of the average tariff on the reshoring investment as well as output quantities.

Proposition 6: *When t_R and t_F are perfect positively correlated,*

(i). K_U^* increases in μ when $\mu < \Psi_K$ and decreases otherwise;

(ii). $E(Q^*)$ increases in μ iff $\mu < \Psi_Q$, $E(Q_L^*)$ decreases in μ iff $\mu < \Psi_{Q_L}$, and $E_{\Omega_2+\Omega_3}(q_{UC}^* +$

[11] We have seen this effect on the mattress industry. Serta Simmons, a large U.S. mattress producer, had to cut its output and workforce prior to filing for bankruptcy protection in 2023. Sinomax, a Chinese mattress company with factories in Tennessee and Arizona, has remained profitable and increased its market share (Berger, 2024).

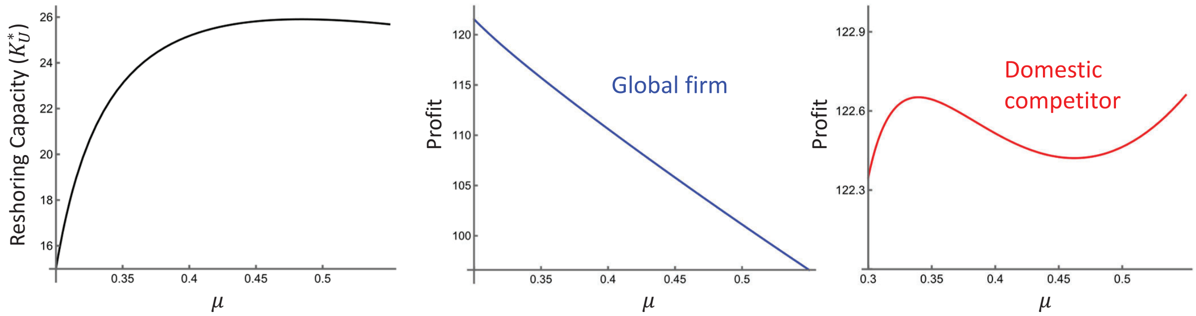


Figure 6: Impact of correlated tariffs ($w_C = 10, w_U = 13, \delta = 2.8, \alpha = 2, C_U = 0.2, t \sim U[\mu - 0.05, \mu + 0, 05], D \sim U[0, 80]$)

$q^*_{UU} + Q^*_L$) increases in μ if $\mu < \Psi_{Dom}$ (the thresholds are defined in the proof).

Since t_R and t_F are correlated, we can no longer separate the effect of μ_R and μ_F. However, in the independent case, we identified the output quantity effect associated with m_A when t_R changes, and the same effect together with the overflow demand effect associated with m_B when t_F changes. Here, when the two tariffs change at the same time, we expect both effects will still take place. Proposition 6 confirms this and shows that in the special case, we can express the threshold conditions in a more intuitive way, in terms of the mean tariff rate.

Proposition 6 implies that when reshoring is feasible, imposing higher tariffs can help boost reshoring investment and domestic production as long as tariff rates are not too high. With a mild cost increase, the reshoring investment is likely to be low. So, the overflow probability is high and the overflow demand effect dominates, which encourages more reshoring. However, when the tariff rate increases to a high level and there is significant reshoring capacity in place, overflow production will decrease. Meanwhile, a high tariff rate also means a high average unit cost of serving the market. The corresponding output quantity effect becomes stronger. When it dominates the overflow demand effect, further increase in the tariff rate may no longer be effective, as illustrated in an example in Figure 6. We observe similar tariff effects on firms' expected profits as discussed in §4.3.

5. The Tax Credit Policy Model

Industrial policies that are profoundly reshaping the clean energy industry, such as the Inflation Reduction Act (IRA) enacted by the Biden administration, undergo lengthier implementation processes and have a significant influence on consumer demand. Economics research has pointed out the significant effect of monetary incentives in the form of tax rebates and tax credits on consumer demand for EVs (see Sallee, 2011; He *et al.*, 2023, and references therein). Motivated by these practices, in this section we develop a tax credit policy model that bears some similarities to the tariff policy model in §3 but captures the above differences.

We continue to consider two firms competing in country U's market—a domestic manufacturer, firm L, and a global firm that used to serve the domestic market using its offshore facility in country C but is considering installing capacity in country U because of the tax incentives provided there. The tax credit is modeled as a random variable t with a support on $[0, \bar{t}]$, pdf $f(\cdot)$, and mean μ. Market demand still follows a linear inverse demand function $p(t, Q, Q_L) = \epsilon(t) - (Q + Q_L)$. The market size is modeled as a function of t and defined as $\epsilon(t) = \epsilon_0 + \gamma t$, where ϵ_0 denotes a constant base market size, and the coefficient γ ($\gamma > 2$) describes the sensitivity of market demand to tax credit. This demand function reflects the fact that tax credits can stimulate more market demand for clean energy products because they lower the out-of-pocket cost that end consumers pay for such products. We continue to assume that demand (and therefore tax credit in this case) is uniformly distributed.

Denote the total landed cost for each unit imported from country C as w_C, and the unit sourcing and production cost in country U as w'_U. Since tax credit only applies at the finished-goods level (i.e., domestically produced products with foreign sourced components do not qualify for tax credits), we only consider two production options for the global firm. For domestically sourced and produced products, the tax credit translates into a discounted price for consumers, $p(t, Q, Q_L) - t$ (in fact, as of January 2024, car dealerships start offering instant tax credit as an upfront discount at purchase; see report in Rivero, 2024), and the manufacturer makes a profit margin of $p(t, Q, Q_L) - w'_U$. Instead, if the global firm produces the product in country C and imports it for sale in country U at the same price $p(t, Q, Q_L) - t$, the firm gains a profit margin of $p(t, Q, Q_L) - t - w_C$.

We consider the operational decisions for the two firms in the following two stages, as illustrated in Figure 7. First, the global firm decides how much domestic capacity to install. As in §3, we consider the capacity decision as irreversible that is made ex ante to policy uncertainty. Then, after the tax credit policy is announced and the subsequent market size realizes, the two firms set output quantities Q and Q_L simultaneously. Since the global firm has two production locations, it must also decide the quantity to produce in each location, Q_U and Q_C. Different from the model in §3, here we assume that the output quantity and production decisions are made ex post to policy uncertainty. Such industrial policies take longer to be implemented, and companies wait to understand their effects in stimulating demand. As a result, operational decisions are often made after demand realization, which in this case, largely depends on the tax credit policy. The two-stage model can be formulated similarly to that in §3, with some modifications. We defer the detailed formulation to the analysis below.

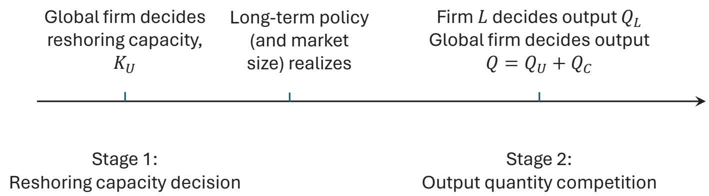


Figure 7: Sequence of events for the tax credit policy model

5.1 Model analysis

We first derive the quantity competition equilibrium at stage 2. Firm L solves the profit maximization problem: $\max_{Q_L \geq 0}[(\epsilon(t) - (Q + Q_L)) - w'_U]Q_L$. Its best response function is the same as in §3: $Q_L(Q) = \frac{\epsilon(t) - Q - w'_U}{2}$. The global firm's stage-2 profit for a given Q_L denoted as $\pi(t, K_U, Q, Q_L)$, however, depends on both its output quantity and production location. When $t < w'_U - w_C$, the global firm can make a higher unit margin by producing in country C. In this case, $\pi(t, K_U, Q, Q_L) = [p(t, Q, Q_L) - t - w_C]Q$, and the global firm's best response function can be derived as $Q(Q_L) = \frac{\epsilon(t) - Q_L - w_C - t}{2}$.

When $t \geq w'_U - w_C$, the global firm can make a higher unit margin by producing in country U. Since the firm only has K_U units of capacity in country U, in the case when the realized market demand is high, the global firm may resort to its existing capacity in country C to meet the extra production beyond K_U. In this case, we can express the global firm's stage-2 profit as:

$$\pi(t, K_U, Q, Q_L) = \begin{cases} [p(t, Q, Q_L) - w'_U]\, Q, & \text{if } Q \leq K_U \\ [p(t, Q, Q_L) - w'_U]\, K_U + \{[p(t, Q, Q_L) - t] - w_C\} \cdot (Q - K_U), & \text{if } Q > K_U. \end{cases}$$

The best response function can be derived as:

$$Q(Q_L) = \begin{cases} \frac{\epsilon(t) - Q_L - w_C - t}{2}, & \text{if } \frac{\epsilon(t) - Q_L - w_C - t}{2} < K_U, \\ K_U, & \text{if } \frac{\epsilon(t) - Q_L - w_C - t}{2} \leq K_U \leq \frac{\epsilon(t) - Q_L - w'_U}{2}, \\ \frac{\epsilon(t) - Q_L - w'_U}{2}, & \text{if } \frac{\epsilon(t) - Q_L - w'_U}{2} > K_U \end{cases} \tag{4}$$

Notice that by defining w'_U as m_A and $w_C + t$ as m_B, the best response function in (4) mirrors (3) derived previously for the tariff policy model. Therefore, we can derive the equilibrium in a similar manner. We state the result in the following proposition.

Proposition 7: *Figure 8 characterizes the equilibrium output quantities (Q^*, Q_L^*) in stage 2. Q^* and Q_L^* are represented by the solid black and blue lines, respectively; the quantities are shown in* *parentheses.*

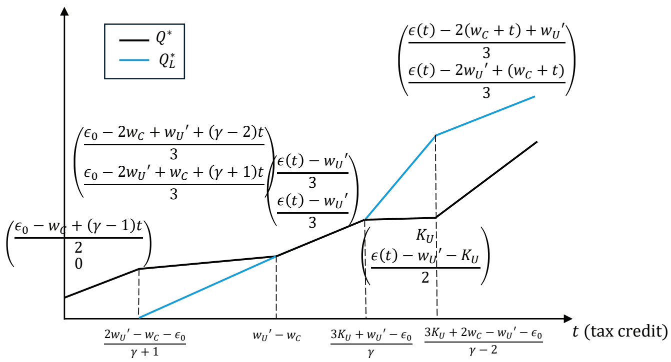


Figure 8: Tax credit policy model: Output quantity equilibrium in Cournot competition

When the tax credit amount is low, i.e., when $t < w'_U - w_C$, producing in the low-cost country, country C, is more profitable than producing in country U. The output quantity equilibrium resembles that in §3. In this case, since the global firm has a lower production cost than the competitor, it maintains a stronger competitive edge in the market. When the tax credit amount is high, i.e., when $t > w'_U - w_C$, the global firm will find producing in the high-cost country, country U, more profitable than producing and importing from country C. Since the imported products do not qualify for the tax credit that is provided only for products with major components sourced and final assembly done in country U, the global firm earns a lower margin on the imports when the tax credit is large enough. We can rewrite the condition as $w_C + t > w'_U$ and interpret the lower margin on the imports as a higher *effective* cost $w_C + t$ compared to those produced in country U, w'_U. Therefore, when $t > w'_U - w_C$, the two firms both produce in country U and compete on the same cost basis. Their equilibrium output quantities are identical. However, when the global firm reaches its production capacity K_U in country U, any quantity beyond this level must be fulfilled by its existing capacity in country C. Here, we observe the same "inertia" behavior as in §3. That is, when $t \in [\frac{3K_U + w'_U - \epsilon_0}{\gamma}, \frac{3K_U + 2w_C - w'_U - \epsilon_0}{\gamma - 2}]$, the global firm does not increase its output quantity to meet the increasing demand. Only when the tax credit (and the resulting demand) is high enough does overflowing production to country C become profitable.

Finally, we look at the global firm's capacity decision in stage 1. The global firm solves the following maximization problem: $\max_{K_U \geq 0} \; R(K_U) - C_U K_U$, where $R(K_U) = E_t[\pi^*(t, K_U)]$ denotes the global firm's expected profit over all possible policy and demand scenarios, $\pi^*(t, K_U) = \pi(t, K_U, Q^*, Q_L^*)$ is the global firm's stage-2 equilibrium profit for realized policy t, and C_U is the per-unit capacity installment cost. We characterize the optimal capacity decision below.

Proposition 8: *When $C_U < C_0 := \int_{w'_U - w_C}^{\bar{t}} (w_C + t - w'_U) f(t)\, dt$, the global firm's optimal reshoring* *capacity K_U^* satisfies the following condition:*

$$\int_{\frac{3K_U^*+w_U'-\epsilon_0}{\gamma}}^{\frac{3K_U^*+2w_C-w_U'-\epsilon_0}{\gamma-2}} \left(\frac{\epsilon_0+\gamma t-w_U'}{2}-K_U^*\right) f(t)\,dt + \int_{\frac{3K_U^*+2w_C-w_U'-\epsilon_0}{\gamma-2}}^{\bar{t}} (w_C+t-w_U')\, f(t)\,dt = C_U.$$

It can be shown that the reshoring feasibility region determined by the threshold C_0 shrinks (expands) when the cost difference between country U and country C widens (reduces). When reshoring is feasible, the optimal reshoring capacity increases in w_C and decreases in w_U'.

6. The Effects of Tax Credit Policies

In this section, we examine how tax credit policy affects the reshoring investment, firms' output quantities and profitability in serving the domestic market. We first adopt the increasing deterministic transformation approach as in §4 to study the effect of tax credit provided to end consumers.

Proposition 9: *[End Consumers Tax Credit] When μ increases:*

(i). The global firm's reshoring capacity increases;

(ii). The global firm's expected output quantity and the total expected production quantity in country U both increase; firm L's expected output quantity can either increase or decrease.

Proposition 9 states that a higher tax credit provided to end consumers can always encourage reshoring investment and lead to higher domestic production. This is different from the effect of tariff policy stated in Propositions 3 and 4. Recall that for tariff policies, we identified two opposite effects: an output quantity effect associated with m_A and an overflow demand effect associated with m_B. When the former effect dominates the latter, an increased tariff rate may not be effective in incentivizing reshoring investment. Here, the tax credit model is different from the tariff policy model in the following way. In the tax credit model, the global firm's output quantity and production decisions are made after the policy announcement, as policy-induced demand materializes only thereafter. The policy-driven production preference is clear at that point. From Proposition 7, we see that the reshoring capacity only matters when the tax credit is higher than $w_U' - w_C$. When the tax credit is lower than this level, the global firm finds it more profitable to serve the market from its capacity in country C. When $t > w_U' - w_C$, the analysis in §5.1 shows that the model is equivalent to the tariff policy model if we define the global optimal cost as $m_A := w_U'$ and the offshoring cost as $m_B := w_C + t$. In this case, the realized tax credit is high enough for the global firm to profitably produce in country U. Therefore, the global optimal cost is w_U', and the lower margin on imports can be interpreted as a higher "effective" cost $w_C + t$

of producing in country C. Since the tax credit t has no effect on m_A, the output quantity effect is absent. Clearly, a higher tax credit increases m_B, so the associated overflow demand effect will lead to a higher reshoring capacity.

Greater tax credits lead to higher reshoring capacity and allow the global firm to produce a larger portion of the domestic demand at the more profitable location, so its expected output increases. Although tax credits also benefit the domestic firm by stimulating a higher market demand, the firm faces intense competition in the domestic market due to the global firm's increased reshoring capacity there. The domestic firm's expected output can either increase or decrease depending on which effect is stronger. Nonetheless, we show that the aggregate domestic production from both firms will increase in the average tax credit amount. As we illustrate in Figure 9, the impact of tax credit on the two firms' profits is similar to its effect on output quantities.

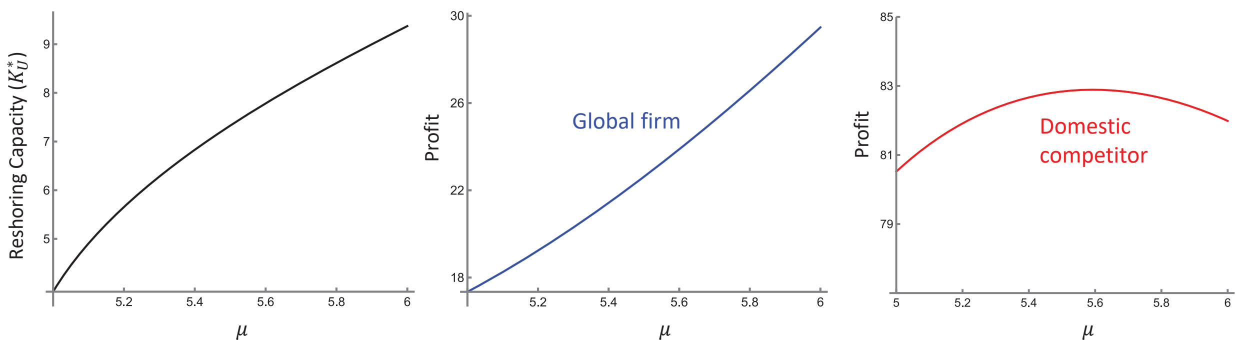


Figure 9: Impact of end-consumer tax credit ($w_C = 10, w'_U = 11, \epsilon_0 = 10, \alpha = 4, t \sim U[\mu - 5, \mu + 5], C_U = 4$)

Finally, we briefly discuss other types of government incentives provided by the IRA, which have less direct impact on market demand but subsidize manufacturing investment. For example, the Advanced Energy Project Credit (IRS, 2022) offers manufacturers investment credit for newly constructed solar and other clean energy facilities. This corresponds to a lower capacity cost C_U in our model. In a similar effort, the Section 45X Advanced Manufacturing Production Credit provides generous tax credits for making specific components within the U.S., including solar and wind energy components. This corresponds to a lower cost w'_U in country U. It is straightforward that a lower C_U will lead to more reshoring investment and higher output quantity for the global firm, which will strengthen the global firm's competitiveness and negatively affect the domestic competitor.

Proposition 10: *[Manufacturer Investment Credit] When C_U decreases:*

(i). The global firm's reshoring capacity increases;

(ii). The global firm's expected output quantity increases; firm L's expected output quantity decreases; the total expected production quantity in country U increases.

Like the manufacturer investment credit, the manufacturing production credit can also lead to more reshoring investment. However, its effect on the production quantity is more nuanced. On one hand, as previously discussed, when manufacturing in country U, the output quantity effect associated with a lower w'_U incentivizes the global firm to increase output. On the other hand, the tax credit applies to the domestic competitor as well, reducing its production cost at the same time. This intensifies the market competition and may eventually reduce the global firm's output. Likewise, the impact on the domestic firm's output is also indefinite due to the same effects. In spite of this, we show that the total quantity produced in country U always increases in the amount of manufacturing production credit.

Proposition 11: *[Manufacturing Production Credit] When w'_U decreases, the global firm's reshoring capacity increases. Furthermore, the total expected production quantity in country U increases.*

Our results in this section support the evidence that since the passage of the IRA, there has been tremendous development in the U.S. solar industry. According to the Solar Energy Industries Association (SEIA, 2024), from 2022 to 2023, over 50 solar manufacturing facilities were announced or expanded by domestic solar manufacturers such as First Solar, as well as by multinational corporations such as Chinese solar companies Trina Solar and Longi, Singapore solar company Maxeon Solar, and Canadian Solar (Kennedy, 2023). A total of 155 gigawatts of new production capacity were announced across the solar supply chain.

7. The Effect of Competition on Reshoring Capacity

In this section, we will examine how the existence of market competition affects reshoring investment. To do this, we compare the models in §§3 and 5 to those without competition, i.e., single-firm models. Denote the optimal reshoring capacity in the competition model and single-firm model by K_U^d and K_U^m, respectively. The following proposition states the comparison results for the tariff model and is illustrated in Figure 10.

Proposition 12: *In the tariff model, there exist thresholds I_1 and I_2 (defined in the proof) such that:*

(i). when $w'_U < \frac{m_A+m_B}{2}$, we have $K_U^d \leq K_U^m$, with equality holds when $C_U \geq C_0^m$.

(ii). when $m_B < w'_U < 2m_B - m_A$, we have: $K_U^d < K_U^m$ if $C_U < I_1$; $K_U^d > K_U^m$ if $I_1 < C_U < C_1^d$; and $K_U^d = K_U^m$ if $C_U \geq C_1^d$.

(iii). when $\frac{m_A+m_B}{2} < w'_U < m_B$, we have: $K_U^d < K_U^m$ if $C_U < I_1$ or $I_2 < C_U < C_0^m$; $K_U^d > K_U^m$ if $I_1 < C_U < I_2$; and $K_U^d = K_U^m = 0$ if $C_U \geq C_0^m$.

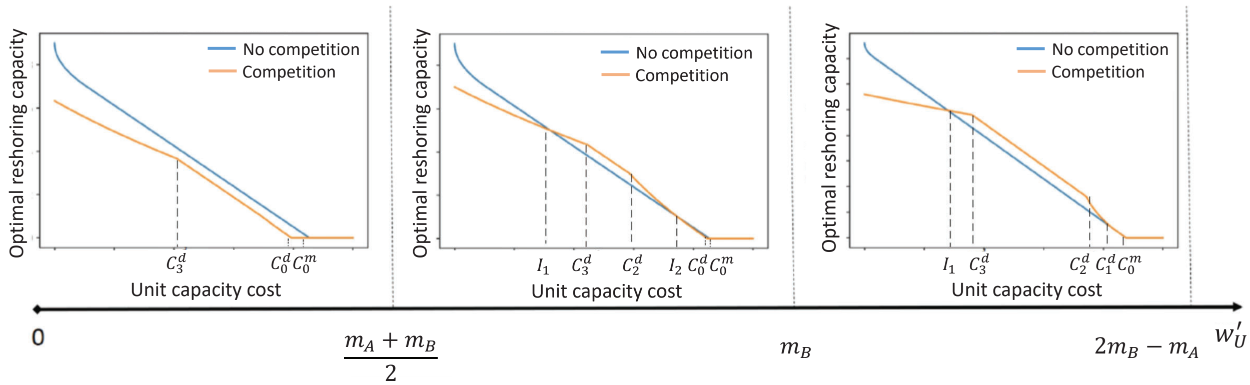


Figure 10: Effect of competition on reshoring capacity (Tariff model)

Conventional wisdom suggests that competition will lead to a smaller market share for individual firms, and hence lower capacity needs. We find that this intuition is correct when domestic production cost is relatively low as in Figure 10 left panel; specifically, when w'_U is lower than the global firm's average cost $\frac{m_A+m_B}{2}$. The reshoring capacity is always lower under competition. However, this intuition may be overturned when domestic production cost is relatively high as in the middle and right panels. In this case, the global firm's lower average cost compared to the domestic competitor's plays to its advantage. It is clear from Figure 3 (ii) and (iii) that in the competition region, a higher reshoring capacity enables the global firm to output more and results in a lower output from the domestic competitor, and hence increases the global firm's market share. In this case, the higher reshoring capacity not only better protects the global firm from uncertain cost but also allows it to aggressively compete through its allocation flexibility between offshore and onshore capacity for the realized trade conditions. The previously referenced example in the mattress industry is illustrative of the latter effect (Berger, 2024).

A similar insight applies to the tax credit model, as stated below.

Proposition 13: *In the tax credit model, there exists threshold I_3 (defined in the proof) such that:*

(i). when $w'_U < \frac{\gamma w_C - \epsilon_0}{\gamma - 1}$, we have $K_U^d < K_U^m$.

(ii). when $w'_U > \frac{\gamma w_C - \epsilon_0}{\gamma - 1}$, we have: $K_U^d < K_U^m$ when $C_U < I_3$, and $K_U^d > K_U^m$ otherwise.

The results in this section imply that the presence of a relatively efficient domestic manufacturing environment may be a hindrance for global firms in establishing onshore production capacity. But when these firms have significant cost advantage, the presence of domestic competition may actually encourage aggressive reshoring investment. This is a concern for the European EV market. When tariffs increase by 21% on top of the existing 10%, aggressive onshore production investments are expected (e.g., Chinese EV maker BYD has started a factory in Hungary). In such markets with cost-disadvantaged local competitors, the imposition of tariffs will lead to aggressive reshoring investments by the more cost-effective global firms to better balance production allocation between their existing Chinese capacity and assembly factories in various European countries.

8. Concluding Remarks

Recent trade protectionist policies in the U.S. and Europe have resulted in substantial cost increases for imported materials and finished products from certain countries, especially China. At the same time, in their transition to clean energy, developed countries worldwide are offering generous monetary incentives to make clean energy products affordable to consumers and to support the growth of domestic supply chain in these industries. Moreover, the current geopolitical environment has intensified the uncertainty around cross-border trade and the regulatory risks associated with industrial and environmental policies. Global firms, in response to elevated risks, have considered restructuring their global supply chains, and one of those alternatives is to "reshore" manufacturing activities from low-cost countries to developed countries (Alfaro & Chor, 2023). This is not an all-or-nothing proposition, and it typically results in rebalancing capacity allocations between offshore and onshore locations. Global firms, by investing in reshoring capacity, add the "real option" of choosing between producing in existing facilities with low cost or using reshored facilities to avoid tariffs and/or leverage subsidies and other incentives. We seek to rigorously argue how the "real option" of the added reshoring capacity affects the reshoring investment level and the balance between onshore and offshore sourcing, and how it allows for effective management of supply-side uncertainty in the presence of evolving, uncertain trade and industrial policies.

We develop a game-theoretic framework to analyze firms' long-term reshoring capacity decision in the face of all uncertainties, the output quantity equilibrium between competing firms upon demand realization, as well as the production allocation decision upon policy realization. In studying the effect of tariff and tax credit policies, we differentiate the model to reflect some key differences between them: Tariff policies (especially in clean energy industries) change frequently and the implementation of new change is almost immediate; they do not directly affect consumer demand, and firms make sales and operational plans with only contingency on the production allocation after tariff realization. Tax credit policies have a direct effect on consumer demand but take a longer time to produce effects, and companies wait in planning sales and production allocation until after the demand effect of these policies is clear. We use a three-stage model to capture the game dynamics in the tariff model in which demand realization and firms' output decisions precede policy realization and production allocation decisions, and a two-stage model for the tax credit model in which demand and policy uncertainties are resolved in the same stage after which firms make their output and production allocation decisions. The main findings and managerial insights from our analysis can be summarized as follows.

First, we find that applying tariffs on different supply chain stages can have different implications on companies' reshoring incentives. Ceteris paribus, a higher finished-good tariff can either increase or decrease reshoring investment, while a higher raw-material tariff always results in less reshoring. On the one hand, the finished-good tariff has two opposite effects: (1) An overflow demand effect: When there is a strong demand exceeding reshoring capacity, a higher cost for imported finished goods increases the cost of producing the overflow quantity at the offshore facility, which encourages investing in higher reshoring capacity. (2) An output quantity effect: A higher cost for imported finished goods increases the average cost of serving the market, which reduces the total output target and capacity needs. A finished-good tariff can lead to an increased or decreased reshoring capacity depending on the dominant effect. Such tariffs may not be effective in encouraging reshoring investment when the tariff and investment are already high and the output quantity effect dominates. On the other hand, a higher raw-material tariff increases the production cost when producing domestically using imported raw materials ex post but has no effect on the cost of overflowing production. In the absence of the overflow demand effect, the output quantity effect always leads to dampened incentive for reshoring. As evidenced by the Trump- imposed tariffs on steel and aluminum, the downstream industries were immediately affected with small, if any, onshore investments.

Second, we show that tax credits provided for consumers purchasing domestically produced product, and those for manufacturers constructing domestic facilities and producing domestically, are effective in increasing reshoring investment. When firms' output and production allocation decisions are made after policy and demand realization, the output quantity effect is irrelevant to reshoring capacity decisions. Domestic capacity only matters when it is more profitable to produce domestically than offshore, but the domestic production cost is not affected by tariff or tax credit policy. Thus, the overflow demand effect is the only one that matters and its effect always encourages more reshoring.

Third, we demonstrate that tariff and tax credit policies may yield distinct impacts on firms' expected profits. Tariffs always hurt the global firm, driving up its average per-unit production cost in serving the market. While tariffs do not directly apply to domestic manufacturers, they indirectly affect them through market competition. Domestic manufacturers may reap benefits when the global firm's reshoring investment is low or when the output quantity effect dominates, yet aggressive reshoring by the global firm can lead to decreased profits for domestic competitors. On the other hand, the tax credit policy can potentially benefit both firms by boosting demand and subsidizing domestic production. However, tax credits could also adversely affect domestic firms' profits when the global firm's reshoring capacity is high, exacerbating competition between them.

Finally, we find that the presence of a relatively efficient domestic manufacturing environment will be a hindrance to global firms in establishing onshore production capacity. But when these firms have significant cost advantages, the presence of domestic competition may encourage aggressive reshoring investment. The increased reshoring capacity not only mitigates cost uncertainty but also enables the global firm to effectively compete with domestic firm by utilizing the "real option" of the onshore capacity in combination with the cost advantages of existing capacity.

Our research makes both theoretical and practical contributions. On the theoretical side, we contribute to the global supply chain literature by modeling industrial-policy-induced supply cost uncertainties at different supply chain stages, and then analyzing their impact on companies' operational decisions. Although in our model the cost uncertainty is caused by trade and industrial policies, future studies can adapt our modeling framework to capture other factors such as shipping cost and carbon taxes that affect the total landed cost to the market. The tariff model enriches the Newsvendor network literature by developing a three-stage modeling framework that incorporates market competition and two ex-post decision-making stages. Our conceptual framework identifies two major effects (output quantity and overflow) that can be used to explain insights on reshoring capacity investments. Future research could generalize our modeling framework to examine other issues such as unobservable capacity and joint capacity investment.

On the practical side, our research provides valuable insights to companies restructuring their global supply chains in reaction to the rapidly changing trade environment and supply chain conditions. We suggest that investing in onshore production can provide value through exercising a valuable "real option" and increase a global firm's competitiveness in an uncertain cost and demand environment. However, the underlying uncertainty together with limited reshoring capacity and cost discrepancies across different production locations create "inertia" in meeting market demand, and eventually lead to overflow excess demand to the offshore location. Our research also partially explains tariff policy outcomes observed in different industries. An implication for the trade policy is that imposing tariffs may not necessarily achieve the desired policy goal. Policymakers should identify the industry sector and product categories the policy will aim at and design tariffs to apply at the right supply chain stage. We caution that imposing very high tariffs may lead to aggressive onshore investment from low-cost global firms. Industrial policies that are targeted at only helping domestic firms to lower their production cost disadvantage may be the only way to effectively protect domestic firms.

Although our model is motivated by the current trade situation between U.S. and China, a recent study by Alfaro & Chor (2023) reports that as the U.S. shifts sourcing away from China to other low-wage countries (especially Vietnam and Mexico), China is still behind many manufacturing activities in those locations. There are already signs that U.S. solar manufacturers and policymakers will consider expanding tariffs to more countries (Tankersley & Rappeport, 2024). Also, in addition to the clean energy industry, the U.S. in general has seen more reshoring intention and activities since 2018 due to various forms of risks (Alfaro & Chor, 2023). Therefore, we expect our research can provide guidelines for companies in those industries when planning for reshoring and for policymakers in crafting trade and industrial policies in the future.

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