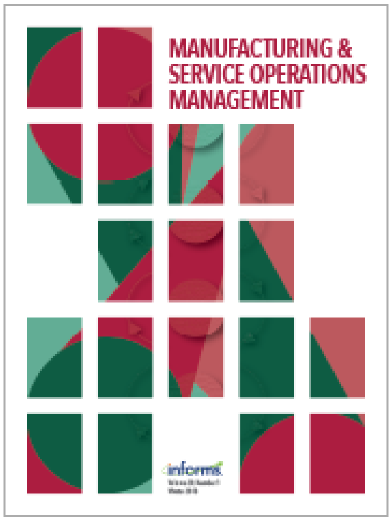

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Flexibility Value of Reshoring Capacity Under Policy Uncertainty and Domestic Competition

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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. Because 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 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 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.

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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 and 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 and 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 concerns about China's excess capacity and the threat of flooding global markets (Tankersley and Rappeport 2024). Domestic solar manufacturers also urge the United States 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 (FG) level (e.g., panels), or will they extend to the component level (solar wafers), as what the tariffs by Trump administration 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 (U.S. Department of Energy 2024). Similarly, for electric vehicle (EV) manufacturers utilizing battery minerals sourced from the United States, and with battery components manufactured and final assembly done in the United States, 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 United States (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.[1] 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 United States, 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 the United States, 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 policies (e.g., imposing tariffs for raw materials (RM) and FG) and industrial policies (e.g., providing tax credits) affect the global firm's reshoring investment and profitability in serving the domestic market? What is the differential impact of the trade and industrial policies on the profitability of the global firm and domestic manufacturers, and in particular, do they always achieve the government objective of protecting domestic manufacturers and increasing total production output in the domestic market? What is the role of competition in the domestic market on reshoring investments?

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 opposing effects associated with these costs. On the one hand, an increased global optimal cost leads to an *output quantity effect* that reduces the output target and the need for reshoring capacity. On the other hand, when demand is high relative to planned reshored capacity, the global firm has to overflow excess production to the offshore location. In this case, 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 policy effect on reshoring investment depends on which of these two effects is present, and when both are present, which one dominates. Specifically, we find that, although tax credit policies lead to more reshoring, tariffs imposed on the RM level have the opposite effect. Although FG tariffs generally encourage reshoring investment, if the output quantity effect dominates, raising the FG tariff may no longer be effective.

We show that the tariff policy always hurts the global firm's profit because tariffs increase its average cost in serving the market. Tariffs also affect the domestic firm's profitability through market competition. Surprisingly, we find that although the domestic firm can benefit from imposed tariffs, its profit may decrease if the global firm aggressively increases its reshoring investment. In contrast, the tax credit policy can benefit both firms by stimulating demand and subsidizing domestic production. However, similar to 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 also provides insights on the role of domestic competition in the global firm's reshoring investments. When domestic firms have relatively low production costs, reshoring is less attractive to the global firm due to intense competition with the efficient domestic competitor. However, domestic competition may encourage more reshoring investment when domestic production costs are relatively high. In this case, increased reshoring capacity not only mitigates cost uncertainty but also enables the global firm to more effectively compete with the domestic firm, especially in the face 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 and 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 and 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 of industrial policies on reshoring investments, as well as their differential impact on competing firms, differentiate our work from these 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 and 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 and 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. Recent global field studies among leading manufacturers (Cohen et al. 2018, Cohen and Lee 2020) indicate that uncertainty around trade and industrial policies has 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 and 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. 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 zero; thus, w_C is effectively the material cost. Because of 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 (imposing tariffs as a percentage of product value is the most common tariff form in practice for products such as solar panels and EVs. This tariff model has also been widely adopted in the literature (Li et al. 2007, Hsu and Zhu 2011, Xu et al. 2018). Assume t_F has a support on $[0,\bar{t}]$,[2] 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 incurs a higher unit production cost than in country C (which is normalized to zero). 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 supplies the U.S. market. Although 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 United States 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 (similar reshoring structures have been considered in the literature (Chen and Hu 2017) and are supported by industry practice (Khan 2025)):

- 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 $w'_U := w_U+\delta$).

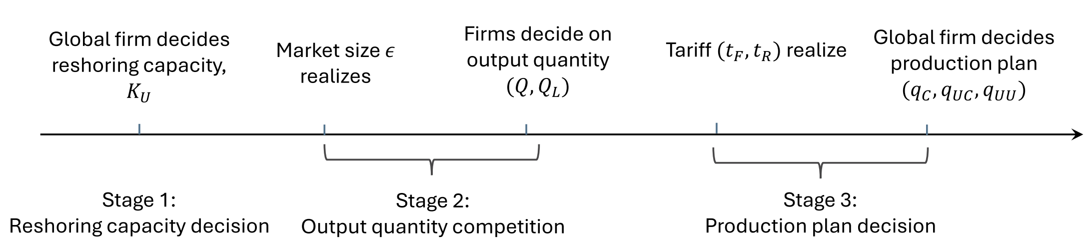
In country U, a domestic manufacturer like U.S.-based First Solar, referred to as firm L, produces locally and sells to the same market. Like the global firm, firm L incurs the total unit cost w'_U. We consider a Cournot competition between the two firms. Assuming that the products of the two firms are 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 United States 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 and 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: $\Pi = \max_{K_U\ge 0} R(K_U) - C_U K_U$, 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.[3] For a given ϵ, firm L solves the profit maximization problem: $\max_{Q_L\ge 0}[(\epsilon-(Q+Q_L))-w'_U]Q_L$. The global firm maximizes its expected operating profit: $\pi(\epsilon,K_U)=\max_{Q\ge 0}(\epsilon-(Q+Q_L))Q-EC(Q,K_U)$, 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

Figure 1. Sequence of Events for the Tariff Policy Model



quantity in country C; q_{UC} denotes the quantity produced in country U using imported RM from country C; and q_{UU} denotes the quantity produced in country U using locally sourced RM. The global firm solves the following cost minimization problem:[4]

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

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. All proofs are included in Online Appendix A.

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, whereas 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 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* (For brevity, when not confusing, we drop "expected" when referring to these costs hereafter). Clearly, we have $m_A < m_B$.

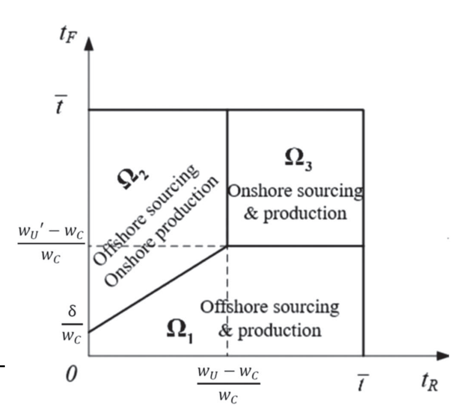
Next, we derive the equilibrium of stage 2 Cournot competition. Firm L solves the profit maximization problem: $\max_{Q_L\geq 0}(\epsilon-(Q+Q_L))Q_L - w'_U Q_L$. The best response function is $Q_L(Q) = \frac{\epsilon - Q - w'_U}{2}$. The global firm solves the profit maximization problem: $\max_{Q\geq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

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

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

Figure 2. Tariff Policy Model: Optimal Sourcing and Production Decision

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 $t_F \in \left(\frac{w'_U - w_C}{w_C}, \bar{t}\right)$	$((Q-K_U)^+, 0, \min\{Q,K_U\})$



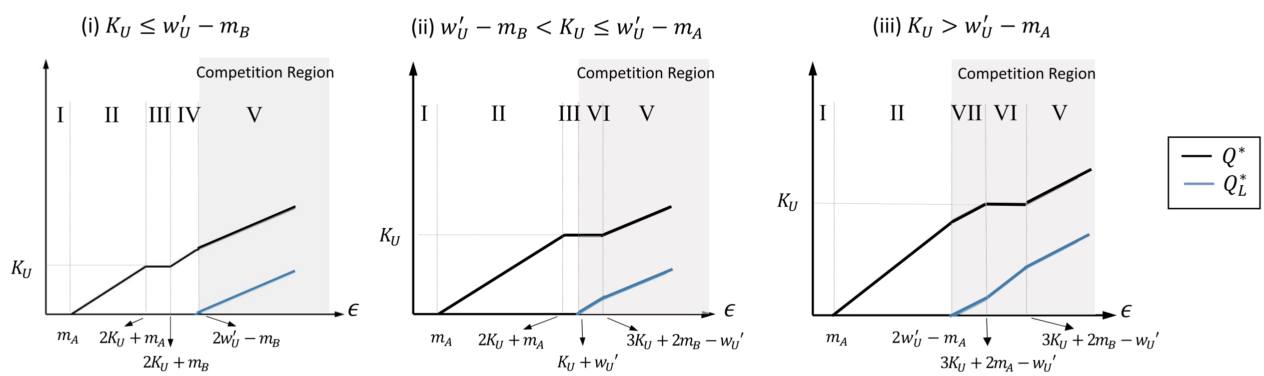
Proposition 1. *The equilibrium output quantities* (Q^*, Q_L^*) *in stage* 2 *are given in Figure* 3.

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, whereas 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,[5] 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(a), the global firm's domestic capacity K_U can fully satisfy its production needs when $m_A \le \epsilon < m_A + 2K_U$. 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. Because 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 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 nonincreasing 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).

Figure 3. (Color online) Tariff Policy Model: Output Quantity Equilibrium in Cournot Competition



Region	(Q^*, Q_L^*)
I	$(0, 0)$
II	$\left(\frac{\epsilon - m_A}{2}, 0\right)$
III	$(K_U, 0)$
IV	$\left(\frac{\epsilon - m_B}{2}, 0\right)$
V	$\left(\frac{\epsilon - 2m_B + w_U'}{3}, \frac{\epsilon - 2w_U' + m_B}{3}\right)$
VI	$\left(K_U, \frac{\epsilon - w_U' - K_U}{2}\right)$
VII	$\left(\frac{\epsilon - 2m_A + w_U'}{3}, \frac{\epsilon - 2w_U' + m_A}{3}\right)$

Proposition 2. *The optimal capacity K_U^* satisfies the following characterizing equations (the thresholds $C_0^m, C_0^d, C_1^d, C_2^d$ are defined in the proof):*

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

$$FOC^m: \int_{2K_U^*+m_A}^{2K_U^*+m_B} (\epsilon - 2K_U^* - m_A) dG(\epsilon) + \int_{2K_U^*+m_B}^{\infty} (m_B - m_A) dG(\epsilon) = C_U$$

$$FOC_1^d: \int_{3K_U^*+2m_A-w'_U}^{3K_U^*+2m_B-w'_U} \left[\frac{\epsilon - 2m_A + w'_U}{2} - K_U^*\right] dG(\epsilon) + \int_{3K_U^*+2m_B-w'_U}^{\infty} (m_B - m_A) dG(\epsilon) = C_U$$

$$FOC_2^d: \int_{2K_U^*+m_A}^{K_U^*+w'_U} [\epsilon - m_A - 2K_U^*] dG(\epsilon) + \int_{K_U^*+w'_U}^{3K_U^*+2m_B-w'_U} \left[\frac{\epsilon - 2m_A + w'_U}{2} - K_U^*\right] dG(\epsilon) + \int_{3K_U^*+2m_B-w'_U}^{\infty} (m_B - m_A) dG(\epsilon) = C_U.$$

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 $C_0^m = \int_{m_A}^{m_B} (\epsilon - m_A) dG(\epsilon) + \int_{m_B}^{\infty} (m_B - m_A) dG(\epsilon)$. Because $\frac{\partial C_0^m}{\partial m_A} < 0$, a reduction in manufacturing costs in country U, w'_U, would raise the threshold C_0^m, thereby making reshoring more feasible. However, the sharp decline in manufacturing costs in country C (as has occurred recently in China) can widen the gap between w'_U and w_C, threatening the feasibility of reshoring. This cost disparity explains the Biden administration's decision to raise tariffs in 2024, following a more than 40% drop in the price of Chinese solar panels to a record low (Tankersley and Rappeport 2024).

4. 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 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 show later, the insights largely hold in the correlation case.

We adopt the concept of deterministic (specifically, linear) transformation of a random variable (Meyer and 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. Although 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 (Tariff Effect on Reshoring Capacity).

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, that is, $\frac{\partial K_U^*}{\partial \mu_R} < 0$.*

Proposition 3(i) states that the FG tariff effect depends on how it affects the two costs—the global optimal cost m_A and offshoring cost 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 $m_A K_U + m_B(Q - K_U)$. Because 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 relatively 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 (an example is presented later in the section). This possible limitation of tariff policy partially explains other policy needs (such as government subsidies) besides trade protectionism for these industries in the United States.

We can explain Proposition 3(ii) using the same underlying effects. An increase in the 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, particularly when reshoring capacity is utilized with imported raw materials (when the optimal stage 3 decision is in Ω_2). Because of 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 used in solar panels. The United States has only recently begun developing its domestic solar supply chain and still depends on China for these materials. Extending tariffs beyond the panel level to these materials would hinder the overall growth of the domestic solar industry. Anecdotal evidence from other industries, where raw materials and components were significantly impacted by tariffs imposed during the Trump administration, supports this result. For instance, U.S. bicycle manufacturers experienced a slowdown in reshoring due to increased component-level tariffs (Behsudi and 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 (Tariff Effect on Expected Output).

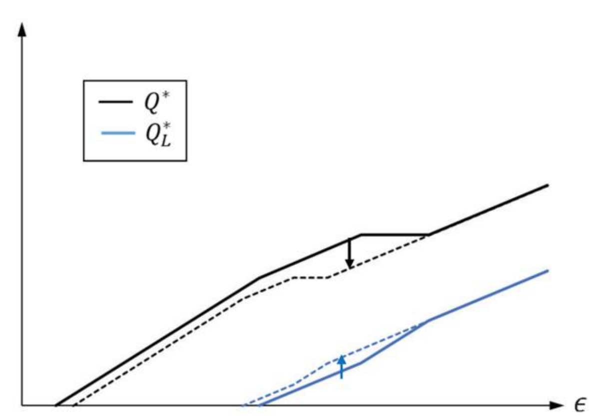
i. *When t_R undergoes an increasing deterministic transformation, we have* $\frac{\partial E(Q^*)}{\partial \mu_R} < 0$, $\frac{\partial E(Q_L^*)}{\partial \mu_R} > 0$, *and* $\frac{\partial E_{\Omega_2+\Omega_3}(q^*_{UC}+q^*_{UU}+Q^*_L)}{\partial \mu_R} < 0$.

ii. *When t_F undergoes an increasing deterministic transformation, we have (1)* $\frac{\partial E(Q^*)}{\partial \mu_F} > 0$ *if and only if (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. The total market output is also lower, which leads to reduced consumer welfare (see discussion in Online Appendix B). Figure 4 illustrates the effect of an increased RM tariff.[6] This result is in line with the empirical findings for the tariffs by the Trump administration. 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.

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

Figure 4. (Color online) Effect of Increased RM Tariff on Firms' Output



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(a). 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(c) 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(a) and illustrated in Figure 5(b). The increased reshoring capacity helps the global firm meet more demand using onshore production for intermediate demand realization; however, a higher 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, whereas the local competitor's expected output decreases. The increase in the global firm's output can dominate the decrease in the competitor's output 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.[7] However, based on the study, the section 301 tariffs had negatively affected the total output in the studied industries and consumer welfare.[8]

4.3. Impact on Profit

Proposition 5 (Tariff Effect on Profit).

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 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, for example, as in Figure 3(a), it cannot effectively mitigate cost surge. This situation plays to the advantage of the domestic firm, because 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(c) 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(b) illustrates, the domestic competitor may become worse off when the region in which it has to lower its output widens.[9]

Figure 5. (Color online) Effect of Increased FG Tariff on Firms' Output

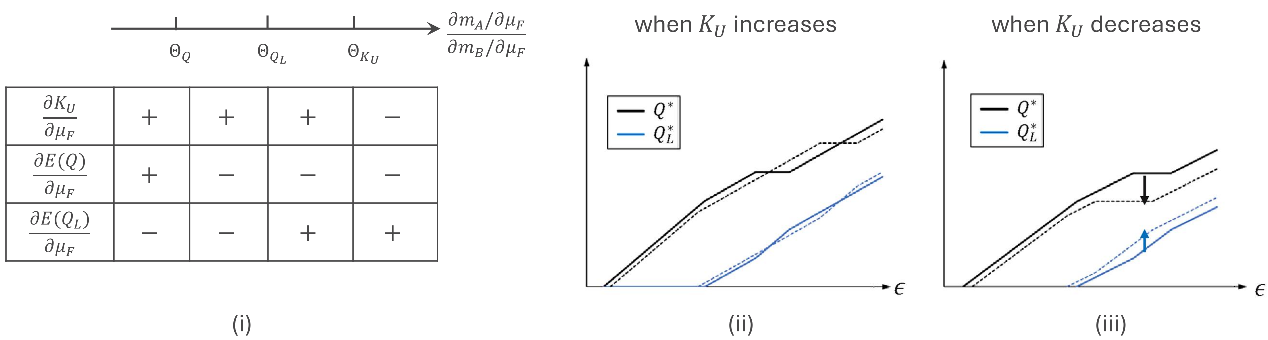
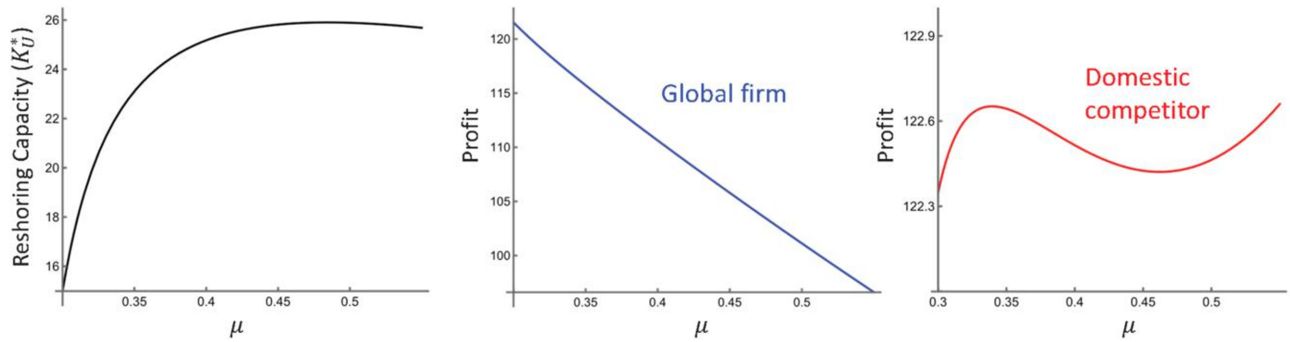


Figure 6. (Color online) An Illustration of Tariff Effect ($w_C = 10, w_U = 13, \delta = 2.8, C_U = 0.2, t_R = \frac{t_F}{2} \sim U[\mu - 0.05, \mu + 0,05]$, $D \sim U[0, 80]$)



To conclude this section, we note that, although the results presented here are established under the assumption that t_R and t_F are independent, Proposition C-1 in Online Appendix C shows that the tariff effects derived in this section remain valid even when t_R and t_F are perfectly positively correlated. Figure 6 illustrates an example. Because the thresholds can be expressed in terms of mean tariff rate, it offers more intuitive insights. Specifically, when reshoring is feasible, moderate tariff increases can stimulate reshoring investment and domestic production. With a mild cost increase, the reshoring investment is likely to be low. Therefore, the overflow probability is high and the overflow demand effect dominates, which encourages more reshoring. However, when tariffs rise significantly and reshoring capacity is well established, overflow production declines. 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 outweighs the overflow demand effect, further tariff hikes may no longer be effective. We observe similar tariff effects on firms' expected profits as discussed in Section 4.3.

5. Tax Credit Policy Model

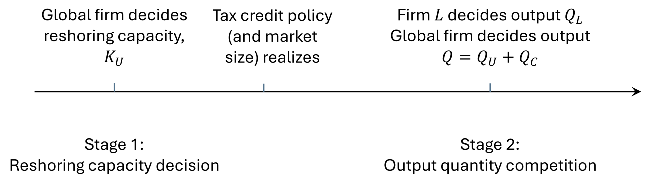
Industrial policies that are profoundly reshaping the clean energy industry, such as the IRA enacted by the Biden administration, undergo lengthier implementation processes and have a significant influence on consumer demand. Economics research has pointed out the significant effect of monetary incentives in the form of tax rebates and tax credits on consumer demand for EVs (see Sallee (2011) and He et al. (2023) and references therein). Motivated by these practices, in this section we develop and study a tax credit policy model that bears some similarities to the tariff policy model in Section 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. Because tax credit only applies at the FG 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; 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 Section 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. Because 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 Section 3, here we assume that the output quantity and

Figure 7. Sequence of Events for the Tax Credit Policy Model



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 Section 3, with some modifications. We defer the detailed formulation to the analysis below.

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 Section 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. Because 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

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

The best response function can be derived as

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

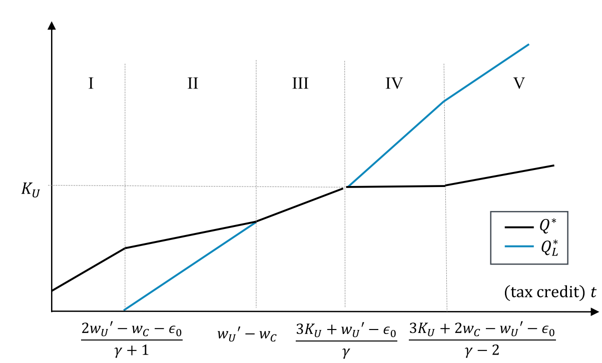
Notice that by defining w'_U as m_A and $w_C + t$ as m_B, the best response function in (4) mirrors (3) for the tariff policy model. Therefore, we can derive the equilibrium in a similar manner. We state the result in the following proposition.

Proposition 6. *The equilibrium output quantities (Q^*, Q_L^*) in stage 2 is given in Figure 8.*

When the tax credit amount is low, that is, 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 Section 3. In this case, because the global firm has a lower production cost than the competitor, it maintains a stronger competitive edge in the market. Note that, although the global firm's production takes place in country C, tax credit still has an impact on its output quantity due to tax credit's influence on end-consumer demand. When the tax credit amount is high, that is, 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

Figure 8. (Color online) Tax Credit Policy Model: Output Quantity Equilibrium in Cournot Competition

Regions	(Q^*, Q_L^*)
I	$\left(\frac{\epsilon_0 - w_C + (\gamma - 1)t}{2}, 0\right)$
II	$\left(\frac{\epsilon_0 - 2w_C + w'_U + (\gamma - 2)t}{3}, \frac{\epsilon_0 - 2w'_U + w_C + (\gamma + 1)t}{3}\right)$
III	$\left(\frac{\epsilon_0 + \gamma t - w'_U}{3}, \frac{\epsilon_0 + \gamma t - w'_U}{3}\right)$
IV	$\left(K_U, \frac{\epsilon_0 + \gamma t - w'_U - K_U}{2}\right)$
V	$\left(\frac{\epsilon_0 - 2w_C + w'_U + (\gamma - 2)t}{3}, \frac{\epsilon_0 - 2w'_U + w_C + (\gamma + 1)t}{3}\right)$



country C. Because 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 with 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 Section 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 7. *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.

5.2. 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 Section 4 to study the effect of tax credit provided to end consumers.

Proposition 8 (End Consumers Tax Credit). *When* μ *increases,*

i. *The global firm's reshoring capacity increases;*

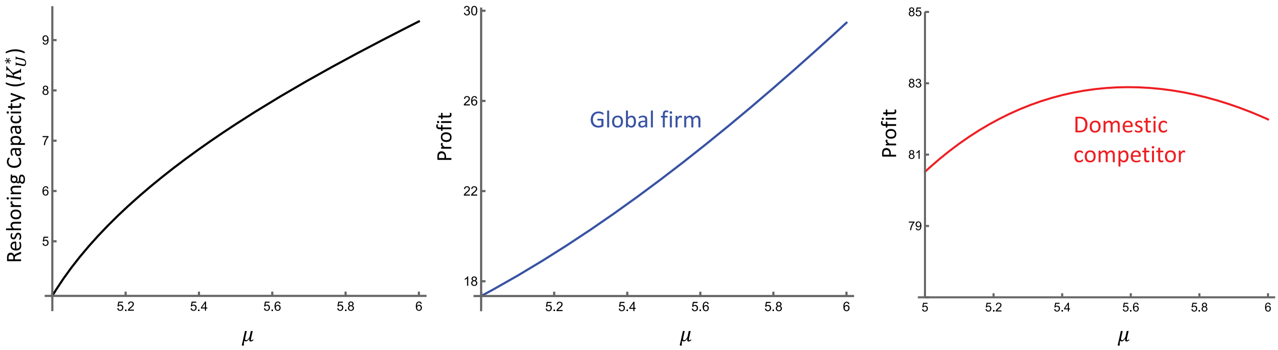
ii. *The global firm's expected output quantity and the total expected production quantity in country U both increase; firm L's expected output quantity can either increase or decrease.*

Proposition 8 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 6, 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 Section 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. Because 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 increased reshoring capacity, enabling the global firm to produce a larger share of domestic demand at the more profitable location, thereby increasing its expected output. Although tax credits also benefit the domestic firm by stimulating higher market demand, the firm faces intense competition in the domestic market due to the global firm's expanded reshoring capacity. As a result, the domestic firm's expected output may either increase or decrease, depending on which effect is stronger. However, we find that the total domestic production from both firms will increase as the average tax credit amount rises. As we illustrate in Figure 9, the impact of tax credit on the two firms' profits is similar to its effect on output quantities.[10]

Finally, we briefly discuss other types of government incentives provided by the IRA, which have less

Figure 9. (Color online) Impact of End-Consumer Tax Credit ($w_C = 10, w'_U = 11, \epsilon_0 = 10, \alpha = 4, t \sim U[\mu - 5, \mu + 5], C_U = 4$)



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 United States, 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 9 (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. The impact on the domestic firm's output is also indefinite due to the same effects. Despite this, we show that the total quantity produced in country U always increases in the amount of manufacturing production credit.

Proposition 10 (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, more than 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.

6. 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 Sections 3 and 5 with those without competition, that is, 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 11. *In the tariff model, there exist thresholds I_1 and I_2 (defined in the proof) such that*

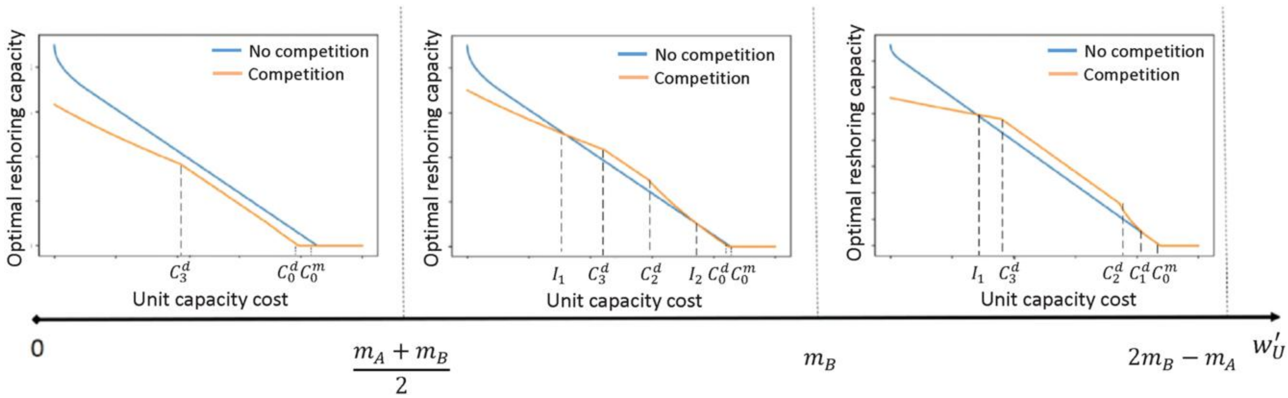
i. *When $w'_U < \frac{m_A + m_B}{2}$, we have $K_U^d \leq K_U^m$, with equality holds when $C_U \geq C_0^m$.*

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 $C_U \geq C_0^m$.*

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

Figure 10. (Color online) Effect of Competition on Reshoring Capacity (Tariff Model)



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 with the domestic competitor's plays to its advantage. It is clear from Figure 3, (b) and (c), 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 12. *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.

7. Concluding Remarks

Recent trade protectionist policies in the United States 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 and 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

Table 1. Summary of Policy Effects

Policy	Effect on reshoring capacity: Output quantity effect (−)	Overflow demand effect (+)	Combined effect	Effect on profit: Global firm	Domestic firm
FG tariff	√	√	↑ or ↓	↓	↑ or ↓ (decrease when reshoring intensifies domestic competition)
RM tariff	√		↓	↓	
Tax credit		√	↑	↑	

face of all uncertainties, the output quantity equilibrium between competing firms upon demand realization, and the production allocation decision on 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 in Table 1 and 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 FG tariff can either increase or decrease reshoring investment, whereas a higher RM tariff always results in less reshoring. On the one hand, the FG 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; and (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. An FG 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 RM 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.

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.

Second, we demonstrate that tariff and tax credit policies may yield distinct impacts on firms' expected profits and industry output, as well as consumer welfare. Tariffs always hurt the global firm, driving up its average per-unit production cost in serving the market. 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. Tariffs tend to negatively affect total output and consumer welfare (except when the overflow demand effect is very strong). On the other hand, the tax credit policy can potentially benefit both firms by boosting demand and subsidizing domestic production, leading to higher total output and consumer welfare. 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. Our conceptual framework identifies two major effects (output quantity and overflow) that can be used to explain insights on reshoring capacity investments. We expect that the insights continue to hold in a more general model with both tariffs and tax credits. In particular, the policy outcome are likely to be determined by which effect(s) are present, and when both are present, the dominant of the two opposite effects. 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 and intense competition in the domestic market.

Although our model is motivated by the current trade situation between United States and China, a recent study by Alfaro and 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 and Rappeport 2024). Also, in addition to the clean energy industry, the United States in general has seen more reshoring intention and activities since 2018 due to various forms of risks (Alfaro and 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.

Endnotes

[1] Alfaro and Chor (2023) show 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.

[2] 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.

[3] 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 multiyear contracts to key suppliers are awarded with clearly stated sales expectations. From such information, capacity is often inferred.

[4] More precisely, the stage 3 problem may be formulated with a 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.

[5] 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."

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

[7] A recent study, Alfaro and 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.

[8] In Online Appendix B, we show that in most situations, higher FG tariffs reduce consumer welfare, unless when the overflow demand effect is much bigger than the output quantity effect, that is, when K_U^* is very high. In the latter case, the global firm sets a high reshoring capacity level and increases its expected output. Although the domestic competitor reduces its output, the global firm's increase in output may lead to the total industry outputting more to the market as a result. In this extreme case, consumers may benefit from the higher industry output and lower price.

[9] 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).

[10] In Online Appendix D, we show that the impact of tax credit on reshoring capacity and firms' output holds with or without the

demand effect (i.e., increasing market demand). However, the demand effect seems to be the driving factor for the global firm's higher profit; in the absence of the demand effect, a higher tax credit hurts (rather than benefits) the global firm.

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