

**Cross-Border Ownership:**  
**An Expanded Model and Application to the U.S. Beer Market**

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Cross-Border Ownership: An Expanded Model and Application to the U.S. Beer Market

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**Abstract**

We construct a model featuring imperfect competition with a generalized number of firms, cross-border ownership, and nested CES utility. We apply this model to the U.S. beer market and test the results of a hypothetical tariff rate increase on imported beer. We find that foreign firms that are related to other domestic producers through cross-border ownership may find it optimal to *increase* the price of their imports in response to the tariff, while foreign firms without domestic subsidiaries unambiguously find it optimal to decrease their producer prices. Conversely, domestic producers that are related to foreign producers through cross-border ownership may *lower* their producer prices in response to the tariff. The intensity of responses is stronger when the domestic subsidiaries are in the same CES nest as the foreign producers, such as when the tariff mostly impacts craft beer.

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# 1 Introduction

The U.S. beer industry is highly concentrated, with just three firms accounting for approximately 70 percent of market share. The industry is also characterised by high levels of cross-border ownership relationships with parent companies owning domestic and foreign producers simultaneously. We apply an imperfectly competitive cross-border ownership model to illustrate the market effects of a hypothetical tariff increase on foreign producers.

The model presented here is an extension of the model presented in Montgomery and Riker (2020). We add a nested CES structure to account for larger degrees of production differentiation between segments of the beer market. The first nest is comprised of mass-produced beers, the bulk of which are domestically produced. Premium beers, including domestic craft beer and many foreign beers, are in the other nest. This allows pricing strategy responses to a tariff to depend on a producer's nest. We also improve upon the original computation of the model by using Python and allowing for a user-defined number of firms to be included in the model, rather than limiting to a fixed number of firms.

The data requirements for the model are fairly modest. We calibrate the baseline model using publicly available U.S. market share data, and select within-nest and between-nest elasticities based on qualitative market features. We find that a 15 percent increase in an import tariff causes domestic craft producers that are related to foreign producers through cross-border ownership to *lower* their producer prices. Conversely, we observe a foreign producer *increases* its price following the tariff. This pricing behavior allows parent companies to shift market share from foreign subsidiaries affected by the tariff to unaffected domestic subsidiaries.

The rest of this paper is organized as follows. Section 2 describes the model and characterizes the model solution. Section 3 describes the U.S. beer market, summarizes data used to calibrate the model, and presents the results of a hypothetical tariff increase. Section 4 compares the application in section 3 to an alternative model specification that eliminates cross-border ownership relationships. Section 5 concludes.

## 2 Model

The market in the model is oligopolistic, with most of the market share being held by a small number of firms that take into account the impact of their price on the overall price index. Specifically, we

use Bertrand competition, so firms set a price and then produce enough quantity to supply the quantity demanded at that price. Firms are differentiated, so prices are not necessarily the same and are not driven down to marginal cost.

The demand functions for each firm are derived from nested CES utility with two nests—mass-produced beer in one nest and craft beer in the other. Firms within the same nest are closer competitors. The elasticity of substitution between the nests is  $\sigma$  while the within-nest elasticity of substitution between firms is given by  $\sigma_m$  or  $\sigma_c$ , depending on the nest. For notational convenience, define  $x(h)$  as a label for the nest that firm- $h$  is in, so  $x(h) = m$  if firm- $h$  is in nest- $m$  and  $x(h) = c$  if firm- $h$  is in nest- $c$ . The nest demand shifters  $\alpha$  and  $1 - \alpha$  can be denoted by  $\alpha_{x(h)}$ , depending on the nest.

Like Montgomery and Riker (2020), our model extension features cross-border ownership. Model users determine the share of each producing firm owned by each other firm. Ownership shares can vary between  $[0, 1]$  and firms can partially or wholly own themselves. Model users also determine which firm sets prices for each producing firm, allowing for parent companies directly control their subsidiaries. The price control parameter determines which firm's profits are maximized when equilibrium prices are set.

## 2.1 Demand Function and Price Indices

The demand function for firm- $h$  is given below.

$$y_h = \alpha_{x(h)} b_h ((1 + t_h) p_h)^{-\sigma_{x(h)}} P_{x(h)}^{\sigma_{x(h)} - \sigma} P^{\sigma - 1} K \quad (1)$$

In this equation,  $b_h$ ,  $t_h$  and  $p_h$  are the demand shifter, tariff rate, and price for firm- $h$ , respectively. The variable  $K$  is the total expenditure in the overall beer market. The price indices  $P$ ,  $P_m$ , and  $P_c$  are defined below with  $\mathbb{M}$  and  $\mathbb{C}$  representing the set of mass-produced beer and craft beer producers, respectively.

$$\begin{aligned}
P &= (\alpha P_m^{1-\sigma} + (1-\alpha)P_c^{1-\sigma})^{\frac{1}{1-\sigma}} \\
P_m &= \left( \sum_{i \in \mathbb{M}} b_i ((1+t_i)p_i)^{1-\sigma_m} \right)^{\frac{1}{1-\sigma_m}} \\
P_c &= \left( \sum_{j \in \mathbb{C}} b_j ((1+t_j)p_j)^{1-\sigma_c} \right)^{\frac{1}{1-\sigma_c}}
\end{aligned}$$

## 2.2 Profit Functions and Pricing Strategy

The profit functions and pricing strategies are determined by the controlling parent firm rather than the individual producers. Define  $o_{\ell h}$  as the share that firm- $\ell$  owns of firm- $h$ . Define  $g_h$  as the marginal cost of producing one unit for firm- $h$ . The profit function for firm- $\ell$  is given below.

$$\Pi_\ell = \sum_{i \in \mathbb{M}} o_{\ell i} (p_i - g_i) y_i + \sum_{j \in \mathbb{C}} o_{\ell f} (p_j - g_j) y_j$$

The pricing decisions for a producing firm depend on the objective function of the firm that chooses the prices, which will either be the producing firm or its parent. For firm- $h$ , define  $r_{\ell h} \equiv 1$  if firm- $\ell$  chooses the price for good- $h$  and  $r_{\ell h} \equiv 0$  otherwise. If  $r_{\ell h} = 1$ , firm- $\ell$  sets the price for good- $h$  to maximize the profit of firm- $\ell$ . Since firm- $\ell$  wishes to maximize their overall profits, not necessarily the profits of just one brand, take the first order condition of parent profit  $\Pi_\ell$  with respect to brand price  $p_h$  to find firm- $\ell$ 's best response function given the prices of all other goods via the

price indices.<sup>1</sup>

$$\begin{aligned}
\frac{\partial \Pi_\ell}{\partial p_h} = & o_{\ell h} y_h + o_{\ell h} (p_h - g_h) \alpha_{x(h)} b_h (-\sigma_{x(h)}) ((1 + t_h) p_h)^{-\sigma_{x(h)} - 1} P_{x(h)}^{\sigma_{x(h)} - \sigma} P^{\sigma - 1} K \\
& + \alpha P_m^{\sigma_m - \sigma} P^{\sigma - 1} \left( (\sigma_m - \sigma) P_m^{-1} \left( \frac{\partial P_m}{\partial p_h} \right) + (\sigma - 1) P^{-1} \left( \frac{\partial P}{\partial p_h} \right) \right) \\
& \times \sum_{i \in \mathbb{M}} o_{\ell h} (p_i - g_i) b_i ((1 + t_i) p_i)^{-\sigma_m} \\
& + (1 - \alpha) P_c^{\sigma_c - \sigma} P^{\sigma - 1} \left( (\sigma_c - \sigma) P_c^{-1} \left( \frac{\partial P_c}{\partial p_h} \right) + (\sigma - 1) P^{-1} \left( \frac{\partial P}{\partial p_h} \right) \right) \\
& \times \sum_{j \in \mathbb{C}} o_{\ell j} (p_j - g_j) b_j ((1 + t_j) p_j)^{-\sigma_m}
\end{aligned}$$

This first derivative can be understood as the parent firm balancing two effects when changing the price of a specific subsidiary. The first line is the direct effect of changing the price of good- $h$  on the profit generated by good- $h$ . This is the usual trade-off between receiving more revenue per unit sold but selling a lower quantity. The following lines are the indirect effect of the price change for good- $h$  on other firms that are owned by firm- $\ell$ . Changing the price of one subsidiary firm impacts the quantities sold of the other subsidiary firms through changes in the price indices, with a bigger impact when the firms are in the same nest. In a Nash equilibrium solution to this model, these first derivatives will be zero.

### 2.3 Computation

The solution to the model is programmed to allow for any (finite) number of firms within each nest, although the current model does not allow for more than two nests. The basic steps are described here.

1. The user constructs spreadsheets with firm market shares, locations, nests, and ownership information and imports these into the program.
2. The user chooses three elasticities of substitution: one between-nest, two within-nest.
3. The program calculates firm- and nest-level demand shifters using the market share data, normalizing prices to 1.

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<sup>1</sup>Using a programming language like Python is essential here – producer characteristics, including ownership, are fed in as a table. The program iterates over each producer, looks at their parent, and constructs the proper first derivative to be fed into a function solver. This setup allows for an arbitrary number of firms.

- This uses the Euler equations for the consumer problem to relate quantity demanded for each firm's product.
4. The program constructs a list of first order condition functions, one for each firm. This involves looping over the firms twice.
    - The outer loop checks each production firm and finds the direct effect of a price change on the profit of the parent company.
    - The inner loop calculates the indirect effect of a price change by the original firm on the profits of the other subsidiaries of the parent company through the change in price indices.
  5. The program uses the first order conditions to calibrate the marginal costs.
    - Assume that the data comes from the market being in equilibrium.
    - Create a wrapper function takes a list of marginal costs (one for each firm) as the input then calls the FOC functions using the previously chosen and calculated parameters, giving the value of the first derivative computed at the point of those parameters.
    - Use `fsolve` or another root (zero) finding routine with the wrapper function to produce a list of marginal costs that are consistent with the first order conditions being satisfied.
  6. The user selects a new experiment to run. For example, apply a tariff to imported products.
  7. The program uses the new value given (e.g. for the tariff) along with the previously chosen, calculated, and calibrated parameters and find a new solution based on the experiment given.
    - (a) This time, create a wrapper for the FOCs that takes output prices as the variable input.
    - (b) Again, use `fsolve` or an alternative to compute new output prices.
    - (c) Use those new prices in conjunction with the demand functions to compute new values for output, revenue, and profit.

## 3 Model Application

### 3.1 The American Beer Market

According to the Brewers Association for Small and Independent Craft Brewers, the United States represents a \$116.0 billion dollar market.<sup>2</sup> The U.S. beer industry itself is comprised of a combination of several large domestic mass-producers, a few large foreign producers, and thousands of small domestic and foreign craft producers. While estimates attribute approximately 70 percent of the 2019 American beer market share to three U.S.-based mass producers, shares of domestic craft and foreign imports have grown steadily in recent years.<sup>3</sup> In 2019, imported beer, including craft and mass-producers, accounted for approximately 19 percent of the U.S. beer market, while wholly owned “independent craft” producers controlled approximately 13 percent of the U.S. market.<sup>4</sup>

The presence of differentiated brands and significant parent-subsidiary relationships add further nuance to the U.S. beer market. In an effort to leverage economies of scale and diversify holdings across market segments, domestic and foreign mass-producers have undergone several high-profile mergers and have also acquired successful independent craft brands. In 2019, the National Beer Wholesalers Association estimated that parent firms and subsidiary brands of Anheuser-Busch Inbev, MillerCoors LLC, and Constellation controlled 73.1 percent of the entire U.S. beer market.<sup>5</sup>

On the consumer side of the market, few sources exist describing substitutability between domestically mass-produced, foreign imported, and craft beer. Using 7 years of consumer purchase data from a Chicago grocery store chain between 1991 and 1997, Gonzales et al. (2014) find that the cross-price elasticity across types of beer (mass-produced, craft, and imports) is close to zero.<sup>6</sup> This could suggest that mass-produced, craft, and import beers represent three distinct markets. However, the period of analysis pre-dates shifts in consumer preferences towards imported and craft brands witnessed over the last decade.

Qualitatively, imported and domestic craft beer brands appear more similar relative to foreign and domestically mass-produced beer. Craft beer, whether produced by a domestic or foreign firm,

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<sup>2</sup>Brewers Association, “National Beer Sales & Production Data” (accessed May 26, 2020).

<sup>3</sup>National Beer Wholesalers’ Association, “The U.S. Beer Industry, 2019” (accessed May 29, 2020).

<sup>4</sup>Estimates of the size of the craft beer market vary depending on definitions used. The above estimate defines craft brewers as firms that produce 6 million barrels of beer or less and is less than 25 percent owned by a non-craft alcohol industry member. National Beer Wholesalers’ Association, “The U.S. Beer Industry, 2019” (accessed May 29, 2020).

<sup>5</sup>National Beer Wholesalers Association, “The U.S. Beer Industry 2019,” (accessed May 26, 2020)

<sup>6</sup>Gonzalez, McCluskey, Mittelhammer, “Beer Snobs do Exist: Estimation of Beer Demand by Type,” *Journal of Agricultural and Resource Economics*, Vol. 39, No.2 (August 2014).



offers a significant variety of categories ranging from hop-filled India pale ales to coffee flavored porters. Conversely, the set of mass-produced varieties is generally more limited and constrained to lager and light beer categories. At the same time, domestic and import craft beer varieties typically cost more than mass-produced brands. As such, we assume that craft beers have higher substitutability with other craft beers, regardless of their production location. Likewise, we assume a high degree of substitutability between mass-produced beers, regardless of their production location. Substitutability between the two nests is positive but low.

### 3.2 Parameter Selection

We use the model to simulate the effect on economic outcomes of a 15 percent ad-valorem tariff on imported beer. To that end, we collected publicly available data on estimates of beer producer market share by brand. Brands were assigned to “craft” or “mass-produced” nests and aggregated by parent, production location, and nest assignment. The Cross-Border Ownership model allows for individual brands to be aggregated if they 1) share the same parent firm, 2) are in the same nest, and 3) have the same applied tariff. For each brand with a known parent firm, we assigned a 100 percent ownership stake and full pricing control to the parent firm.

Throughout the data collection process, we attributed 80.8 percent of total U.S. expenditure on beer across 16 aggregated firms representing unique parent, production location, and nest combinations. The remaining market share was assigned to a “domestic craft residual mass” and an “imported craft residual mass” based on industry estimates of market share estimates of independent domestic craft producers and non-mass-produced imports. Those residuals were further divided into 50 identical firms with small market shares approaching a monopolistically competitive outcome without entry or exit. Tables 1 and 2 describe how firms and market shares were allocated across each possible combination of nest and production location. A more detailed description of firm-level parameters can be found in table 3.

In addition to firm market shares, ownership structures, CES nests, and production location parameters, the Cross-Border Ownership model requires users assign within-nest and Armington CES parameters. As mentioned previously, the little evidence available suggests that there is low substitutability between mass-produced, domestic craft beer, and imported brands. Although we distinguish beer categories by mass-produced and craft nests, we continue to assume low levels of substitutability between product categories. As such, we assigned a value of two to the Armington

Table 1: Number of firms by location and nest

	Domestic	Foreign	Total
Mass	4	2	6
Craft	58	54	112
Total	62	56	

Table 2: Cumulative market share by location and nest

	Domestic	Foreign	Total
Mass	58.6%	4.6%	63.2%
Craft	23.2%	13.6%	36.8%
Total	81.8%	18.2%	

CES parameter. Within the craft and mass-produced nests, we assign more moderate values of four and six, respectively.

### 3.3 Model Results

Figure 1, featured below, shows how firms alter their prices following the implementation of a 15 percent tariff on imported beer. In Figure 1, each firm has been colored to reflect shared parent companies. This shows patterns in parent firms' brand-level pricing strategies. In particular, we find that domestic craft firms that share the same parent as a foreign craft producer lower their prices following the implementation of a tariff. For example, "Constellation DM Craft," which is comprised of several domestic craft brands and owned by Constellation, is related to foreign craft

and foreign mass-produced firms through the parent company. Following the 15 percent tariff, it lowered its producer prices by 1.06 percent. The same trend can be seen with domestic craft firms owned by Heineken and AB InBev, both of which are similarly related to foreign brands through cross-border ownership.

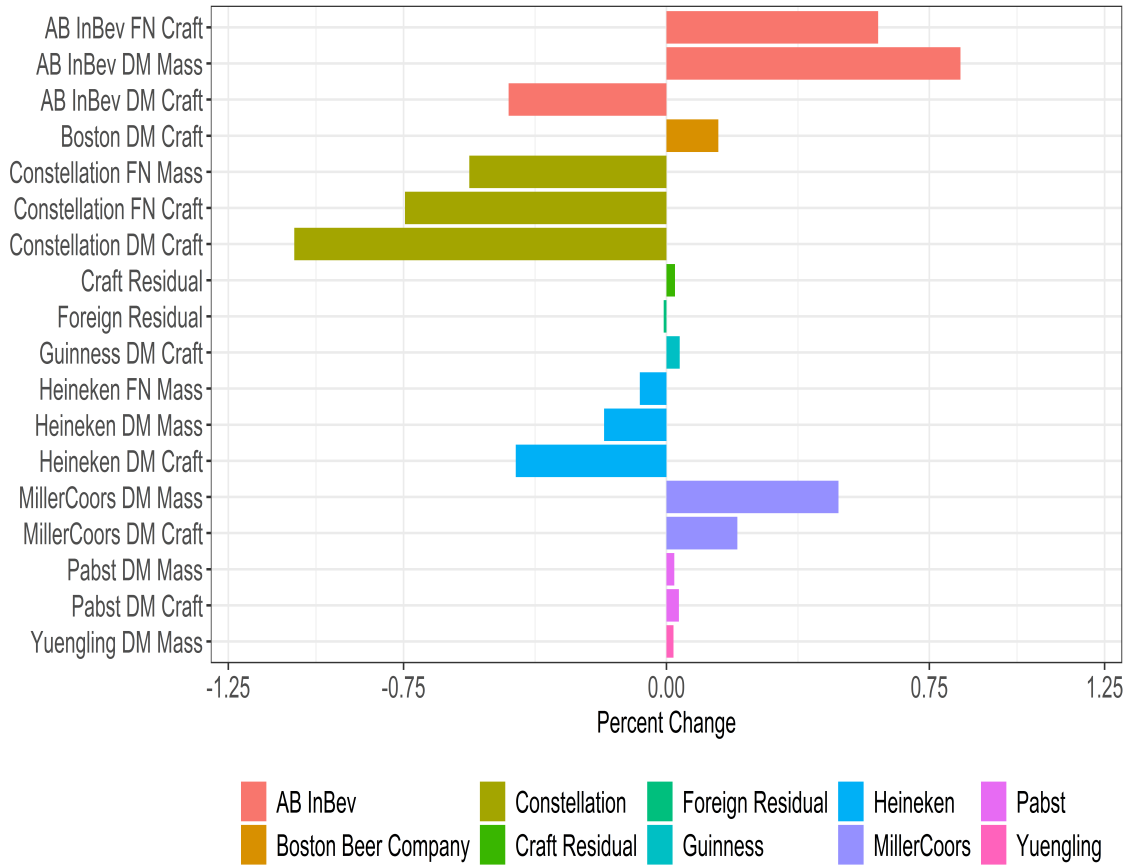
The decreases in prices post-tariff observed in some domestic craft producers runs counter typical results from a standard Bertrand competition framework that does not include cross-border ownership. Domestic craft producers lowering their prices in the face of a tariff on foreign producers is the result of our model capturing cross-border ownership relationships between firms and is consistent with findings from the 3-firm model with cross-border ownership presented by Montgomery and Riker (2020). We interpret this process as parent companies strategically attempting to retain profits by ceding market share from their foreign holdings to other domestic subsidiaries that are unaffected by the tariff. As profits from foreign subsidiaries are reduced from the effect of the tariff, domestic subsidiaries benefit from increases in market share and increase their profits in the new equilibrium. Parent firms' strategies of reducing producer prices of related domestic subsidiaries further exacerbates this shift in subsidiary profitability and helps parent companies retain more profits than models without foreign ownership would predict.

The nested-CES structure of our model appears to greatly reduce any incentive for parent firms to lower prices of their domestic mass-produced holdings following the tariff, since most of the import producers are classified in the craft category. Notably, we find that AB InBev *increases* the price of its domestic mass-produced firm in the new equilibrium. This response is likely due to the allocation of foreign market share across craft and mass-produced nests, coupled with the selection of a low between-nest Armington CES parameter. In our U.S. beer market specification, only 7.2 percent of the market share in the mass-produced nest was allocated to foreign firms, compared to 37 percent in the craft nest. As such, we expect smaller equilibrium effects on producers in the mass-produced nest. At the same time, our selection of a low between-nest Armington CES parameter minimizes the extent to which within-nest price changes affect outcomes in the opposing nest.

Ultimately, the magnitude of the price effects in our reported specification are small, likely due to the small amount of market share controlled by foreign producers in our specification, coupled with the selection of relatively high within-nest elasticities of substitution. Most firms change their prices by less than 1 percent following the imposition of a 15 percent tariff. As expected, foreign and craft residual firms, reported as single firms in figure 1, produce the smallest change in prices in the new

equilibrium due. We find that as the number of firms included in the residual market calculation increases, their equilibrium price continues to shrink, approaching the short-run (no entry or exit) monopolistically competitive outcome where these firms only respond to the small change in the price index.

Figure 1: Equilibrium Change in Producer Prices



Figures 2 and 3 show that a 15 percent tariff on foreign beer producers results in large shifts in demand away from foreign producers. For these figures, we grouped each firm by production location and nest assignment. Doing so illustrates the extent to which changes in quantities demanded and firm profits are determined by the combination of firms' production location and nest assignment. Figures 2 and 3 make clear that changes in quantities and profits are dominated by variation between nest and production location clusters. Foreign producers assigned to the mass-produced nest see the largest declines in equilibrium quantities and profits. This is likely the result of the high within-nest elasticity chosen for the mass-produced nest, coupled with the relatively small proportion of expenditure allocated to foreign firms in the mass-produced nest. Conversely, domestic craft

producers witness larger gains in equilibrium quantities and profits relative to domestic firms in the “mass-produced” nest.

Figure 2: Equilibrium Change in Quantities by Firm

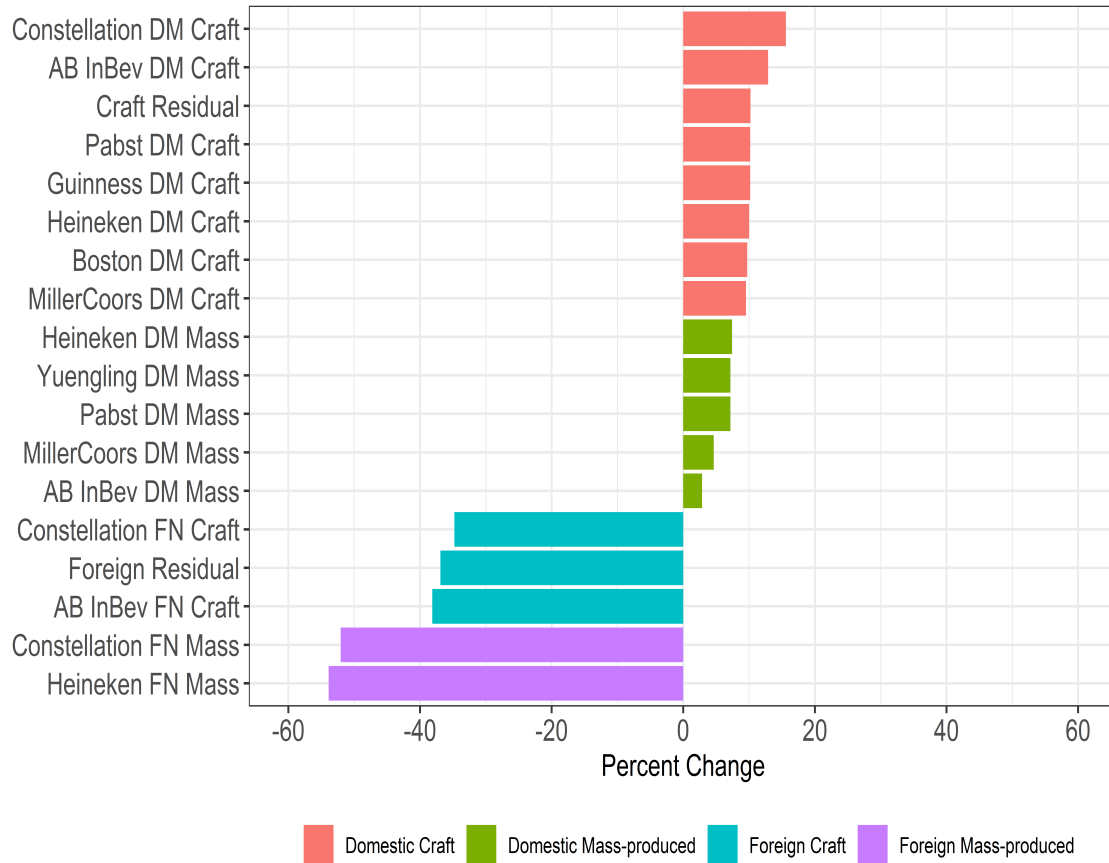
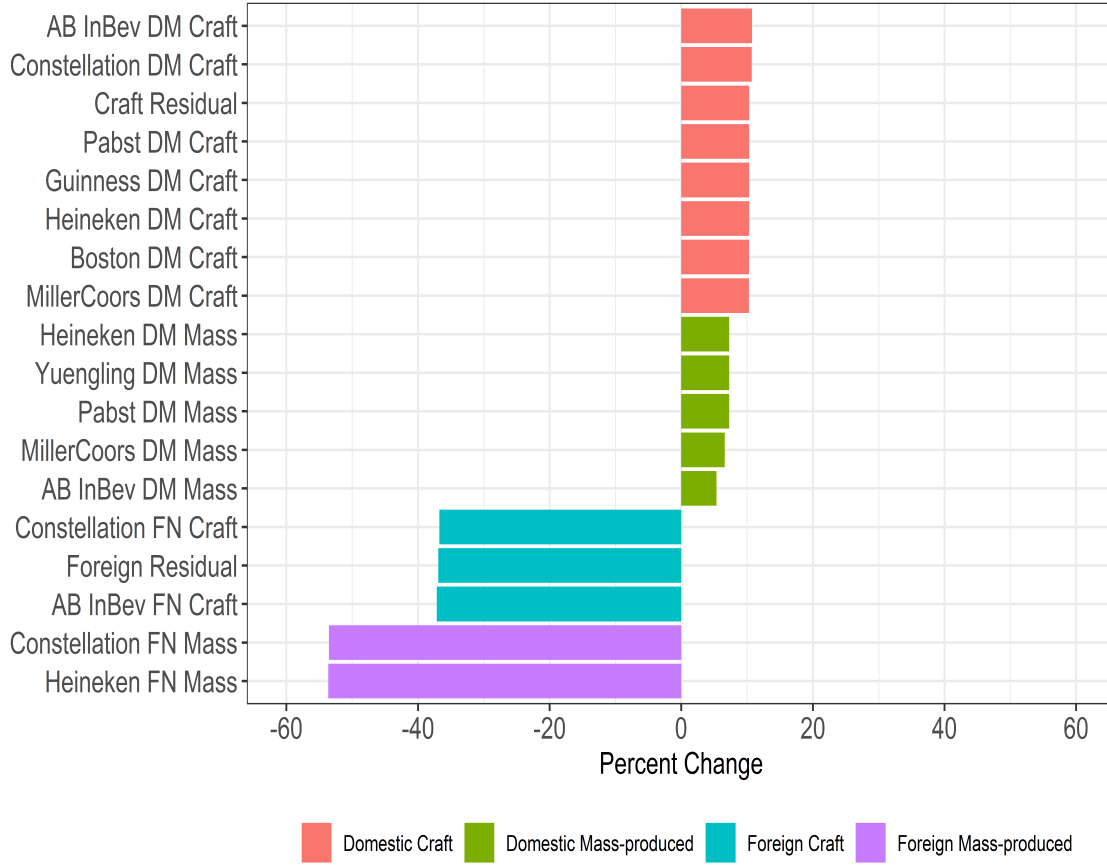


Figure 3: Equilibrium Change in Profits by Firm



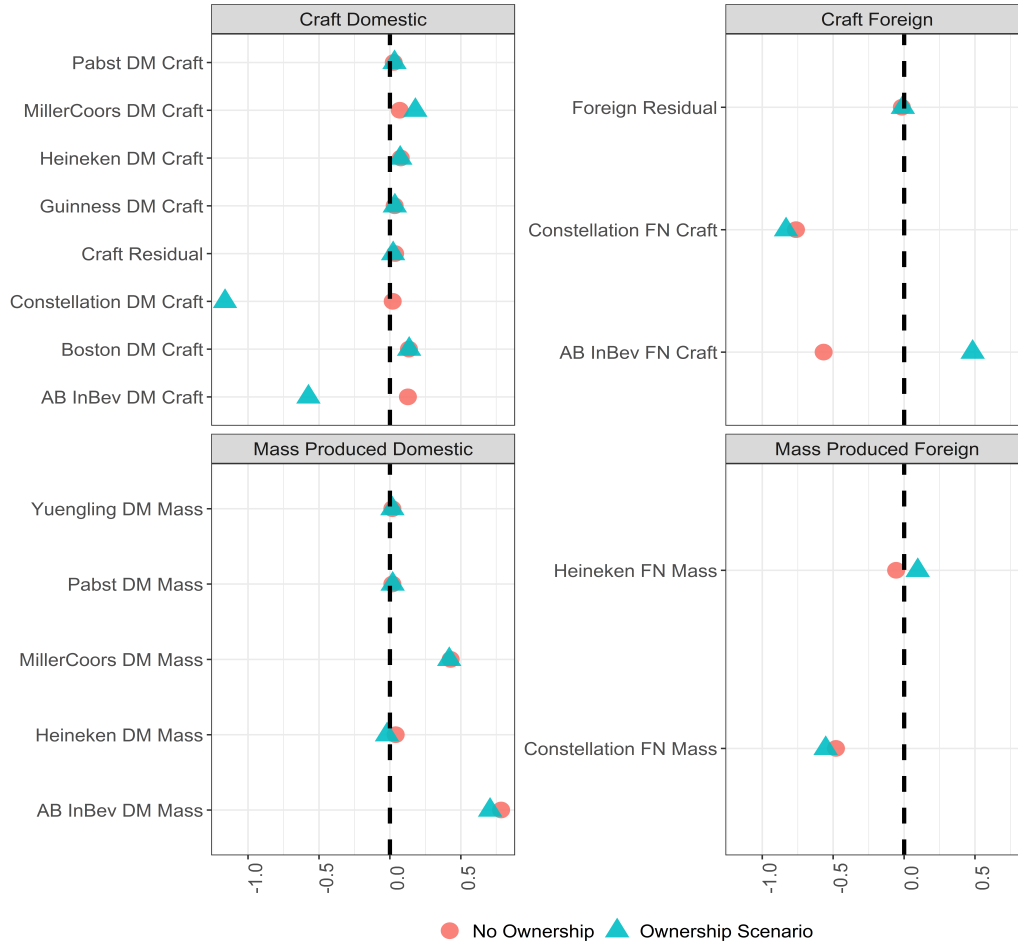
## 4 Alternative Specifications

### 4.1 Eliminating Parent Firm Ownership

In addition to our main model specification, we present results of a counterfactual simulation where we assume no parent-subsidary relationships between firms exist across market nests or production locations. In this counterfactual scenario, each firm wholly owns itself and exerts control over its own pricing strategy. The firms are still aggregated based on the previous characteristics (real parent, nest, and production location), but ties to other aggregated firms are cut. Figure 4 compares firms' equilibrium price changes for the main specification (red) and the no-ownership counterfactual. As reported in section 3, figure 4 shows domestic craft subsidiaries that share a parent with foreign craft producers choose to reduce their prices in the main specification. However, these same domestic craft producers raise their prices in the alternative scenario that does not include any cross-border ownership relationships. At the same time, the inclusion of cross-border ownership results in price

increases among some foreign producers that are related to large domestic producers. In particular, foreign producers owned by Heineken and AB Inbev both raise their prices in the scenario with cross-border ownership. Firms that are wholly owned without any subsidiary relationships are relatively unaffected by the presence of ownership relationships amongst other firms in the model. For example, firms such as Yuengling, Guinness, and the residual firms show negligible differences in price changes across the specifications illustrated in figure 4.

Figure 4: Percent Changes in Firms' Prices, Main vs. No-ownership Counterfactual



## 5 Conclusion

This model provides useful extensions to the cross-border ownership model from Montgomery and Riker (2020) by allowing a generalized number of firms. Furthermore, the addition of a nested-CES structure allows for model users to capture nuances in product substitutability across firms.

Using Python allows for much more flexibility than the earlier spreadsheet-based solver, while still maintaining most of the ease-of-use. Ideally, the model and methods introduced in this paper and the related Python program can be used as a template for future partial equilibrium models. Furthermore, the Python structure allows for easily-implementable comparative statics and counterfactuals. For example, the program can be run with many different sets of elasticity parameters to evaluate the sensitivity of the model to such changes. These modifications can be automated, and ultimately this would allow for model-agnostic analytic tools to be built for other Python-based PE models. Developing these tools and applying them to this particular model is the next big step in this line of research.

The beer industry was a natural choice for applying the cross-border ownership model due to the presence of large parent companies that own brands which produce both inside and outside the United States. Incorporating a hypothetical tariff on imported beers causes parent companies with large domestic craft beer subsidiaries to actually *increase* the price on their imported craft beer, a result that is qualitatively different than the case without the ownership structure. In the calibrated model, these price effects are low in magnitude, likely driven in part by the relative size of the import and craft shares, especially given that only firms owning moderately sized subsidiaries in both markets would substantially change their behavior. Other markets with a similar ownership structure but higher competition from imported products may see bigger price effects.



## A Beer Market Application Parameter Matrix

Table 3: Parameter Matrix for Main Model Specification

Firm	Parent	Production location	Nest	Market Share	Controlling Firm	Initial tariff	Final tariff
AB InBev DM Mass	AB InBev	domestic	0	35.4	0	0	0
AB InBev FN Craft	AB InBev	foreign	1	3.5	0	0	0.15
MillerCoors DM Mass	MillerCoors	domestic	0	21	2	0	0
Constellation FN Craft	Constellation	foreign	1	4.6	3	0	0.15
Heineken FN Craft	Heineken	foreign	1	2.5	4	0	0.15
Pabst DM Mass	Pabst	domestic	0	1.1	5	0	0
Yuengling DM Mass	Yuengling	domestic	0	1.1	6	0	0
Guinness DM Craft	Guinness	domestic	1	0.5	7	0	0
Foreign Residual	Foreign Residual	foreign	1	3	8	0	0.15
Craft Residual	Craft Residual	domestic	1	16.2	9	0	0
Boston DM Craft	Boston Beer Company	domestic	1	1.9	10	0	0
AB InBev DM Craft	AB InBev	domestic	1	1.8	0	0	0
Constellation DM Craft	Constellation	domestic	1	0.3	3	0	0
MillerCoors DM Craft	MillerCoors	domestic	1	1	2	0	0
Heineken DM Craft	Heineken	domestic	1	1.1	4	0	0
Pabst DM Craft	Pabst	domestic	1	0.4	5	0	0
Constellation FN Mass	Constellation	foreign	0	4.1	3	0	0.15
Heineken FN Mass	Heineken	foreign	0	0.5	4	0	0.15

## B Technical Appendix

### B.1 Nested CES Demand from Nested CES Utility

$$u(d, f) = \left( \alpha^{\frac{1}{\sigma}} d^{\rho} + (1 - \alpha)^{\frac{1}{\sigma}} f^{\rho} \right)^{\frac{1}{\rho}}$$

where:

$$q_m = \left( \sum_{i \in \mathbb{M}} a_i^{\frac{1}{\sigma_m}} x_i^{\rho_m} \right)^{\frac{1}{\rho_m}}$$

$$q_c = \left( \sum_{j \in \mathbb{C}} b_j^{\frac{1}{\sigma_c}} y_j^{\rho_c} \right)^{\frac{1}{\rho_c}}$$

Define three price indices.

$$P = \left( \alpha P_m^{1-\sigma} + (1-\alpha) P_c^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

$$P_m = \left( \sum_{i \in \mathbb{M}} a_i p_i^{1-\sigma_m} \right)^{\frac{1}{1-\sigma_m}}$$

$$P_c = \left( \sum_{j \in \mathbb{C}} b_j p_j^{1-\sigma_c} \right)^{\frac{1}{1-\sigma_c}}$$

## B.2 Expenditure on General Types

$$\max U^\rho$$

$$\text{s.t. } q_m P_m + q_c P_c = K$$

$$\mathcal{L} = \alpha^{\frac{1}{\sigma}} d^\rho + (1-\alpha)^{\frac{1}{\sigma}} f^\rho + \lambda(K - q_m P_m - q_c P_c)$$

$$\frac{\partial \mathcal{L}}{\partial q_m} = \alpha \rho q_m^{\rho-1} - \lambda P_m$$

$$\frac{\partial \mathcal{L}}{\partial q_c} = (1-\alpha) \rho q_c^{\rho-1} - \lambda P_c$$

Set the partial derivatives equal to zero, then set equal to one another. Rearrange to  $m$  in terms of  $c$ .

$$q_m = \left( \frac{P_m}{\alpha^{\frac{1}{\sigma}}} \right)^{-\sigma} \left( \frac{P_c}{(1-\alpha)^{\frac{1}{\sigma}}} \right)^\sigma$$

Plug into the budget constraint to get the share of  $K$  spend on  $c$  (share spent on  $m$  is similar).

Rewrite with price index  $P$ .

$$\begin{aligned}
q_c &= \frac{(1-\alpha)P_c^{-\sigma}K}{\alpha P_m^{1-\sigma} + (1-\alpha)P_c^{1-\sigma}} \\
&= \left( \frac{(1-\alpha)P_c^{-\sigma}}{P^{1-\sigma}} \right) K \\
K_c &\equiv q_c P_c \\
&= \left( \frac{(1-\alpha)P_c^{1-\sigma}}{P^{1-\sigma}} \right) K
\end{aligned}$$

$K_m$  is defined similarly.

### B.3 Expenditure on Specific Types

How much of  $K_c$  is spent on each specific type  $y_j$ ?

$$\begin{aligned}
&\max q_c^{\frac{1}{\rho_c}} \\
&\text{s.t. } \sum_{j \in \mathbb{C}} p_j y_j \leq K_c \\
&\mathcal{L} = q_c^{\frac{1}{\rho_c}} + \lambda (K_c - \sum_{j \in \mathbb{C}} p_j y_j)
\end{aligned}$$

Take the first order condition with respect to  $y_j$  for  $j \in \mathbb{C}$ .

$$\frac{\rho_c b_j^{\frac{1}{\sigma_c}} y_j^{\rho_c - 1}}{p_j} = \lambda$$

Use the first order conditions to construct Euler equations between  $y_1$  and each other  $y_j$  for  $j \in \mathbb{C}$ .

$$y_j = \left( \frac{b_j}{b_1} \right) p_j^{-\sigma_c} p_1^{\sigma_c} y_1$$

Plug the Euler equations into the budget constraint. Rearrange to find the demand function for  $y_1$ . The demand functions for  $y_j$  for  $j \in \mathbb{C}$  and for  $x_i$  for  $i \in \mathbb{M}$  are similar.

$$\begin{aligned}
y_1 &= \frac{K_c}{\sum_{j \in \mathbb{C}} \left( \frac{b_j}{b_1} p_j^{-\sigma_c} p_1^{\sigma_c} \right) p_j} \\
&= \frac{b_1 p_1^{-\sigma_c} K_c}{\sum_{j \in \mathbb{C}} b_j p_j^{1-\sigma_c}} \\
&= \left( \frac{b_1 p_1^{-\sigma_c}}{P_c^{1-\sigma_c}} \right) K_c \\
&= \left( \frac{b_1 p_1^{-\sigma_c}}{P_c^{1-\sigma_c}} \right) \left( \frac{(1-\alpha) P_c^{1-\sigma}}{P^{1-\sigma}} \right) K \\
&= (1-\alpha) b_1 p_1^{-\sigma_c} P_c^{\sigma_c-\sigma} P^{\sigma-1} K
\end{aligned}$$

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