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Beer Excise Taxes and the Craft Beverage and Modernization Tax Reform Act

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In December 2017, the Craft Beverage and Modernization Tax Reform Act (CBMTRA) lowered federal beer excise taxes for a period of 2 years, and the Taxpayer Certainty and Disaster Tax Act of 2020 made the reduction permanent. We evaluate the ramifications of the CBMTRA on producers, consumers, and tax receipts and quantify potential differential effects among the microbrewing, regional brewing, and macrobrewing sectors. Although the excise tax reduction was supposed to primarily support the microbrewing sector, we find that the CBMTRA provided a larger combined benefit to the regional brewing and macrobrewing sectors.

Key words: craft beer, equilibrium displacement model

Introduction

Alcohol excise taxes have historically been one of the largest global generators of tax revenues. In the United States, beer excise taxes have existed continuously since 1862 and steadily increased during the 20th century. In December 2017, the Craft Beverage and Modernization Tax Reform Act (CBMTRA), as part of the Tax Cuts and Jobs Act, lowered federal excise taxes (or provided tax credits) on distilled spirits, wine, and beer for a period of 2 years. At the end of 2019, Congress extended the legislation through December 2020. On December 27, 2020, the Taxpayer Certainty and Disaster Tax Act of 2020 made the CBMTRA tax reductions permanent. These bills had nearly unanimous bipartisan support: The 2020 bill had 77 cosponsors in the US Senate and 351 cosponsors in the House (Marisic, 2020b). The final vote was even stronger.

Although the oldest continuously operating US brewery—Yuengling, founded 1829—is considered a craft brewery, the contemporary US craft brewing industry began in 1965 when Anchor Brewing (which is now wholly owned by the Japanese macrobrewer Sapporo) introduced beer varieties that provided alternatives to the light pilsners and lagers generally produced by US macrobrewers. The Brewers Association (2022) characterizes an American craft brewer as small, independent, and innovative, while noting that they also tend to be highly involved in local communities. These attributes have engendered widespread support for craft brewing across the United States (Austin, 2010).

A major purpose of the CBMTRA was to encourage investment in the craft brewing industry and provide support not only for brewers but also for their agricultural, tourism, hospitality, and manufacturing partners (Marisic, 2020a). In 2017, Oregon Senator Ron Wyden introduced the

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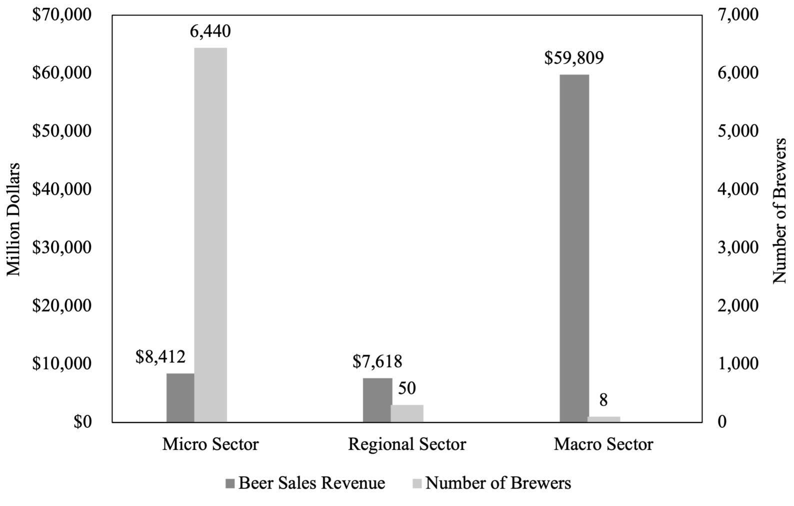

Figure 1. Beer Sales Revenue and Number of Brewers by Sector, 2017

CBMTRA by saying, "Oregon's economy earns significant benefits from the jobs and small business growth created by our state's world-renowned craft beer, wine and spirits producers" (Wyden, 2017). When the 2017 bill passed, Bob Pease, CEO of the Brewers Association, which represents small independent brewers, released this statement:

> This is a monumental day for small and independent craft brewers. America's small, Main Street brewers—6,000 strong and located in every state and virtually every congressional district in the country—are incredibly pleased Congress has recognized that they have great growth potential. Our expectation is that small brewers will use their savings related to the recalibration of the federal excise tax on beer to invest in their breweries, expand their operations, create more jobs and hire more American workers. (Nurin, 2017)

Once implemented, the CBMTRA reduced beer excise tax payments by one-half for 99% of US brewers, as most breweries are relatively small. However, despite specifying "craft beverages" in its name, the CBMTRA was not written exclusively for US craft-scale producers—midsized brewers and macrobrewers also received tax relief. Because of their scale, it may be that the larger brewers were the greatest beneficiaries of the updated tax code. Figure 1 illustrates the substantial scale differences within the brewing industry. Eight macrobrewers had total beer sales revenue of $59.8 billion in 2017, while 6,440 microbrewers (craft brewers) had total beer sales revenue of only $8.4 billion.

Our research effort centers on this question: Does the CBMTRA provide a larger benefit to regional brewers and macrobrewers than to the small-scale craft brewers for which it is named? While the legislation was under congressional review, editorials suggested this could be the case (Looney, 2018). We investigate this question by creating equilibrium displacement models (EDMs) for the microbrewing, regional brewing, and macrobrewing sectors. The models are used to examine CBMTRA's impact on producers, consumers, and tax receipts as well as on malting barley, labor, nonlabor, and equity capital input providers. EDMs allow us to estimate the effect of the CBMTRA on changes in equilibria among demand and supply relationships within each brewing sector. In addition, we perform a sensitivity analysis of the results that generate confidence intervals for the EDM estimates.

While Luckstead and Devadoss (2021) develop a theoretical model to simulate the impact of the CBMTRA among other counterfactuals, we empirically estimate the distributional effects of the tax cut on three brewery segments. Based on our analysis of consumer and producer surplus changes, tax payments, and deadweight losses, the results indicate that the CBMTRA had a larger combined positive impact on the regional brewing and macrobrewing sectors than on the microbrewing sector.

History of US Alcohol Excise Taxes

Prior to the American Revolution, alcohol products were primarily produced within households (Risen, 2013). Nonetheless, the southern colonies imposed duties on imported spirits, and New York taxed local alcohol production (Conlon, 1940). Following the Revolutionary War, alcohol excise taxes served as an important source of revenue for the US government and were frequently used to raise funds to support American military campaigns. Congress levied the first federal alcohol excise tax on whiskey in 1791 at the behest of Treasury Secretary Alexander Hamilton. Its purpose was to settle federal debts incurred during the Revolutionary War (Alcohol and Tobacco Tax and Trade Bureau, 2018).

Whiskey served an important value-added role as American settlers pushed westward in the 1800s. The production of whiskey mitigated problems of bulk grain storage and transportation, often served as a medium of exchange, and was more profitable for farmers relative to selling grain as an unprocessed commodity (Wood, 2011; Risen, 2013). Not surprisingly, US alcohol excise taxes were immediately unpopular, leading to the (failed) Whiskey Rebellion of 1791–1794 (Risen, 2013). General discontent, however, caused the taxes to be repealed in 1802. Congress later reauthorized excise taxes on the production and sale of alcoholic beverages in 1813 and 1862 to finance the War of 1812 and the American Civil War (Conlon, 1940).

The federal government has continuously levied excise taxes on spirits and beer since the summer of 1862—the latter of which began in September of that year (Alcohol and Tobacco Tax and Trade Bureau, 2013). A $1.00/barrel excise tax on beer (a barrel contains 31 gallons) was levied between 1862 and 1898, except for 2 years in which it was reduced to $0.60/barrel (Congressional Research Service, 1999). To help finance the Spanish–American war, the excise tax on beer was doubled to $2.00/barrel between 1898 and 1901 (Weisman, 2004; Alcohol and Tobacco Tax and Trade Bureau, 2013). Imported beer was exempt from excise taxes until the passage of the War Revenue Act in October 1917 (Conlon, 1940). Beer taxes increased steadily during the 20th century, reaching $3.00/barrel during World War I, $8.00/barrel by the end of World War II, and $9.00/barrel in 1951 during the Korean Conflict (Congressional Research Service, 1999; Alcohol and Tobacco Tax and Trade Bureau, 2013).

Between 1862 and 1950, the US Treasury Department issued stamps for distillers, vintners, and brewers to affix to bottles and barrels indicating that excise taxes had been paid (West, 1979). The first federal beer stamps were issued in 1866 (National Postal Museum, 1866). Individual states began implementing their own excise taxes on alcohol at the end of Prohibition in 1933 and also issued stamps. Many beer stamps were "particularly large and showy and... well engraved" (Troutman, 2012, p. 84; Naimi et al., 2018).

Beginning with the initial imposition of alcohol excise taxes in 1791, resistance to them has been continuous, with many viewing their imposition as illegal government overreach, interference with livelihoods, or moralistic meddling (Conlon, 1940; Risen, 2013). The resistance to beer excise taxes has been well organized. In November 1862, 37 brewers founded the Lager-Beer Brewers Association in response to beer taxes levied during the Civil War (Bamforth, 2009). This trade organization was modeled after medieval brewer guilds (United States Brewers' Association, 1896). The association was renamed the United States Brewers' Association in 1864 and reorganized as the Beer Institute in 1986. Regardless of its name, the Beer Institute has consistently lobbied for free trade and reductions in excise taxes for the brewing industry (United States Brewers' Association, 1896; Beer Institute, 2021).

Although alcohol excise taxes were used to fund military campaigns between the Revolutionary War and the Korean Conflict, the current purpose of such taxes is less clear. In 2019, alcohol excise tax revenues totaled $10 billion, which was 10% of all total federal excise tax receipts. Given that federal government revenues in 2019 totaled $3.46 trillion, it does not appear that US government funding is highly dependent on the receipt of alcohol excise taxes (Congressional Budget Office, 2020).

Previous Research

Many studies have evaluated various impacts of alcohol and beer excise taxes. For example, Anderson (2010) examines differences in alcohol excise taxes across countries, while Deconinck, Poelmans, and Swinnen (2016) consider tax revenues generated by beer excise taxes in the Dutch Republic that were used to finance the sixteenth- and seventeen-century Dutch Revolt. The impact of beer excise taxes on market concentration in various countries has been examined (Loretz and Oberhofer, 2016; Stubbs, 1999), while game theory has been used to evaluate the role of beer excise taxes on price competition (Rojas, 2008). The pass-through impacts of beer excise taxes onto retail prices have been considered (Rojas and Shi, 2011; Russell and van Walbeek, 2016; Shrestha and Markowitz, 2016), as have potential impacts of beer excise taxes on entry into the craft brewing industry (Wyld, Pugh, and Tyrrall, 2010; Sozen and O'Neill, 2018).

While the rationale for beer taxation has varied, the incidence of excise taxes depends on consumers' own-price elasticity of demand for beer and producers' own-price elasticity of supply for beer. Recent studies have compared the own-price elasticities of demand for craft beer versus national brands and found the former (which is generally produced by relatively small breweries) to be slightly less inelastic than the latter (Toro-González, McCluskey, and Mittelhammer, 2014). These differences have implications for the incidence of reduced excise taxes on consumers and producers as well as among microbrewers, regional brewers, and macrobrewers. For example, Luckstead and Devadoss (2021) develop a theoretical model that indicates consumers receive benefits from reductions in beer excise taxes because of lower prices and increased consumption. In addition, they suggest that an excise tax reduction would cause the craft brewing sector to expand while the macrobrewing sector would contract because of differences in the level of competition between the sectors.

The Craft Beverage and Modernization Tax Reform Act

US beer excise taxes have existed since 1862. Between 1976 and 1989, all breweries were levied a $9.00/barrel excise tax. Beginning in 1990, excise taxes on breweries producing less than 60,000 barrels annually were reduced to $7.00/barrel, while breweries producing more than 60,000 barrels annually continued to pay an excise tax of $9.00/barrel. In 1991, the excise tax on larger breweries was increased to $18.00/barrel.

The Craft Beverage and Modernization Tax Reform Act (CBMTRA) lowered federal excise taxes on beer for a period of 2 years. A major purpose of the act was to encourage investment in the craft brewing industry and support craft brewers in the face of increasing competitive pressures from each other and from regional and national brewers (Marisic, 2020a). On December 27, 2020, the Taxpayer Certainty and Disaster Tax Act of 2020 made the CBMTRA tax reductions permanent.

For the 6,440 brewers in 2017 that produced fewer than 60,000 barrels a year (the microbrewing sector), the $7.00/barrel excise tax was lowered to $3.50/barrel in 2018. For brewers that produced more than 60,000 barrels but less than 2 million barrels (the regional brewing sector), the pre-CBMTRA excise tax was $7.00/barrel for the first 60,000 barrels and $18.00/barrel for the remainder. The CBMTRA lowered the tax on regional brewers to $3.50/barrel for the first 60,000 barrels and $16.00/barrel for production between 60,000 and 2 million barrels. Based on the 2017 production of 50 regional brewers, the weighted average tax was $15.22/barrel. In 2018, the CBMTRA reduced the weighted average tax to $12.84/barrel, which represents a 15.2% reduction.

The CBMTRA only slightly reduced tax rates on the eight macrobrewers with annual production exceeding 2 million barrels. In 2017, the excise tax for these brewers was \$18.00/barrel. In 2018, the CBMTRA reduced the tax to \$16.00/barrel on the first 6 million barrels of production but maintained an \$18.00/barrel tax for all production that exceeded 6 million barrels. Given the production levels of macrobrewers in 2017, the CBMTRA reduced the weighted average tax from \$18.00/barrel to \$17.59/barrel, which represented a 2.3% reduction.

It may initially appear that the microbrewing sector was the primary beneficiary of the CBMTRA tax cuts, as this sector realized a 50% reduction in the excise tax rate. Regional brewers and macrobrewers experienced only a 3% reduction in tax payments because the \$18/barrel excise tax continues on 70% of all beer production. While the CBMTRA lowered per barrel excise taxes on microbeer producers by a larger amount, in both absolute and percentage terms relative to regional beer and macrobeer producers, trade associations across the entire beer industry were heavily involved in lobbying for the CBMTRA. It may be that larger brewers received more benefits from the CBMTRA than smaller brewers because of their production scale.

Research Methodology and Equilibrium Displacement Models

We evaluate the impacts of the CBMTRA using equilibrium displacement models (EDMs) for three brewery sizes—microbeer, regional beer, and macrobeer production. EDMs are frequently used for policy analyses because they allow for the quantification of changes in price and quantity equilibria among vertically and/or horizontally related markets. EDMs are also widely used to estimate both short- and long-term impacts of exogenous economic shocks and regulatory actions. Because complex interactions often exist among markets, EDMs provide a comprehensive approach to modeling changes in market equilibria.

EDMs are derived from, and represent a set of, comparative static results expressed in elasticity form. One major advantage of such models is that they allow researchers to use elasticities and input shares to estimate the relative importance of various supply/demand shifters on market equilibria (i.e., generally price and quantity) outcomes.

Constructing an Equilibrium Displacement Model

We construct EDMs for three sizes of the brewing industry based on annual production levels: microbrewers (firms producing less than 60,000 barrels), regional brewers (firms producing between 60,000 and 2 million barrels), and macrobrewers (firms producing more than 2 million barrels). The basic EDM for each of the three production sizes is developed following Atwood and Brester (2019), Brester, Atwood, and Boland (2023), Gardner (1988), and Wohlgenant (2011) as

$$E\left(q_k^D\right) = \eta_k^D E\left(p_k^D\right),\ k = 1,2,3, \tag{1}$$

$$E\left(p_k^S\right) = \sum_j K_{kj} E\left(w_j^D\right),\ k = 1,2,3, \tag{2}$$

$$E\left(x_{ki}^D\right) = E\left(q_{ki}^S\right) + \sum_j K_{kj}\sigma_{kij} E\left(w_j^D\right),\ k = 1,2,3,\ i = 1,2,3,4, \tag{3}$$

$$E\left(x_i^S\right) = \sum_j \varepsilon_{ij} E\left(w_j^S\right),\ i = 1,2,3,4, \tag{4}$$

where q_k^D is the quantity demanded of the kth beer (i.e., micro, regional, macro); p_k^D is the consumer demand price of the kth beer; η_k^D is the own-price elasticity of demand for the kth beer; p_k^S is the producer supply price of the kth beer; q_k^S is the quantity supplied of the kth beer; x_{ki}^D is the quantity

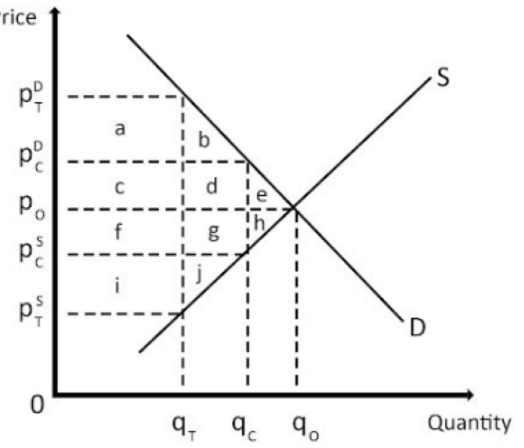

Figure 2. Consumer and Producer Surplus, Tax Receipts, and Deadweight Loss Areas

demanded for input i used to produce the kth beer; w_j^D is the demand price for input j; x_i^S is the quantity supplied of input i; w_j^S are input j supply prices; σ_{kij} are Allen elasticities of substitution between inputs i and j for the kth beer; ε_{ij} are own- and cross-price supply elasticities of inputs i and j; K_{kj} are the cost shares of input j such that $K_{kj} = \frac{w_j x_{kj}^d}{\boldsymbol{w}'\boldsymbol{x}_k^d}$, where $\boldsymbol{w}$ and $\boldsymbol{x}$ are vectors of the input prices and quantities used to produce the kth beer with $\sum_j K_{kj} = 1$; and $E(\cdot)$ represents percentage changes such that $E(\cdot) = \frac{d(\cdot)}{(\cdot)}$.[1]

Silberberg (1990) notes that $\sum_j K_{kj}\sigma_{kij} = 0$ is necessary for the system of equations to "add up" or, more precisely, be homogeneous of degree 0 in input and output prices. This logical condition is analogous to the concept of a lack of "money illusion" in consumer theory. That is, the homogeneity condition implies that no output response should occur if all input prices were, say, doubled along with the output price. Hence, only relative input and output prices, as opposed to absolute prices, influence production behavior. In the absence of this condition, EDM outcomes are not consistent with economic theory.

Equation (1) represents the demand for each beer type. Equations (2) and (3) represent the production technologies and first-order conditions for profit maximization for each beer type. Equation (4) represents input supply functions.

We define four inputs used to produce beer (i.e., barley, labor, nonlabor, and owners' equity capital) and assume that input supply quantities are functions of only their own-input prices. Hence, we assume that $\varepsilon_{ij} = 0$ for $i \neq j$. Because an excise tax currently exists, the initial demand price of beer (p_k^D) is greater than the initial supply price of beer (p_k^S). The latter represents the marginal cost of producing beer. For each brewer size, Figure 2 illustrates the pre-CBMTRA excise tax effects. In the absence of an excise tax, the equilibrium price and quantity would be p_o and q_o. Prior to the CBMTRA, excise taxes caused the demand price of beer (p_T^D) to be above the no-tax price equilibrium (p_o) while its supply price (p_T^S) was below the no-tax price equilibrium. The difference between the two represents the size of the excise tax prior to the CBMTRA reduction. At these two price levels, the quantity exchanged in the market is q_T. In addition, we assume that, within any annual time period, beer markets clear such that the quantities demanded and supplied are equal (i.e., $q_k = q_k^D = q_k^S$). The one output, four-input EDM for each brewery size is developed in the online supplement (available online at www.jareonline.org).

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[1] EDM models can accommodate cross-price elasticities of demand, η_{kh}^D, among micro, regional, and macro beer. However, because Toro-González, McCluskey, and Mittelhammer (2014) report very small cross-price elasticities of demand between craft and noncraft beers, we assume zero cross-price elasticities of demand across these beer sectors.

Table 1. Parameter Values and Initial Conditions for the Equilibrium Displacement Models

Parameter	Microbreweing Sector	Regional Brewing Sector	Macrobrewing Sector
η^D	−0.212	−0.212	−0.126
ε_1	0.17	0.17	0.17
ε_2	0.35	0.35	0.35
ε_3	1.00	1.00	1.00
ε_4	1.44	1.44	1.44
K_1	0.131	0.150	0.165
K_2	0.255	0.180	0.102
K_3	0.346	0.310	0.278
K_4	0.268	0.360	0.455
σ_{11}	0.00	0.00	−1.68
σ_{12}, σ_{21}	0.00	0.00	0.00
σ_{13}, σ_{31}	0.00	0.00	1.00
σ_{14}, σ_{41}	0.00	0.00	0.00
σ_{22}	−1.36	−3.44	−8.18
σ_{23}, σ_{32}	1.00	2.00	3.00
σ_{24}, σ_{42}	0.00	0.00	0.00
σ_{33}	−0.74	−1.16	−1.69
σ_{34}, σ_{43}	0.00	0.00	0.00
σ_{44}	0.00	0.00	0.00
p^D ($/barrel)	642.69	642.69	335.48
Average tax ($/barrel)	7.00	15.22	18.00
p^S ($/barrel)	635.69	627.47	317.48
p^S/p^D	0.989	0.976	0.946
q (million barrels)	13.09	11.85	178.28
Industry size ($millions)	8,412	7,618	59,809
Initial tax receipts ($millions)	91.63	180.40	3,209

Parameterizing EDMs for the Microbrewing, Regional Brewing, and Macrobrewing Sectors

Table 1 presents the values used to parameterize the EDMs for the microbrewing, regional brewing, and macrobrewing sectors. The own-price elasticity of demand for microbeer and regional beer are assumed to be equivalent. We use −0.212 as this value, following Toro-González, McCluskey, and Mittelhammer's (2014) estimate for craft beer. The own-price elasticity of demand for macrobeer (−0.126) is also obtained from that study.

One of the primary inputs into beer production is malt produced from malting barley. Barley is the third largest feed grain crop produced in the United States after corn and grain sorghum. Approximately 75% of US barley acreage is planted to a malting (as opposed to a feed) variety, and 90% of malting barley is used for beer production. Because of a lack of malt data and given that barley and malt have a near fixed proportional relationship, we consider malting barley as a primary input into beer production. Thus, we require an estimate of its own-price elasticity of supply (ε_1).

Equation (5) presents generalized least squares estimates of regressing the natural logarithm of annual US barley production between 1980 and 2020 onto the natural logarithm of US barley price lagged one period, a linear trend term, a one-period lagged dependent variable, and an autoregressive error parameter:

$$\ln bprod_t = 3.97 + 0.17 \ln dbpr_{t-1} - 0.023T + 0.35 \ln bprod_{t-1} + 0.037\rho_{t-1},$$

(5) (5.08) (2.31) (−5.89) (2.88)

$$\bar{R}^2 = 0.887,\ SE = 0.144,\ \bar{Y} = 5.68,\ DW = 1.933,\ DF = 35$$

where $\ln bprod$ is the natural logarithm of US annual barley production; $\ln dbpr$ is the natural logarithm of the deflated US annual price of barley; T is a linear trend; ρ_{t-1} is a first-order autoregressive error term; t-values are in parentheses; $\bar{R}^2$ is the adjusted R^2 statistic; SE is the standard error of the regression; $\bar{Y}$ is the mean of the dependent variable; DW is the Durbin–Watson statistic; and DF is the degrees of freedom. US annual barley production and prices are obtained from the US Department of Agriculture (2021). Prior to the natural logarithm transformation, the price of barley was deflated by the GDP implicit price deflator (2015 = 100) obtained from the US Bureau of Economic Analysis (2021).

Because of natural logarithm transformations, the regression results directly generate a short-run own-price barley supply elasticity (ε_1) of 0.17. Given that barley production and planted barley acreages are highly correlated, this estimate is comparable to the Lin et al. (2000) estimate of the elasticity of planted barley acreage with respect to barley price (0.28).

Labor is considered a second input into beer production. Bargain and Peichl (2016) report a large number of published labor supply elasticity estimates. Depending upon demographics, the mean values reported in these studies range from 0.11 to 0.59. Therefore, we use the midpoint of this range (0.35) as our estimate of the own-price supply elasticity of labor (ε_2).

A third input is defined as all other nonlabor inputs used to produce beer. The short-run elasticity of supply of nonlabor inputs represents an amalgam of various machinery and manufacturing products. Gallaway, McDaniel, and Rivera (2003) estimate Armington supply elasticities for 309 SIC-code manufacturing industries. Although Armington elasticities represent import supply responses to changes in domestic prices, they should be reasonable approximations for nonlabor input supply responses given the global manufacturing environment. Gallaway, McDaniel, and Rivera report short-run supply elasticities for many of the inputs used by the brewing industry (e.g., 0.80 for paperboard boxes, 1.02 for packaging materials, and 1.34 for fabricated metal products). The supply elasticities for many other inputs used by the brewing industry generally fall within this range. Consequently, we use an estimate of 1.0 as the elasticity of supply for nonlabor inputs (ε_3).

Owners' equity capital represents financial inputs used by brewing companies. That is, owners' equity is the residual claimant of business profits and losses. Therefore, it is a variable input that is determined by the interactions of inputs, production activities, and output markets. This balance sheet financial metric changes as business activity either increases or reduces its value. Of course, financial capital can also be added to a business activity at any time. Goolsbee (1998) estimates short-run own-price elasticities of financial capital supply ranging from 1.14 to 1.74. We use the midpoint of this range (1.44) for the own-price elasticity of supply for equity capital (ε_4).

The values for the factor cost shares of x_1 (K_1), x_2 (K_2), x_3 (K_3), and x_4 (K_4) are developed using proprietary benchmark data from the Brewers Association, estimates reported by Tremblay and Tremblay (2005), and personal communications. These data are used to calculate factor cost shares for barley, labor, and nonlabor inputs. The fourth factor cost share (equity capital) is calculated by subtracting the sum of the factor cost shares for the first three inputs from 1.0. The largest factor cost share for the microbrewing sector is for nonlabor inputs (0.346) with almost equal factor cost shares associated with labor (0.255) and owners' equity capital (0.268).

Relative to the microbrewing sector, regional brewing factor cost shares of labor and nonlabor inputs are lower (0.180 and 0.310), while the factor cost share of owners' equity capital is larger (0.360). These changes represent increased use of investment capital and nonlabor inputs (e.g., machinery) in the regional brewing sector. The factor cost share of barley is slightly larger than its cost share in the microbrewing sector. Regional brewers purchase larger quantities of barley malt and, presumably, receive quantity and transportation discounts. However, decreases in labor and nonlabor factor cost shares in this sector cause the barley cost share for regional brewers to increase slightly.

The factor cost shares for each of the four inputs are also different for the macrobrewing sector relative to the microbrewing and regional brewing sectors. The cost shares continue the pattern that occurred between the microbrewing and regional brewing sectors. Again, the macrobrewing sector's cost share of barley ($K_1 = 0.165$) increases slightly relative to the regional brewing sector, even though the macrobrewing sector is likely able to source barley malt at a lower absolute cost relative to smaller breweries. Given the increase in brewer size, the cost share of labor and nonlabor inputs decline ($K_2 = 0.102, K_3 = 0.278$), while the cost share of owners' equity increases ($K_4 = 0.455$) because of larger financial investments required by the macrobrewing sector.

For microbreweries and regional breweries, we assume that barley (i.e., malt) cannot be substituted for any of the other three inputs used to produce beer. Therefore, we set the associated Allen elasticities of substitution ($\sigma_{12} = \sigma_{21} = \sigma_{13} = \sigma_{31} = \sigma_{14} = \sigma_{41}$) equal to 0 (Table 1). However, given that macrobrewers are able to substitute various inputs, such as corn syrup and rice, for malt (and hence barley), we set the macrobrewing elasticity of substitution of barley with respect to nonlabor inputs ($\sigma_{13} = \sigma_{31}$) equal to 1.0 for this sector. We assume that owners' equity cannot be substituted for either labor or nonlabor inputs in any of the brewing sectors, so that $\sigma_{14} = \sigma_{41} = \sigma_{24} = \sigma_{42} = \sigma_{34} = \sigma_{43} = 0.0$.

The substitutability between labor and nonlabor inputs probably increases with brewery scale. Thus, the elasticities of substitution between labor and nonlabor inputs ($\sigma_{23} = \sigma_{32}$) are assumed to be 1.0,2.0, and 3.0 for microbrewers, regional brewers, and macrobrewers, respectively. The terms σ_{11}, σ_{22}, σ_{33}, and σ_{44} must be calculated for each brewing sector and included in the model if the economic system is to be homogeneous of degree 0 in all prices and allow the system to add up (Silberberg, 1990). The procedure for calculating these values is presented in the online supplement and the results are reported in Table 1.

Table 1 indicates that average price of microbeer (p^D) in 2017 was \$642.69/barrel (Nielsen/IRI, 2017). Excise taxes place a price "wedge" between the price that consumers pay for goods and services and the price producers receive for their output (i.e., the marginal cost of production). Because the excise tax during this period was \$7.00/barrel, the producer price of microbeer (p^S) was \$635.69/barrel and initial tax collections are estimated as \$91.63 million (Table 1). The average annual consumer price for regional beer is assumed to equal that of microbeer (\$642.69/barrel). However, regional brewers face higher federal excise tax rates than microbrewers. The weighted average excise tax for regional brewers in 2017 was \$15.22/barrel, so that the price received by regional brewers prior to the CBMTRA was \$627.47/barrel, with estimated initial tax collections of \$180.40 million. Finally, the average annual consumer price for macrobeer in 2017 was \$335.48/barrel. Therefore, the original producer price of macrobeer was \$317.48/barrel, with estimated initial taxes of \$3,209 million.

CBMTRA EDM Results for the Microbrewing Sector

The CBMTRA reduced the tax on microbrewers from \$7.00/barrel to \$3.50/barrel, causing the initial tax-induced price wedge between consumer and producer prices to decline and beer output to increase. Figure 2 illustrates this change as a lowering of the demand price to p_C^D and a raising of the supply price to p_C^S. The difference between the two represents the CBMTRA's smaller excise tax. A reduction in the excise tax also increases the quantity exchanged in the market from q_T to q_C. An exogenous shock to the price wedge is used to implement the CBMTRA in the EDM for the microbrewing sector. The size of the shock needed to generate this smaller difference is endogenous to the model. Consequently, a search routine is used to vary the size of the shock until the price wedge is reduced to the CBMTRA level of \$3.50/barrel. A shock of −0.0055 (−0.55%) is needed to generate this result.

Table 2. Changes in the Endogenous Variables, Surplus, Tax Receipts, and Deadweight Losses for the CBMTRA Tax Reduction

Variable	Microbreweing Sector	Regional Brewing Sector	Macrobrewing Sector
q^D	0.08%	0.06%	0.01%
p^D	−0.39%	−0.27%	−0.10%
p^S	0.16%	0.10%	0.02%
x_1	0.08%	0.06%	0.01%
x_2	0.06%	0.04%	0.01%
x_3	0.10%	0.07%	0.02%
x_4	0.08%	0.06%	0.01%
w_1	0.49%	0.33%	0.04%
w_2	0.17%	0.10%	0.02%
w_3	0.10%	0.07%	0.02%
w_4	0.06%	0.04%	0.009%
Consumer surplus ($millions)	32.79 (0.39%)	20.45 (0.27%)	62.59 (0.11%)
Producer surplus ($millions)	13.17 (0.16%)	7.95 (0.10%)	11.11 (0.02%)
Barley producer surplus ($millions)	5.36 (0.49%)	3.83 (0.34%)	4.04 (0.04%)
Labor producer surplus ($millions)	3.61 (0.17%)	1.41 (0.10%)	1.48 (0.02%)
Nonlabor producer surplus ($millions)	2.91 (0.10%)	1.63 (0.07%)	3.09 (0.02%)
Equity producer surplus ($millions)	1.29 (0.06%)	1.08 (0.04%)	2.49 (0.009%)
Consumer taxes ($millions)	−32.81	−20.46	−62.59
Producer taxes ($millions)	−13.18	−7.95	−11.11
Total taxes ($millions)	−45.99	−28.41	−73.70
Consumer deadweight loss gained ($millions)	0.047	0.078	0.0041
Producer deadweight loss gained ($millions)	0.010	0.017	0.0007
Total deadweight loss gained ($millions)	0.057	0.095	0.0048

Notes: Values in parentheses represent percentage changes relative to the size (total revenue) of each industry in 2017.

Changes in the Endogenous Variables for the Microbrewing Sector

Table 2 presents changes in the endogenous variables that result from entering an exogenous shock of −0.0055 in the microbrewing sector's parameterized EDM. The $3.50/barrel decline in the excise tax causes the quantity demanded of microbeer (q^D) to increase by 0.08% as the consumer price of microbeer (p^D) declines by 0.39%. The producer price of microbeer (which represents its marginal cost, p^S) increases by 0.16%. Note that the difference between the consumer and producer prices has narrowed by 0.55 percentage points, which is the value used to implement the CBMTRA tax reduction.

Table 2 also presents changes in input use and prices, which all increase because the production of microbeer increases. The use of barley (x_1) increases by 0.08%, while its price (w_1) increases by 0.49%. The demand for labor (x_2) increases by 0.06%, while the price of labor (w_2) increases by 0.17%. The use of nonlabor inputs (x_3) increases by 0.10%, while its price (w_3) increases by 0.10%. Finally, the demand for equity capital (x_4) increases by 0.08%, while its price (w_4) increases by 0.06%.

Microbrewing Sector Changes in Surplus, Tax Receipts, and Deadweight Losses

Table 2 also presents changes in surplus that occur because of the CBMTRA tax reduction in the microbrewing sector. The calculations are illustrated using the areas presented in Figure 2. In the absence of excise taxes, the equilibrium price and quantity of microbeer would occur at p_o and q_o. However, the original excise tax caused a wedge to be placed between consumer prices (p_T^D) and producer prices (p_T^S), causing output to decline to q_T. Table 1 presents the values for these variables. The CBMTRA tax reduction lowers consumer prices to p_C^D, increases producer prices to p_C^S, and increases output to q_C. These new values are obtained by using the EDM results for percentage changes in each and applying them to their initial values. These calculations allow for estimates of changes in surplus, tax receipts, and deadweight losses as a result of the CBMTRA.

For example, consumer surplus is increased by area ($a + b$) in Figure 2. Using the percentage changes from the EDM, the reduction in consumer price to p_C^D and increase in output to q_C increases consumer surplus by $32.79 million. Such values must be compared to a metric to provide a sense of scale. Total consumer surplus cannot be calculated by integrating under the illustrated linear demand curve because the true shape of the microbeer demand function is unknown (Just, Hueth, and Schmitz, 2004). The linear depiction in Figure 2 represents a linear approximation to the (unknown) true microbeer demand function. Consequently, we choose to compare changes in surplus to the overall market size of the sector by multiplying the average annual consumer price per barrel of microbeer by the average annual quantity of microbeer produced in 2017. Table 1 indicates that this value is $8,412 million. Therefore, the increase in consumer surplus represents 0.39% of the total revenue of microbeer production.

The CBMTRA tax reduction increases aggregate producer surplus, as the producer price increases to p_C^S and output increases to q_C. This change is indicated by area ($i + j$). Again, using the initial producer price and quantity presented in Table 1 and increasing both by the percentages obtained from the EDM, the CBMTRA tax reduction increases producer surplus by $13.17 million, which is 0.16% of the 2017 microbeer market size. The incidence of producer surplus can be calculated for individual input suppliers following similar procedures. Barley producers gain $5.36 million of producer surplus (0.49% of the size of the microbrewing sector), while labor surplus increases by $3.61 million (Table 2). Nonlabor inputs and equity providers gain smaller amounts of surplus ($2.91 million and $1.29 million, respectively).

The EDM results and Figure 2 also allow for changes in tax receipts generated by the CBMTRA tax reduction on microbeer production to be calculated. The total reduction in tax receipts from the microbrewing sector equals $45.99 million (Table 2). Table 1 shows that 2017 tax receipts from the microbrewing sector totaled $91.63 million ($7.00/barrel multiplied by 13.09 million barrels). Therefore, the CBMTRA reduction in tax receipts from this sector represents (the expected) 50% reduction in total tax receipts, after allowing for rounding errors.

Although beer excise taxes are levied on producers, both consumers and producers share in the payment of the tax (e.g. Mankiw, 2018). The original share of taxes paid by consumers is indicated by area ($a + c$) in Figure 2. After the CBMRTA tax reduction, consumers now pay area ($c + d$). The change in tax receipts paid by consumers is the difference of these two areas (i.e., $a - d$). Table 2 indicates that tax collections from consumers declined by $32.81 million. In addition, producers also experience a reduction in their tax payments. Figure 2 indicates that producers initially paid taxes indicated by area ($i + f$). Following the tax reduction, producers pay taxes indicated by area ($f + g$). The difference between these areas is given by area ($i - g$). Table 2 indicates that producer tax payments declined by $13.18 million.

Consumer reductions in tax payments are larger than those of producers because of relative demand and supply elasticities. Although the own-price elasticity of supply of microbeer is not needed to construct the microbrewing sector's EDM, the model can be used to calculate it (Brester, Atwood, and Boland, 2023). For the microbrewing industry, the own-price elasticity of supply is calculated to be 0.53. Hence, reductions in tax payments are larger for consumers than for producers because the own-price elasticity of demand for microbeer (−0.212) is more inelastic than its own-price elasticity of supply (0.53).

Finally, Table 2 also presents changes in deadweight losses resulting from the excise tax decrease. Given the initial tax, Figure 2 indicates that consumer deadweight losses were represented by area $(b + d + e)$. After the CBMTRA lowered the excise tax, consumer deadweight losses are reduced to area (e). Consequently, consumer deadweight losses are reduced by area $(b + d)$, or \$0.047 million. Likewise, producer initial deadweight losses are represented by area $(g + h + j)$. After the tax reduction, producer deadweight losses are represented by area (h). Table 2 indicates that the change in producer deadweight losses (area $g + j$) equals \$0.010 million. Therefore, total deadweight losses are reduced by \$0.057 million. Although these amounts appear to be relatively small, the reduction in total deadweight loss represents 75% of the deadweight losses (\$0.076 million) caused by the original \$7.00/barrel excise tax on the microbrewing industry.

CBMTRA EDM Results for the Regional Brewing Sector

The CBMTRA reduced beer excise taxes on regional brewers from \$7.00/barrel to \$3.50/barrel for the first 60,000 barrels of production. Excise taxes on production above this level were reduced from \$18/barrel to \$16/barrel. The weighted average excise tax resulting from the CBMTRA based on 2017 quantities was \$12.84/barrel. The CBMTRA reduced the excise tax-induced price wedge between consumer and producer prices and increased regional beer output. To implement this change, the exogenous shock needed to reduce the price wedge to \$12.84/barrel is again found using a search routine. The result is that a −0.0037 (−0.37%) shock to the price wedge is required to generate this change within the model.

Changes in the Endogenous Variables for the Regional Brewing Sector

Table 2 presents changes in the endogenous variables that result from entering an exogenous shock of −0.0037 into the regional brewing sector's EDM. The \$2.38/barrel weighted average decline in the excise tax on regional brewers causes the quantity demanded of regional beer (q^D) to increase by 0.06%, as the consumer price of regional beer (p^D) declines by −0.27%. The producer price of regional beer (which represents its marginal cost, p^S) increases by 0.10%. Note that the difference between consumer and producer prices has narrowed by 0.37 percentage points, which is the value used to generate the tax reduction.

Table 2 also presents changes in input use and prices, which all increase because of the increase in regional beer production. The use of barley (x_1) increases by 0.06%, while its price (w_1) increases by 0.33%. The demand for labor (x_2) increases by 0.04%, while its price (w_2) increases by 0.10%. The use of nonlabor inputs (x_3) increases by 0.07%, while its price (w_3) increases by 0.07%. Finally, the demand for equity capital (x_4) increases by 0.06%, while its price (w_4) increases by 0.04%.

Regional Brewing Sector Changes in Surplus, Tax Receipts, and Deadweight Losses

Table 2 presents changes in surplus for the regional brewing sector caused by the CBMTRA tax reduction. Again, these values are calculated based on the areas presented in Figure 2, while using the regional brewing sector's initial prices, quantities, and the EDM results of the CBMTRA legislation. Consumer surplus increases by \$20.45 million, representing 0.27% of the total revenue generated by regional beer production. Similarly, the CBMTRA increases aggregate producer surplus by \$7.95 million, which is 0.10% of the regional beer market size.

Table 2 also presents the incidence of this surplus on input suppliers. Barley producers gain \$3.83 million of producer surplus, while labor surplus increases by \$1.41 million. Nonlabor inputs and equity providers gain \$1.63 million and \$1.08 million of surplus.

The EDM results and Figure 2 allow for the calculation of changes in tax receipts from the regional beer sector that result from the CBMTRA. Table 2 indicates that tax collections from consumers decline by $20.46 million. Furthermore, tax receipts paid by producers decline by $7.95 million for a total reduction in tax receipts from the regional brewing sector of $28.41 million. Again, the relative differences in tax receipts result from the fact that the own-price elasticity of demand for regional beer (−0.212) is more inelastic than its EDM-calculated own-price elasticity of supply (0.55). In 2017, tax receipts from the regional brewing sector totaled $180.40 million (Table 1). Therefore, the CBMTRA reduces tax receipts from the regional brewing sector by $28.41 million, a 15.7% reduction.

Finally, changes in deadweight losses resulting from the excise tax decrease are also presented in Table 2. Consumer deadweight losses decline by $0.078 million, while producer deadweight losses decline by $0.017 million. Total deadweight losses decline by $0.095 million. Although these amounts appear to be relatively small, deadweight losses caused by the original excise tax totaled $0.328 million. Therefore, total deadweight losses are reduced by 29% because of the decline in excise taxes on the regional brewing industry.

CBMTRA EDM Results for the Macrobrewing Sector

The CBMTRA reduced the weighted average tax on macrobrewers from $18.00/barrel to $17.59/barrel. To implement this change, an exogenous shock to the price wedge of −0.0012 (or −0.12%) is required. This value is again obtained using a search routine.

Changes in the Endogenous Variables for the Macrobrewing Sector

Table 2 presents changes in the endogenous variables that result from a −0.12% exogenous shock to the price wedge in the EDM. The $0.41/barrel weighted average decline in the excise tax on macrobrewers causes the quantity demanded of macrobeer (q^D) to increase by 0.01%, as the consumer price of macrobeer (p^D) declines by −0.10%. The producer price of macrobeer (which represents its marginal cost, p^S) increases by 0.02%. Note that the difference between the consumer and producer prices has narrowed by 0.12 percentage points, which is the value used to drive the tax reduction.

Table 2 also presents changes in input use and prices, which all increase because the production of macrobeer increases. The use of barley (x_1) increases by 0.01%, while its price (w_1) increases by 0.04%. The demand for labor (x_2) increases by 0.01%, while its price (w_2) increases by 0.02%. The use of nonlabor inputs (x_3) increases by 0.02% while, its price (w_3) increases by 0.02%. Finally, the demand for equity capital (x_4) increases by 0.01%, while its price (w_4) increases by 0.009%.

Macrobrewing Sector Changes in Surplus, Tax Receipts, and Deadweight Losses

Table 2 presents changes in surplus in the macrobrewing sector caused by the CBMTRA tax reduction. Again, these values are calculated based on the areas presented in Figure 2, while using the macrobrewing sector's initial prices, quantities, and EDM results for the CBMTRA reduction in excise taxes. Consumer surplus increases by $62.59 million. This represents 0.11% of the total revenue generated by macrobeer production. The CBMTRA increases aggregate producer surplus by $11.11 million, which is 0.02% of the macrobeer market size.

The CBMTRA also reduced the excise taxes paid by both consumers and producers. Table 2 indicates that tax collections from consumers decline by $62.59 million. Furthermore, tax receipts paid by producers decline by $11.11 million for a total reduction of $73.70 million in tax receipts from the macrobrewing sector. The relative differences between consumers and producers in tax receipts occur because the own-price elasticity of demand for macrobeer (−0.126) is more inelastic than its EDM-calculated own-price elasticity of supply (0.71). In 2017, tax receipts from the macrobrewing sector totaled $3.21 billion (Table 1). The CBMTRA reduced tax receipts from this sector by 2.3%.

Table 3. Total Changes in Surplus, Tax Receipts, and Deadweight Losses and 95% Confidence Intervals for the CBMTRA Tax Reduction

Variable	CBMTRA Tax Reduction ($millions)	95% Confidence Interval ($millions)
Consumer surplus	115.83 (0.15%)	109.81, 119.56
Producer surplus	32.22 (0.04%)	28.38, 38.41
Barley producer surplus	13.23 (0.11%)	10.32, 19.32
Labor producer surplus	6.50 (0.07%)	5.17, 8.57
Nonlabor producer surplus	7.64 (0.03%)	6.22, 9.12
Equity producer surplus	4.87 (0.02%)	4.15, 5.74
Consumer taxes	−115.86	−119.59, −109.83
Producer taxes	−32.25	−38.44, −28.40
Total taxes	−148.10	−148.26, −148.00
Consumer deadweight loss gained	0.128	0.117, 0.137
Producer deadweight loss gained	0.028	0.024, 0.030
Total deadweight loss gained	0.156	0.141, 0.167

Aggregated and Brewery-Level CBMTRA Effects

Table 3 presents a summary of annual changes in surplus, tax receipts, and deadweight losses for all three brewing sectors resulting from the CBMTRA. Consumer surplus increases by $115.83 million, which is 0.15% of the size of the aggregate brewing sector in 2017. Producer surplus increases by $32.22 million. Of this total, barley producers receive the largest gain in producer surplus ($13.23 million). Consumers pay $115.86 million less in excise taxes, and producers pay $32.25 million less. The CBMTRA reduces total deadweight losses.

Note that the stated purpose of the CBMTRA was to benefit and encourage production of the craft (i.e., micro) brewing sector (Marisic, 2020a). Indeed, CBMTRA tax reductions on both a per barrel and percentage basis were largest for the microbrewing sector. However, the production scale of the regional brewing and macrobrewing sectors causes their collective benefits to exceed that of the microbrewing sector. That is, while the microbrewing sector's producer surplus increases by $13.17 million, the sum of the regional brewing and macrobrewing sectors' producer surplus increases by $19.06 million (Table 2).

Furthermore, differences in brewery concentration across the sectors lead to even greater differences in distributional effects. In 2017, 6,440 microbrewers, 50 regional brewers, and 8 macrobrewers existed (Figure 1). Simply dividing each sector's change in producer surplus by the number of brewers in each sector yields per brewer surplus changes of $2,045 for microbrewers, $159,000 for regional brewers, and $1,388,750 for macrobrewers (Table 4).

Because of market concentration differences, however, producer surplus is not evenly distributed across brewers within a sector because excise taxes are levied on barrels of production. Therefore, larger brewers within each sector receive a larger portion of the added surplus. The eight brewers in the macrobrewing sector are dominated by two firms. In 2017, ABInbev held a 49% share of US macrobeer production, followed by MillerCoors with 28%. The remaining six brewers totaled 23%. Of the $11.11 million producer surplus increase, ABInbev received $5.44 million and MillerCoors

Table 4. Distribution of Producer Surplus among Sectors and Brewers Generated by the CBMTRA Tax Reduction

Sector/Brewery	Number of Brewers	Producer Surplus ($millions)	Producer Surplus per Brewer ($)
Microbrewing sector	6,440	13.17	2,045
Regional brewing sector	50	7.95	159,000
Macrobrewing sector	8	11.11	1,388,750
ABInbev	1	5.44	5,443,900
Miller Coors	1	3.11	3,110,800
Other macro	6	2.56	425,883
Totals	6,498	32.23	4,960

$3.11 million. The remaining six brewers received a collective increase in producer surplus of $2.56 million, which is an average of only $0.425 million per brewer. Similar distribution issues exist for both the regional brewing and microbrewing sectors. For the microbrewing sector, approximately 70% of brewers produced less than 1,000 barrels in 2017. The average increase in producer surplus for each microbrewer ($2,045) is relatively small, which leads one to wonder whether these small increases will enable them "to invest in their breweries, expand their operations, create more jobs and hire more American workers" (Nurin, 2017).

Likewise, the distribution of reductions in producer tax payments is highly concentrated. Regional brewing and macrobrewing sectors' producer tax payments were collectively reduced by $19.06 million, while the microbrewing sector's producer tax payments were reduced by $13.18 million. As with producer surplus, the largest tax reductions went to those brewers producing the largest number of barrels in each sector.

Sensitivity Analyses

We evaluate the sensitivity of the EDM CBMTRA results to variations in elasticity estimates (Davis and Espinoza, 1998). We use triangular distributions for the simulations and specify ranges for the demand and input supply elasticities. Toro-González, McCluskey, and Mittelhammer (2014) reported a range of −0.232 to −0.193 for the own-price elasticity of demand for microbeer and regional beer and a range of −0.138 to −0.114 for the own-price elasticity of demand for macrobeer.

For the own-price barley supply elasticity, the regression results generated an estimate of the long-run own-price supply elasticity of 0.26. We use this as the upper end of the range. For the lower end, we subtract the difference between the short and long-run estimates (0.09) from the short-run estimate (0.17) to obtain 0.08. Bargain and Peichl (2016) report a range of own-price labor supply elasticity estimates from 0.11 to 0.59. Therefore, we use their estimates for the range of our labor supply elasticities. For the nonlabor supply elasticity, we use the range reported by Gallaway, McDaniel, and Rivera (2003) for supply inputs used by the brewing industry (0.80 to 1.34). Finally, we use Goolsbee's (1998) range of 1.14 to 1.74 for the own-price supply elasticity of owners' equity.

We also consider ranges for the Allen elasticities of substitution for each brewing sector. We allowed the elasticity of substitution between labor and nonlabor inputs ($\sigma_{23} = \sigma_{32}$) to vary between 0.50 and 1.50 for the microbrewing sector, 1.50 to 2.50 for the regional brewing sector, and 2.50 to 3.50 for the macrobrewing sector. In addition, the elasticity of substitution between barley and nonlabor inputs ($\sigma_{13} = \sigma_{31}$) in the macrobrewing sector is allowed to vary between 0.50 and 1.50.

We use procedures similar to those described in Brester, Marsh, and Atwood (2009) to estimate confidence intervals for the EDM results. The process simulates N joint sets of possible EDM parameters, iteratively inserts each set into each EDM, records the resulting EDM output results, and computes EDM results with α-percent confidence intervals as quantiles of the N simulated outcomes. We first independently estimate N realizations of a marginal distribution for each EDM parameter of interest, while maintaining negative own-price demand elasticities and positive own-price supply elasticities. The marginal distributions need not be of the same family, but we use triangular marginals given that our sample of elasticity estimates from the literature are in the form of ranges, which allows us to maintain minimal structure on the distributions. The triangular marginal distribution is based on three parameters—a minimum value (a), a maximum value (b), and a modal value (c). The mean of the triangular distribution is given by $\mu = (a + b + c)/3$. Hence, given a mean μ, the modal value is obtained as $c = 3\mu - (a + b)$.

We simulate $N = 1{,}000$ potential own-price elasticities of demand using the above ranges, which results in their distributions as $\eta^D \sim TR(\mu = -0.212, a = -0.232, b = -0.193)$ for microbeer and regional beers and $\eta^D \sim TR(-0.126, -0.138, -0.114)$ for macrobeer. Own-price elasticities of input supplies were assumed to be distributed $\varepsilon_1 \sim TR(0.08, 0.17, 0.26)$ for barley, $\varepsilon_2 \sim TR(0.35, 0.11, 0.59)$ for labor, $\varepsilon_3 \sim TR(1.00, 0.80, 1.34)$ for nonlabor, and $\varepsilon_4 \sim TR(1.44, 1.14, 1.74)$ for owners' equity. For the microbrewing sector, the elasticity of substitution between labor and nonlabor inputs is assumed to be distributed $\sigma_{23} = \sigma_{32} \sim TR(1.00, 0.50, 1.50)$. For the regional brewing sector, we assume $\sigma_{23} = \sigma_{32} \sim TR(2.00, 1.50, 2.50)$. The macrobrewing sector's elasticity of substitution between labor and nonlabor inputs is assumed to be distributed $\sigma_{23} = \sigma_{32} \sim TR(3.00, 2.50, 3.50)$, while the elasticity of substitution between barley and nonlabor inputs is assumed to be distributed as $\sigma_{13} = \sigma_{31} \sim TR(1.00, 0.50, 1.50)$.

We continue with the assumption of independence between each demand and supply elasticity estimate as well as among the elasticities of substitution.[2] After developing 1,000 sets of potential demand and input supply elasticities, the EDM is solved for each set. The 1,000 sets of EDM outcomes are then used to develop confidence intervals as quantiles of the simulated results. The results are reported in Table 3 as 95% confidence intervals for changes in surplus, tax receipts, and deadweight losses. All of the mean estimates are statistically significant at the 0.05 level. For example, the point estimate for changes in total consumer surplus for the CBMTRA is \$115.86 million, and its 95% confidence interval is \$109.81 million to \$119.56 million. The 95% confidence interval for mean estimate of total tax receipts forgone from the CBMTRA (−\$148.10 million) is −\$148.26 million to −\$148.00 million. The total deadweight losses that would be gained from the CBMTRA was estimated to be \$0.156 million with a 95% confidence interval of \$0.141 million to \$0.167 million.

Summary

The CBMTRA reduced deadweight losses in the brewing sector and increased both consumer and producer surplus while lowering tax payments. We note that these effects are, as expected, relatively small because beer excise taxes are small relative to product values. These effects, however, represent annual changes that accumulate over time. The positive annual impacts on consumers are larger than those of producers because the own-price elasticities of demand for each beer sector are more inelastic than the relevant own-price elasticities of supply. Consumer surplus increases primarily because of lower prices and, to a lesser extent, increased consumption. Producer prices increase by a smaller amount relative to the decline in consumer prices, but producers gain surplus and deadweight losses decline.

Although the CBMTRA reduced excise taxes across all alcohol categories, our research is specific to the beer production sector and does not include impacts on other participants in the beer supply chain, such as wholesalers/distributors and retailers. We find that CBMTRA reductions in beer excise taxes provided larger combined benefits for the regional brewing and macrobrewing sectors relative to the microbrewing sector. Except for the consumption of beer at on-site breweries, which is the case for most microbeer production, others in the supply chain share in the realized increases in producer surplus. The extent would be based on their relative elasticities of supply and demand, which is often

[2] Brester, Marsh, and Atwood (2009) demonstrate the use of copula procedures for developing marginals if the analyst believes the marginal distributions are not independent.

dependent on bargaining power and local regulations such as retail beer sales laws, franchise rules, and self-distribution allowances.

Our results demonstrate the need for policymakers—and their constituents—to carefully evaluate the unintended consequences of legislation. As each version of the CBMTRA was considered, legislators, lobbyists, craft beer producers, and consumers celebrated the occasion as "a huge break for mom-and-pop businesses" (Nurin, 2017). Interestingly, while the general popular press touted the CBMTRA benefits for small craft brewers, *Wine-Searcher* published an editorial in 2017 entitled "Craft Tax Gives Fat Cats the Cream" (Gray, 2017). The editorial closes by saying "the only thing crafty about the Craft Beverage Modernization and Tax Reform Act is the deceptive name."

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Online Supplement: Beer Excise Taxes and the Craft Beverage and Modernization Tax Reform Act

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Constructing the General Equilibrium Displacement Model

We construct an EDM for three sizes of the brewing industry based on annual production: microbrewers (firms producing less than 60,000 barrels), regional brewers (firms producing between 60,000 and 2 million barrels), and macrobrewers (firms producing more than 2 million barrels). The basic EDM for each of the three production sizes is developed following Atwood and Brester (2019), Gardner (1988), and Wohlgenant (2011) as:

(S1) $$E(q_k^D) = \eta_k^D E(p_k^D),\ k = 1, 2, 3$$

(S2) $$E(p_k^S) = \sum_j K_{kj}\, E\left(w_j^D\right),\ k = 1, 2, 3$$

(S3) $$E(x_{ki}^D) = E(q_{ki}^S) + \sum_j K_{kj}\, \sigma_{kij} E\left(w_j^D\right),\ k = 1, 2, 3, i = 1, 2, 3, 4$$

(S4) $$E(x_i^S) = \sum_j \varepsilon_{ij}\, E\,(w_j^S),\ i = 1, 2, 3, 4;$$

where q_k^D is the quantity demanded of the *k*th beer (i.e., micro, regional, macro); p_k^D is the consumer demand price of the *k*th beer; p_k^S is the producer supply price of the *k*th beer; q_k^S is the quantity supplied of the *k*th beer; x_{ki}^D is the demand for inputs used to produce the *k*th beer; w_j^D are input demand prices; x_i^S are the quantity supplied of inputs; w_j^S are input supply prices; σ_{kij} are Allen elasticities of substitution between inputs *i* and *j* for the *k*th beer; ε_{ij} are own- and cross-price elasticities of input supplies; η_k^D is the own-price elasticity of demand for the *k*th beer**,** K_{kj} are factor cost shares ($K_{kj} = \frac{w_j x_{kj}^d}{\Sigma_i w_i x_{ki}^d}$) for the *k*th beer such that $\sum_j K_{kj} = 1$; and $E(\cdot)$ represents percentage changes such that $E(\cdot) = \frac{d(\cdot)}{(\cdot)}$.

Silberberg (1990) notes that $\sum_j K_{kj}\, \sigma_{kij} = 0$ is necessary for the system of equations to add-up or, more precisely, be homogeneous of degree 0 in input and output prices. This logical condition is analogous to the concept of a lack of money illusion in consumer theory. That is, the homogeneity condition implies that no output response should occur if all input prices were, say doubled, along with the output price. Hence, only relative input and output prices influence production behavior as opposed to absolute prices. In the absence of this condition, EDM outcomes are not consistent with economic theory.

Equation (S1) represents the demand for each beer type. Equations (S2) and (S3) represent the production technologies and first-order conditions for profit maximization for each beer type. Equation (S4) represents input supply functions.

We define four inputs used to produce beer (i.e., barley, labor, nonlabor, and owner equity capital) and assume that input supply quantities are functions of only their own-input prices rather than influenced by the price of other inputs. Hence, we assume that $\varepsilon_{ij} = 0$ for $i \neq j$. Because an

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excise tax had already existed, the demand price of beer (p_k^D) is greater than the supply price of beer (p_k^S). The latter represents the marginal cost of producing beer. In addition, we assume that, within any annual time period, beer markets clear such that the quantities demanded and supplied are equal (i.e., $q_k = q_k^D = q_k^S$).

Therefore, a one output, four-input EDM for each brewer size is written as

(S5) $$E(q^D) = \eta^D E(p^D) + E(\theta_1)$$

(S6) $$E(p^S) = K_1 E(w_1^D) + K_2 E(w_2^D) + K_3 E(w_3^D) + K_4 E(w_4^D) + E(\theta_2)$$

(S7) $$E(x_1^D) = E(q^S) + K_1\sigma_{11}E(w_1^D) + K_2\sigma_{12}E(w_2^D) + K_3\sigma_{13}E(w_3^D) + K_4\sigma_{14}E(w_4^D) + E(\theta_3)$$

(S8) $$E(x_2^D) = E(q^S) + K_1\sigma_{21}E(w_1^D) + K_2\sigma_{22}E(w_2^D) + K_3\sigma_{23}E(w_3^D) + K_4\sigma_{24}E(w_4^D) + E(\theta_4)$$

(S9) $$E(x_3^D) = E(q^S) + K_1\sigma_{31}E(w_1^D) + K_2\sigma_{32}E(w_2^D) + K_3\sigma_{33}E(w_3^D) + K_4\sigma_{34}E(w_4^D) + E(\theta_5)$$

(S10) $$E(x_4^D) = E(q^S) + K_1\sigma_{41}E(w_1^D) + K_2\sigma_{42}E(w_2^D) + K_3\sigma_{43}E(w_3^D) + K_4\sigma_{44}E(w_4^D) + E(\theta_6)$$

(S11) $$E(x_1^S) = \varepsilon_1 E(w_1^S) + E(\theta_7)$$

(S12) $$E(x_2^S) = \varepsilon_2 E(w_2^S) + E(\theta_8)$$

(S13) $$E(x_3^S) = \varepsilon_3 E(w_3^S) + E(\theta_9)$$

(S14) $$E(x_4^S) = \varepsilon_4 E(w_4^S) + E(\theta_{10}).$$

Equation (S5) represents consumer demand for beer in which all arguments other than own-price are held constant. Equations (S6)-(S10) represent the beer industry's aggregate production function and the first-order conditions for profit maximization. Equation (S11) represents the supply of barley (input 1), equation (S12) represents the supply of labor (input 2), equation (S13) represents the supply of nonlabor inputs (input 3), and equation (S14) represents the supply of owner equity capital (input 4) used to produce beer.

Equations (S5)–(S14) represent behavioral equations that can be used to model several types of exogenous shocks. Specifically, the model can be used to estimate changes in equilibria to the endogenous variables that result from (positive or negative) shocks to consumer demand (θ_1) and/or input supplies ($\theta_7, \theta_8, \theta_9, \theta_{10}$). Exogenous shocks to production technologies can be modeled using θ_2, θ_3, θ_4, θ_5, and θ_6 although the size of these shocks are not independent of each other.

Excise taxes place a price "wedge" between the price that consumers pay for goods and services and the price producers receive for their output (i.e., the marginal cost of production). Consequently, an equilibrium equation must be added to the 10 behavioral equations above to account for the price wedge in the output market and to quantify the impact of changes in excise taxes. Because of the initial excise tax, a difference initially existed between the price that consumers pay for output (p^D) and the price producers receive for output (p^S). Therefore, the equilibrium condition for this relationship is developed as

(S15) $$p^D = p^S.$$

Totally differentiating equation (S15) results in

(S16) $$dp^D = dp^S.$$

Multiplying both sides of equation (S16) by $\frac{1}{p^D}$ results in

(S17) $$\frac{dp^D}{p^D} = \frac{dp^S}{p^D}.$$

Multiplying the right hand-side of equation (S17) by $\frac{p^S}{p^S}$ yields

(S18) $$\frac{dp^D}{p^D} = \frac{p^S}{p^S}\frac{dp^S}{p^D}.$$

Upon rearranging and changing to proportional elasticity notation, we obtain

(S19) $$E(p^D) = \left(\frac{p^S}{p^D}\right) E(p^S) + E(\theta_{11}).$$

Note that if an excise tax did not already exist, the consumer and producer price of output would be equal so that $\left(\frac{p^S}{p^D}\right) = 1.0$.

The EDM for each brewer size is, therefore, equations (S5)–(S14) and equation (S19). Moving the endogenous variable of the EDM to the left hand-side results in

(S20) $$E(q^D) - \eta^D E(p^D) = E(\theta_1)$$

(S21) $$E(p^S) - K_1 E(w_1^D) - K_2 E(w_2^D) - K_3 E(w_3^D) - K_4 E(w_4^D) = E(\theta_2)$$

(S22) $$E(x_1^D) - E(q^S) - K_1\sigma_{11} E(w_1^D) - K_2\sigma_{12} E(w_2^D) - K_3\sigma_{13} E(w_3^D) - K_4\sigma_{14} E(w_4^D) = E(\theta_3)$$

(S23) $$E(x_2^D) - E(q^S) - K_1\sigma_{21} E(w_1^D) - K_2\sigma_{22} E(w_2^D) - K_3\sigma_{23} E(w_3^D) - K_4\sigma_{24} E(w_4^D) = E(\theta_4)$$

(S24) $$E(x_3^D) - E(q^S) - K_1\sigma_{31} E(w_1^D) - K_2\sigma_{32} E(w_2^D) - K_3\sigma_{33} E(w_3^D) - K_4\sigma_{34} E(w_4^D) = E(\theta_5)$$

(S25) $$E(x_4^D) - E(q^S) - K_1\sigma_{41} E(w_1^D) - K_2\sigma_{42} E(w_2^D) - K_3\sigma_{43} E(w_3^D) - K_4\sigma_{44} E(w_4^D) = E(\theta_6)$$

(S26) $$E(x_1^S) - \varepsilon_1 E(w_1^S) = E(\theta_7)$$

(S27) $$E(x_2^S) - \varepsilon_2 E(w_2^S) = E(\theta_8)$$

(S28) $$E(x_3^S) - \varepsilon_3 E(w_3^S) = E(\theta_9)$$

(S29) $$E(x_4^S) - \varepsilon_4 E(w_4^S) = E(\theta_{10})$$

(S30) $$E(p^D) - \left(\frac{p^S}{p^D}\right) E(p^S) = E(\theta_{11}).$$

Using linear algebra, equations (S20)–(S30) can be written as:

(S31) $$\begin{bmatrix} 1 & -\eta^D & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & -K_1 & -K_2 & -K_3 & -K_4 \\ -1 & 0 & 0 & 1 & 0 & 0 & 0 & -K_1\sigma_{11} & -K_2\sigma_{12} & -K_3\sigma_{13} & -K_4\sigma_{14} \\ -1 & 0 & 0 & 0 & 1 & 0 & 0 & -K_1\sigma_{21} & -K_2\sigma_{22} & -K_3\sigma_{23} & -K_4\sigma_{24} \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 & -K_1\sigma_{31} & -K_2\sigma_{32} & -K_3\sigma_{33} & -K_4\sigma_{34} \\ -1 & 0 & 0 & 0 & 0 & 0 & 1 & -K_1\sigma_{41} & -K_2\sigma_{42} & -K_3\sigma_{43} & -K_4\sigma_{44} \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\varepsilon_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\varepsilon_2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\varepsilon_3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\varepsilon_4 \\ 0 & 1 & -\frac{p^S}{p^D} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} E(q) \\ E(p^D) \\ E(p^S) \\ E(x_1) \\ E(x_2) \\ E(x_3) \\ E(x_4) \\ E(w_1) \\ E(w_2) \\ E(w_3) \\ E(w_4) \end{bmatrix} = \begin{bmatrix} E(\theta_1) \\ E(\theta_2) \\ E(\theta_3) \\ E(\theta_4) \\ E(\theta_5) \\ E(\theta_6) \\ E(\theta_7) \\ E(\theta_8) \\ E(\theta_9) \\ E(\theta_{10}) \\ E(\theta_{11}) \end{bmatrix}.$$

In a general form, equation (S31) can be written as:

(S32) $$\boldsymbol{Ay} = \boldsymbol{b},$$

where $\boldsymbol{A}$ is an $11x11$ matrix of parameters, $\boldsymbol{y}$ is an $11x1$ vector of endogenous variables, and $\boldsymbol{b}$ is an $11x1$ vector of exogenous shocks. After parameterizing the $\boldsymbol{A}$ matrix, the system's endogenous variables can be solved for any exogenous shock ($\boldsymbol{b}$) as:

(S33) $$\boldsymbol{y} = \boldsymbol{A}^{-1}\boldsymbol{b}.$$

An EDM for the Microbrewing Sector

Table 1 presents the values used to parameterize the $\boldsymbol{A}$ matrix in equation (S31) for the microbrewery (and both regional brewery and microbrewery) sizes. An own-price elasticity of demand (η^D) for craft (i.e., micro) beer of –0.212 is obtained from Toro-González, McCluskey, and Mittelhammer (2014).

One of the primary inputs into beer production is malt produced from malting barley. Barley is the third largest feed grain crop produced in the United States, after corn and grain sorghum. Approximately 75% of US barley acreage is planted to a malting (as opposed to a feed) variety, and 90% of malting barley is used for beer production. Because of a lack of malt data and given that barley and malt have a near fixed proportional relationship, we consider malting barley as a primary input into beer production. Thus, we require an estimate of its own-price elasticity of supply (ε_1). Equation (S34) presents the generalized least squares results of regressing the natural logarithm of annual US barley production between 1980 and 2020 onto the natural logarithm of US barley price lagged one period, a linear trend term, a one-period lagged dependent variable, and an autoregressive error parameter:

$$\text{(S34)}\quad \ln bprod_t = \underset{(5.08)}{3.97} + \underset{(2.31)}{0.17} \ln barpr_{t-1} - \underset{(-5.89)}{0.023}\, T + \underset{(2.88)}{0.35} \ln bprod_{t-1} + 0.037\, \rho_{t-1},$$

$$\bar{R}^2 = 0.887;\ SE = 0.144;\ \bar{Y} = 5.68;\ DW = 1.933;\ DF = 35,$$

where $\ln bprod$ is the natural logarithm of US annual barley production; $\ln barpr$ is the natural logarithm of the real price of barley; T is a linear trend; ρ_{t-1} is a first-order autoregressive error term; *t*-values are in parentheses; $\bar{R}^2$ is the adjusted R-squared statistic; *SE* is the standard error of the regression; $\bar{Y}$ is the mean of the dependent variable; *DW* is the Durbin-Watson statistic; and *DF* is the degrees of freedom. US annual barley production and prices are obtained from the USDA (2021). Prior to the natural logarithm transformation, the price of barley was deflated by the GDP implicit price deflator (2015 = 100) obtained from US Bureau of Economic Analysis (2021).

Because of natural logarithm transformations, the regression results directly generate a short-run own-price barley supply elasticity of 0.17. Given that barley production and planted barley acreages are highly correlated, this estimate is comparable to the USDA (2000) estimate of the elasticity of planted barley acreage with respect to barley price (0.28).

Labor is considered a second input into beer production. Bargain and Peichl (2016) report a large number of published labor supply elasticity estimates. Depending upon demographics, the mean values of these studies range from 0.11 to 0.59. Therefore, we use the midpoint of this range (0.35) as our estimate of the own-price supply elasticity of labor (ε_2).

A third input is defined as all other nonlabor inputs used to produce beer. The short-run elasticity of supply of nonlabor inputs represents an amalgam of various machinery and manufacturing products. Gallaway, McDaniel, and Rivera (2003) estimate Armington supply elasticities for 309 SIC-code manufacturing industries. Although Armington elasticities represent import supply responses to changes in domestic prices, they should be reasonable approximations for nonlabor input supply responses given the global manufacturing environment. Gallaway, McDaniel, and Rivera (2003) report short-run supply elasticities for many of the inputs used by the brewing industry (e.g., 0.80 for paperboard boxes, 1.02 for packaging materials, and 1.34 for fabricated metal products). The supply elasticities for many other inputs used by the brewing industry generally fall within this range. Consequently, we use an estimate of 1.0 as the elasticity of supply for nonlabor inputs (ε_3).

Owners' equity capital represents financial inputs used by brewing companies. That is, owners' equity is the residual claimant on business profits and losses. As such, it is a variable input that is determined by the interactions of inputs and market output. This balance sheet financial element changes as business activity either increases or reduces its value. Of course, financial capital can also be added to a business activity at any time. Goolsbee (1998) reports a range of short-run own-price elasticity of supply estimates for financial capital of 1.14 to 1.74. We use the midpoint of this range (1.44) for the own-price elasticity of supply for equity capital (ε_4).

The values for the factor cost shares of x_1 (K_1), x_2 (K_2), x_3 (K_3), and x_4 (K_4) are developed using proprietary benchmark data from the Brewers Association, estimates reported by Tremblay and Tremblay (2005) and personal communications. These data are used to calculate factor cost shares for barley, labor, and nonlabor inputs. The fourth factor cost share (equity capital) is calculated by subtracting the sum of the factor cost shares for the first three inputs from 1.0. The largest factor cost share is for nonlabor inputs (0.346) with almost equal factor cost shares associated with labor (0.255) and owners' equity capital (0.268).

We assume that barley (i.e., malt) cannot be substituted for any of the other three inputs in the production of microbeer. Therefore, $\sigma_{12} = \sigma_{13} = \sigma_{14} = \sigma_{21} = \sigma_{31} = \sigma_{41} = 0.0$. In addition, we assume that owners' equity cannot be substituted for either labor or nonlabor inputs so that $\sigma_{42} = \sigma_{43} = \sigma_{24} = \sigma_{34} = 0.0$. We also assume that the Allen elasticity of substitution between labor and nonlabor inputs is equal to 1.0 so that $\sigma_{23} = \sigma_{32} = 1.0$.

The terms σ_{11}, σ_{22}, σ_{33}, and σ_{44} must be calculated and included in the model if the economic system is to be homogeneous of degree zero in all prices and allow for the system to add up (Silberberg, 1990). These values are calculated as

$$\sigma_{11} = -\frac{(K_2*\sigma_{12})+(K_3*\sigma_{13})+(K_4*\sigma_{14})}{K_1} = 0.0,\ \sigma_{22} = -\frac{(K_1*\sigma_{21})+(K_3*\sigma_{23})+(K_4*\sigma_{24})}{K_2} = -1.36,$$

$$\sigma_{33} = -\frac{(K_1*\sigma_{31})+(K_2*\sigma_{32})+(K_4*\sigma_{34})}{K_3} = -0.74, \text{ and } \sigma_{44} = -\frac{(K_1*\sigma_{41})+(K_2*\sigma_{42})+(K_3*\sigma_{43})}{K_4} = 0.0.$$

Finally, the average price of a barrel of microbeer (p^D) in 2017 was $642.69 (Nielsen/IRI, 2017). Because the excise tax during this period was $7.00/barrel, the producer price for a barrel of microbeer (p^S) was $635.69 (Table 1). Therefore, the ratio of the producer price to the consumer price of microbeer (p^S/p^D) equals 0.989.

Using the values presented in Table 1 for the microbrewing sector, the ***A*** matrix in equation (S31) is parameterized as

$$\text{(S35)} \quad \begin{bmatrix} 1 & 0.212 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & -0.13 & -0.26 & -0.35 & -0.27 \\ -1 & 0 & 0 & 1 & 0 & 0 & 0 & 0.00 & 0.00 & 0.00 & 0.00 \\ -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0.00 & 0.35 & -0.35 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0.00 & -0.26 & 0.26 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.17 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.35 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.00 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.44 \\ 0 & 1 & -0.989 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

An EDM for the Regional Brewing Sector

Several changes are needed to the ***A*** matrix used to represent the microbrewing sector in equation (S35) to tailor the EDM to the regional brewing sector. Although we continue to use the same own-price elasticity of demand and inputs as for microbeer, the factor cost shares for each of the four inputs are different for the regional brewing sector relative to the microbrewing sector.

Table 1 presents the factor cost shares for the regional brewing EDM (Tremblay and Tremblay, 2005). Relative to the microbrewing sector, the factor cost shares of labor and nonlabor inputs are lower (0.180 and 0.310) while the factor cost shares of owners' equity capital increases (0.360). These changes represent increased use of investment capital and nonlabor inputs (e.g., machinery) in the regional brewing sector. The factor cost share of barley is slightly larger than its cost share in the microbrewing sector. Although large breweries are able to purchase larger quantities of barley malt and, presumably, receive quantity and transportation discounts, the decreases in labor and nonlabor factor costs shares per barrel cause the barley cost share for regional brewers to increase slightly.

We also assume that regional brewers have a greater ability than microbrewers to substitute nonlabor inputs for labor inputs because of scale efficiencies. Hence, we set the elasticity of substitution between nonlabor and labor inputs ($\sigma_{32} = \sigma_{23}$) equal to 2.0. The changes in factor cost shares and the elasticity of substitution of labor to nonlabor inputs necessitates the recalculation of each σ_{ii} as:

$$\sigma_{11} = -\frac{(K_2 * \sigma_{12}) + (K_3 * \sigma_{13}) + (K_4 * \sigma_{14})}{K_1} = 0.0,\ \sigma_{22} = -\frac{(K_1 * \sigma_{21}) + (K_3 * \sigma_{23}) + (K_4 * \sigma_{24})}{K_2} = -3.44,$$

$$\sigma_{33} = -\frac{(K_1 * \sigma_{31}) + (K_2 * \sigma_{32}) + (K_4 * \sigma_{34})}{K_3} = -1.16, \text{ and } \sigma_{44} = -\frac{(K_1 * \sigma_{41}) + (K_2 * \sigma_{42}) + (K_3 * \sigma_{43})}{K_4} = 0.0.$$

Finally, the average annual consumer price for regional beer is assumed to equal that of microbeer ($642.69/barrel). However, regional brewing companies face higher Federal excise taxes than microbrewing companies. The weighted average excise tax for regional brewing companies in 2017 was $15.22/barrel so that the price received by regional brewers prior to the CBMTRA was $627.47/barrel. Therefore, the ratio of the producer price of regional beer to the consumer price of regional beer (p^S/p^D) equals 0.976.

Using the values presented in Table 1 for the regional brewing sector, the ***A*** matrix in equation (S31) is parameterized as:

$$\text{(S36)} \quad \begin{bmatrix} 1 & 0.212 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & -0.15 & -0.18 & -0.31 & -0.36 \\ -1 & 0 & 0 & 1 & 0 & 0 & 0 & 0.00 & 0.00 & 0.00 & 0.00 \\ -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0.00 & 0.62 & -0.62 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0.00 & -0.36 & 0.36 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.17 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.35 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.00 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.44 \\ 0 & 1 & -0.976 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

An EDM for the Macrobrewing Sector

Several changes are needed to the ***A*** matrix in equation (S36) to tailor the regional EDM to the macrobrewing sector. Table 1 presents the values used in the ***A*** matrix in equation (S36) that represent the macrobrewing sector. First, we use Toro-Gonzalez, McCluskey, and Mittelhammer's (2014) estimate of the own-price elasticity of demand for macrobeer of –0.126. Second, the factor cost shares for each of the four inputs are different for the macrobrewing sector relative to the microbrewing and regional brewing sectors. Table 1 presents the factor cost shares used for the macrobrewing EDM. The cost shares continue the pattern that occurred between the microbrewing and regional brewing sectors. Given the increase in brewer size, the cost share of labor and nonlabor inputs decline, while the cost share of owners' equity increases given the larger investments needed in the macrobrewing sector. Again, the macrobrewing sector's cost share of barley increases slightly relative to the regional brewing sector even though the macrosector is likely able to source barley at a lower absolute cost relative to smaller breweries.

We also assume that macrobrewers have more ability than microbrewers or regional brewers to substitute labor for other nonlabor inputs because of scale efficiencies. Hence, we set the elasticity of substitution between labor and nonlabor inputs ($\sigma_{23} = \sigma_{32}$) equal to 3.0. In addition, macrobreweries have the ability to substitute various inputs, such as corn syrup and rice, for malt (and, hence) barley. Therefore, we set the elasticity of substitution of barley with respect to other nonlabor inputs $\sigma_{13} = \sigma_{31}$ equal to 1.0. These changes in factor cost shares and elasticity of substitutions necessitate the recalculation of each σ_{ii} as:

$$\sigma_{11} = -\frac{(K_2*\sigma_{12})+(K_3*\sigma_{13})+(K_4*\sigma_{14})}{K_1} = -1.68,\ \sigma_{22} = -\frac{(K_1*\sigma_{21})+(K_3*\sigma_{23})+(K_4*\sigma_{24})}{K_2} = -8.18,$$

$$\sigma_{33} = -\frac{(K_1*\sigma_{31})+(K_2*\sigma_{32})+(K_4*\sigma_{34})}{K_3} = -1.69, \text{ and } \sigma_{44} = -\frac{(K_1*\sigma_{41})+(K_2*\sigma_{42})+(K_3*\sigma_{43})}{K_4} = 0.0.$$

Finally, the average annual consumer price for macrobeer in 2017 was $335.48/barrel. Therefore, the original producer price of macrobeer is $317.48/barrel because of the initial $18/barrel excise tax. As a result, the ratio of the producer price of macrobeer to the consumer price of macrobeer (p^S/p^D) equals 0.946.

Using the values presented in Table 1 for the macrobrewing sector, the ***A*** matrix in equation (S31) is parameterized as:

$$\text{(S37)} \quad \begin{bmatrix} 1 & 0.126 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & -0.17 & -0.10 & -0.28 & -0.46 \\ -1 & 0 & 0 & 1 & 0 & 0 & 0 & 0.28 & 0.00 & -0.28 & 0.00 \\ -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0.00 & 0.83 & -0.83 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 & -0.17 & -0.31 & 0.47 & 0.00 \\ -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.17 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -0.35 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.00 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1.44 \\ 0 & 1 & -0.946 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$