Product Switching, Adaptation and Firm Survival in the Brewing Industry during Prohibition

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Abstract

This paper studies the adaptation of firms to reductions in demand, and how this process can make firms more resilient to future demand shocks. I focus on the American brewing industry during the early twentieth century. Many states and counties chose to prohibit the sale and production of alcohol in the years leading up to the 1919 federal prohibition. Because of high transportation costs, local prohibition in nearby markets reduced the demand for beer production for some breweries more than others. Using novel micro-data at the brewery level, I show that breweries adapted to this first shock by acquiring machinery such as carbonators to produce alternative products like soft drinks. This initial investment strategy allowed them to endure federal prohibition (1919-1933), when no brewery was allowed to produce or sell beer. Breweries that faced the average reduction in demand due to local prohibitions were 12 percent more likely to survive the entire prohibition period (local + federal) than breweries not affected by local prohibitions. Higher survival rates are consistent with a model in which firms adapt to reductions in demand by making irreversible investments in other products, thereby endogenously increasing their ability to respond to future shocks, rather than with models in which firm survival depends exclusively on exogenous productivity.

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1 Introduction

Firms often face reductions in demand for their products due to government regulations, trade reforms or the innovation of their competitors. One way that firms can adapt to demand reductions is by switching to new products. The flexibility necessary to switch between products is possibly the outcome of investment decisions that firms have made in the past (e.g. to adopt new machinery). This paper shows that exposure to small demand shocks can make firms more resilient to future, potentially larger demand shocks by encouraging firms to make investments that facilitate product switching.

An empirical analysis of firm decisions in the face of sequential demand shocks imposes several requirements on the data. First, there must be an initial demand reduction that is heterogeneous across firms but uncorrelated with other determinants of future survival, like productivity or input prices. Second, there must be a subsequent demand reduction that is common across firms. Third, the data must contain measures of the multiple types of capital in which firms invest, as well as the multiple goods that firms produce, during both demand reductions.

This paper approaches this problem by studying the American brewing industry during the gradual enactment of Prohibition (1914-1933). Breweries experienced two sequential shocks. Between 1914 and 1918, many states and counties became dry.[1] That is, they chose to prohibit the sale and production of alcohol. Breweries located *in wet counties* experienced a reduction in demand during local prohibition, because they could no longer ship beer *to dry counties.* This first shock was heterogeneous across breweries, because the transportation costs to dry counties differed across breweries. The second shock came with federal prohibition in 1919, when all breweries were prohibited from selling beer.[2] The

[1]By 1914, some states and counties in rural areas and in the south were already dry. However, the level of demand from those counties was low in the first place, due to the prevalence of religious denominations opposed to the consumption of alcohol.

[2]After December 1918, breweries were not allowed to produce beer (Arnold and Penman, 1933, p. 178)

enactment of Federal Prohibition required a constitutional amendment and lasted for 14 years, until it was repealed (again by constitutional amendment) in 1933. The experimental variation in this study arises in the era of local prohibition, when some breweries were exposed to large demand shocks, while others were insulated from these local shocks. Later, all breweries faced the common shock of federal prohibition.

I collected a dataset of 1300 breweries between 1914 and 1933 to study the adaptation of breweries to Local and Federal prohibition. In particular, I observe the machines that breweries buy, the goods that breweries produce and the decisions that breweries make in regard to remaining in business or closing down. I link this dataset to county-level information on exposure to reductions in demand during local prohibition, and follow the adaptation and survival of breweries throughout both local and federal prohibition.

Breweries survived Federal Prohibition by switching to other products that shared inputs with the production of beer, like soft drinks and malt extract. Yet, some breweries were more likely to adapt and survive than others. Breweries that faced larger reductions in demand during local prohibition reduced their investment in beer-specific capital and bottling, but increased their investment in soda-specific capital. When Federal Prohibition arrived, those breweries were more likely to produce alternative products and survive. Furthermore, among the breweries alive before local prohibition started, those who faced early reductions in demand were 6 percentage points more likely to survive *both local and federal prohibition.* In other words, breweries that faced 5 additional years of hardship adapted earlier and survived the entire period.

These empirical outcomes are consistent with a model of multi-product firms that face variable demand conditions over time. I develop such a model, and use it to understand the implications of adaptation for the investment and survival decisions of firms. In particular, I obtain testable implications from adaptation that would not occur if the exit of the least

After July 1919, breweries were not allowed to sell beer (idem, p. 171).

productive firms was the only mechanism at work. These testable implications guide my empirical strategy. In addition, the model states explicit assumptions under which my results could potentially apply to other empirical settings.[3]

In the model, a subset of firms adapt to demand reductions by diversifying their product mix, as in the theoretical work of Penrose (1959, p. 140), Helfat and Eisenhardt (2004), Levinthal and Wu (2010) and Bloom et al. (2014). Diversification is accompanied by irreversible investments in machinery that is specific to the new products. This machinery reduces the incremental cost of switching to other products in the event of a new demand reduction, because part of the cost is already sunk when the new demand reduction occurs. Hence, firms are more likely to survive future demand reductions if they have experienced shocks in the past. Furthermore, firms are more likely to survive the entire period, including the period of the initial shock, because adaptation shifts the margin of survival: the option to invest increases the threshold marginal cost above which firms choose to survive both shocks.

This higher overall survivability is the result of the adaptation of firms through investment, as opposed to a statistical result caused by the early exit of the least productive firms (selection). To show this, I shut-down the investment channel in the model. Therefore, survival is determined exclusively by the exogenous component of the marginal costs. After an initial demand shock, firms with high marginal costs close down. In consequence, *conditional on surviving the first demand shock*, firms are more likely to survive the second shock. However, having experienced an initial shock has no effect on overall survivability: conditional on being alive *before* the first shock, the probability of surviving *both* shocks does not depend on having experienced a first shock. Yet, in the data, I find that experiencing a first shock does increase overall survivability, as predicted by a model that allows for firm adaptation

[3]Firms in the model: (i) pay a fixed cost of production each period (ii) can switch products by paying a non-recoverable cost (iii) exogenously differ in their marginal costs and (iv) have a limited capacity with rival uses across products, so reductions in demand diminish the opportunity cost of producing other goods. An example of the last assumption is a plant that can be used for bottling beer or soft drinks. Another example is an entrepreneur that must prioritize their time across products.

through irreversible investments.

The mechanism described in this paper can generalize to other industries where irreversible investments play an important role. For example, at the start of World War I, Dupont obtained 97% of its sales from the market for explosives (Chandler, 1990, p. 175). When the demand for explosives fell at the end of the War, Dupont used its existing capacity to expand into other chemical products. Six years later, the share of explosives on Dupont's sales had fallen to 50%. The company's report for that year noted that diversification "tends to avoid violent fluctuations in total sales, should one industry suffer a severe depression" (ibid, p. 176). Irreversible investments play two roles in this mechanism. First, they create capital that can be used towards the manufacture of alternative products when demand falls for the first time. Second, because the initial shock induces irreversible investments in product switching, diversification becomes persistent and increases resilience in the long run.

This paper contributes to the literature on how firms and industries evolve in response to reductions in demand. The existing literature shows that reductions in demand accelerate the exit of the least productive firms (Bresnahan and Raff, 1991; Caballero and Hammour, 1994; Foster et al., 2014), whereas the most productive firms adapt by changing managerial practices (Freiman and Kleiner, 2005; Aghion et al., 2015), switching products (Chandler, 1969, 1990; Agarwal and Helfat, 2009) and innovating (Bloom et al., 2015). My paper builds on this literature in order to answer a novel question: does exposure to demand reductions make firms more resilient to future, potentially larger demand reductions? I am able to answer this question by using an empirical strategy in which firms within the same industry face an initial shock of heterogeneous intensity, followed by a common, larger, shock. This empirical strategy is made possible by a novel dataset that I collected by visiting brewery archives, public archives and collaborating with breweriana collectors. Overall, the main contribution of this paper is to show that exposure to early, mild demand reductions can endogenously increase the survivability of firms to future demand reductions.

My results contribute to the analysis of policies that can influence demand at the industry level, like regulation, trade policy, international sanctions, and sectoral changes in government spending. It also has potential implications for the literatures on policy gradualism (Leamer, 1980; Dewatripont and Roland, 1992, 1995; Brusco and Hopenhayn, 2007), the evolution of competitive advantage at the industry level (Porter, 1990, 1996), the distribution of productivity across firms (Hopenhayn, 1992; Bernard et al., 2010, 2011), the geographical location of industries (Fujita et al., 2001), and the performance of firms during demand reductions (Aggarwal and Wu, 2015; Aghion et al., 2015). I examine these implications in the concluding remarks of this paper.

After reviewing the existing literature in section 2, I describe my data in section 3. In section 4, I provide an overview of the American brewing industry during the early twentieth century, the evolution of Prohibition over time and space, and the adaptation of breweries to Prohibition. In section 5, I present a theoretical framework that generates testable implications that guide my empirical strategy. Finally, I present my identification strategy and explain my empirical results. I conclude by discussing the implications of my results for contemporary policy.

2 Related Literature

The main contribution of this paper is explained in the introduction. This paper also contributes to a number of literatures in organizational economics, industrial organization, trade and economic history.

First, this paper contributes to the literature on how firms and industries evolve in response to reductions in demand. The existing literature has placed a large emphasis on how reductions in demand accelerate the exit of the least productive firms (Bresnahan and Raff, 1991;

Caballero and Hammour, 1994).[4] Yet, in a stationary setting the level of demand increase the market share of the most productive firms, but have no effect on the life cycle properties of the firms in the industry in the long run (Hopenhayn, 1992). The empirical findings of this paper show that repeated exposure to demand reductions make firms less likely to exit over time. Furthermore, because the most productive firms are the most likely to survive the initial shock and the most likely to diversify their product mix (Hopenhayn, 1992; Bernard et al., 2010), my result suggests that the most productive firms become less likely to exit over time.

More generally, my paper contributes to the literature on how changes in the economic environment induce firms to specialize or diversify their product mix. For example, increased access to the Canadian market induced U.S. exporters to specialize in their main products (Bernard et al., 2011), increased competition in the computing hardware market induced IBM to switch to business computing services (Agarwal and Helfat, 2009), compositional shifts in demand since 2011 induced defence contractors to switch towards counter-terrorism products (Aggarwal and Wu, 2015), the Great Depression induced large manufacturing firms to diversify their product mix (Chandler, 1969), the end of World War I induced Dupont to diversify from explosives to other chemical products (Chandler, 1990, p. 175), and increased competition from Chinese imports induced European firms to innovate into new products (Bloom et al., 2015).[5] My paper contributes to this literature by showing empirically that initial increases in diversification can become permanent due to irreversible investments and their effect on the survivability of firms to future shocks.

[4]Caballero and Hammour (1994), reductions in demand accelerate the exit of low-productive firms and slow-down the entry of high-productive firms. Their analysis of job market flows suggests that the exit channel is more important than the entry channel during recessions. This is consistent with the results from Bresnahan and Raff (1991), who show that the Great Depression induced the exit of automobile producers with lower scale and lower (average labor) productivity. Scott and Ziebarth (2015) shows that selection on the basis of productivity does not hold in the radio industry, which did not exhibit economies of scale at the time. The brewing industry exhibits large economies of scale, however, so the automotive industry studied by Bresnahan and Raff (1991) is more closely related to this paper.

[5]Bernard et al. (2011) show that US firms that faced larger reductions in Canadian tariffs (i.e. that experienced an *increase* in market access) reduced the range of their products in response.

My mechanism builds upon the existing theory of multi-product firms. In Penrose (1959, p. 140), reductions in demand increase diversification and product-switching by firms. This increase in diversification is driven by inputs with rival uses across products -like bottling plants with increasing marginal costs or limited capacity- because there is a reduction in the opportunity cost of using those inputs in the alternative products (Levinthal and Wu, 2010). These increases in diversification are not driven by inputs with non-rival uses across products, as in Panzar and Willig (1981), because otherwise firms would have implemented diversification before the reduction in demand. Non-recoverable capital with rival uses across products generate inter-temporal economies of scope, because the sequential production of different products by the same firm is less costly than their production by different firms that enter and exit the market in response to the demand of each product (Helfat and Eisenhardt, 2004). Non-recoverability is key for product-switching to be more profitable for incumbents than for entrants, because otherwise the market for capital would equalize the costs for both groups (Teece, 1980). My mechanism is also related to the work Bloom et al. (2014), in which increased competition induce firms to use trapped factors towards the creation of new products. Because demand shocks generate path dependence in the industry, this paper is also related to the work of Adner and Levinthal (2001). Overall, the adaptation of breweries to prohibition is an example of strategic renewal, as defined by Agarwal and Helfat (2009). My results provide empirical support for the predictions of these theories in a context of demand reductions induced by regulation.

Because the inter-temporal channel in this paper is driven by investment, this paper also builds on the literature that links demand uncertainty and investment dynamics. In this literature, demand uncertainty reduces the responsiveness of entry and investment to demand fluctuations (Baldwin, 1988; Guiso and Parigi, 1999; Bloom et al., 2007; Collard-Wexler, 2013). Hence, if the volatility of demand increases, firms are less likely to disinvest in response to small reductions in demand. In my paper, demand uncertainty increases investment in capital that can produce multiple products, and actual demand reductions increase investment in capital that produces alternative products. Both types of investments make the firm more resilient to future shocks.

My work builds on existing findings by economic and business historians. Sechrist (1986) and García-Jimeno (2015) study the political economy of prohibition. McGahan (1991), Kerr (1998) and Stack (2000, 2010) describe the structure of the brewing industry during the Prohibition era. Local prohibition increased brewery mortality (Wade et al., 1998), increased the birth rate of soft drink producers (Hiatt et al., 2009), and induced Anheuser-Busch to produce non-alcoholic beverages (Plavchan, 1969). Furthermore, multiple breweries survived federal prohibition by switching products (Feldman, 1927; Cochran, 1948; Plavchan, 1969; Ronnenberg, 1998; Tremblay and Tremblay, 2005). My contribution to the historical literature is twofold. First, I provide a causal mechanism that connects these pieces of evidence, generates new testable implications, and provides a basis for discussing the external validity of my results. Second, I collect a novel data-set from primary sources that allows for a rigorous quantitative analysis at the firm-level, as opposed to the current focus on either particular breweries or state-level data.

3 Data

I collected a novel dataset of 1375 breweries over 19 years to measure the adaptation of breweries to Prohibition. I use the dataset for both the historical overview and the empirical results in this paper. I start by describing the data that I use to measure the exposure of breweries to Local Prohibition. Then, I describe the data that I use to measure the adaptation of breweries to both Local and Federal prohibition, as well as the persistent effects of adaptation.

I calculate the exposure of breweries located in wet counties to local prohibition in surrounding areas by combining information from three county-level sources: the prohibition status of each county between 1914 and 1918, the population of each county in 1914 and 1918 (calculated as a linear interpolation between the census years of 1910 and 1920), and the transportation costs between each pair of counties in 1890.[6] These sources are combined into a measure of the "wet market access" for each county. This measure adapts the formula of Donaldson and Hornbeck (2015) by including the internal market for each county, excluding destination counties were the distribution of beer is not allowed, and using a different parameter for the elasticity of shipments with respect to transportation costs. The calculation is explained in detail in section 6.

The prohibition status of each county was originally collected by Robert P. Sechrist (2012). The population of each county was obtained from census data, which was downloaded from the NHGIS website (Minnesota Population Center, 2011). The transportation costs between each pair of counties in the US were kindly provided by Dave Donaldson and Richard Hornbeck (2015). Their calculation of transportation costs uses information on the railroad and waterway networks from Atack (2013) and Fogel (1964).

My brewery-level dataset contains information on machinery acquisition, product choice, bottling, canning and the decision to stay in or exit the market from 1914 to 1937. I also observe the production of each brewery in 1898. I collected this data from directories and industry journals published during the prohibition era. The journals provide news items reporting when breweries acquire new machines or buildings. I consider that a brewery has acquired a machine related to a product if the brewery and the machine/product are mentioned in the same news item of the journal. The journals also published lists of breweries with information on whether they were producing sodas or soft-drinks and whether they had bottling or canning plants. For 1898, the lists also contain the output of each brewery in that year. I consider that a brewery is alive if it appears both in the journals' brewery lists and in the database of breweries of the American Breweriana Association, which also contains a list

[6] The use of transportation costs from 1890 favours my identification strategy, as I argue in section 6.

of names that I used as the initial step for matching breweries across sources and over time.

Here a paragraph describing my matching algorithm.

My data on machinery acquisition was collected from two sources. Between 1914 and 1918, the data is taken from the *New Plants and Improvements* section of the *Western Brewer*, and industry journal of the time. Between 1919 and 1932, the data is taken from an index of the same journal (or its successor journal). The index was constructed by Randy Carlson. I collected information on the product mix of breweries in 1923 from the *Beverage Blue Book*, a directory of soft drink producers, cereal beverage producers and former brewers published by *H.S. Rich & Co.* I collected information on bottling in 1914 from the *American Brewing Trade List and Internal Revenue Guide for Brewers*, a directory of brewers published by the *American Brewers' Review.* My information on bottling and canning for 1937 comes from the *Buyer's Guide and Brewery Directory*, a directory of brewers published by *Brewery Age.* Finally, my production data for 1898 was obtained from the *Brewers' Guide*, a directory of brewers published by the *American Brewers' Review.*

4 Historical Background: How Breweries Survived Prohibition

At the turn of the twentieth century, brewing was the fifth largest manufacturing industry in the United States, as measured by value added.[7] In 1905, there were 1847 breweries producing 50 million barrels of beer per year in a country of 84 million people.[8,9,10] On average, each

[7] Breweries produced 3% of the value added, used 4% of the capital, and employed 1% of the workers in the manufacturing sector. Own calculations from United States Bureau of the Census (1907)

[8] Sources: Bureau of Internal Revenue (1905), United States Bureau of the Census (1907) and United States Bureau of the Census (2000)

[9] Almost all the beer was sold in the US market: Exports were only 0.07% of output, whereas imports were only 0.34% of consumption. Own calculations from United States Brewers' Association (1907)

[10] 1 barrel = 31 gallons $\approx$ 117 liters $\approx$ 331 servings of 12 fl/355 ml $\approx$ 6 batches of Manning Brewery.

brewery produced 27 thousand barrels per year and employed 37 workers.[11]

Breweries were heterogeneous in their scale and production methods. 27 percent of breweries produced one thousand barrels per year or less, whereas 4 percent of breweries produced one hundred thousand barrels per year or more.[12]

Large breweries —like Pabst and Anheuser-Busch— used laboratories, mechanical refrigerators and pasteurizers. This machinery allowed for large scale in production, as well as low variability in the quality of beer across batches, seasons and geographic markets (McGahan, 1991; Kerr, 1998; Stack, 2010)[13] A subset of the large breweries, known as the National Shippers, distributed beer at the national level.[14] Beer was brewed in a single location and distributed by railroad to a network of branches and agencies that covered most of the country (McGahan, 1991; Stack, 2000).[15] Wisconsin's Pabst, for example, sold over one million barrels per year using a national network of fifty branches and five hundred agencies (Cochran, 1948).[16]

Distant locations were served using bottles —as opposed to kegs— because bottles did not require refrigeration while being transported, so their transportation costs were lower (Kerr, 1998) In contrast, close locations were mainly served using kegs because beer in kegs was considered to have a better taste and was cheaper to produce (Stack, 2010)

Despite enjoying lower marginal costs of production, large breweries co-existed with medium and small breweries. Co-existence was allowed by large transportation costs, product differ-

[11]Own calculations from United States Bureau of the Census (1908)

[12]The interquartile range of the annual output distribution was 29 thousand barrels per year. Own calculations from Wahl and Henius (1898)

[13]The low variability in quality was an integral part of the differentiation strategy of large brewers. In fact, it was widely emphasized in their national advertising campaigns (Stack, 2010)

[14]Six breweries distributed their beer at the national level: Schlitz, Pabst, Blatz, Lemp, Anheuser-Busch and Christian Moerlein (Stack, 2010)

[15]Single plant production was the norm in the industry until the early 50s, when water treatment innovations allowed brewers to produce beer of similar quality across plants (Tremblay and Tremblay, 2005, p. 33).

[16]By 1910, 4% of its beer was sold in Texas (Cochran, 1948)

entiation, and a distribution system based on saloon ownership and exclusivity contracts with saloon owners (Kerr, 1998; Stack, 2000). Small, craft breweries were able to survive by selling beer to in-town saloons using kegs.[17] Medium-sized breweries, in contrast, distributed beer at the regional level using both bottles and kegs. Overall, geographical markets were served by a mixture of national, regional and local breweries. For example, consumers in Kansas City bought their beer in 348 saloons supplied by 22 breweries from 6 states (Maxwell and Sullivan, 1999)

Most breweries were located in the Mid-Atlantic, the Mid-West and California (Figure 1). There were few breweries in the South because the main religious denominations in the South were opposed to the consumption of alcohol.[18] In contrast, breweries were common in large population centers in the North and West. Chicago, with its large population of German immigrants, had 58 breweries in 1903.

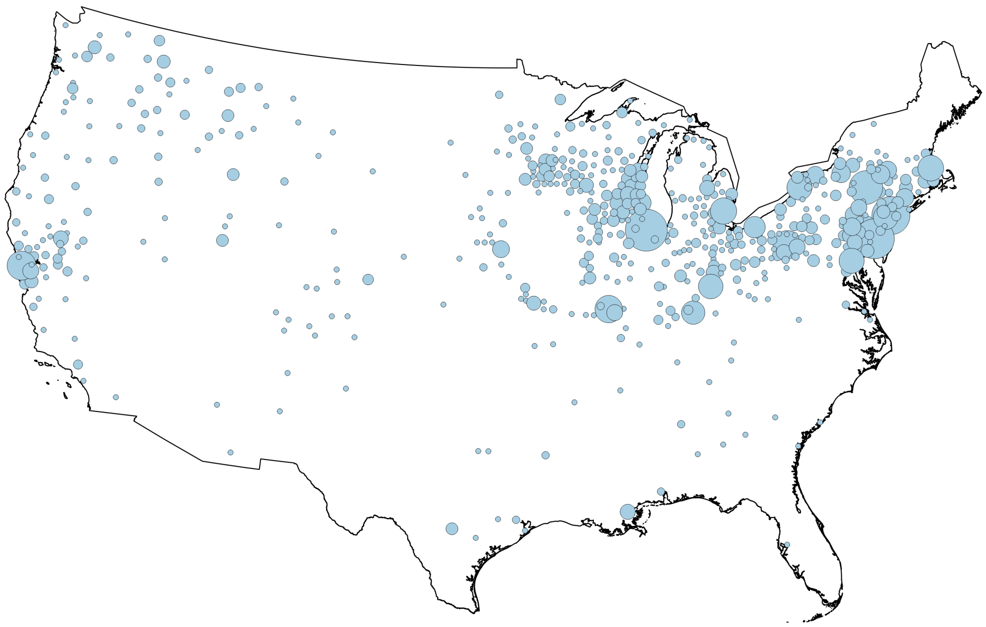
Starting in the second half of the nineteenth century, coalitions of religious and women's rights groups —like the Woman's Christian Temperance Union— campaigned to restrict the distribution of alcoholic beverages. In some states, their lobby gave rise to state bans on the distribution of alcoholic beverages, or, alternatively, the permission of local options, which allowed for decisions at the county, town or even the ward level (Rowntree and Sherwell, 1900, p. 255)[19] By 1914, 38 percent of Americans lived in dry locations.[20] However, most

[17]In fact, there were only 8 retailers per brewery on average (Own calculations from Bureau of Internal Revenue, 1905, p. 56)

[18]For example, 70% of members of all religious denominations in the South were Baptists or Methodists (Own calculations from the Census of Religious Bodies, obtained through Minnesota Population Center, 2011) The Southern Baptist Convention denounced the consumption of Alcoholic Beverages in 1896 (Southern Baptist Convention, 1896) John Welley, the founder of Methodism, denounced the consumption of alcohol in 1743 (Fox and Hoyt, 1852, p. 200) Religion continues to shape the location of breweries today (Gohmann, 2015)

[19]For example, Kentucky's constitution of 1891 allowed for local options in the following terms: "The General Assembly shall, by general law, provide a means whereby the sense of the people of any county, city, town, district or precinct may be taken, as to whether or not spirituous, vinous or malt liquors shall be sold, bartered or loaned therein, or the sale thereof regulated."(Legislative Research Commission of Kentucky, 2015, p. 9)

[20]Own calculations using local prohibition data from Sechrist (2012) and a linear interpolation of census population data from Minnesota Population Center (2011)



The area of each circle is proportional to the number of breweries in each county in 1903.
There were 61 breweries in Cook County (where Chicago is located) in that year.

Figure 1: Number of Breweries in 1903, per County

dry locations were located in the religious South and in rural areas were the demand for beer was low in any case. This situation changed between 1914 and 1918, when many state and counties with higher population density and proximity to the breweries became dry. By 1918, the percentage of Americans living in dry counties had increased to 55 percent.[21] The map of Figure 2 shows the gradual advance of prohibition over space and time.

Most breweries were located in counties that remained wet until federal prohibition. However, the advance of local prohibition imposed a substantial reduction on these breweries, because they were no longer allowed to ship beer to dry counties.[22] Even for those breweries that

[21]Ibid.

[22]Shipments not intended for distribution were also forbidden: "The shipment or transportation, in any manner or by any means whatsoever of any spirituous, vinous, malted, fermented, or other intoxicating liquor of any kind from one State, Territory, or District of the United States, or place noncontiguous to, but subject to the jurisdiction thereof, into any other State, Territory, or District of the United States, or place noncontiguous to, but subject to the jurisdiction thereof, which said spirituous, vinous, malted, fermented, or other intoxicating liquor is intended by any person interested therein, to be received, possessed, sold, or in any manner used, either in the original package, or otherwise, in violation of any law of such State, Territory,

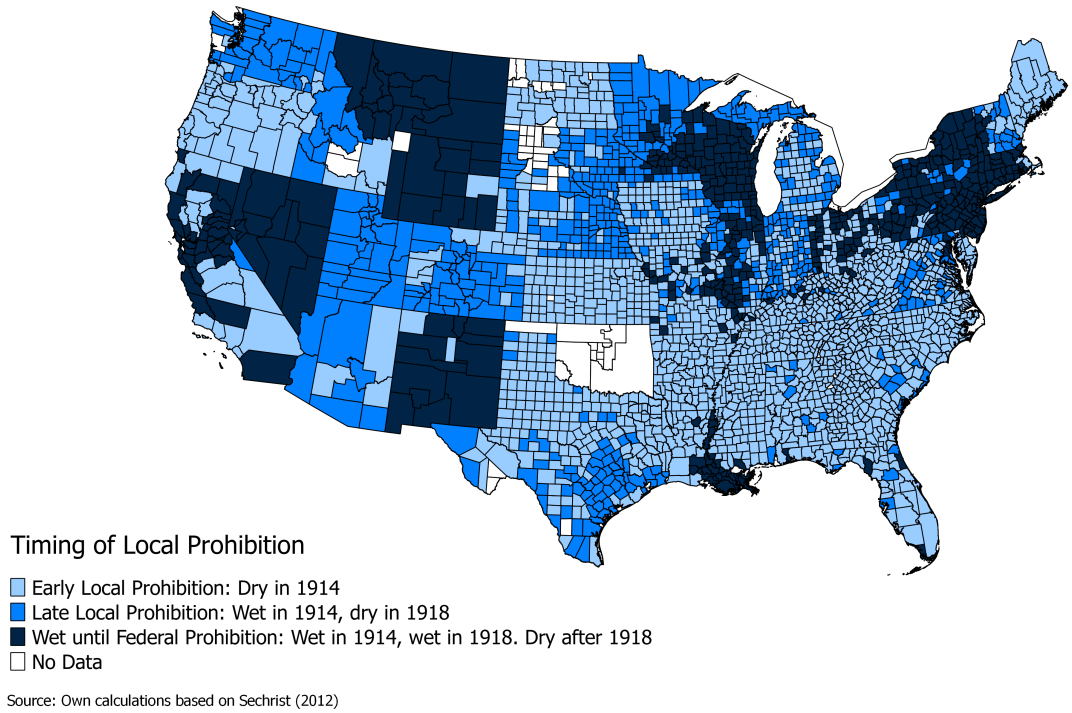


Figure 2: Gradual advance of prohibition over space and time

decided to illegally ship their beer, the costs of evading the Law and the disappearance of the main distribution channel at destination —the saloon— implied a reduction in demand.

The effect of local prohibition on demand was acknowledged by the brewers themselves. For example, the third vice-president of Anheuser-Busch blamed local prohibition as the cause of the reduction in sales between 1913 and 1914 (Plavchan, 1969, p. 133) In 1916, Anheuser-Busch released a nonalcoholic cereal beverage made with barley malt, rice, hops, yeast and water —the same ingredients as beer. The company spent 15 million dollars developing this new product (Plavchan, 1969, p. 163)[23] The empirical section of this paper shows that, more generally, breweries affected by local prohibition were more likely to buy machinery that could be used in the production of other products.

Federal prohibition began in December 1918, when a national ban on beer production came

or District of the United States, or place noncontiguous to, but subject to the jurisdiction thereof, is hereby prohibited." Webb-Kenyon Act of 1913.

[23]About 212 million dollars of 2013, using the Historical Consumer Price Index for all Urban Consumers.

into effect (Arnold and Penman, 1933, p. 178).[24,25] Although breweries were not allowed to produce beer, they were still allowed to sell their inventories. However, after July 1919, breweries were not allowed to sell beer either (idem, p. 171). Federal prohibition became permanent in January 1920, when a constitutional amendment banned "the manufacture, sale, or transportation of intoxicating liquors within, the importation thereof into, or the exportation thereof from the United States and all the territory".[26,27] federal prohibition lasted for 14 years, until it was repealed in 1933 by a new constitutional amendment.[28]

Federal prohibition had a substantial impact on brewery survival. Most exit decisions took place during the early years of federal prohibition: Out of the 1091 breweries alive in 1918, only 561 survived to 1923, and 517 survived until the end of prohibition, in 1933.

Most surviving breweries switched to products that shared inputs with the production of beer, like cereal beverages, sodas, malt extract and ice cream.[29,30] By 1923, 58 percent of breweries were producing cereal beverages, 35 percent were producing soft drinks and only 5 percent were idle.[31,32,33] The low percentage of idle plants suggests that breweries in 1923

[24] The efforts of the Temperance Movement towards federal prohibition had started in 1913, when the Anti-Saloon League —the leading temperance organization— made a series of organizational changes towards that goal (Kerr, 1985). The efforts, including a failed attempt at changing the constitution in 1914, were unsuccessful until the entrance of the US into World War I. The war switched public opinion against industries related to German immigrants, like the brewing industry.

[25] The original purpose of the ban had been to save cereal towards the war effort. However, the ban entered into effect one month after the signature of the Armistice with Germany and was formally kept in place until the start of Federal Prohibition on the grounds that the mobilization of troops had not ended yet.

[26] Eighteenth Amendment to the United States Constitution. The Amendment was passed by the Senate in August 1917, was passed by the House of Representatives on December 1917, was ratified by the states in January 1919 and entered into effect in January 1920

[27] The Volstead Act (1919) defined intoxicating liquor as any beverage containing more than 0.5% alcohol

[28] Repeal was the consequence of a gradual change in public opinion driven by the disastrous consequences of Prohibition on crime and law enforcement (García-Jimeno, 2015)

[29] The production process for cereal beverages largely overlapped with the production process for beer. For example, one techinque involved producing beer first, and then extracting the alcohol with a dealcoholizing plant. The production of sodas used the same bottling equipment as the production of beer. The production of malt extract involved the same malting process as the production of beer. Ice cream production made use of the refrigeration equipment used for the lagering and transportation of beer

[30] For example, Anheuser-Busch (Plavchan, 1969, p. 154)

[31] Plants are considered idle if they were not manufacturing goods, but had not disposed of their equipment yet.

[32] Own calculations from H.S. Rich & Co. (1923)

[33] That year, the output of cereal beverages containing less than one percent of alcohol by volume was 5.3

saw federal prohibition as a permanent shock.

Illegal brewing had, if anything, a negative impact on the survival of pre-prohibition breweries. The illegal alcohol market was ultimately dominated by new entrants with comparative advantage in evading the law, rather than by the highly visible pre-prohibition brewers. Bootleggers received high profit rates —1.150% in Chicago, according to contemporary accounts (Beman, 1927, p. 106)— but also faced high probabilities of closing down by the force of other bootleggers or the State. The risk was particularly high during the initial years of federal prohibition, when the law was enforced the most (García-Jimeno, 2015). Just in 1921, 125 cereal beverage producers were placed under seizure for violations of the law.[34]. In any case, most alcoholic beer was not manufactured by bootleggers, but brewed at home by the consumers themselves (Ronnenberg, 1998)

When federal prohibition ended in 1933, breweries started producing beer again. The end of federal prohibition was accompanied by the adoption of the beer can (McGahan, 1991).[35] Before Prohibition, breweries did not can their beer due to technical problems.[36] These problems were solved in 1933 (Maxwell, 1993). Four years later, in 1937, 9 percent of the breweries were already canning their beer. Cans be used to produce sodas as well, so breweries that were already producing soda had a larger incentive to adopt canning [The empirical implications of this incentive will be checked in the empirical section of future versions of this paper].

This historical overview shows that breweries adapted to prohibition by switching to other products. Two major empirical questions remain: i) Did Local Prohibition increase the resilience of breweries to Federal Prohibition? (and how?). ii) Did Local Prohibition influence

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million barrels (Bureau of Internal Revenue, 1923)

[34](Bureau of Internal Revenue, 1922, p. 31)

[35]Beer cans reduce transportation costs because they weight less, are easier to keep cool and block the light better than bottles. Furthermore, unlike bottles, beer cans are not returned to the brewery to be recycled (McGahan, 1991)

[36]The metal in pre-prohibition cans reacted with the beer, altering its flavor. Furthermore, cans were not capable to withstand the pressure induced by pasteurization (Maxwell, 1993)

the adoption of canning after Federal Prohibition ended? (and how?).

5 Theoretical Framework

This section provides a dynamic model in which multi-product firms experience shifts in the demand for their products. An initial demand shift leads firms to diversify and diversification increases the probability that they survive future demand shifts. The model provides a testable implication that cannot be generated by selection alone (i.e. the exit of the least productive firms on the basis of exogenous productivity), but can be generated by adaptation (i.e. irreversible investments that endogenously increase the survivability of firms). This testable implication guides the empirical analysis of the remaining sections of this paper.

The model has two periods: $t \in \{1, 2\}$. Each period, firms can manufacture two products: the main product –which I call beer (b)– and the alternative product –which I call soda (d, for soft drink). For simplicity, I assume that each firm is a monopolist on a variety of each of the products. The inverse demand for product k that firm i experiences in period t is given by the function $p(q_{k,i,t}; a_{k,t})$, which is decreasing in the quantity produced ($q_{k,i,t}$) and increasing in a demand shifter ($a_{k,t}$) that is common across firms but changes over time. We can think of prohibition as shifting the demand for beer by reducing $a_{b,t}$. Each period, $a_{b,t}$ is randomly drawn from a support that contains three values: high (α_H), medium (α_M) and low (α_L). In contrast, the demand shifter for soda is fixed over time at a lower-medium level ($a_{d,t} = \alpha_D$, with $\alpha_L < \alpha_D < \alpha_M$).

Firms differ in their marginal costs of production. In particular, the marginal costs for firm i are constant, equal across products, fixed over time, and heterogeneous across firms ($c_{b,i} = c_{d,i} = c_i$). The cumulative distribution of marginal costs across firms is strictly increasing. In addition to the marginal costs, firms pay a fixed cost every period (f). This fixed cost incorporates maintenance costs (e.g. \$3,000 at one of Anheuser-Busch's bottling plants in 1918), as well as the opportunity cost of firm resources with market value (e.g. the alternative uses of the entrepreneur's time). The heterogeneity in marginal costs, together with the fixed cost, incorporates a selection mechanism into the model: reductions in demand induce the exit of those firms with the largest marginal costs.

Firms have a limited capacity that must be shared across product lines. In particular, $q_{b,i,t} + q_{d,i,t} \leq \overline{q}$. One can think of this restriction as the result of scarce resources within the firm that have rival uses across product lines, like a plant that can be used for bottling beer or soft drinks, or the limited time of the entrepreneur. The shadow value of these resources decreases when de production of a given good decreases. As a result, the (marginal) opportunity cost of producing soda falls when the production of beer falls. This limited capacity restriction incorporates the concept of non-scale resources used by the management literature (Helfat and Eisenhardt, 2004; Levinthal and Wu, 2010). Because capacity cannot be sold, one can also think of this restriction as incorporating trapped factors of production as in Bloom et al. (2014).

In order to enter the soda market for the first time, firms pay a non-recoverable diversification cost denoted by (ρ). The payment of this cost can represent the irreversible investments that firms make in soda-specific machinery and distribution methods. For example, Anheuser-Busch used de-alcoholization machines to produce Budweiser near-beer in 1920 (Plavchan, 1969). These machines had few alternative uses other than the production of near-beer.

At the start of each period, the firm observes its survival status at the end of last period, whether it already paid the diversification cost, and the current demand shifter for beer. Each period, the firm makes three choices in order to maximize profits. If the firm is still alive, the firm chooses whether to close down or survive. Exit is irreversible. If the firm has not paid the diversification cost yet, the firm chooses whether to remain specialized on beer or enter the soda market by paying the diversification cost. Finally, the firm chooses how much to produce of each good.

The essence of the model comes from the interaction between two forces. On the one hand, the fixed cost (f) generates economies of scope between the main and the alternative products.[37] On the other hand, the limited plant capacity induces firms to specialize when the demand for beer is high, because the opportunity of producing soda is too high in that case.[38] Whether the firm diversify, specialize or exit, depends on its exogenous endowment of marginal costs (c) and the evolution of demand. Because diversification requires irreversible investments, the history of demand reductions influences the survival of firms in the future.

Let $\pi_S(a_{b,t}, c_i)$ denote the static profits of a firm that has not paid the diversification cost, and therefore can only produce beer in a given period.[39] Let $\pi_D(a_{b,t}, c_i)$ denote the static profits of a firm that has already paid the diversification cost, and therefore can produce both beer and sodas in a given period.[40] In period 1, a firm choose to diversify, specialize or exit depending on whether the following conditions hold:

$$\pi_D(a_{b,1}, c_i) + E_{a_{b,2}}\left[\pi_D(a_{b,2}, c_i)\right] - \rho \geq \pi_S(a_{b,1}, c_i) + E_{a_{b,2}}\left[max\{\pi_S(a_{b,2}, c_i), \pi_D(a_{b,2}, c_i) - \rho\}\right] \quad (1)$$

$$\pi_D(a_{b,1}, c_i) + E_{a_{b,2}}\left[\pi_D(a_{b,2}, c_i)\right] - \rho \geq 0 \quad (2)$$

$$\pi_S(a_{b,1}, c_i) + E_{a_{b,2}}\left[\pi_S(a_{b,2}, c_i)\right] \geq 0 \quad (3)$$

[37] Under regularity conditions, economies of scope are equivalent to the existence of sharable inputs between products (Panzar and Willig, 1981)

[38] Teece (1980) presents a more detailed discussion on how the gains from diversification are limited by congestion and transaction costs within the firm.

[39] $\pi_S(a_{b,t}, c_i)$ is given by:

$$\begin{aligned} \pi_S(a_{b,t}, c_i) \;=\; & \max_{q_b} \quad p(q_b; a_{b,t})q_b - c_i q_b - f \\ & \text{s.t.} \quad q_b \leq \overline{q} \end{aligned}$$

[40] $\pi_D(a_{b,t}, c_i)$ is given by:

$$\begin{aligned} \pi_D(a_{b,t}, c_i) \;=\; & \max_{q_b, q_d} \quad p(q_b; a_{b,t})q_b - c_i q_b + p(q_d; a_d)q_d - c_i q_d - f \\ & \text{s.t.} \quad q_b + q_d \leq \overline{q} \end{aligned}$$

In condition 1, the profits under diversification are larger than the profits under specialization. In condition 2, the profits under diversification are positive. In condition 3, the profits under specialization are positive. If conditions 1 and 2 hold, the firm pays the diversification cost and survives by producing both products in each period. If condition 1 does not hold, but condition 3 holds, the firm survives, specializes in beer and does not pay the diversification cost. If conditions 2 and 3 do not hold, the firm closes down.

Because profits from both soda and beer are decreasing in marginal costs, conditions 1 - 3 define thresholds of marginal costs below which firms choose to survive and diversify. These thresholds depend on the level of demand in period 1. If beer demand is high enough, the [marginal] opportunity cost of producing soda is too high, and most firms specialize in beer. Decreases in beer demand liberate resources, reducing the [marginal] opportunity cost of producing soda for diversified firms, and increasing the threshold under which condition 1 holds. However, reductions in demand also decrease the threshold under which the survival condition (2) holds. For high and medium levels of demand, the first effect dominates and there is an increase in the share of firms that diversify, unconditional on survival. For low levels of demand, the second effect dominates and there is a decrease in the share of firms that diversify, unconditional on survival.

In what follows, I discuss the effect of sequential reductions in beer demand on the investment and survival decisions of firms. In particular, I compare two scenarios. In the first scenario, firms experience an initial reduction in beer demand from α_H to α_M, followed by a further reduction in beer demand from α_M to α_L (i.e. $a_{b,1} = \alpha_M$ and $a_{b,2} = \alpha_L$). This scenario represents the demand sequence experienced by breweries affected by local prohibition in other counties. In the second scenario, firms do not experience an initial reduction in beer demand, and instead experience a large reduction in beer demand from α_H to α_L in period 2 (i.e. $a_{b,1} = \alpha_H$ and $a_{b,2} = \alpha_L$). This scenario represents the demand sequence experienced by breweries not affected by local prohibition. In both scenarios, the demand for sodas remain fixed at $a_{d,t} = \alpha_D$. I show that the gradual reduction in beer demand (first scenario) generates higher two-period survival rates than the sudden reduction in beer demand (second scenario). The appendix provides restrictions in the functional form of the demand function, as well as the parameters, for the increased survival to hold.[41]

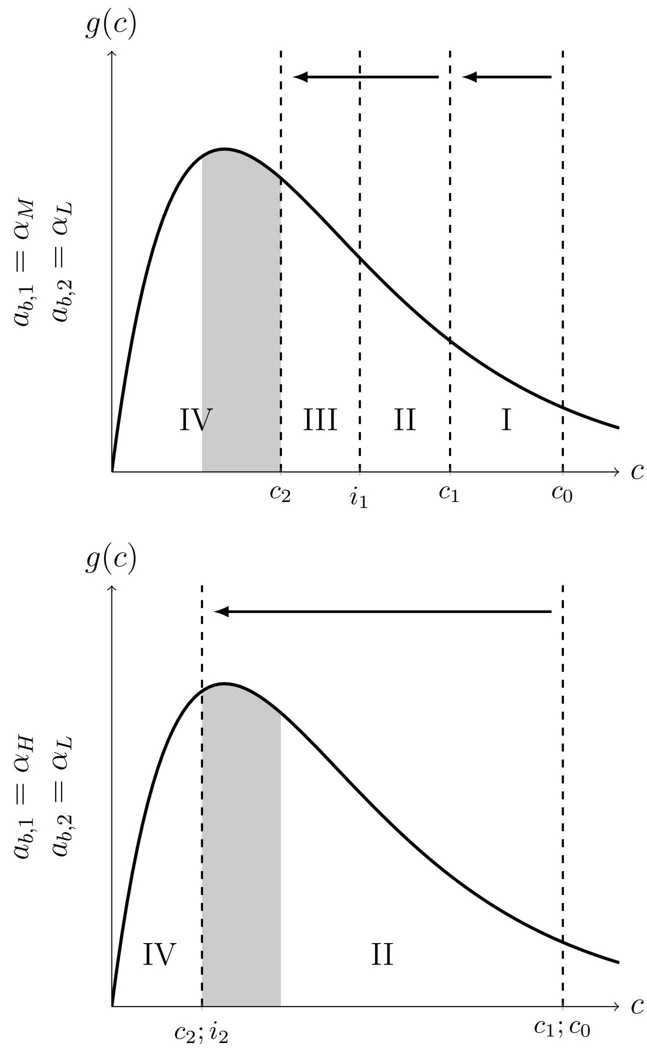
Figure 3 illustrates how survival in period 2 depends *both* on the level of demand experienced by the firm in period 1 and the exogenous marginal costs of the firm. The top plot represents the effect of a gradual reduction of demand, with $a_{b,1} = \alpha_M$ and $a_{b,2} = \alpha_L$. When demand falls from α_H to α_M in period 1, three outcomes can occur. Firms to the right of c_1 close down because profits from the beer market are not enough to cover the fixed cost for those firms (area I). Firms between c_1 and i_1 survive by specializing in beer (area II). For those firms, profits from the beer market alone are large enough to cover the fixed cost, but profits from the soda market are not large enough to cover the diversification cost.[42] Finally, firms to the left of i_1 pay the investment cost and survive by producing both beer and soda (areas III and IV). For these firms, profits in the soda market over two periods are large enough to cover the diversification cost.

When demand falls to a low level in period 2 ($a_{b,2} = \alpha_L$), variable profits from the beer market are too low to compensate for the fixed costs of the firms. Hence, firms can survive only by entering the soda market. Firms with large marginal costs close down, including the beer-specialized firms (area II) and a subset of the diversified firms (area III). Only firms

[41]The main restriction on the demand function is to be additively separable on the demand shifter. This restriction simplifies the expressions that result from the application of the envelope theorem on the profit functions when finding derivatives. Most results are based on the following (derived) properties of the static profit functions, which allow for single-crossing conditions throughout the proof:

$$\frac{\partial \pi_S}{a_b} \geq \frac{\partial \pi_D}{\partial a_b} \geq 0$$
$$\frac{\partial \pi_D}{\partial c_i} \leq \frac{\partial \pi_S}{\partial c_i} \leq 0$$

[42]For low values of (α_M), firms can only survive by diversifying, so area II is empty. In this case, the main testable implication on survival in the second period still holds. However, because multiple breweries survived local prohibition while still specializing in beer production, I ignore this case in the discussion.



Shaded area: share of additional breweries that survive due to an early reduction in demand

Figure 3: Survival pattern of breweries, if adaptation is allowed

with low marginal costs remain alive. The survival rate over both periods is given by area IV.

The bottom plot of figure 3 represents the decisions of firms that experience high demand in the first period, followed by a sudden reduction in demand in the second period ($a_{b,1} = \alpha_H$ and and $a_{b,2} = \alpha_L$). When demand in period 1 is high, surviving firms specialize in beer because the [marginal] opportunity cost of producing soda is too high. During period 2, the least productive firms exit (area II), whereas the most productive firms pay the investment cost and survive by producing both goods. The survival rate over both periods is given by area IV.

Figure 3 also shows that there is a set of firms that survive period 2 if $a_{b,1} = \alpha_M$, but close down if $a_{b,1} = \alpha_H$. Firms under the shaded area diversify when $a_{b,1} = \alpha_M$ in period 1. When demand is low during the second period, the diversification cost is already sunk so the firm does not have to pay it in order to survive. In contrast, the same firms do not diversify when $a_{b,1} = \alpha_H$ in period 1, because the opportunity cost of producing soda is too high in that period. These firms close down during period 2 because the variable profits from both markets are not enough to cover both the fixed cost and the investment cost. Hence, under certain values of the parameters, the share of firms that survive over both periods (area IV) is higher when $a_{b,1} = \alpha_M$ than when $a_{b,1} = \alpha_H$:

$$P\left(S_2 = 1 \mid a_{b,1} = \alpha_M \cap a_{d,2} = \alpha_L\right) > P\left(S_2 = 1 \mid a_{b,1} = \alpha_H \cap a_{d,2} = \alpha_L\right) \tag{4}$$

Testable implication (4) is the result of adaptation, and does not occur when firms select exclusively on the basis of exogenous marginal costs. To show this, I shut down the investment channel in the model by setting $\rho = 0$ or $\rho \to \infty$. In the first case, diversification is costless. In the second case, firms are unable to diversify because it is too expensive. In both cases, the early exit of firms with large marginal costs still occurs. Yet, implication (4) does not hold. When no adaptation is at work, the only effect of the initial demand reduction is to induce an early exit of firms that would have exited during the second demand reduction in any case (i.e. the firms with large marginal costs). The initial reduction in demand does not change the behaviour of firms in the second period. Hence, when no adaptation is at work, overall survival is not affected by the existence of an initial reduction in demand.

Figure 4 illustrates the survival decisions of firms in the absence of adaptation. In the top plot, an initial demand reduction shifts the cost threshold to the left, inducing the exit of

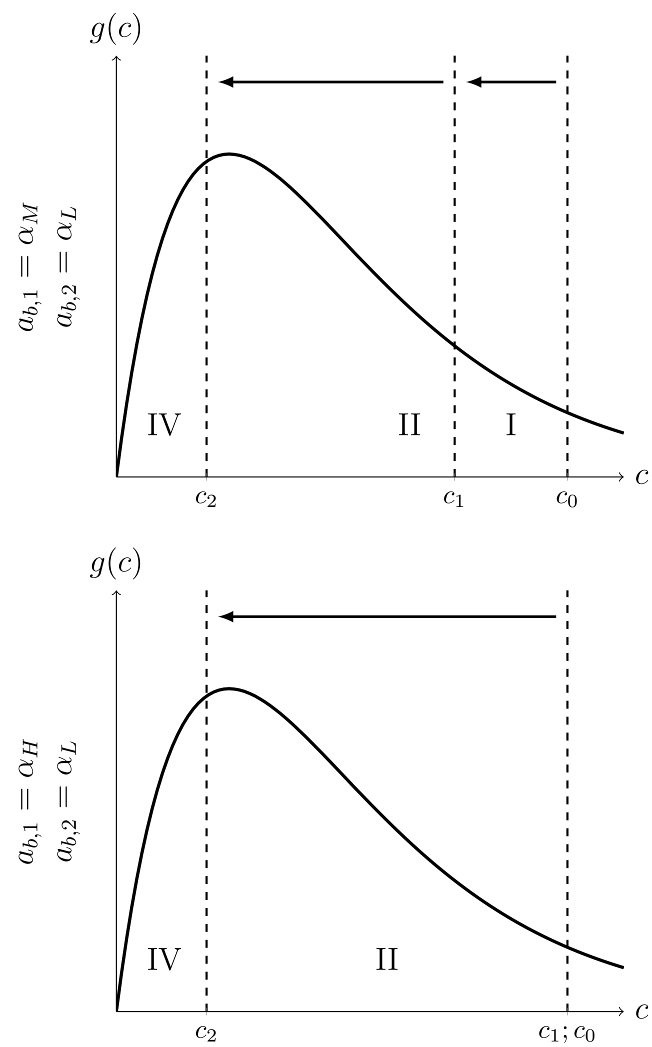


Figure 4: Survival pattern of breweries, if adaptation is not allowed

firms. A subsequent demand reduction shifts the threshold further, inducing the exit of more firms. The fraction of firms that survive both periods is given by area IV. In the bottom plot, there is no initial reduction in demand. During period 2, a large reduction in demand shifts the survival threshold to the left, inducing the exit of firms. Because there are no irreversible investments, the threshold of survival at the end of period 2 does not depend on the level of demand in period 1. Hence, the fraction of firms that survive both periods (area IV) is the same in both plots, and implication (4) does not hold. It is still true that, conditional on survival in period 1, the probability of survival is higher when firms experience an initial reduction in demand (area IV divided by area II). However, the probabilities in implication (4) are *unconditional* on survival in period 1 (area IV). In the absence of adaptation, the unconditional probability of survival does not change when firms experience an initial reduction in demand.

The theoretical model in this section shows that firms adapt to reductions in demand by switching to other products. When switching to other products requires irreversible investments, these investments make firms more likely to survive future reductions in demand. In fact, overall survival can increase, as stated in implication (4). In contrast, when adaptation through irreversible investments is not allowed, implication (4) does not hold. The remaining sections of this paper show that implication (4) holds for the American brewing industry during the Prohibition era. This result, together with additional evidence from machine acquisition and product switching, confirms that adaptation was an important determinant of brewery survival during prohibition

6 Empirical Strategy

In the theoretical model from last section, initial shifts in demand induce changes in the capital structure and product scope, which can help firms survive later demand shocks. Local prohibition induces variation in demand over time and across breweries, providing an experimental setting to test the predictions from the theoretical model.

Local prohibition shifted the demand experienced by breweries *in wet counties*, because they could not ship beer *to dry counties* any more.[43,44,45] The impact of this shift is heterogenous

[43] More precisely: given a price schedule across markets, breweries would sell less beer during local prohibition than before local prohibition. Alternatively: during local prohibition, breweries would need to reduce their prices in wet markets in order to sell the same quantity as before local prohibition.

[44] Even though breweries were not able to sell beer in dry counties, they were still able to buy inputs from there. For example, breweries continued to buy hops from the Pacific Coast, even though most hops producing areas had became dry by 1916. By the time of local prohibition, the Pacific was already the leading hops-producing area in the United States (Edwardson, 1952)

[45] As mentioned in the historical framework, local prohibition induces reductions in demand even if breweries smuggle beer to dry counties, due to the costs of evading the Law and the disappearance of the main

across breweries, because the transportation costs to dry counties are heterogeneous as well. A measure of the reduction in demand, therefore, has to take into account both the decisions of the newly dry counties and the transportation costs from the breweries to those counties.

I measure the size of the demand shift at the county level by estimating the effect of local prohibition in surrounding areas on market access. Market access is a measure of total potential demand that is commonly used in the economic geography literature (Harris, 1954; Head and Mayer, 2004). In trade models of differentiated products with CES preferences across varieties and economies of scale (e.g. Redding and Venables, 2004), changes in market access summarize the demand shifts that occur across different locations in space.[46] Following Donaldson and Hornbeck (2015), my empirical implementation of market access is a sum of populations across counties, where each county is weighted by a function of its transportation cost to the county where the brewery is located. However, I adapt their implementation of market access for the purposes of this paper. In particular, I only include wet counties as destinations in the calculation, because beer could only be sold in wet counties.[47] In addition, I include the "home" county in the calculation, because the local market was an important sales destination for most breweries.[48] In consequence, the *Wet Market Access (WMA)* for breweries located in county i in year t is defined as:

$$WMA_{i,t} = \sum_{j \in J} \left(\frac{Pop_{j,t}}{\tau_{h,i}^{\theta}} \right) (Wet_{j,t}) \tag{5}$$

where J is the set of counties in the US, $Pop_{j,t}$ is the population in county j in year t, and $Wet_{j,t}$ is a binary variable that takes the value of one if county j was wet in year t and zero otherwise. $\tau_{i,j,t}$ is the iceberg transportation cost between county i and county j in 1890, as

distribution channel at destination —the saloon.

[46]The formula for market access can also be derived from models with homogeneous products and productivity heterogeneity across firms (as in Donaldson and Hornbeck, 2015)

[47]I consider the effects of beer smuggling on my estimates below

[48]I assume that distributing beer within counties is costless, so the iceberg transportation cost from a county to itself is one.

estimated by Donaldson and Hornbeck (2015) In trade models with product differentiation, CES preferences across varieties, and economies of scale, the structural interpretation of θ is one minus the elasticity of substitution between the different varieties of the good.[49] Hence, θ is negatively related to product differentiation in the industry of interest. With large numbers of varieties, like in the beer industry, θ can be estimated as the elasticity of trade with respect to trade costs. For my empirical application, I use $\theta = 2.55$, which is the estimate of Caliendo and Parro (2015) for the food industry. Note: For the estimations in this draft I actually used $\theta = 4$. I will update my estimations; I don't think things will change, but we will see.

Wet market access can change over time for three reasons: changes in transportation costs, changes in population, and changes in the dry status of counties. Because late local prohibition only lasted four years, I assume that transportation costs do not change. In that case, changes in market access for breweries located in county i between year s and year t can be decomposed as follows:

$$\begin{aligned}
\Delta_{st} WMA_i = & \left. \begin{aligned} & -\sum_{j \in J} \left[\frac{Pop_{j,s}}{\tau_{i,j,s}^{\theta}} \right] Wet_{j,s} \left(1 - Wet_{j,t}\right) \\ & + \sum_{j \in J} \left[\frac{Pop_{j,t}}{\tau_{i,j,t}^{\theta}} \right] \left(1 - Wet_{j,s}\right) Wet_{j,t} \end{aligned} \right\} \begin{array}{c}\text{Change due to} \\ \text{Local} \\ \text{Prohibition}\end{array} \\
& + \sum_{j \in J} \left[\left(\frac{Pop_{j,t}}{\tau_{i,j,t}^{\theta}} \right) - \left(\frac{Pop_{j,s}}{\tau_{i,j,s}^{\theta}} \right) \right] Wet_{j,s} Wet_{j,t} \Big\} \begin{array}{c}\text{Change due to} \\ \text{population} \\ \text{growth}\end{array}
\end{aligned} \tag{6}$$

The first line is the decrease in market access induced by counties that switched from wet to dry between periods s and t. 615 counties (j) switched from wet to dry between 1914 and 1918. The second line is the increase in market access induced by counties that switched from dry to wet between periods s and t. Only 52 counties (j) switched from dry to wet between 1914 and 1918. The sum of the first and second line is the change in market access

[49] In models with homogeneous products and productivity heterogeneity (e.g. Eaton and Kortum, 2002; Donaldson and Hornbeck, 2015), θ is a parameter that is inversely related to the spread of the distribution of productivities

induced by local prohibition, keeping population constant. The third line is the increase in market access induced by population growth in counties (j) that remained wet throughout the period. 489 counties remained wet throughout the period.[50]

Local prohibition induced large reductions in market access for the counties that remained wet between 1914 and 1918. All wet counties (489) experienced reductions in wet market access due to local prohibition, and 408 counties experienced overall reductions in wet market access. On average, wet counties lost 11% of their market access due to local prohibition and experienced a 9% reduction in their overall wet market access. At the brewery level, these average losses are 9% and 4%, respectively. Although all breweries experienced market access losses due to local prohibition, there is large variation across space in the intensity of the losses: 10% of breweries experienced losses in market access of 2% or less, whereas 10% of the breweries experienced losses in market access of 19% or more.[51]

My empirical strategy uses local prohibition as an instrument for decreases in market access, allowing for the estimation of the effect of decreases in market access on changes in the capital stock (i.e. investment), the product scope and the survival status of breweries. For each of these outcomes (which are changes in state variables), I estimate the following system of equations at the brewery level ($\text{Outcome}_{h,i}$ denotes the outcome of brewery h in county i):

$$\text{Outcome}_{h,i} = \beta_0 + \beta_1 \left[-\Delta_{14,18} ln\left(WMA_{h,i}\right)\right] + u_{h,i} \tag{7}$$

$$\left[-\Delta_{14,18} ln\left(WMA_{h,i}\right)\right] = \gamma_0 + \gamma_1 \left[-\frac{\text{Change due to local prohibition}_{h,i,14,18}}{WMA_{h,i,14}}\right] + v_{h,i} \tag{8}$$

where "$\text{Change due to local prohibition}_{h,i,14,18}$" is the component of the change in Wet Market Access (WMA) that was induced by local prohibition, as defined in equation (6). From

[50] 1570 counties, mostly rural and in the South, remained dry throughout the period

[51] At the brewery level, the descriptive statistics of the market losses due to local prohibition are as follows. Mean: 9%. Median: 7%. Standard deviation: 7%. Inter-quartile range: 10%. The map in Figure 5 (below) shows the spatial distribution of these losses.

now on, I refer to the instrument in equation (8) as "Market Access Lost to Prohibition". The endogenous variable $[-\Delta_{14,18} ln\left(WMA_{h,i}\right)]$ is the log-reduction in wet market access during the Local Prohibition period.

I conduct this estimation on a set of breweries that satisfies three conditions: (i) being alive at the start of local prohibition (1914) (ii) being located in counties that remained wet throughout local prohibition (1914-1918) and (iii) being a bottler of beer. I focus on bottlers because the reductions in market access caused by local prohibition only had a first order effect on breweries that shipped beer to other counties. As mentioned in the historical overview, non-bottlers distributed their beer exclusively in kegs and were mostly focused in local markets.[52] At the start of local prohibition, 71% of the brewers were bottlers.

The main object of interest in equations (7) and (8) is β_1: the effect of reductions in market access induced by local prohibition on the outcomes of interest. I examine the following outcomes:

Beer-specific investment (e.g. keg washer) during local prohibition. Binary variable that takes the value of one if the brewery acquired beer-specific machinery between 1914 and 1918, and zero otherwise. Following the theoretical model, the predicted value of β_1 is negative in this case: reductions in market access caused by local prohibition induce reductions on the investment in beer machinery during local prohibition.

Bottling investment during local prohibition. Binary variable that takes the value of one if the brewery acquired bottling machinery between 1914 and 1918, and zero otherwise. Bottling machinery can be used to produce both soda and beer. Following the theoretical model, the predicted value of β_1 is negative in this case: reductions in market access caused by local prohibition induce reductions on the investment in bottling machinery during local prohibition.

[52] In the next section, I show that local prohibition had no effect *within* the set of non-bottlers, as expected

Soda-specific investment (e.g. carbonator) during local prohibition. Binary variable that takes the value of one if the brewery acquired soda-specific machinery between 1914 and 1918, and zero otherwise. Following the theoretical model, the predicted value of β_1 is positive in this case: reductions in market access caused by local prohibition induce increases on the investment in soda machinery during local prohibition.

Soda production during federal prohibition.[53] Binary variable that takes the value of one if the brewery produced sodas in 1923, and zero otherwise. Following the theoretical model, the predicted value of β_1 is negative in this case: reductions in market access caused by local prohibition induce increases on the probability that a brewery will produce sodas during federal prohibition.

Overall survival: Binary variable that takes the value of one if the brewery survived between 1914 and 1933, and zero otherwise. The variable is named "overall survival" because the period 1914-1933 covers *both* Local and federal prohibition. β_1 can be positive thanks to the investments of firms during local prohibition. This is, adaptation can increase the probability that a brewery will survive the *joint* period of Local and federal prohibition. Very importantly, the sample is the set of breweries alive in 1914 (at the start of local prohibition), as opposed to the set of breweries alive in 1918 (at the start of federal prohibition).

The system of equations (7) and (8) is identified as long as the share of market access lost to local prohibition is uncorrelated with the error term $u_{h,i}$. In order to examine the plausibility of this assumption, consider the variables included in $u_{h,i}$ when the outcome of interest is overall survival.

As suggested by the theoretical model, the main component of $u_{h,i}$ is the exogenous component of marginal costs/productivity of firm h at the start of local prohibition. $u_{h,i}$ also contains variables that are not included in the theoretical model but that could plausibly in-

[53] I have found no evidence that breweries were producing sodas before the start of local prohibition. For example, Anheuser Busch released its cereal beverage —Bevo— in 1916 (Plavchan, 1969, p. 160)

fluence survival, like the liquidity constraints that the firm faces and the prices of production inputs. A necessary condition for identification is, therefore, that changes in local prohibition *in other counties* are not correlated with these variables. In what follows, I argue that, in my setting, the potential violations of this condition drive the estimate towards zero. Hence, my estimates are a lower bound of the (positive) effects of local prohibition on the overall survival of firms.

The map in Figure 5 shows, at the county level, the reduction in market access induced by local prohibition decisions in other counties (illustrated via shading). The size of each bubble also shows the number of breweries in each county. One possible source of concern is that local prohibition had a *smaller* impact in counties with large home markets, because home markets cushioned breweries from the local prohibition decisions of other counties. Home market size might be positively correlated with the productivity of breweries due to the pro-competitive effects of larger markets, lower financial constraints, or economies of agglomeration. In all those cases, counties with large home markets will tend to have the most productive firms. Hence, local prohibition might have had the lowest impact in those counties with the most productive firms. This would generate a negative correlation between the instrument in Equation 8 and the error term in Equation 7 This negative correlation would asymptotically bias the estimate of β_1 downwards (i.e. towards zero; given my prediction that β_1 is positive).

Another possibility is that the most productive breweries may have had larger resources to make political lobby against local prohibition in nearby counties. In this case, market loss due to local prohibition would be negatively correlated with productivity. Again, this would bias the estimate of β_1 downwards (i.e. towards zero; given my prediction that β_1 is positive).

In order to check for other possible sources of endogeneity, I also run a placebo test by estimating the model from equations (7) and (8) on the sample of non-bottlers. Supply side factors —like within-county changes in input markets— have an effect in both bottlers and non-bottlers. In contrast, local prohibition should not have an effect on the demand

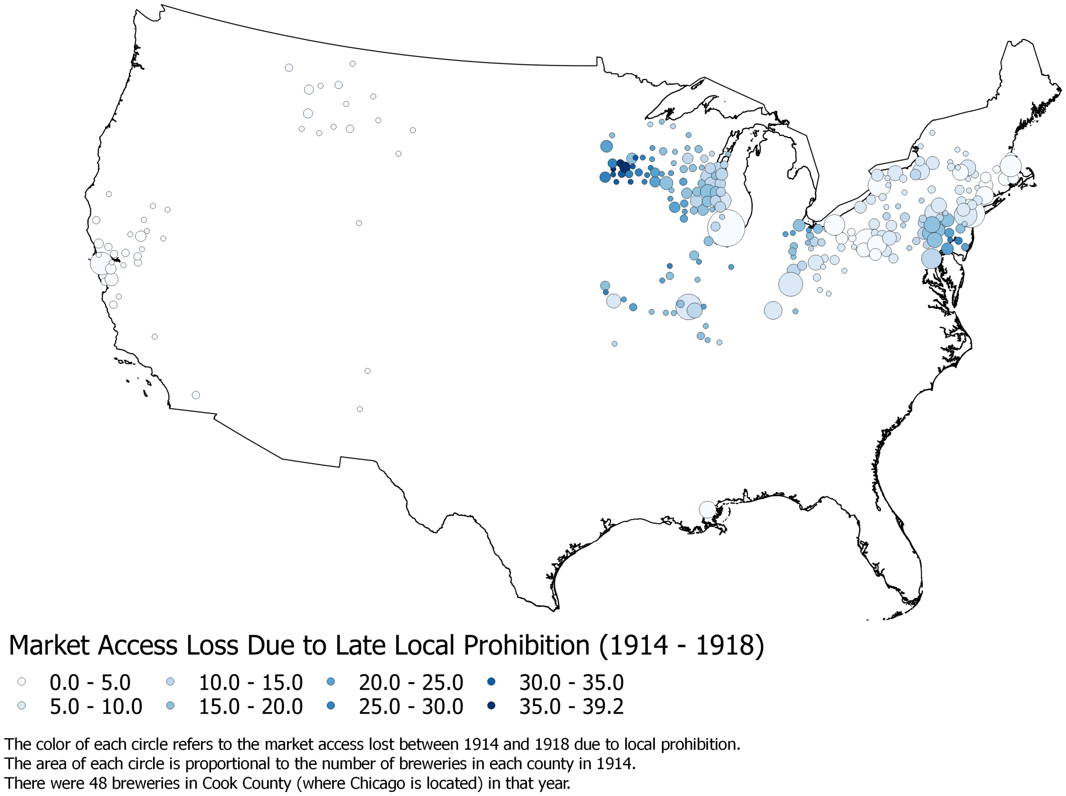


Figure 5: Market Access Loss due to Prohibition, by county, 1914-1918

experienced by non-bottlers, because non-bottlers did not ship beer to other counties.[54] In consequence, any impact on the outcomes of non-bottlers would be the result of correlations between the instrument and the error term, or the result of second order, positive effects through the price of factors, as in Melitz (2003)[55] As it will shown below, local prohibition does not generate variation in outcomes within the set of non-bottlers. This suggests that the variation in outcomes within the set of bottlers is effectively generated by reductions in demand.

[54]Alternatively, the transportation costs for non-bottlers are too high, so my measure of market access should not be correlated with the demand experienced by non-bottlers.

[55]If my treatment was a discrete variable, the intuition of my placebo test would be the same as the intuition of a dif-in-dif-in-dif estimator, in which (i) the difference between breweries measures de intensity of the demand shift (ii) the difference across time controls for fixed characteristics of breweries and (iii) the difference between bottlers and non-bottlers controls for supply shocks that are common across both groups.

7 Results

Figure 6 provides estimates of the reduced-form effect of local prohibition on the investment, product mix and survival choices of the bottlers.[56] The results are based on a linear probability model estimated in the sample of bottlers that were alive at the start of local prohibition (1914). Regression tables, robustness exercises and probit estimates are shown in the appendix. All the results in Figure 6 are generated by variations in demand *within* the set of bottlers.

Compared with breweries that did not experience reductions in demand, breweries that experienced the average reduction in demand during local prohibition are less likely to invest in beer-specific machinery, less likely to invest in bottling (i.e. common-use machinery) and more likely to invest in soda-specific machinery during local prohibition. Furthermore, the same set of breweries is more likely to produce sodas during federal prohibition, and to survive the overall Prohibition period, including Local and federal prohibition. The latter result is remarkable: breweries that faced five additional years of hardship were 5 percentage points more likely to survive the entire period because they adapted earlier. This increase in survival represents 10% of the overall survival rate of the period. All the results are consistent with the predictions from the theoretical model.

In order to confirm that local prohibition affects outcomes through reductions in market access, I use the share of market access lost to local prohibition as an instrument for reductions in market access; and then estimate the effect of market access on investment, product-mix and survival. In particular, I estimate γ_1 and β_1 from equations (7) and (8) using a two-stage least-squares procedure on a linear probability model (the appendix shows robustness

[56] That is, the effect of loss of market access to local prohibition on each outcome, or an estimate of $\gamma_1\beta_1$ from equations 8 and 7. This term is obtained by replacing equation (8) into equation (7), which yields:

$$\text{Outcome}_{h,i} = \beta_0 + \gamma_0\beta_1 + \gamma_1\beta_1 \left[-\frac{\text{Change due to local prohibition}_{h,i,14,18}}{WMA_{h,i,14}} \right] + e_{h,i}$$

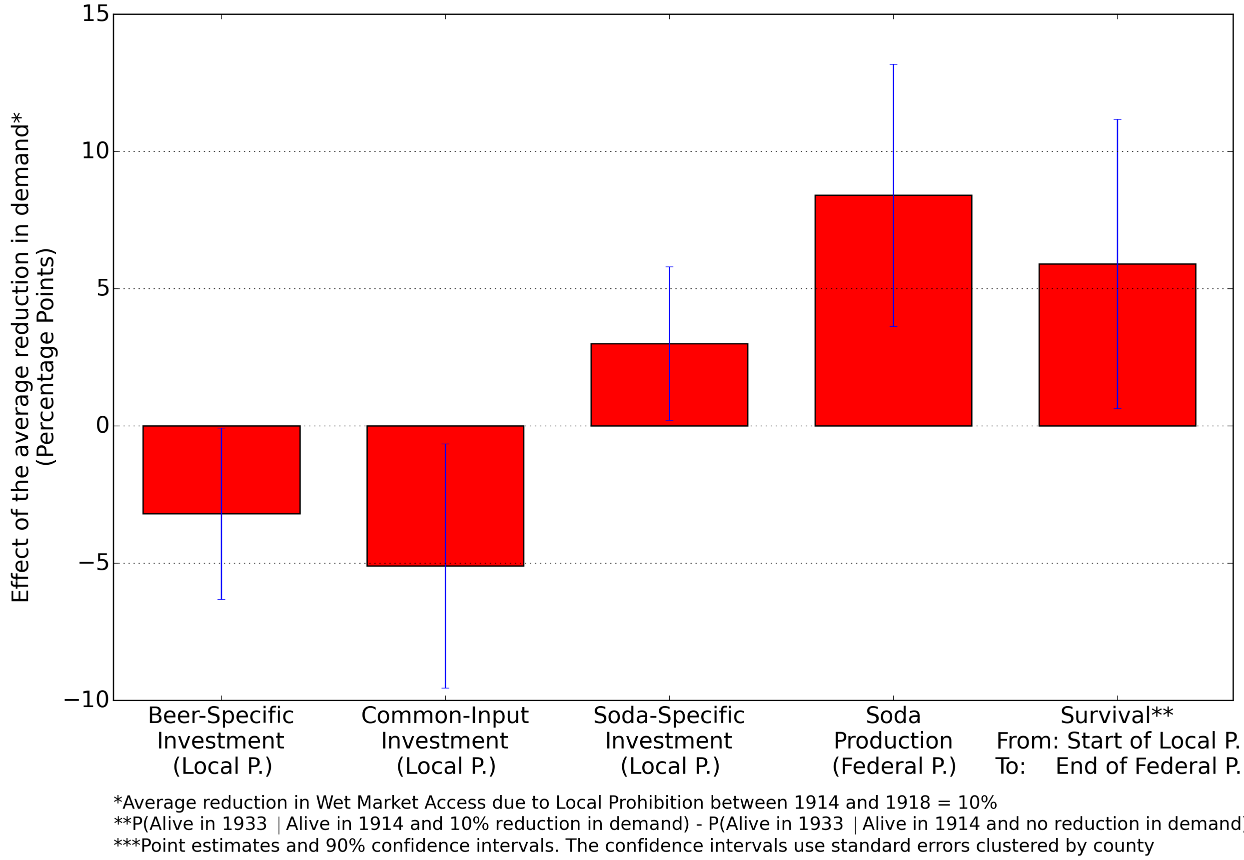


Figure 6: Effect of local prohibition on multiple outcomes for bottlers, 1914-1933

exercises, including maximum likelihood estimates of β_1 for a probit model).

Table 1 contains estimates of the first stage (equation 8) for both bottlers and non-bottlers.[57] In this section I focus on the results for bottlers —I will use the results for non-bottlers in the next section. The instrument is strong: the share of market access lost to prohibition have a large predictive power on log-reductions in market access. The variation in the instrument explains 89% of the variation in the endogenous variable and the F-statistic of the first stage is 881. Most of the variation in market access between 1914 and 1918 is due to local prohibition.

Table 2 shows that breweries that faced larger reductions in demand during local prohibition

[57]Note: In this version I show the table controlling for market size. In future versions I will show the table without controls, because endogenous controls may generate bias in the estimates. In any case, I will show the table with controls in the appendix.

Table 1: Dependent variable: ↓ Ln(Wet M. A.) (1914-1918)

	(1) Non-Bottler 1914	(2) Bottler 1914
Share of M.A. lost to proh. (1914-1918)	1.20***	1.22***
	(0.05)	(0.04)
Ln(Wet M. A.) (1914)	-0.01	-0.00
	(0.01)	(0.00)
Constant	0.05	-0.04
	(0.08)	(0.05)
Observations	193	511
R^2	0.888	0.883

First stage of the instrumental variables estimates
Breweries alive in 1914, in locations that were wet in both 1914 and 1918
Non-Bottler 1914: Subsample of breweries that were no bottlers in 1914
Bottler 1914: Subsample of breweries that were bottlers in 1914
Standard errors in parentheses and clustered by county
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

were less likely to invest in beer-specific capital or common-input capital, but more likely to invest in soda-specific capital during local prohibition. When federal prohibition arrived, these breweries were more likely to produce alternative products (sodas). Overall, breweries that faced larger reductions in demand during local prohibition were more likely to survive the whole period, including Local and federal prohibition.[58]

The results in this section all point in the same direction: bottlers adapted to local prohibition by investing in capital that provided flexibility later, when federal prohibition arrived. As a result, bottlers that faced reductions in demand during the local prohibition period were more likely to survive the whole period, including Local and Federal prohibitions.

[58]All dependent variables in table 2 only take the values of 0 or 1.

Table 2: Bottlers: Effect of reductions in market access

	Beer-Specific Investment (Local P.)	Common Input Investment (Local P.)	Soda-Specific Investment (Local P.)	Soda production (Federal P.)	Survival From: Start of Local P. To: End of Federal P.
↓ Ln(Wet M. A.) (1914-1918)	-0.27*	-0.42*	0.25*	0.69***	0.49*
	(0.15)	(0.22)	(0.14)	(0.24)	(0.26)
Ln(Wet M. A.) (1914)	0.04***	0.06***	-0.01	-0.03*	0.04**
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Constant	-0.35***	-0.48***	0.24*	0.63***	0.01
	(0.10)	(0.17)	(0.13)	(0.21)	(0.23)
Observations	511	511	511	511	511

Instrumental variables estimates. Instrument: Share of M.A. lost to proh. (1914-1918)

Breweries alive in 1914, in locations that were wet in both 1914 and 1918

Standard errors in parentheses and clustered by county

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

8 Placebo Test

My main results are generated by variations in demand within the set of bottlers. As a placebo test, I estimate the same models using the set of non-bottlers, to check whether changes within the set of non-bottlers generate the same results. Figure 7 provides estimates of the reduced-form effect of local prohibition on the investment, product mix and survival choices of the non-bottlers. The conclusion of Figure 7 is clear: Variations in demand induced by local prohibition had *no effect* in the investment, product-mix or survival decisions of non-bottlers. In addition, the null hypothesis of no effect cannot be statistically rejected. Non-bottlers were not affected by local prohibition in other counties because they did not ship beer to other counties in the first place. However, they were subject to the same-supply shocks as bottlers. The null-effect of local prohibition *within* non-bottlers suggests that the effect of local prohibition *within* bottlers was caused by changes in their demand.

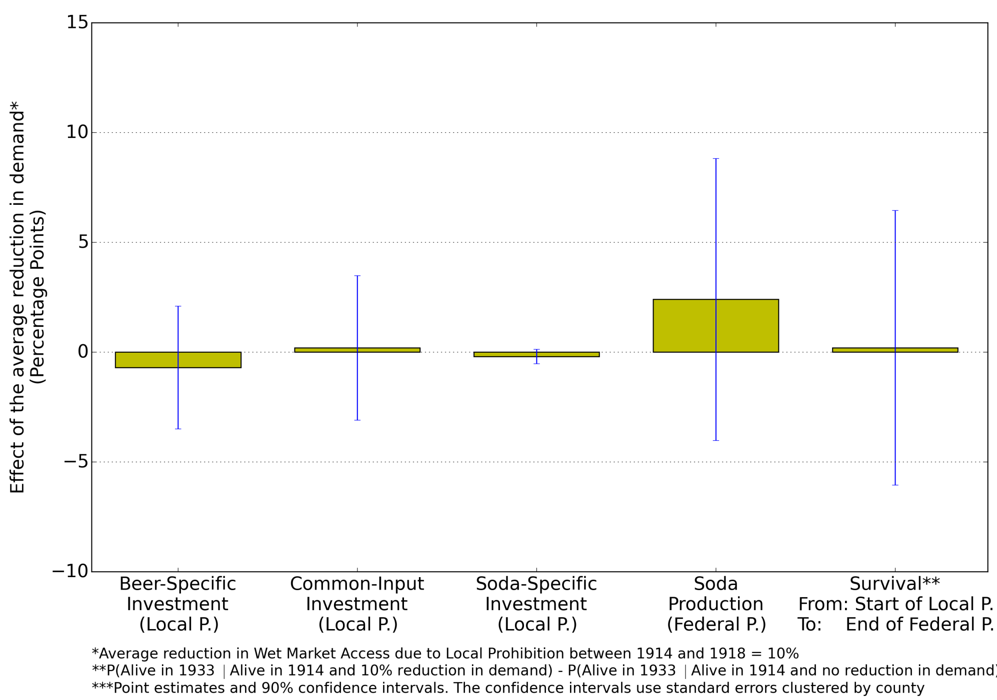


Figure 7: Effect of local prohibition on multiple outcomes for Non-bottlers, 1914-1933

9 Conclusions

This paper shows that demand reductions in the early history of a firm can affect its trajectory and response to future demand reductions. In particular, firms can become increasingly resilient to demand reductions over time. Increased resilience is the result of the adaptation mechanisms that firms use when demand falls (as opposed to selection of firms into or out of production). My natural experiment (local and federal prohibition of alcohol) and my brewery-level data-set are particularly suited for this task, because I can measure multiple shocks in demand over time and across firms. Furthermore, I can directly observe plant-level decisions in terms of investment, product-mix and survival, which allow me to follow the adaptation of firms throughout the shocks.

My mechanism is driven by an inter-temporal trade-off between the gains from specialization and the gains from diversification. This trade-off is the result of irreversible investments in a context of multi-product firms. Irreversible investments are common in many industries of today, like the aerospace industry (Ramey and Shapiro, 2001). Multi-product firms are also very common: firms that span multiple industries account for 81 percent of the manufacturing output and 28 percent of the number firms in the US (Bernard et al., 2010).[59] These industries can face reductions in demand due to regulation, trade policy and price changes for complementary and substitute goods.

My results suggest that increased gradualism in economic policy at the industry level can facilitate the adaptation of firms through product-switching. In consequence, increased gradualism can allow for higher survival rates in the industry directly affected by the policy, and increased competition in alternative industries not directly affected by the policy.

[59]Industries are defined as four-digit SIC categories in the US manufacturing census (ibid).

10 Appendix

To be written.

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