

Advertising and Demand for Addictive Goods: The Effects of E-Cigarette Advertising

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Abstract

Although TV advertising for traditional cigarettes has been banned since 1971, advertising for electronic cigarettes remains unregulated. The effects of e-cigarette ads have been heavily debated by policymakers and the media, though empirical analysis of the market has been limited. To analyze this question, I leverage access to county-level sales and advertising data on cigarettes and related tobacco products, along with detailed data on the consumption behavior of a panel of households. I exploit a discontinuity in advertising along television market borders to present descriptive evidence that suggests that e-cigarette advertising reduces aggregate demand for traditional cigarettes. Analyzing household purchase data, I find evidence of addiction and that individuals reduce their consumption of traditional cigarettes after buying e-cigarettes, further suggesting that the products are substitutes. I then specify a structural model of demand for cigarettes that incorporates addiction and allows for heterogeneity across households. The model enables me to leverage the information content of both datasets to identify variation in tastes across markets and the state dependence induced on choice by addiction. I show how the model can be estimated linking both datasets in a unified estimation procedure. Using the demand model estimates, I evaluate the impact of a proposed ban on e-cigarette television advertising. I find that in the absence of e-cigarette advertising, demand for traditional cigarettes would increase, suggesting that a ban on e-cigarette advertising may have unintended consequences.

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1 Introduction

Smoking cigarettes is still the leading cause of preventable death in the United States, killing more than 480,000 people a year. As a result, cigarette advertising remains a public health issue that is intensely debated by cigarette companies, policy makers, and academic researchers. Although all TV and radio advertising for traditional cigarettes has been banned since 1971, attention to the advertising ban has been renewed by the entry of e-cigarettes into the market. E-cigarettes first entered the US market in 2007 and quickly grew to become a \$2 billion industry by 2014 (Crowley (2015)). E-cigarette advertising does not fall under the tobacco advertising ban and thus remains unregulated. Advertising for e-cigarettes has proliferated in recent years on television, online, and in print media outlets. By 2013, e-cigarette marketing spending exceeded \$79 million with the majority of spending going towards TV and magazine advertising (Kantar Media (2014), Kim, Arnold, & Makarenko (2014)).¹ Activists advocating for a ban on e-cigarette advertising argue that e-cigarette ads glamorize smoking and that e-cigarettes may act as a gateway into smoking traditional cigarettes and marijuana. Proponents of e-cigarettes argue that e-cigarettes may be used as a tool to effectively help quit smoking and thus e-cigarette advertising may reduce demand for tobacco cigarettes. To date, there exists little empirical evidence in support of either of these positions.

In this paper, I use data from 2010 to 2014 to empirically test whether e-cigarette advertising increases or decreases demand for traditional cigarettes and consider the implications of proposals to ban e-cigarette advertising. I use both descriptive and structural methods to analyze this issue and find that e-cigarette advertising reduces demand for traditional cigarettes. At current levels of advertising, my counterfactual analysis predicts a 3% increase in cigarette demand as a result of an e-cigarette advertising ban.² This is an economically significant increase that is comparable in magnitude to the decrease in overall smoking prevalence in the US between 2010 and 2011.

Although the market for e-cigarettes is still small relative to tobacco cigarettes, awareness and use of e-cigarettes has been growing steadily in recent years. Giovenco, Lewis, & Delnevo

¹Kim et al. (2014) use data from Kantar Media and Nielsen to estimate that in 2011, \$6.4 million of e-cigarette ad spending was split across the following media: TV (50%), magazines (22%), internet (17%), radio (6%), and newspapers (6%). In 2012, \$18.3 million in e-cigarette ad spending was split between TV (27%), magazines (59%), internet (1%), radio (9%), and newspapers (4%). The authors predict that going forward "TV expenditures will likely outpace other channels given the recent national cable network campaigns for blu eCigs and NJOY."

²These numbers may be revised as the model is updated and new data is incorporated.

(2014) surveyed a random sample of current and former smokers in June 2013 and found that almost half (47%) of respondents had tried an e-cigarette product at least once, though only 4% of respondents reported established use.³ Despite being a quickly growing new category, much is still unknown about e-cigarettes to date. Existing research relating to e-cigarettes has generally been focused on addressing three types of questions: i) what are the health effects of e-cigarettes to users and non-users, ii) are e-cigarettes an effective tool to help smokers quit smoking, and iii) do e-cigarettes hamper existing tobacco control efforts. This paper primarily relates to the third category.

In general, whether e-cigarettes have a positive or negative impact on public health and tobacco control depends on the interplay between the potential benefits to current smokers and the undesired adoption of nicotine products by non-smokers. The World Health Organization's 2014 report on electronic nicotine delivery systems discusses the two primary arguments made by advocates for a ban on e-cigarette advertising: the gateway and renormalization effects. The *gateway* effect refers to the possibility that e-cigarettes will lead more non-smokers to initiate nicotine use and that once addicted to nicotine, non-smokers will be more likely to switch to smoking cigarettes than they would if they were not e-cigarette users. The *renormalization* effect refers to the possibility that marketing that portrays e-cigarettes as an attractive product will increase the attractiveness of cigarettes as well. The WHO (2014) report acknowledges that the existence and magnitude of the gateway and renormalization effects is an empirical question that is still understudied due to the limited availability of data.

Advocates for a ban on e-cigarette advertising often bring up both the gateway and renormalization effects in the context of teen consumption, as teens have rapidly increased their use of e-cigarettes in recent years. The 2014 National Youth Tobacco Survey found that for the first time, middle and high school students used e-cigarettes more than any other tobacco product, including conventional cigarettes. However, middle and high school students did not increase their overall tobacco use between 2011 and 2014; the increase in e-cigarette use was offset by a decline in traditional cigarette and cigar use. Still, researchers are concerned about the long-term consequences of teenagers adopting e-cigarettes since surveys indicate that about 90% of current smokers first tried cigarettes as teens and that about 75% of teen smokers continue to smoke as adults (2012 Surgeon General's Report). A recent longitudinal study of high school students in LA found that teenagers who had tried e-cigarettes in the past

³Established use defined as having used an e-cigarette product more than 50 times.

were more likely to initiate use of combustible tobacco over the year-long study relative to students who had not used e-cigarettes at the initiation of the study (Leventhal et al. (2015)). While directionally consistent with the gateway effect, the authors are careful to point out that these results are not causal. My ability to study the important question of youth adoption of e-cigarettes is unfortunately limited by the short window of data available on the nascent industry. Although this paper does not address the long-run effects of youth adoption, it contributes to our basic understanding of the balance between the positive and negative effects of e-cigarette advertising.

To my knowledge, this paper provides the *first* empirical analysis of the effects of e-cigarette advertising on demand for traditional cigarettes and e-cigarettes. First, I use store sales data and local advertising data to determine whether e-cigarette advertising increases or decreases demand for cigarettes. Identifying advertising effects can be challenging and is the focus of a large body of academic research. Randomization and instrumental variables are tools frequently used by researchers to identify causal effects of advertising. My strategy for identifying advertising effects is a hybrid regression discontinuity differences in differences approach based on the recent work of Shapiro (2016), and similar to the identification approaches taken by Card & Krueger (1994) and Black (1999). The idea is to take advantage of discontinuities in television market borders that lead similar individuals to be exposed to different levels of advertising. In this way, each border discontinuity can be thought of as a natural experiment through which we can learn about the causal effect of advertising.

I present difference-in-differences regressions which indicate that e-cigarette advertising increases demand for e-cigarettes and decreases demand for traditional cigarettes. After identifying advertising effects in the aggregate data, I use household purchase panel data to document the substitution patterns between e-cigarettes and traditional cigarettes. Household purchase patterns indicate that e-cigarettes are a substitute to traditional cigarettes. The household data also reveals a pattern of addiction; current period demand for cigarettes is increasing in past consumption.

Finally, to quantify the effects of a proposed ban on e-cigarette advertising, I construct and estimate a model of demand for cigarettes that allows me to leverage the strengths of both aggregate and household data. The demand model aggregates in an internally consistent way, such that equations governing household and aggregate demand are functions of the same underlying structural parameters. The model enables me to utilize the information content of

the two datasets in a unified way to identify the two main primitives of interest – heterogeneity in tastes for products and advertising, and the persistence in choices generated by addiction. I estimate the model by adapting an integrated procedure proposed by Chintagunta & Dubé (2005) that recovers mean utility levels and unobserved demand shocks from aggregate data and identifies parameters governing heterogeneity off of household purchase data. I extend this procedure to a model with state dependence which allows me to identify addiction using the household data. Finally, I show how the discontinuities I exploit in the descriptive linear models port to the more complex, nonlinear structural model in an intuitive way, thus showing how to leverage the same identification in all model specifications. I then use the estimated model parameters to predict the impact of a ban on e-cigarette advertising and other alternative policy interventions.

My research contributes to the ongoing policy debate as to whether e-cigarette TV advertising should be banned and suggests that a ban on e-cigarette advertising may have unintended consequences. More generally, my approach contributes to the study of advertising in categories with state dependence and to the analysis of substitution and complementarities in demand across categories. The methodology I develop to study this question is useful beyond just the study of addictive goods and can be used to estimate aggregate demand for any type of consumer packaged good that exhibits state dependent demand.

In the sections that follow, I review the existing literature on addiction and cigarette advertising and describe the industry context in more detail. Then I discuss my identification strategy and present descriptive analyses of aggregate and household-level purchase data. Motivated by these results, the second half of the paper introduces a demand model for cigarettes and describes an integrated estimation procedure that utilizes both the aggregate and household data. I then use the demand estimates in a counterfactual analysis to predict the impact on cigarette demand of a ban on e-cigarette TV advertising. Finally, I conclude the paper by summarizing the key findings and outlining directions for future research.

2 Literature Review

My research is primarily related to the literatures on addiction and advertising in the cigarette industry. In the sections below I discuss the existing work in these areas and how it relates to my research.

2.1 Addiction

A large body of literature in economics and marketing has analyzed markets for addictive goods. In classic models of addiction, a good is considered to be addictive if past consumption of the good raises the marginal utility of present consumption. There are generally two classes of economic models of addiction: myopic models and models with forward-looking consumers. Myopic models allow past consumption to affect current consumption decisions, but assume that consumers are not forward-looking about the fact that their consumption in the current period will affect their utility from consumption in future periods. Researchers have empirically tested for addiction in the cigarette market and found strong evidence that current consumption is increasing in past consumption (Houthakker & Taylor (1970), Mullahy (1985)). In myopic models of addiction, increases in current and past prices will reduce current consumption (Baltagi & Levin (1986), Jones (1989)), but increases in future prices will not affect current consumption. On the other hand, in the “rational addiction” model, forward-looking consumers consider the future implications of addictive consumption when making consumption decisions in the current period (Becker & Murphy (1988), Gordon & Sun (2014)). Consistent with the rational addiction model, empirical studies have found evidence that consumers reduce their consumption in the current period in response to increases in past, current, and expected future prices (Pashardes (1986), Chaloupka (1991), Becker, Grossman, & Murphy (1994)). However, many researchers object to the perfect foresight assumption of the rational addiction model (Winston (1980), Akerlof (1991)). In response to these concerns, researchers have attempted to address perceived inconsistencies in the perfect foresight assumption by allowing for learning and bounded-rationality (Orphanides & Zervos (1995), Suranovic, Goldfarb, & Leonard (1999)).

Many empiricists have applied myopic and forward-looking models of addiction to data in order to measure the responsiveness of demand for addictive goods to changes in price. Researchers have found that temporary price changes for addictive goods have little impact on demand. However, long-run responses to permanent price increases are substantially larger than short-run reductions in demand (Chaloupka & Warner (1999)). These results suggest that ignoring the addictive nature of demand for tobacco and other drugs will lead to biased predictions of long-run responses to price changes.

In my analysis, I present a myopic model of cigarette addiction in which past consumption

is complementary to current consumption. I do not model rational addiction in the sense that individuals in my model are not forward-looking. This modeling assumption yields an individual level demand model that can be aggregated in an internally consistent way. Allowing for forward-looking behavior would make this aggregation intractable and would inhibit my ability to combine both individual and aggregate data in estimation.

2.2 Cigarette Advertising

My analysis is closely related to research measuring the effects of cigarette advertising on demand for cigarettes. In particular, a large stream of research has focused on measuring the effects of the 1971 ban on cigarette TV advertising (Ippolito, Murphy, & Sant (1979), Schneider, Klein, & Murphy (1981), Porter (1986), Baltagi & Levin (1986), Kao & Tremblay (1998), McAuliffe (1988), Seldon & Doroodian (1989), Franke (1994)). Despite extensive work in the area, research has produced mixed results. Many studies conclude that the ban did not significantly reduce cigarette consumption, while others have found evidence that the marginal productivity of cigarette advertising fell after the ban (Tremblay & Tremblay (1995)). Schneider et al. (1981) provides empirical evidence showing that the advertising ban led to a 5% net *increase* in per capita tobacco consumption as a result of price reductions resulting from cutting advertising costs. Researchers have pointed to but not resolved the potential endogeneity of advertising and advertising regulation, as well as firms' ability to substitute advertising to other media as factors that have complicated empirical analyses of the effects of the advertising ban (Saffer (1998), Stewart (1993)). Other papers have focused on analyzing firms' responses to the advertising ban. Eckard (1991) focuses on the effects of the ban on competition between firms and industry concentration while Qi (2013) explains the increase in total industry ad spending after the ban as a combination of dynamic competition and firms learning about ad effectiveness.

My work primarily relates to the stream of papers that seek to measure the effects of advertising regulation on cigarette demand. While the majority of these studies were limited to using data on aggregate advertising expenditures, I am able to address the endogeneity of advertising using detailed weekly, market-level data on advertising intensity and an identification strategy which exploits across-market variation in advertising over time. As I currently do not model the supply side of the market, my analysis will not capture firms' strategic responses to a potential ban on e-cigarette television advertising of the type considered by Eckard (1991) and

Qi (2013).

In the marketing literature, a recent paper by Wang, Lewis, & Singh (2015) studies countermarketing strategies including excise taxes, smoke-free restrictions, and antismoking advertising campaigns and compares the effects of these policy levers to the effects of print advertising for cigarette products. My work is related to the extent that e-cigarette advertising is another tool that can be used to shift demand for traditional cigarettes.

2.3 E-Cigarette Advertising and Demand

Existing empirical analysis of the e-cigarette industry has reported basic statistics on advertising exposure and calculated price elasticities using aggregate data. Duke et al. (2014) document the increase in youth and young adult exposure to e-cigarette advertising, but they do not link this advertising exposure to purchase outcomes. Huang, Tauras, & Chaloupka (2014) use quarterly market-level data and fixed effects regressions to measure the own- and cross-price elasticities of e-cigarettes and traditional cigarettes. The authors estimate price elasticities for e-cigarettes between -1.2 and -1.9 and positive but not statistically significant cross-price elasticities between e-cigarettes and traditional cigarettes. They find elasticities for e-cigarettes that are 2-3 times higher than elasticities that have been estimated for traditional cigarettes. My research builds on this descriptive analysis of the e-cigarette industry and considers the effects of e-cigarette advertising on demand for traditional and electronic cigarettes.

3 Empirical Setting

3.1 Tobacco Advertising Ban

The Surgeon General released its groundbreaking report linking smoking to lung cancer and increased mortality in 1964. Soon after, Congress passed the Federal Cigarette Labeling and Advertising Act of 1965 which required a health warning label on all cigarette packages. Despite the increased awareness about the negative health effects of smoking that was generated by these interventions, cigarettes remained one of the most advertised products on TV. Under pressure to reduce youth exposure to cigarette ads, in 1969 Congress approved the Public Health Cigarette Smoking Act, which banned *all* advertising for cigarettes on any medium of electronic communication subject to the jurisdiction of the FCC. The legislation effectively

prohibited cigarette advertising on TV and radio. The ban went into effect on January 1, 1971, and is still in effect today.

Despite this restriction, cigarette companies continue to market their product aggressively. The FTC reports that in 2012 the major cigarette manufacturers spent \$9.168 billion on cigarette advertising and promotion (FTC (2015)). The majority of cigarette marketing spending comes in the form of promotional allowance, a category which includes price discounts and payments made to retailers and wholesalers to facilitate the sale or placement of cigarettes. Price discounts paid to cigarette retailers and wholesalers to reduce the price of cigarettes to consumers make up the largest share (85%) of marketing spending in 2012 with a total of \$7.802 billion. Promotional allowances paid to retailers to facilitate the sale or placement of cigarettes and incentive payments given to wholesalers accounted for another 8% of cigarette marketing spending. The remaining spending was distributed across the following categories: coupons (2.6%), adult-only public entertainment (1.2%), point-of-sale advertising (0.7%), direct mail advertising (0.5%), magazine advertising (0.3%), online advertising (0.2%) and outdoor advertising (0.03%).

3.2 E-Cigarettes

In 2004, the Chinese company Ruyan introduced the world's first e-cigarette. The product entered the US market soon after in 2007. An e-cigarette is an electronic device that contains a nicotine-based liquid. When heated, the liquid becomes a vapor which the user inhales. E-cigarettes do not contain tobacco and do not produce smoke because they do not use combustion. There are two main variants of e-cigarettes – a durable, re-usable product that can be recharged with included batteries and refilled with replacement cartridges, and a disposable product. Many e-cigarette companies sell both a refillable and a disposable device. Although e-cigarettes vary greatly in appearance, the most popular brands bear a close physical resemblance to traditional cigarettes. E-cigarettes are available in many flavor varieties including tobacco, mint, cotton candy, and bubble gum. Opponents to e-cigarettes argue that these flavors increase the product's attractiveness to youth.

Until early 2012, the e-cigarette market was composed of many small independent brands. In April 2012, Lorillard (the 3rd largest US tobacco company) acquired Blu eCigs for \$135 million. They became the first of the Big Tobacco companies to enter the e-cigarette market. Reynolds (the 2nd largest US tobacco company, now merged with Lorillard) launched

its own brand Vuse in July 2013. Altria (the largest US tobacco company) launched its own brand, MarkTen, in August 2013.

Compared to tobacco cigarettes, e-cigarettes are more loosely regulated. E-cigarettes are sold in retail stores and online and are not federally taxed as are traditional tobacco cigarettes. Until early 2016, e-cigarette minimum purchase age restrictions were determined by state governments, with no federal age restrictions like those imposed on cigarette purchases. In May 2016, the FDA finalized a rule that extends its regulatory authority to cover all tobacco products including e-cigarettes. Among other changes, this regulation set 18 as a national minimum age to purchase e-cigarettes. The FDA has also raised concerns about the lack of quality control and consumer protection standards in the industry. The low barriers of entry have led to a proliferation of hundreds of firms. In order to address this concern, the FDA's 2016 regulation includes a requirement that e-cigarette manufacturers apply for FDA authorization to market their products and that they include a nicotine warning statement on all e-cigarette packaging and advertisements.⁴

With the increasing popularity of e-cigarettes, a growing body of literature has developed around studying the health effects of e-cigarette use and second-hand exposure. The long-term health effects of e-cigarettes are still being investigated by clinical researchers, but initial studies seem to indicate that e-cigarettes appear to be less harmful than traditional cigarettes, but more harmful than abstaining from nicotine products altogether. Most e-cigarettes contain nicotine, the highly addictive stimulant found in tobacco cigarettes that raises the heart rate, increases blood pressure, and constricts blood vessels (Benowitz & Gourlay (1997)). Long-term exposure to nicotine has been linked to hypertension and heart diseases, including congestive heart failure and arrhythmias. Nicotine has also been shown to negatively affect the neurological development of adolescents and developing fetuses. E-cigarettes, however, do not contain tar and other cigarette residues that are the ingredients in traditional combustion cigarettes that have been shown to cause lung cancer. Researchers are also interested in the effects of second-hand exposure to e-cigarette aerosol, which can help inform whether e-cigarette use should be regulated indoors as is the smoking of traditional cigarettes. E-cigarette aerosol is not simply water vapor. It contains chemicals including formaldehyde and acetaldehyde, though these chemicals are present at rates 9 to 450 times lower than in smoke from combustible cigarettes (Crowley (2015)). Nonetheless, a recent report by the Royal College of Physicians

⁴The statement reads "WARNING: This product contains nicotine. Nicotine is an addictive chemical."

asserts that e-cigarettes are only 5% as harmful as traditional cigarettes (Royal College of Physicians (2016)).

A second stream of research has explored whether e-cigarettes are an effective smoking cessation tool. Proponents of e-cigarettes argue that they deliver nicotine to the user without many of the harmful byproducts contained in tobacco smoke and that e-cigarettes may be a more effective smoking cessation aid than other existing products because they mimic the tactile and sensory process of smoking. Although e-cigarettes have not yet been approved as a smoking cessation device by any government agency, a 2015 report released by Public Health England concludes that electronic cigarettes “can help people to quit smoking and reduce their cigarette consumption” (McNeill et al. (2015)). The report goes on to recommend that the British government begin to regulate e-cigarettes as a prescription-based nicotine replacement therapy. The C.D.C. in the US has taken an opposing stance, maintaining the position that “There is currently no conclusive scientific evidence supporting the use of e-cigarettes as a safe and effective cessation tool at the population level. The science thus far indicates most e-cigarette users continue to smoke conventional cigarettes” (Tavernise (2016)). Based on the marginally positive but limited existing studies that explore the efficacy of e-cigarettes as a smoking cessation tool, The World Health Organization concludes that “the use of ENDS [electronic nicotine delivery systems] is likely to help some smokers to switch completely from cigarettes to ENDS” and that e-cigarettes may “have a role to play in supporting attempts to quit” for smokers who have previously attempted and failed to quit using other cessation aids.

3.3 E-Cigarette Advertising

The primary goal of this paper is to determine the effect of e-cigarette advertising on demand for cigarettes. It is thus important to understand the messages that e-cigarette ads communicate to viewers. On one hand, e-cigarette advertising may reduce aggregate consumption of cigarettes by encouraging smokers to switch from traditional cigarettes to e-cigarettes. Alternatively, e-cigarette ads could generate positive spillovers if they increase demand for the category of cigarettes as a whole or if they portray e-cigarettes as a complement to traditional cigarettes.

Matthew Myers, president of the Campaign for Tobacco-Free Kids, has expressed concern that “e-cigarettes are using the exact same marketing tactics we saw the tobacco industry use in the 50s, 60s and 70s [...] The real threat is whether, with this marketing, e-cigarette makers will undo 40 years of efforts to deglamorize smoking.” The Lucky Strike cigarette and Blu

e-cigarette ads in Figure 1 illustrate the similarities in advertising tactics that have generated concern that e-cigarette advertising will hinder existing tobacco control efforts and renormalize cigarettes in society. Characteristics of these ads include asserting an independent identity and associating nicotine use with celebrities, fashion, and youth.

Ad spillovers may also arise if consumers either consciously or subconsciously confuse the product that is being advertised. For example, in the FIN advertisement on the left of Figure 2, the physical appearance of the product is virtually indistinguishable from that of a traditional cigarette. On the company website, FIN describes its product as an “electronic cigarette that looks and feels like a traditional cigarette.” This physical similarity is important because it raises the possibility that viewers could misinterpret ads for e-cigarettes to be ads for traditional cigarettes. In an experimental study, Maloney & Cappella (2015) found that e-cigarette advertisements with visual depictions of people using e-cigarettes increased daily smokers’ self-reported urge to smoke a tobacco cigarette relative to daily smokers who saw e-cigarette ads without visual cues. The same study also found that former smokers in the visual cues condition self-reported lower intentions to continue to abstain from smoking tobacco cigarettes relative to former smokers in the no visual cues condition. These results suggest that e-cigarette advertisements with visual depictions of use may generate positive spillovers and increase demand for traditional cigarettes.

Other e-cigarette ads, such as the Blu ad in Figure 2, inform consumers about the fact that e-cigarettes do not fall under most indoor smoking bans that apply to traditional cigarettes. Although the prevailing tobacco control message has been that tobacco use should not be started and if started it should be stopped, the underlying message communicated by these ads is that you do not need to quit smoking, you may continue to smoke cigarettes when permitted, and you can supplement your nicotine consumption with e-cigarettes when you are prohibited from smoking indoors or in public places. Jason Healy, the founder and President of Blu eCigs, describes his own consumption behavior in this way, saying he has a traditional cigarette in the morning, but vapes during the day. The additional nicotine consumption coming from supplemental vaping indoors may reinforce addiction and increase demand for cigarettes in the future. In short, these ads may increase demand for traditional cigarettes by suggesting that e-cigarettes are complementary to traditional cigarettes.

To summarize, to the extent that e-cigarettes act as a substitute to traditional cigarettes, e-cigarette advertising can decrease demand for cigarettes. To the extent that e-cigarette ads

Figure 1: E-Cigarette Ads Use the Same Marketing Tactics Used by Traditional Cigarette Ads



Figure 2: E-Cigarette Ads May Generate Positive Ad Spillovers



and usage generate positive spillover effects for traditional cigarettes either through renormalization or complementarities, e-cigarette advertising can *increase* demand for cigarettes. In the sections that follow, I explore both the net effect of advertising on cigarette demand as well as heterogeneity in this effect across individuals and markets.

3.4 Data

Ultimately, whether e-cigarette advertising increases or decreases demand for cigarettes is an empirical question. Data on both purchase volume and advertising intensity is necessary in order to tease out which effect of e-cigarette advertising dominates. I analyze retail sales data, household purchase panel data, and market-level TV advertising data collected by AC Nielsen. Each of these datasets is described in more detail below.

3.4.1 Retail Sales Data

The AC Nielsen database includes weekly store sales data reporting prices and quantity sold at the UPC-level. The data records sales of e-cigarettes, traditional cigarettes, and smoking cessation products including the nicotine patch and gum. Store location is specified at the county level. The data is available from 2010–2014 and the sample is partially refreshed annually.⁵

There are 59 brands and 471 unique e-cigarette UPCs recorded in the retail sales data. These UPCs are a mixture of rechargeable kits, refill cartridges, and disposable e-cigarettes. Rechargeable kits cost between \$30–50, refills (sold in 3–5 cartridge packs where each cartridge is roughly equivalent to 1–2 packs of cigarettes) cost between \$10–15, and disposable e-cigarettes (equivalent to 1.5–2 packs of cigarettes) cost about \$10.

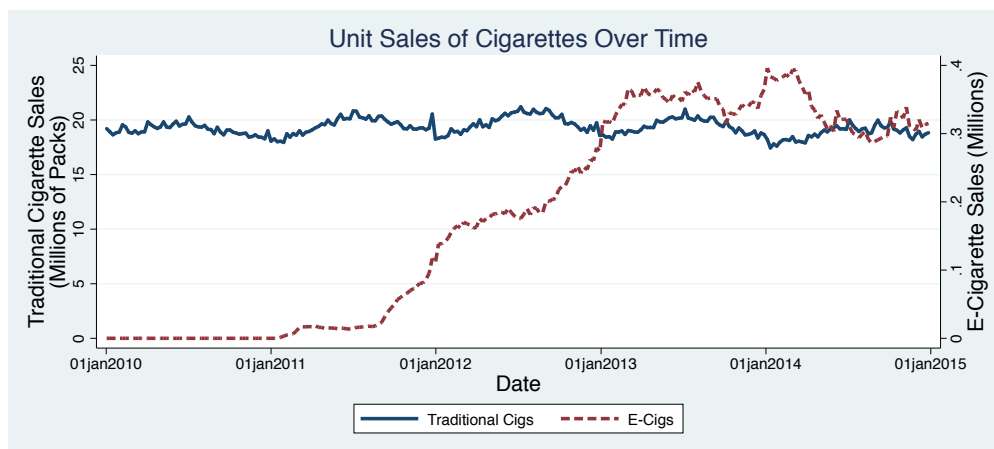
Cigarettes are sold primarily as packs (20 cigarettes in a pack) and cartons (10 packs in a carton). I focus on purchases of these package sizes. The average price of a pack of cigarettes varies extensively across markets due to differences in state and local excise taxes. The quantity-weighted average price of a pack of cigarettes across all stores in the panel is \$5.54, but this price varies across counties from a low of \$3.22 in Oregon County, MO to a high

⁵Each year the retail data tracks sales from approximately 35,000 individual stores pertaining to roughly 90 retail chains. The sample has reasonably high coverage of traditional grocery outlets with weaker coverage of convenience stores. As of 2011, estimated coverage as a percent of all commodity volume by channel was: Food (53%), Drug (55%), Mass Merchandise (32%), and Convenience Store (2%).

of \$10.55 in Bronx County, NY.

Figure 3 plots the trend in aggregate cigarette and e-cigarette sales over time for the 32,847 stores who are active in the panel each year between 2010–2014. E-cigarette sales were low until mid 2011, when the quantity of units sold began to grow rapidly. The plot shows that there is seasonality in the quantity of cigarette packs sold with lower sales during the winter and higher sales during summer months.

Figure 3: Trend in Weekly Sales of Cigarettes and E-Cigarettes



3.4.2 Household Purchase Data

AC Nielsen also collects daily UPC-level purchase data for a sample of approximately 50,000 US households. The household panel extends from 2010–2014. Purchases of e-cigarettes, traditional cigarettes, and smoking cessation products are all recorded. The data reports price paid, number of units purchased, and, when available, identifying information for the store at which the purchase was made. Like the store sample, the household sample is also partially refreshed annually.

Between 2010–2014, 1,906 households made a total of 7,772 purchases of any type of e-cigarette product. Of the 881 of these households who are tracked in the panel for all five years, 83% of households are observed to buy cigarettes before buying e-cigarettes for the first time, 3% of households are observed purchasing e-cigarettes before later making a purchase of traditional cigarettes for the first time, and the remaining 14% of households never report any purchases of cigarettes. It is these latter two groups of households that policy makers are

especially worried about.

It is also interesting to look at whether heavier or lighter smokers are more likely to buy e-cigarettes. Table 1 reports descriptive statistics for the subset of households who purchased at least one pack of cigarettes in 2014 and who were tracked in the sample every year from 2010-2014. A comparison of the households who only ever purchase cigarettes and those who purchase both traditional and e-cigarettes shows that heavier smokers are more likely to buy e-cigarettes.

Table 1: Dollars Spent on Cigarettes by Households in 2014

	N HH	Median \$ Cigs	Mean \$ Cigs
HHs Who Only Ever Buy Cigs	3,130	112.98	561.11
HHs Who Ever Buy Both Cigs and E-Cigs	577	565.17	992.98

Note: Statistics calculated on the set of households who purchased traditional cigarettes in 2014. Households assigned to buckets using purchases in 2010 – 2013.

3.4.3 Advertising Data

Weekly, product-level television advertising data from 2009–2014 comes from AC Nielsen. The data records ad impressions, units, expenditures, and gross rating points (GRPs). GRPs are a measure of advertising intensity, calculated as exposures per capita.

Figure 4 plots the trend in total e-cigarette advertising impressions over time. There was very little advertising until mid 2012, at which point the number of ad impressions began to grow quickly. Firms buy advertising at both the national and local Designated Market Area (DMA) level.⁶ Table 2 reports the break-down of e-cigarette TV advertising across media type. The majority of advertising is bought nationally, but about a quarter of ad-spending is spent on local advertising. Although the majority of advertising is at the national level, there is extensive variation in local advertising both across DMAs and over time. This variation will be very useful for identification.

The data records advertising for e-cigarette brands as well as smoking cessation products. Tables 3 and 4 report market shares for the top e-cigarette and smoking cessation brands. From

⁶Cable, Network, and Syndicated advertising is purchased at the national level while Spot and Clearance Spot advertising is purchased at the local level.

2010 to 2014, Blu eCigs was the market leader amongst e-cigarette brands with 57.8% of e-cigarette store sales and over 74% of all e-cigarette ad impressions. Lorillard acquired Blu in April 2012, shortly before the observed spike in advertising in mid 2012. Nicorette and Nicoderm CQ are the dominant brands in the smoking cessation category, with over 97% of store sales and 99% of the advertising for products in this category.

Figure 4: Trend in E-Cigarette TV Ad Impressions

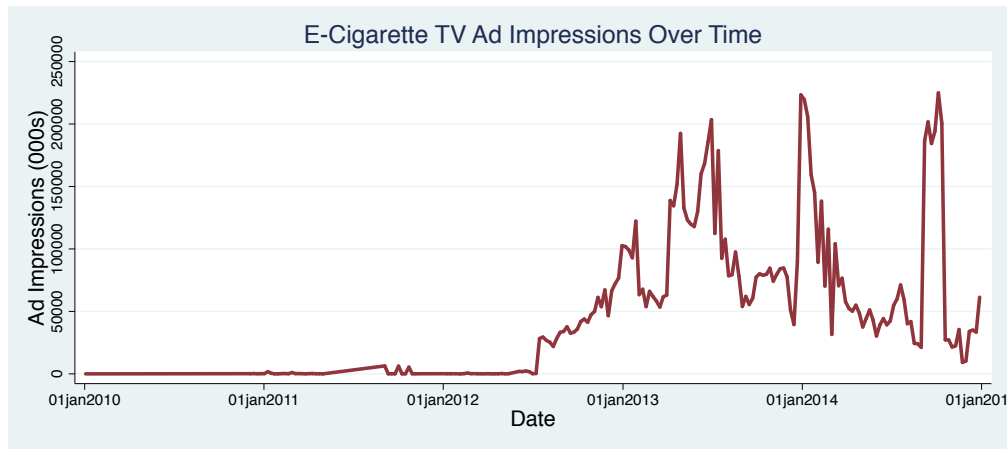


Table 2: E-Cigarette Advertising Market Share by Media Type (2010–2014)

	Media Type	Unit Share	Dollar Share	Impression Share
National	Cable	40.6%	73.4%	85.7%
	Network	2.2%	3.0%	6.4%
	Syndicated	0.1%	0.4%	0.5%
Local	Spot	48.5%	23.1%	6.6%
	Network Clearance Spot	4.9%	0.0%	0.6%
	Syndicated Clearance Spot	3.7%	0.0%	0.2%
Total		103,565	\$54,185,012	10,328,566,000

Table 3: E-Cigarette Brands by Market Share (2010–2014)

	Market Share	Ad Impression Share
Blu (Lorillard)	57.8%	74.1%
Vuse (RJ Reynolds)	1.1%	10.7%
NJOY	8.5%	8.4%
Fin	12.0%	4.2%
Other	20.6%	2.7%
Total	\$289,500,000	10,328,566,000

Table 4: Smoking Cessation Brands by Market Share (2010–2014)

	Market Share	Ad Impression Share
Nicorette	79.2%	58.2%
Nicoderm CQ	18.3%	40.7%
Other	2.5%	0.00%
Total	\$791,500,000	74,587,688,000

3.4.4 Other Data Sources

Yearly county population data comes from the US Census Bureau. Data on changes to local cigarette excise taxes and indoor smoking restrictions comes from the American Nonsmokers' Rights Foundation.

4 Descriptive Analysis

In this section I explore the purchase and advertising data further in order to better understand the role of advertising in the market and identify the substitution patterns between e-cigarettes and traditional cigarettes. First, using market-level data I show that e-cigarette advertising increases demand for e-cigarettes and decreases demand for traditional cigarettes. Next, I illustrate the substitution patterns between traditional and e-cigarettes and show evidence of addiction using the household purchase data.

4.1 Identifying Advertising Effects with Aggregate Data

4.1.1 Identification Strategy

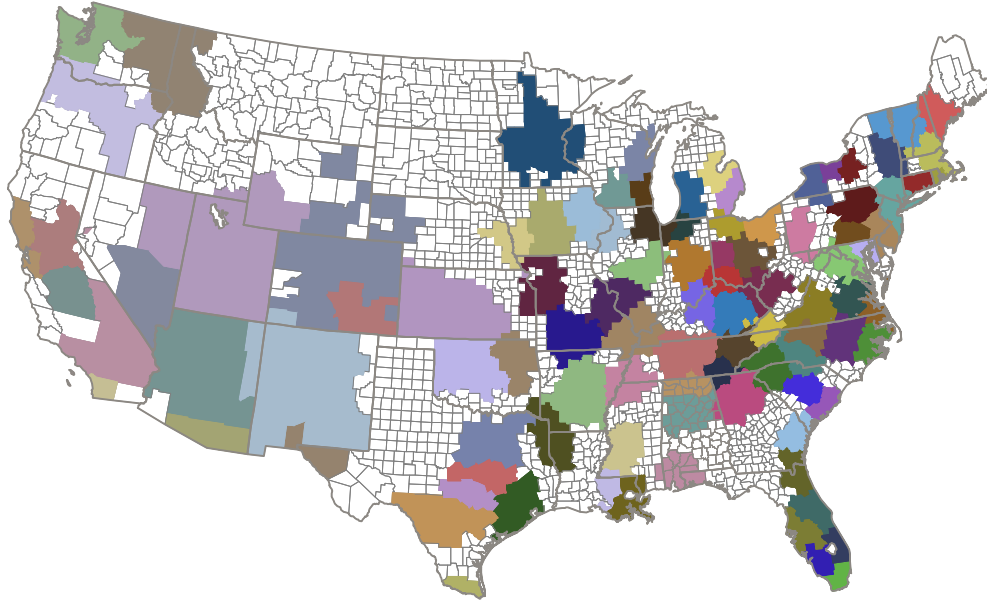
I am ultimately interested in measuring the causal effect of e-cigarette advertising on cigarette demand. Identifying the causal effect of advertising is complicated by the fact that local advertising is not assigned randomly. The concern is that firms might target higher levels of advertising to markets with higher demand or increase advertising in periods with high demand. If not accounted for, this endogeneity would lead to biased estimates of the effects of e-cigarette advertising.⁷

I address this endogeneity concern by exploiting a discontinuity in local advertising markets that was first pointed out by Shapiro (2016). AC Nielsen delineates local television markets or Designated Market Areas (DMAs) by grouping counties based on their predicted interest in TV program content and quality of over-the-air TV signal. Firms buy local advertising at the DMA level, so all households residing in a given DMA see the same television programming and ad content. Although nearly all households now watch TV using cable or satellite dish as opposed to watching over-the-air, it is still the case that television providers show households within a given DMA the same television content. Thus, if advertisers don't uniformly buy advertising across DMAs, households on opposite sides of a DMA border can be exposed to different levels of advertising. I refer the reader to Shapiro (2016) for a thorough discussion of television advertising markets.

Identification comes from comparing sales in counties just to the left of a border to sales in counties just to the right of the border over time. I aggregate store sales to the county level because county is the finest level of geographic variation I observe in the store sales data. The identifying assumption is that these border counties experience the same unobserved demand shocks, and thus, in the absence of an advertising intervention, sales in these bordering markets would follow the same trend. This strategy is analogous to the approaches used in important early studies on program evaluation including Card & Krueger (1994)'s study of minimum wage effects and Black (1999)'s analysis of the economic value of education. However, while Card and Krueger use state boundaries and Black looks across school district attendance boundaries, DMA boundaries do not necessarily coincide with state or other geo-political boundaries that

⁷Appendix A presents DMA-level fixed effects regressions as a comparison to the border strategy results. The direction of the effects of e-cigarette advertising remains the same, but the standard errors in the DMA-level regressions are much larger than in the following border analysis.

Figure 5: Top 100 DMAs

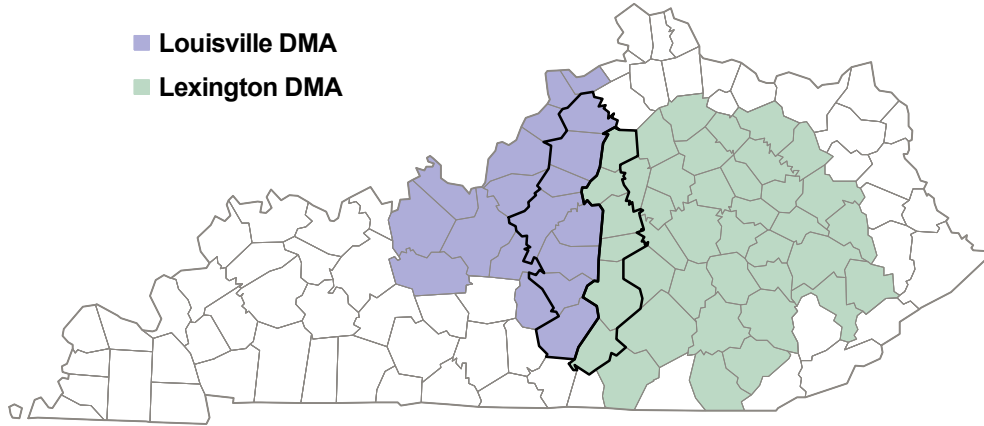


we worry would likely be correlated with advertising and demand for cigarettes. A map of the top 100 DMAs ranked by viewership is shown in Figure 5.

DMAs tend to be centered around cities, while the borders between DMAs tend to fall in more rural areas. Firms tend to set advertising for a given DMA based on the urban center of the DMA, where the majority of the population resides. This suggests that we might see different levels of advertising at the border between two DMAs, but that these differences are not being driven by differences in the characteristics of households in these rural border areas. The intuitive way to think about identification here is that the individuals living on either side of a border are similar on unobservables, but they are exposed to different levels of advertising because of differences in the major cities located at the centers of their respective DMAs. If this is true, then we can think of each border as a natural experiment with two treatment groups. In the absence of differences in advertising, we would expect demand to follow the same trend on either side of the border. Thus, ad effects will be identified off of the covariance between differences in advertising and deviations from the common trend in sales.

Take, for example, the border between the Louisville, KY and Lexington, KY DMAs shown in Figure 6. There are 8 counties in the Louisville DMA that share a border with a county in the Lexington DMA and 6 counties in the Lexington DMA that share a border with a county in the

Figure 6: Louisville and Lexington DMA Border Counties



Louisville DMA. The population of these border counties makes up a small share of the total population of their corresponding DMAs; the border county population share of the Louisville and Lexington DMAs are 9% and 12% respectively. I focus on borders between the top 100 DMAs, resulting in 150 borders and 300 border-markets. The median and mean border county population shares across these border-markets are 9% and 16% respectively.

The identification strategy relies on the extent to which there is variation in advertising intensity both across borders and over time. Figure 7 plots the weekly e-cigarette ad GRPs in the Louisville and Lexington DMAs. Neither DMA is exposed to any local e-cigarette advertising in 2010, but there is variation in the extent to which the two DMAs are exposed to advertising after 2010. Because previous research has found that there can be long-lasting effects of advertising, I construct a discounted cumulative stock of advertising GRPs assuming a weekly depreciation rate of $\delta = 0.9$ such that $A_{tm} = \sum_{\tau=0}^t \delta^{t-\tau} a_{\tau m}$.⁸ Figure 8 plots the advertising stock over time for these bordering DMAs.

Table 5 reports statistics summarizing the variation in advertising stocks for the entire border sample. The average difference in advertising stock across each pair of border markets is 21.25 GRPs, confirming that there is a discontinuity in advertising across neighboring DMAs. The coefficient of variation calculated for each market as the standard deviation in weekly ad

⁸I use the advertising depreciation rate of $\delta = 0.9$ that Dubé, Hitsch, & Manchanda (2005) estimate using weekly ad GRP data. Advertising data from 2009 is used to construct the discounted ad stock for smoking cessation products. There was no e-cigarette advertising prior to 2010, so there is no initial conditions problem. In Appendix C, I consider the robustness of this choice of depreciation rate by estimating the reduced form analyses assuming different depreciation rates and find that the results are substantively similar.

Figure 7: Weekly E-Cigarette Ad GRPs in the Louisville and Lexington DMAs

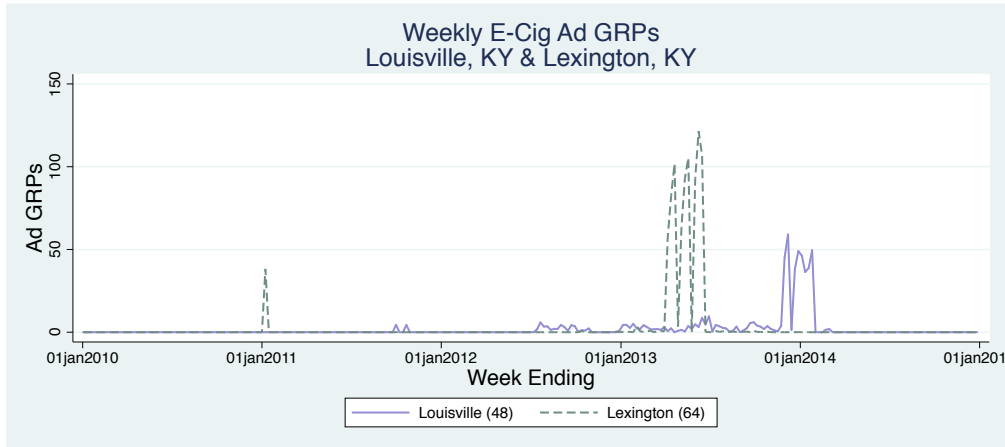
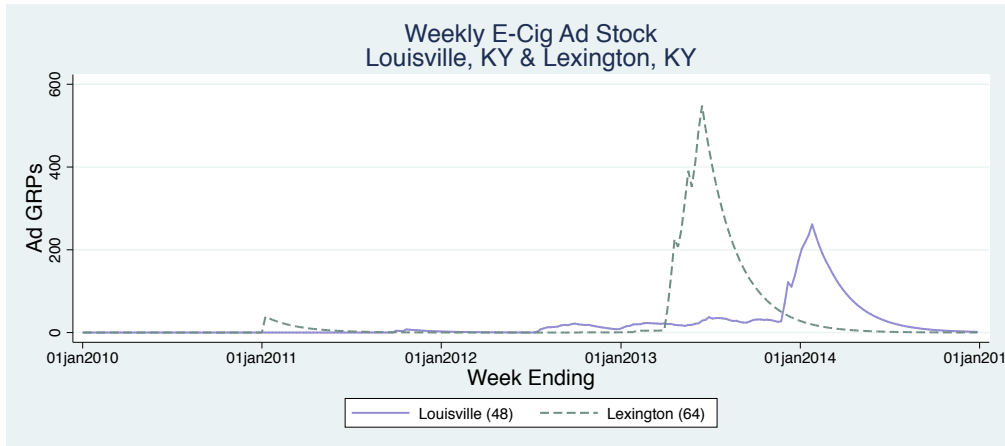


Figure 8: Weekly E-Cigarette Ad Stock in the Louisville and Lexington DMAs



GRPs divided by the mean weekly GRPs is large and shows that there is variation in advertising over time. These statistics confirm that the data contains significant variation in advertising both across borders and within markets over time.

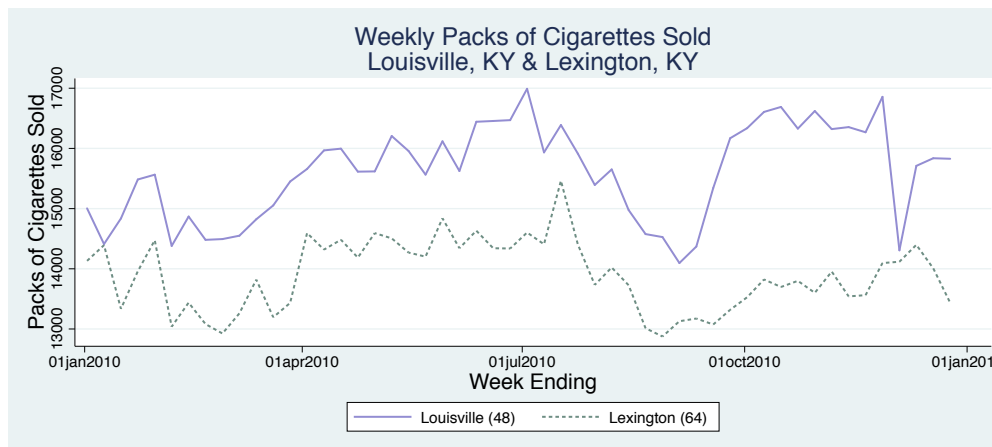
Recall that the identifying assumption is that sales on either side of a border would follow the same trend in the absence of an advertising intervention. To explore whether this assumption is credible, I compare the trend in cigarette sales in border markets before e-cigarette companies began to advertise. Figure 9 plots the total number of packs of cigarettes sold in the border counties in the Louisville and Lexington DMAs in 2010. In the absence of differences in e-cigarette advertising, sales in the two markets seem to follow the same trend. The correlation

Table 5: Variation in Advertising for the Border Market Sample

	N	Min	Median	Mean	Max
Ave E-Cig GRP Stock	300	0.03	14.88	21.84	138.45
Ave Absolute Dif in E-Cig GRP Stock	150	0.70	21.25	27.89	139.54
Coeff Var E-Cig GRPs	300	1.64	3.56	4.01	10.00

in 2010 sales is $\rho = 0.54$. Figure 10 plots a histogram of the correlation in 2010 sales across all border markets. The median border in the sample has a correlation in weekly cigarette sales in 2010 of $\rho = 0.52$.⁹ However, sales in a small number of bordering markets are un-correlated or even negatively correlated in 2010. In Appendix D I test the sensitivity of the results to the common trends assumption by restricting the sample to only the set of borders with a correlation in 2010 sales above $\rho = 0.5$. The results are consistent in sign and the magnitude of the ad effects becomes slightly larger.

Figure 9: Weekly Packs of Cigarettes Sold in Louisville and Lexington DMA Border Counties in 2010

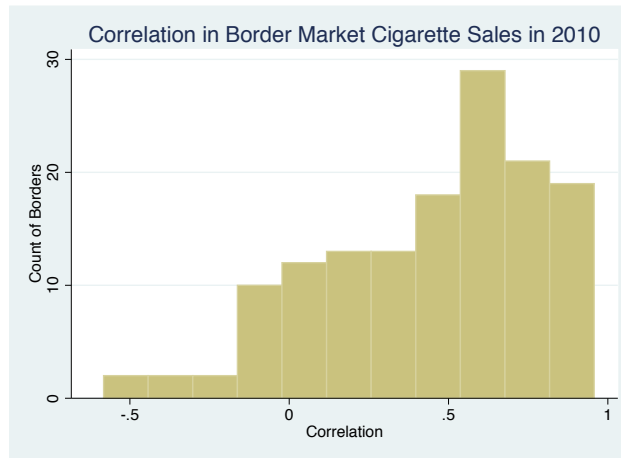


Note that the key identifying assumption has only to do with common *trends* and that time invariant differences across bordering markets are not a concern and will ultimately be absorbed by a set of market fixed effects.¹⁰ Thus, the identifying assumption would only be

⁹I also calculate the correlation in the first-differenced series to determine whether the positive correlation in sales is primarily driven by a common linear time trend or by common weekly shocks. The median correlation in changes in weekly sales across border markets is $\rho_{\Delta} = 0.40$ and the correlation in differenced weekly sales for the Louisville and Lexington DMA border markets is $\rho_{\Delta} = 0.49$.

¹⁰This is true if ad-responsiveness is not a function of population characteristics. To the extent that ad-

Figure 10: Distribution of Correlation in Weekly Cigarette Sales Across Borders in 2010



violated if there were an unobserved shock on one side of the border that was correlated with both sales and advertising. I could think of two such shocks that could differentially affect one side of the border and be correlated with sales of cigarettes and advertising for e-cigarettes: (i) changes to county excise taxes and (ii) changes to county indoor smoking legislation. If a county on one side of a DMA border increased cigarette excise taxes, demand for cigarettes would have fallen on that side of the border in response to the price increase and e-cigarette companies might have increased their advertising to that DMA. Similarly, if a county on one side of a DMA border approved more stringent indoor smoking bans, demand for cigarettes might have fallen in response to the increased inconvenience of smoking and e-cigarette companies might have increased their advertising to that market. In order to address these concerns, I obtained a dataset collected by the American Non-Smokers' Rights Foundation non-profit organization that records changes to cigarette excise taxes and indoor smoking bans at the city, county, and state level. The data requires additional cleaning before I can incorporate it into my analyses, but going forward I plan to use this data to control for changes to taxes and smoking restrictions.

Another impediment to the identification strategy could arise if cigarette companies are strategically responding with their own marketing spending. According to the FTC, the majority (85%) of marketing spending by cigarette companies in 2012 came in the form of price discounts that were passed on to consumers. These discounts will be reflected in the prices in

responsiveness is a function of characteristics, I can check that the bordering markets have similar demographics. This comparison is reported in Appendix E.

my dataset and will thus be controlled for in the empirical analysis. The Nielsen advertising database records print advertising expenditures for cigarette companies, but the vast majority of this spending is at the national level. I expect its effects to be uniform on either side of DMA borders and unlikely to be a problem for my identification strategy.

Finally, the question of the external validity of these estimates must be raised. This border discontinuity identification strategy allows me to measure unbiased casual effects of e-cigarette advertising for a specific sub-population of individuals who reside in border markets. The ultimate goal of this paper is to predict the demand response to a nationwide ban on e-cigarette TV advertising. Thus, when drawing inference from these estimates, it is important to keep in mind how these markets differ from the overall population in the US. In Appendix E I use US Census data to explore the differences in demographics between border counties and non-border counties. I find that individuals residing in border counties on average are slightly older, less educated, and have lower income. Border counties have a lower share of black residents and a lower population density compared to non-border counties. Research by the American Lung Association (Shan, Jump, & Lancet (2012)) shows that rural areas tend to be associated with higher rates of adult and adolescent smoking, and that youth in rural areas tend to start smoking at a younger age. These results suggest that to the extent that I am measuring advertising effects for a specific sub-population, this sub-population may be one that policy-makers are especially concerned about.

4.1.2 Fixed Effects Regression Results

In this section I discuss the implementation of the identification strategy and then present the estimation results. At a high level, the approach is to only use data for border markets and to include a rich set of market and border-time fixed effects that allow markets to have different levels of sales and border-specific flexible time trends. I describe these steps below in the context of the descriptive analysis. I later describe in Section 6 how to implement this border discontinuity approach within the context of my more complex non-linear model.

First, the sample is restricted to the set of stores that were active in the full panel from 2010–2014 and are located in a border county. All counties in a given DMA on a given border are grouped together into a market. For example, the 8 counties in the Louisville DMA that border the Lexington DMA form a market and sales in stores in these counties will be aggregated to form total market sales. The 6 counties in the Lexington DMA that share a border with

a county in the Louisville DMA make up the comparison market. The dependent variables of interest are total number of cartridges of e-cigarettes sold and total number of packs of cigarettes sold by stores in each market each week.¹¹ I focus on sales of refill cartridges and disposable e-cigarettes because these products have similar prices and are a better measure of e-cigarette consumption.¹² To construct price series for each market from the store sales data, I calculate the weighted average price for a pack of cigarettes and price per cartridge of refill and disposable e-cigarette products. I also look at sales of nicotine patches and nicotine gum, and I construct the price series for these products as the average price per unit paid for a patch and piece of gum.

I implement the identification strategy by including a set of market fixed effects and a set of border-week fixed effects. The market fixed effects control for time invariant differences across markets and allow each market to have its own average level of sales. Border-week fixed effects allow each border to have its own flexible trend in sales that will, for example, capture the observed seasonality in cigarette sales and will allow the specific seasonality pattern to differ between borders in New York and borders in Florida.

The *differences in differences* specification is shown in Equation 1. The unit of observation is a market-border-week where m denotes market, b denotes border, and t denotes week. The advertising stocks for e-cigarettes and smoking cessation products are denoted by A_{mt}^e and A_{mt}^q . Equation 1 is estimated separately for e-cigarettes, cigarettes, nicotine patches, and nicotine gum via OLS. Table 6 presents the estimation results.

$$Q_{mt} = \beta_m + \beta_{bt} + \phi_e A_{mt}^e + \phi_q A_{mt}^q + \alpha \vec{p}_{mt} + \epsilon_{mt} \quad (1)$$

First, looking at the first column in Table 6, the positive and significant coefficient on e-cigarette advertising indicates that, as expected, advertising for e-cigarettes increases demand for e-cigarettes. A one standard deviation (92 GRPs) increase in the e-cigarette ad stock results in a 5% increase in sales relative to the mean quantity of e-cigarettes sold. The effect of advertising for the Nicorette and Nicoderm CQ smoking cessation products is negative and about one fourth the magnitude of the own-advertising coefficient. The e-cigarette price coefficient is negative and significant as expected. The cigarette and nicotine patch cross-price coefficients are estimated to be positive and statistically significant, suggesting that these products are substitutes to e-cigarettes.

¹¹A carton of cigarettes counts as 10 packs.

¹²E-cigarette cartridges are most commonly sold in packs of 3–5.

Table 6: Difference in Differences Regression Results

	(1)	(2)	(3)	(4)	(5)
	E-Cig Cartridges	Packs Cigs	Total Nicotine	Nicotine Patches	Nicotine Gum
E-Cig Ad Stock	0.191*** (0.035)	-2.811*** (0.806)	-2.429*** (0.787)	-0.013 (0.012)	-0.494** (0.207)
Smoking Cessation Ad Stock	-0.047*** (0.013)	-0.478 (0.315)	-0.573* (0.309)	-	-
Nicotine Patch Ad Stock	-	-	-	-0.079*** (0.021)	-0.214 (0.267)
Nicotine Gum Ad Stock	-	-	-	-0.0004 (0.012)	0.232 (0.151)
Price E-Cig Cartridge	-6.774*** (1.097)	68.48*** (10.56)	54.93*** (11.45)	1.029*** (0.260)	4.347 (4.884)
Price Pack Cigs	163.2*** (18.09)	-6,698*** (393.3)	-6,371*** (382.5)	-8.404 (6.104)	-443.2*** (99.96)
Price Nicotine Patch	10.49*** (2.693)	-36.28 (43.59)	-57.25 (43.21)	-8.615*** (0.855)	-6.873 (13.65)
Price Nicotine Gum	-5.691 (17.50)	-204.9 (295.0)	-216.3 (291.5)	-14.03** (5.939)	-2,136*** (116.9)
DMA-Border FE	Y	Y	Y	Y	Y
Week-Border FE	Y	Y	Y	Y	Y
N Obs	52,236	52,236	52,236	52,236	52,236
E-Cig Ad Elasticity	0.02	-0.004	-0.003	-0.002	-0.003
% ΔQ from 1 SD ↑ A ^e	4.86%	-0.90%	-0.76%	-0.54%	0.65%

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column 2 of Table 6 regresses the number of packs of cigarettes sold in each market on the set of independent regressors and fixed effects. In column 2 there is a negative and significant effect of e-cigarette advertising on demand for traditional cigarettes. Contrary to all of the arguments that have been made as to why e-cigarette advertising might increase cigarette sales, I find evidence that e-cigarette advertising is actually *decreasing* demand for traditional cigarettes. The magnitude of this effect does appear small (a one standard deviation increase in e-cigarette advertising results in a -0.90% decrease in cigarette demand), but it is economically significant when compared to the fact that the overall incidence of smoking in the US is falling at a rate of about 1.5% per year (Centers for Disease Control and Prevention (2013)). Furthermore, the positive coefficient on e-cigarette price provides additional evidence that smokers treat e-cigarettes as a substitute to traditional cigarettes. In contrast, the coefficients on advertising and prices for smoking cessation products are not statistically significant in column 2. I calculate an own-price elasticity of -1.23 for traditional cigarettes, which is larger than the range of cigarette price elasticities of -0.4 and -0.8 that have been found in previous work (Gordon & Sun (2014)). The entry into the market of e-cigarettes, a perhaps closer substitute to traditional cigarettes, could explain this increase in the price-elasticity of cigarettes.

The observed increase in e-cigarette consumption and decrease in cigarette consumption as a result of e-cigarette advertising raises the question, what happens to total nicotine consumption in response to an increase in e-cigarette advertising? Under the conservative assumption that each e-cigarette cartridge is equivalent to 2 packs of cigarettes in terms of nicotine content, I calculate total nicotine consumption as the total number of “equivalent” packs of cigarettes and e-cigarettes purchased in each market-week.¹³ Column 3 reports how this total nicotine consumption varies in response to e-cigarette advertising. I find that an increase of 1 e-cigarette ad GRP results in a net decrease in total nicotine consumption, and some of that nicotine consumption is now coming in the less harmful form of e-cigarettes.¹⁴

¹³Nicotine content per cigarette pack and per e-cigarette cartridge may vary across brands. I abstract away from these differences for the purpose of this “back of the envelope” analysis.

¹⁴This analysis is potentially limited by the data at hand. While the Nielsen data has coverage of purchases of e-cigarettes made in traditional retail channels, the data does not record purchases of e-cigarettes made at local “vape” shops. In a note published in August 2015, Wells Fargo analyst Bonnie Herzog writes “Because a large portion of VTM [vaporizer, tank and mod] sales occur online and in vape shops – neither of which are tracked by Nielsen – the Nielsen data is no longer capturing the full e-vapor category. [...] While Nielsen’s data is useful directionally we believe the e-cigarette unit and pricing data remains difficult to rely on given Nielsen is not yet reporting ‘equivalent’ units in this category” (Haar (2015)). Thus, it is possible that the Nielsen data is underestimating the increase in e-cigarette consumption as a result of e-cigarette advertising.

When interpreting these results, it is important to keep in mind that nicotine itself is not the component of tobacco cigarettes that has been strongly linked with adverse health effects and mortality. The medical literature is careful to draw this distinction. For example, Benowitz & Gourlay (1997) notes, “It is important to recognize that cigarette smoke is a complex mixture of chemicals that includes not only nicotine but also potentially cardiotoxic substances, such as carbon monoxide, oxidant gases and polycyclic aromatic hydrocarbons. The role of nicotine, if any, in causing acute or chronic cardiovascular disease has not been definitely demonstrated” (pp. 1422-1423). Thus, while the result that total nicotine consumption appears to decrease in response to e-cigarette advertising is interesting and informative about consumption patterns, the reduction in purchases of tobacco cigarettes shown in Column 2 is by itself an important finding for health policy.

The analysis thus far has considered the effect of e-cigarette advertising on demand for cigarette products. Given that the results suggest that consumers treat e-cigarettes as a substitute to traditional cigarettes, it is also informative to look at the effect of e-cigarette advertising on demand for traditional nicotine replacement therapies – the nicotine patch and nicotine gum. Columns 4 and 5 present the regression results for the nicotine patch and gum products. I find that e-cigarette advertising has a business stealing effect on these smoking cessation products. The coefficient on e-cigarette advertising is negative and has a statistically significant effect on demand for nicotine gum, which is the dominant smoking cessation product with 80% market share. Additionally, the coefficient on e-cigarette price is positive and significant. These results indicate that consumers are using e-cigarettes as a substitute to the nicotine patch and gum. This could be a concern for policy makers because it suggests that e-cigarette advertising shifts consumers away from clinically proven smoking cessation aids to e-cigarettes, which have not yet been proven to be effective in helping smokers quit. In columns 4 and 5 I separate out advertising for the patch and gum in order to capture any cross-product effects. I find that advertising for the nicotine patch decreases demand for patches, which is an unexpected finding. The price of nicotine gum also has a negative effect on demand for patches, suggesting that nicotine patches and gum may be complements.¹⁵ Ad effects for the nicotine gum are not measured with precision.

¹⁵In their clinical practice guidelines on treating tobacco use and dependence, the U.S. Department of Health and Human Services (2008) reports that using nicotine gum and patches together leads to higher long-term abstinence rates relative to other treatments.

Together these results lead to the following conclusions. (1) E-cigarette advertising increases demand for e-cigarettes and reduces demand for traditional cigarettes. (2) Consumers treat e-cigarettes and smoking cessation products as substitutes. In the next section, I further explore the substitution patterns between products using household purchase panel data.

4.2 Substitution Patterns and Addiction in Household Data

Thus far, the aggregate data indicates that e-cigarette advertising increases demand for e-cigarettes and reduces demand for traditional cigarettes. In this section, I examine household panel data to determine whether households increase or decrease their consumption of cigarettes after buying e-cigarettes, and whether there is evidence of cigarette addiction. Relative to the aggregate data, the household data is more transparent in revealing these substitution patterns over time.

I analyze the weekly purchases of cigarettes for the 7,667 households who ever buy a cigarette or e-cigarette product and who are tracked in the panel for all 5 years. 881 (11%) of these households ever buy an e-cigarette. To test for patterns consistent with addiction, I analyze how recent cigarette purchases affect whether a household purchases any cigarettes at all, denoted by the binary variable \tilde{c}_{it} , and the number of packs of cigarettes a household purchases in that week, c_{it} . This framework for modeling addiction is consistent with the Becker & Murphy (1988) theory of addiction, in which past consumption is complementary to current consumption. Because previous research has also found evidence of stockpiling of cigarettes, a force that works in opposition to addiction, I include three different variables related to past purchases to illustrate the opposing effects of addiction and stockpiling. First, I include \tilde{c}_{it-1} , a binary variable indicating whether a household purchased any cigarettes last week. Then, I also separately include the quantity of cigarettes purchased last week, c_{it-1} , and a stock variable that represents the total number of packs of cigarettes purchased in the three weeks before that, C_{it} . Separating the choice to purchase last week from the quantity purchased last week, and the quantity of very recent purchases (last week) from other recent purchases (the three preceding weeks) allows me to illustrate the opposing forces of addiction and stockpiling. I also include variables recording the total quantity of e-cigarette cartridges, nicotine patches, and pieces of nicotine gum purchased in the preceding 4 weeks by each individual, denoted by E_{it} , P_{it} and G_{it} respectively. Finally, the regression includes household fixed effects, such that the coefficients are identified off of within-household variation over time, and week fixed

effects, which capture aggregate trends and seasonality in cigarette sales. Standard errors are clustered at the household level.

$$\tilde{c}_{it} = \alpha_i + \alpha_t + \beta_1 \tilde{c}_{it-1} + \beta_2 c_{it-1} + \beta_3 C_{it} + \gamma_1 E_{it} + \delta_1 P_{it} + \delta_2 G_{it} + \epsilon_{it} \quad (2)$$

I use the same estimation equation when analyzing the number of packs of cigarettes households purchase, c_{it} .

The first column of Table 7 presents the regression results when the binary choice to purchase any cigarettes is the left hand side variable. The coefficient on purchasing cigarettes in the previous week is positive and significant, which is consistent with addiction. However, purchasing *more* packs in the previous week is less likely to be associated with a purchase this week, which is consistent with stockpiling. More purchases over the previous 4 weeks, which are less likely to have stock carry-over in the current week, are associated with a higher purchase incidence this week, again consistent with addiction. These patterns provide evidence that, setting stockpiling aside, households are more likely to buy in the current period if they have purchased more in the past. Finally, the coefficients on the variables recording past purchase quantities of e-cigarettes and smoking cessation products are negative and significant, indicating that individuals are less likely to purchase a cigarette product when they have purchased more of these alternative nicotine products recently.

The second column presents the regression results when the number of cigarette packs purchased is the left hand side variable. The results are similar, again showing evidence of addiction, stockpiling, and substitution. The coefficient on incidence in the previous week is positive, consistent with addiction, while the coefficient on purchase quantity in the previous week is negative, consistent with stockpiling. The coefficients on the variables recording past purchase quantities of e-cigarettes and smoking cessation products are negative and significant, indicating that individuals reduce their purchase quantity of cigarettes when they have purchased more of these alternative nicotine products recently. The key difference to emphasize in this analysis is that larger past purchase quantities of tobacco cigarettes are associated with higher current period tobacco cigarette purchase incidence and quantity, while larger past purchase quantities of e-cigarettes are associated with lower tobacco cigarette purchase incidence and quantities.¹⁶ Although we cannot interpret these results as causal, these substitution patterns

¹⁶I estimate the same models using monthly data in order to assess the sensitivity of this analysis to the length of the time window. With monthly data the coefficients on tobacco cigarette purchase quantity in the past month become positive (no longer a pattern consistent with stockpiling), while all other coefficients remain the same sign.

Table 7: Household Addiction and Substitution Patterns Between Cigarettes and E-Cigarettes

	Cig Purchase Incidence	Cig Packs Purchased
Cig Purchase in Previous Week	0.136*** (0.005)	0.273*** (0.097)
Cig Packs in Previous Week	-0.006*** (2.73e-04)	-0.080*** (0.009)
Cig Packs in Previous 4 Weeks	0.005*** (2.45e-04)	0.107*** (0.009)
E-Cig Cartridges in Previous 4 Weeks	-0.001*** (4.09e-04)	-0.029*** (0.008)
Nicotine Patches in Previous 4 Weeks	-9.11e-04*** (3.06e-04)	-0.019*** (0.004)
Nicotine Gum in Previous 4 Weeks	-5.95e-05** (2.66e-05)	-6.95e-04** (3.04e-04)
N Obs	1,970,419	1,970,419
HH FE	Y	Y
Week FE	Y	Y
Mean DV	0.143	1.410
Last Week Cig as % of DV	95.5%	19.4%
Effect + 1 Pack Cigs in Prev 4 Weeks as % of DV	1.95%	3.61%
Effect + 1 E-Cig Cartridge in Prev 4 Weeks as % of DV	-0.48%	-0.97%

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Magnitude of change post e-cigarette reported as percent of average DV for those households who ever purchase an e-cigarette. E-cigarette users are on average heavier smokers than non e-cigarette users, with an average weekly purchase incidence of 0.273 and average number of packs purchased of 2.97.

are consistent with e-cigarettes acting as a substitute, as opposed to as a gateway to traditional cigarettes through nicotine addiction.

In the preceding sections, I presented reduced form evidence that e-cigarette advertising increases demand for e-cigarettes and reduces demand for cigarettes. Analysis of household panel data further showed that households tend to reduce their consumption of cigarettes after they purchase e-cigarettes and that addiction is an important force at play in this market. In the following section, I present a structural model of demand for cigarettes that is motivated by these empirical findings. The model will allow me to (i) simultaneously account for advertising effects and addiction, (ii) implement more efficient joint estimation using both aggregate and household data, (iii) control for unobserved heterogeneity in preferences, and (iv) evaluate counterfactual scenarios that predict the response in cigarette demand to a proposed ban of e-cigarette TV advertising.

5 An Integrated Micro-Macro Model of Demand

5.1 Overview

My descriptive analysis of market-level sales and advertising data indicates that e-cigarette advertising reduces demand for traditional cigarettes. These results suggest that banning e-cigarette advertising may have unintended consequences and actually lead to an increase in aggregate cigarette consumption. The magnitude of this effect is of great importance to policy makers as they consider whether to impose a ban on advertising for e-cigarettes. In the following sections, I develop a structural model of demand for cigarettes and use the estimated preference parameters to predict the counterfactual demand for cigarettes that would have been observed in the absence of e-cigarette advertising.

I specify a structural model that (i) harnesses the information content of both individual and aggregate data in an efficient and internally consistent way, (ii) incorporates dynamic dependencies that arise as a result of nicotine addiction, and (iii) identifies advertising effects accounting for endogeneity using the border strategy approach. The existing literature has addressed each of these individually, but I believe my paper is the first to unify these objectives within a single cohesive framework. I discuss each of these aspects of the model in turn below.

In theory, I could use either the aggregate or household-level data to estimate demand for cigarettes. However, each dataset has its relative merits and limitations. The aggregate data

measures advertising effects with less noise and can be used to recover unobserved aggregate demand shocks, while the household data is more transparent in revealing patterns of addiction and heterogeneity in the population. For these reasons, I leverage both datasets to estimate demand for cigarettes. Specifically, I propose an individual-level demand model that aggregates in an internally consistent way, such that the equations that govern household and aggregate demand are functions of the same parameters. In order to estimate the model, I adapt an integrated estimation procedure developed by Chintagunta & Dubé (2005), who illustrate how to combine household and aggregate store level data to estimate the parameters of a discrete choice random coefficients model of demand. The intuition behind their estimation approach is to take advantage of the relative merits of each dataset to simultaneously (i) estimate the mean effects of marketing activities, (ii) account for endogeneity in prices, and (iii) allow for heterogeneity across households. As Chintagunta and Dubé point out, although heterogeneity in the population can be identified using only aggregate data (Berry, Levinsohn, & Pakes (1995)), household panel data is more informative about heterogeneity than store level data. At the same time, there is usually little to no information in household panel data that can be used to account for the endogeneity of marketing variables, but aggregate data can be used to account for this endogeneity (Berry et al. (1995)).¹⁷ Motivated by these facts, Chintagunta and Dubé propose a method to use aggregate data to estimate mean preference parameters and address the endogeneity problem and household-level data to estimate the distribution of heterogeneity.

I extend this micro-macro demand model to account for dynamic dependencies that arise as a result of nicotine addiction. State-dependence is not incorporated in the Chintagunta and Dubé approach, but it is key to the analysis of addiction. The incorporation of state dependence, however, complicates the aggregate demand system considerably, since demand is no longer independent across time. In order to capture this persistence across time, I adapt a formulation due to Caves (2004). Caves presents an aggregate structural model of demand for cigarettes that incorporates addiction as a form of category-level state dependence where a consumer's utility from buying a cigarette product in the current period is higher if he purchased a cigarette product in the previous period. He allows for heterogeneity in the form of discrete types, estimating his model with high and low types in ad responsiveness.¹⁸ I combine Caves'

¹⁷Subsequent work has shown that supplementing the model with household moments can generate more realistic model-predicted substitution patterns (Petrin (2002) and Berry, Levinsohn, & Pakes (2004)).

¹⁸In another category, Horsky, Pavlidis, & Song (2012) also estimates an aggregate structural model with state dependence, though the model does not allow for unobserved heterogeneity.

model, which was developed originally for only aggregate data, with Chintagunta and Dubé’s estimation strategy, while extending Caves’ algorithm significantly to allow for a continuous distribution of heterogeneous preferences in price and ad responsiveness. I find that allowing for a rich continuous distribution of heterogeneity is important to correctly separate the impact of addiction – a form of state dependence – from persistent unobserved tastes, an observation well known to econometricians at least since Heckman (1981). The incorporation of a continuous distribution of heterogeneity increases the computational cost of the estimator significantly.

The final modeling challenge I face is how to incorporate the identification of advertising effects within the structural model, an element that has not always been a focus of the existing literature on nicotine addiction. The same intuition behind identification in the reduced form setting holds in the structural model as well. I estimate the model only using data for stores and individuals located within border markets, and I include market-border and border-time fixed effects. In Section 6 I explain in further detail how the structural model accommodates these fixed effects.

Ultimately, I contribute to the literature by combining these separate streams of research to carefully identify advertising effects in a model with addiction using both individual and aggregate data within a unified framework. While in theory Caves’ model is identified using only aggregate data, in this paper I show how to incorporate individual level data to improve the efficiency of estimation and the flexibility of the heterogeneity specification. I extend the estimation procedure developed by Chintagunta & Dubé to a model with state dependence, and I illustrate how regression discontinuity identification can be ported into the structural model.

In the sections below, I first lay out the equations characterizing individual-level demand and then show how the model aggregates and accommodates unobserved heterogeneity. Next, I describe the estimation procedure in more detail. Finally, I present the estimation results and use the model estimates to consider the implications of a proposed ban on e-cigarette advertising.¹⁹

5.2 Individual Level Model

I specify an individual-level discrete choice model where consumers choose whether to buy a pack of cigarettes, a carton of cigarettes, or not to make a purchase. To incorporate addiction,

¹⁹In Appendix F I use model simulations to show that the model is well identified and that combining aggregate and household data leads to increased estimation efficiency.

an important characteristic of the cigarette market, I allow utility from consuming in the current period to be increasing in consumption in the previous period. This simple model of addiction is consistent with the Becker & Murphy (1988) model of addiction in which past consumption is complementary to current consumption.

Denote an individual's indirect utility function from consuming product j by equation 3. The indirect utility is a function of observed variables and unobserved product characteristics. Observed variables include current prices p and e-cigarette and smoking-cessation advertising A . These variables, together with a set of product intercepts, are grouped into the matrix X . Also observed is an indicator c_{it-1} denoting whether the individual consumed any of the inside goods in the previous period. Note that addiction operates at the category level and c_{it-1} is not product specific; c_{it-1} takes on a value of 1 if the individual purchased either a pack or a carton of cigarettes in the previous period and a 0 otherwise. The unobserved (to the econometrician) components of the indirect utility function include ξ_{jmt} which captures systematic shocks to aggregate demand including, for example, unobserved marketing activity, and ε_{ijt} , a stochastic error term which is assumed to be distributed type I extreme value. The deterministic part of utility from consuming the outside good is normalized to 0.

$$u_{ijt} = \beta_j + \alpha p_{jt} + \phi A_{mt} + \gamma c_{it-1} + \xi_{jmt} + \varepsilon_{ijt} \quad (3)$$

$$u_{i0t} = \varepsilon_{i0t} \quad (4)$$

Integrating out the distribution of stochastic errors ε_{ijt} , the probability that an individual will purchase product j is given by equation 5.

$$P_{ijt}(X_{it}, c_{it-1}) = \frac{e^{X_{jt}\theta + \xi_{jt} + \gamma c_{it-1}}}{1 + \sum_k e^{X_{kt}\theta + \xi_{kt} + \gamma c_{it-1}}} \quad (5)$$

5.3 Aggregate Model

Conditional on past consumption status, the probability of buying a product is just the logit probability given by equation 5. Let s_{jmt} denote the market share of product j in market m in week t and s_{0mt} denote the market share of the outside good. I calculate aggregate market shares by weighting the purchase probabilities conditional on consumption status by the probability of having that consumption status, which in this case is just the combined market shares of the

inside goods in the previous period.

$$s_{jmt} = Pr(j|X_{jmt}, c_{t-1} = 1)Pr(c_{t-1} = 1) + Pr(j|X_{jmt}, c_{t-1} = 0)Pr(c_{t-1} = 0) \quad (6)$$

$$= \frac{e^{X_{jmt}\theta + \xi_{jmt} + \gamma}}{1 + \frac{1}{k} e^{X_{kmt}\theta + \xi_{kmt} + \gamma}} (1 - s_{0mt-1}) + \frac{e^{X_{jmt}\theta + \xi_{jmt}}}{1 + \frac{1}{k} e^{X_{kmt}\theta + \xi_{kmt}}} s_{0mt-1} \quad (7)$$

5.4 Incorporating Unobserved Heterogeneity

Thus far, I have shown how to derive aggregate demand from a homogenous demand model with state dependence. In this section I extend the model to include unobserved heterogeneity in consumer types. The key insight is that the joint distribution of heterogeneity and state dependence is not stationary; rather, it evolves over time. For example, if consumers vary in their sensitivity to price, then an increase in price will decrease the probability that price-sensitive consumers buy today, which affects the joint distribution of consumer types and consumption states in the next period. In particular, prices in the current period affect the joint distribution of state dependence and heterogeneity in all subsequent periods. I allow the coefficients on price and advertising to vary across the population, as shown in equation 8.

$$u_{ijt} = \beta_j + \alpha_i p_{jt} + \phi_i A_{mt} + \gamma c_{it-1} + \xi_{jmt} + \varepsilon_{ijt} \quad (8)$$

As in the previous section, in order to obtain aggregate market shares I integrate out unobserved heterogeneity and the stochastic demand shocks. In the model with heterogeneity, I calculate aggregate market shares by integrating the purchase probabilities conditional on consumption status and consumer type against the joint distribution of consumption status and consumer heterogeneity.

$$s_{jt} = \int_{\Theta \times \{0,1\}} Pr(j|\theta_i, c_{t-1}) dF_{\theta_i \times c} \quad (9)$$

The discussion above does not assume any particular joint distribution between unobserved heterogeneity and state dependence. In the estimation section below, I make specific assumptions about that distribution and show how to numerically evaluate the above integral.

Discussion

Before moving on to the estimation procedure, I first discuss some of my modeling assumptions. First is the decision to use a discrete choice model instead of explicitly modeling purchase

quantities. Past work on addiction has assumed that addiction operates through the effect of past purchase quantities on current purchase quantity (Becker & Murphy (1988), Gordon & Sun (2014)). The household panel data would in theory allow me to model quantities; however, the panel is thin. The aggregate data is richer and allows me to identify advertising effects with more precision, but it limits my ability to model purchase quantities.²⁰ In order to be able to harness the richness of the aggregate data, I choose to model purchase incidence in a discrete choice framework. Within this framework, I am able to accommodate purchase quantities by allowing consumers to make a discrete choice over pack sizes. Cigarettes are primarily sold in uniform packages of packs (20 cigarettes) and cartons (10 packs), so the pack size proliferation that is often observed in CPG categories is not binding in this case.

A separate but related assumption is that only the previous week’s purchase decision affects current period consumption and that consumers are not forward looking. An assumption closer to observed consumer behavior and patterns of addiction might allow additional lags of purchase decisions to affect current choices. I choose to work with the simpler one period lag because the model with state dependence can be estimated using aggregate data. Although this may be a strong restriction on consumer behavior, my econometric specification is still flexible. My estimation allows for heterogeneity across households and includes market and time fixed effects, which allow me to capture a variety of observed data patterns.

6 Estimation and Results

6.1 Estimation with Unobserved Heterogeneity

The model discussion above did not rely on any specific assumptions about the distribution of unobserved heterogeneity. In my model implementation, I assume that unobserved heterogeneity follows a normal distribution, but to facilitate exposition, I first introduce the model with R discrete types. Specifically, suppose individuals are drawn from a distribution with R latent types such that an individual’s preference parameter vector is $\theta_r \in \Theta$. For each type, the probability of purchasing product j is again the familiar logit probability $Pr(j|\theta_r, c_{t-1} = 1)$ if the individual purchased in the previous period and $Pr(j|\theta_r, c_{t-1} = 0)$ if they did not.

In the initial period, the population of consumers is distributed across these types

²⁰Hendel & Nevo (2013) model purchase quantities using aggregate data, but need to impose other simplifying assumptions in order to make their model tractable with aggregate data.

and consumption states according to some joint distribution $Pr(\theta_r, c_{t=0})$.²¹ In subsequent periods, the marginal probability of being a certain type $Pr(\theta_r)$ remains constant, but the joint distribution of consumer types and consumption status $Pr(\theta_r, c_t)$ evolves as the heterogeneous population responds to variation in prices and advertising. The joint distribution updates each period according to the recursion in equation 10.

$$Pr(\theta_r, c_t = 1) = Pr(c_t = 1 | \theta_r, c_{t-1} = 1) \times Pr(\theta_r, c_{t-1} = 1) + Pr(c_t = 1 | \theta_r, c_{t-1} = 0) \times Pr(\theta_r, c_{t-1} = 0) \quad (10)$$

The recursion shows that the probability of being a specific type r and smoking in the current period $c_t = 1$ is equal to the probability that a smoker of type r continues smoking in the current period plus the probability that a non-smoker of type r begins smoking in the current period.

Finally, aggregate market shares are obtained in the model with R latent types by weighting the logit probability of purchase for each individual type by the joint distribution of types and consumption status in the population. Specifically, the integral describing market shares in equation 9 becomes a summation over discrete types, as shown in equation 11.

$$s_{jt} = \sum_{r=1}^R [Pr(j | \theta_r, c_{t-1} = 1) \times Pr(\theta_r, c_{t-1} = 1) + Pr(j | \theta_r, c_{t-1} = 0) \times Pr(\theta_r, c_{t-1} = 0)] \quad (11)$$

Now, I discuss how to extend the model to allow for a continuous heterogeneity distribution. I assume that the distribution of random coefficients follows a normal distribution, and I estimate the mean $\bar{\theta}$ and variance Σ of the distribution. Let $v_i \sim N(0, 1)$ and Λ be the Cholesky decomposition of Σ s.t. $\theta_i = \bar{\theta} + \Lambda v_i \sim N(\bar{\theta}, \Sigma)$. The indirect utility function in equation 8 can be decomposed into common and individual-specific components, as shown in equation 12, where $\delta_{jmt} = X_{jmt} \bar{\theta} + \xi_{jmt}$ captures the mean aggregate utility level and $\mu_{ijt}(X_{jmt}, c_{it-1}; \Sigma, \gamma) = X_{jmt} \Lambda v_i + \gamma c_{it-1}$ represents heteroskedastic deviations from the mean utility level. Note that δ is the mean utility level for those who did not consume in the previous period, and addiction, or the increase in utility coming from having consumed in the previous period, is captured in μ .

$$u_{ijt} = \beta_j + \alpha_i p_{jt} + \phi_i A_{mt} + \gamma c_{it-1} + \xi_{jmt} + \varepsilon_{ijt} = \delta_{jmt}(X_{jmt}, \xi_{jmt}; \bar{\theta}) + \mu_{ijt}(X_{jmt}, c_{it-1}; \Sigma, \gamma) + \varepsilon_{ijt} \quad (12)$$

²¹Equation 10 relies on an initial condition $p_{rc} = Pr(\theta_r, c_{t=0})$ that pins down the initial joint distribution. I discuss how I resolve this initial conditions problem in more detail in the estimation section below.

The additional layer of complication in incorporating a continuous distribution of unobserved heterogeneity is in how to evaluate the integral in equation 9 and how to update the joint distribution of unobserved heterogeneity and state dependence each period. In a standard random coefficients model, the typical approach to integrating out unobserved heterogeneity is to take draws from the latent distribution and approximate the integral using Monte Carlo integration. The key insight to implementation of a continuous distribution of unobserved heterogeneity in the aggregate model with state dependence is that once R draws are taken from the latent normal, we are basically back in the world of an R -type latent class model. Equation 10 approximates the joint distribution of heterogeneity and state dependence and equation 11 can be used to obtain the model-predicted aggregate market shares.

6.2 Estimation Procedure

At a high level, I estimate the mean utility parameters $\bar{\theta}$ and recover unobserved demand shocks ξ_{jmt} from aggregate data and estimate the heterogeneity distribution Σ and addiction parameter γ from household panel data. The estimation steps are described in detail below.

1. **Aggregate Data Step:** Given a guess of the heterogeneity and addiction parameters ($\tilde{\Sigma}, \tilde{\gamma}$), for each market m , product j , and time period t , I compute $\delta_{jmt} = X_{jmt} \bar{\theta} + \xi_{jmt}$ that equates the model predicted market share to the observed market share in the aggregate data. I calculate observed market shares by dividing total store sales in each market by the adult population of that market. The model-predicted market share $s(X, \delta; \Sigma, \gamma)$ is given by equation 9. In practice, I approximate the integral over the joint distribution of consumer heterogeneity and state dependence using Monte Carlo integration. I take R draws $\nu_r \sim N(0, 1)$ and for the given guess of $\tilde{\Sigma}$ calculate $\theta_r = \bar{\theta} + \tilde{\Lambda} \nu_r \sim N(\bar{\theta}, \tilde{\Sigma})$. Then I use equations 10 and 11 to calculate the model-predicted aggregate market shares. Conditional on $\tilde{\Sigma}$ and $\tilde{\gamma}$, the model predicted share is given by

$$s_{jmt} = \sum_{r=1}^R \left[\frac{e^{\delta_{jmt} + X_{jmt} \tilde{\Lambda} \nu_r + \tilde{\gamma}}}{1 + \sum_k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} \nu_r + \tilde{\gamma}}} \times Pr(\theta_r, c_{t-1} = 1) + \frac{e^{\delta_{jmt} + X_{jmt} \tilde{\Lambda} \nu_r}}{1 + \sum_k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} \nu_r}} \times Pr(\theta_r, c_{t-1} = 0) \right] \quad (13)$$

and the joint distribution of heterogeneity and state dependence is given by

$$\begin{aligned}
Pr(\theta_r, c_t = 1) &= \frac{k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} v_r + \tilde{\gamma}}}{1 + k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} v_r + \tilde{\gamma}}} \times Pr(\theta_r, c_{t-1} = 1) \\
&+ \frac{k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} v_r}}{1 + k e^{\delta_{kmt} + X_{kmt} \tilde{\Lambda} v_r}} \times Pr(\theta_r, c_{t-1} = 0)
\end{aligned} \tag{14}$$

The recursion in equation 14 relies on knowing the joint distribution of heterogeneity and consumption status, $p_{r1} = Pr(\theta_r, c_{t=0} = 1)$ and $p_{r0} = Pr(\theta_r, c_{t=0} = 0)$, in the initial period. The literature has typically resolved this type of initial conditions problem by either treating the initial probability distribution as parameters of the model to estimate, or by using an initial period of data as a burn-in period to forward simulate the distribution (Erdem, Imai, & Keane (2003)). I take the second approach and use the first quarter of data for each market to forward simulate the joint distribution. For each guess of the parameters, I re-calculate the series of probabilities governing the evolving joint distribution of heterogeneity and state dependence for the initial burn-in period and obtain p_{r1} and p_{r0} .²² I then use the remaining data for each market, starting in the second available quarter, as the initial period in estimation.

With the equations describing model-predicted shares in hand, I calculate the δ s that equate observed and model-predicted shares using the BLP contraction mapping algorithm described in equation 15 (Berry et al. (1995)). The values of δ_{jmt} must be calculated iteratively each period because state dependence causes the current period share to depend on the previous unobserved demand shock ξ_{jmt-1} .

$$\delta_{m \cdot t}^{h+1} = \delta_{m \cdot t}^h + \ln S_{m \cdot t} - \ln s(X_{m \cdot t}, \delta_{m \cdot t}^h; \tilde{\Sigma}, \tilde{\gamma}) \tag{15}$$

2. **Household Data Step:** Given the current guess of $\tilde{\delta}$, I estimate Σ and γ via maximum likelihood with household data. Each household is matched to its aggregate data counterpart. Substituting the appropriate $\tilde{\delta}$ into the household's indirect utility function,²³ the probability that a household buys a given product in a given period is given by equation

²²I assume equal probabilities of smoking and not smoking for each type in the first week of the burn-in period, such that the probability of having a given type and smoking consumption status at the beginning of the burn-in period is equal to $\frac{1}{2R}$. I have tried a variety of different starting values and found that the joint distribution converges to the same steady state within the burn-in period.

²³In model simulations in Appendix F, I assume that households face the same prices as those used to generate

16. Integrating out the distribution of unobserved heterogeneity, the likelihood for each individual is then given by equation 17. In practice, I approximate the integral using a Monte Carlo simulation using the same R draws from the standard normal, and I estimate the parameters Σ and γ by maximizing the likelihood in equation 18 via maximum simulated likelihood.

$$P_{ijt}(X_{imt}, \tilde{\delta}_{imt}, c_{it-1}, \Sigma, \gamma) = \frac{\exp[\tilde{\delta}_{imjt} + X_{imjt}\Lambda v_i + \gamma c_{it-1}]}{1 + \sum_{k=1}^K \exp[\tilde{\delta}_{imkt} + X_{imkt}\Lambda v_i + \gamma c_{it-1}]} \quad (16)$$

$$L_i(Y_i|X_i, \tilde{\delta}_i; \Sigma, \gamma) = \prod_{t=1}^{T_i} \prod_{j=1}^J P_{ijt}(X_i, \tilde{\delta}_i, c_{it-1}, \Sigma, \gamma)^{Y_{ijt}} dF_v \quad (17)$$

$$\mathcal{L}(Y|X, \tilde{\delta}; \Sigma, \gamma) = \sum_{i=1}^N \log[L_i(Y_i|X_i, \tilde{\delta}_i; \Sigma, \gamma)] \quad (18)$$

3. **Iterate Until Convergence:** I iterate steps 1 and 2 until the estimated parameters (δ, Σ, γ) do not differ by more than a threshold of 10^{-6} .
4. **Estimate Linear Parameters from Aggregate Data:** After the model parameters have converged, I then use the fact that $\delta_{mjt} = X_{mjt}\bar{\theta} + \xi_{mjt}$ to estimate the linear parameters $\bar{\theta}$. For now, I estimate $\hat{\theta} = (X'X)^{-1}X'\hat{\delta}$ via OLS. In future work I hope to account for the potential endogeneity of prices by instrumenting for price in a linear IV regression.

I calculate standard errors for Σ and γ , the model parameters identified off of the household data, by inverting the hessian at the optimum of the likelihood function. Standard errors for the remaining linear parameters are calculated using a parametric bootstrap. I take draws from the asymptotic distribution of $\Omega = (\Sigma, \gamma)$, and for each draw ω_n I calculate the implied vector $\delta(\omega_n)$ that equates observed and model-predicted shares. Then for each $\delta(\omega_n)$ vector, I estimate the linear parameters $\hat{\theta}_n$. The standard errors are recovered from the variance of the distribution of the estimates of the linear parameters.

the aggregate data. Then the δ that equates the model-predicted aggregate market shares to the observed market shares can just be plugged into the household ML model. In the actual dataset used for estimation, the household price series records the prices actually paid by households while the aggregate price series records the average price of cigarettes in that market, which will not be the same. In order to resolve this inconsistency, on each iteration I calculate a household-specific δ_i . For each iteration or guess of θ_2 , I use the BLP contraction to solve for δ_m . I then estimate $\hat{\theta}_1^{OLS} = (\hat{\beta}, \hat{\alpha}, \hat{\phi})$ and back out $\hat{\xi}_m = \delta_m - X_1\hat{\theta}_1$ which is used to construct the household-specific $\hat{\delta}_{im} = \hat{\beta}_m + \hat{\alpha}p_i + \hat{\phi}A_m + \hat{\xi}_m$ using the household price series p_i . These household-specific δ_i 's are then plugged into the likelihood function for the household ML estimation.

6.3 Identification

Before presenting the model estimates, I first discuss identification and highlight how I incorporate the border counties identification strategy into the estimation of the structural model. I estimate the model using aggregated store data for *only* those stores in border county markets and household data for *only* those households who reside within border counties. Thus, the same regression discontinuity identification from the linear model applies here — the nonlinear estimator is also only based on the behavior of marginal consumers at borders. In total I have data for 272 markets and 150 households. The fact that the linear parameters are estimated in a simple linear regression allows me to continue to include border-market and border-time fixed effects. Specifically, I include a set of 1,587 border-market and border-quarter fixed effects in the structural estimation. It would be impossible to include this many parameters in a typical non-linear optimization routine. The linear regression stage is thus an important component of the model that allows me to incorporate regression discontinuity identification into the structural model.

Finally, the household purchase data identifies the parameters pinning down the heterogeneity distribution and state dependence, while the aggregate data identifies the mean utility parameters. Although state dependence can be identified using aggregate data based on the co-movement of current market shares and variation in past prices, household data allows us to explicitly observe the dependence across a given household's purchases over time. Similar intuition applies regarding the identification of unobserved heterogeneity.

6.4 Estimation Results

Table 8 presents the estimated model parameters.²⁴ The first column reports estimates for the homogeneous model. The second column reports estimates for the model with random coefficients on price and advertising. Focusing on the estimates for the model with heterogeneity, the mean coefficients on price and advertising for e-cigarettes and smoking cessation products are all estimated to be negative. The estimated standard deviations of the heterogeneity distribution are large relative to the means, especially for e-cigarette advertising, implying that advertising will increase demand for cigarettes for some individuals. The difference in product intercepts $\beta_p - \beta_c$ gives the estimated relative preference for packs over cartons of cigarettes.

²⁴Current estimates using data through 2012. Updated model results with 2013 data are in progress.

Once heterogeneity is included in the model, the magnitude of the addiction parameter γ decreases. In the absence of heterogeneity, any serial correlation generated by unobserved heterogeneity is absorbed into γ . This result is consistent with the findings of Dubé, Hitsch, & Rossi (2010).

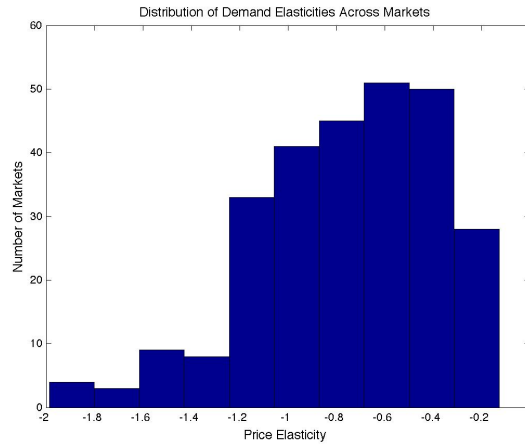
Table 8: Model Estimation Results

	Homogeneous	Heterogeneous	
		$\bar{\theta}$	σ_{θ}
α	-0.7920 (0.0099)	-0.6701 (0.0246)	0.5678 (0.0077)
ϕ_e	0.0003 (0.0002)	-0.0242 (0.0005)	0.0255 (0.0009)
ϕ_q	0.0002 (0.0002)	-0.1866 (0.0004)	0.1199 (0.0005)
$\beta_p - \beta_c$	3.5708 (0.0045)	3.6025 (0.0115)	
γ	3.2576 (0.0345)	0.5409 (0.0530)	
Market FEs	Y	Y	
Border-Quarter FEs	Y	Y	

In order to build intuition around the estimation results, I calculate the implied short-run demand elasticities for each market. The short run elasticity captures the responsiveness of demand to a one-time price increase in the same week. I calculate short-run elasticities using equation 19. The distribution across markets of the average short-run demand elasticity of a pack of cigarettes is shown in Figure 11. The mean short-run demand elasticity across markets is -0.75.

$$\begin{aligned}
\eta_{jmt} &= \frac{p_{jmt}}{s_{jmt}} \frac{\partial s_{jmt}}{\partial p_{jmt}} \\
&= \frac{p_{jmt}}{s_{jmt}} \int_{\Theta \times \{0,1\}} \alpha_i s_{ijmt|c} (1 - s_{ijmt|c}) dF_{i \times c} \\
&= \frac{p_{jmt}}{s_{jmt}} \sum_{(\theta_r \times c_{t-1}) \in \{\theta_1, \dots, \theta_R\} \times \{0,1\}} \alpha_r s_{rjmt|c_{t-1}} (1 - s_{rjmt|c_{t-1}}) Pr(\theta_r, c_{t-1})
\end{aligned} \tag{19}$$

Figure 11: Distribution of Average Demand Elasticities Across Markets



Since the effect of addiction creates dynamic dependencies in demand over time, I also plan to look at the long run elasticity of demand to see how a price increase in one week affects demand in future periods. The long-run elasticity requires forward simulating demand.

7 Counterfactual E-Cigarette Ad Ban

In April 2015, the American College of Physicians published an opinion paper on e-cigarettes in the *Annals of Internal Medicine* that, among other regulatory requests, called for a prohibition on e-cigarette television advertising (Crowley (2015)). The ACP cited concerns that youth exposure to e-cigarette advertisements has increased dramatically in recent years and that e-cigarette advertising may help contribute to a re-normalization of smoking that will “reverse the progress made to stigmatize smoking and reduce its appeal among young people.” Like the World Health Organization, the ACP also expressed concern that e-cigarettes may act as a gateway to a lifetime of nicotine addiction and increased probability of using other tobacco products, including combustible cigarettes. To date, there exists little to no empirical evidence that supports these arguments. To my knowledge, this paper provides the first empirical analysis of the effects of e-cigarette advertising on demand for traditional cigarettes and e-cigarettes.

The previous sections provided empirical evidence that e-cigarette advertising has led to a reduction in sales of tobacco cigarettes. In this section, I use the demand model estimates from Section 6 to predict the effect on cigarette demand if regulators were to instate a ban on

e-cigarette TV advertising. Specifically, I impose a counterfactual ban on e-cigarette advertising beginning in the second half of 2012 and use the model estimates to forecast weekly demand over the next six months. Setting weekly e-cigarette advertising to 0 in the second half of 2012, I calculate the counterfactual ad stock over this period. Then, using the estimated parameters $\hat{\theta}$, $\hat{\Sigma}$, $\hat{\gamma}$ and demand shocks $\hat{\xi}_{jmt}$, I calculate the counterfactual market shares for packs and cartons of cigarettes. I sum the market shares for packs and cartons to get the total market share of cigarette products.

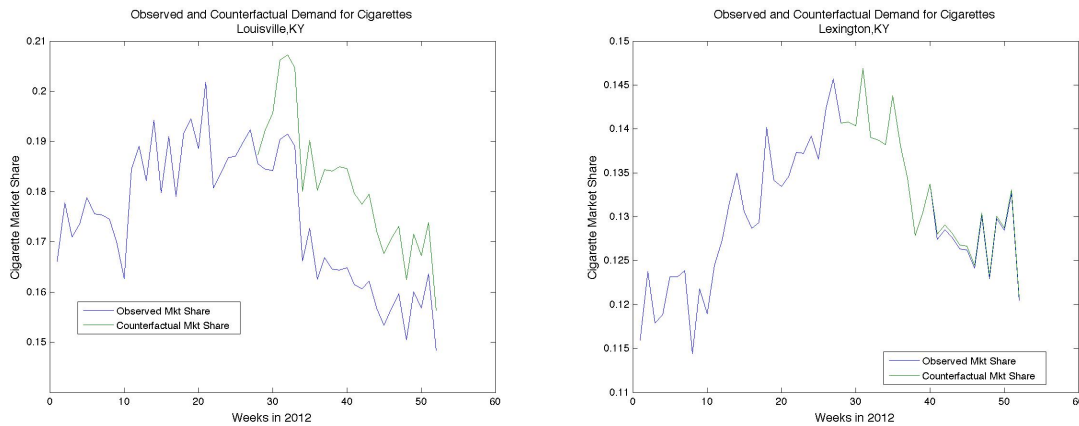
Banning e-cigarette advertising leads to an increase in the market share of tobacco cigarettes because the mean coefficient on e-cigarette advertising $\hat{\phi}_e$ is negative. The magnitude of the increase in share varies across markets. Markets with low levels of advertising are not affected much by the ban, while markets with high advertising intensity see a larger increase in demand for cigarettes. For example, recall that in the case of Louisville and Lexington, KY, Louisville was exposed to significantly more advertising than Lexington in the second half of 2012 (see Figures 7 and 8). Thus, the counterfactual predicts that cigarette demand would have increased significantly in Louisville if an e-cigarette advertising ban had been instated, while demand in Lexington would have remained relatively unchanged under such a ban. Figure 12 plots the weekly observed and model-predicted counterfactual cigarette market shares for Louisville and Lexington in 2012. Table 9 reports statistics on the distribution across all markets of changes in cigarette market share in the last week of 2012. The median percent increase in market share as a result of the ban is 2.64%. Though small, this is an economically significant increase given that between 2010 and 2011, the population share of current smokers in the US fell from 19.3% to 19%, a 1.55% decline (Centers for Disease Control and Prevention (2013)).

Table 9: Counterfactual Increase in Cigarette Demand Across Markets

	Min	25%	Median	75%	Max
Increase in Mkt Share	0.00	0.00	0.10	0.49	7.50
Pct Increase in Mkt Share	0.00%	0.29%	2.64%	12.06%	151.49%

Many of the pro-regulation arguments made by researchers, clinicians, and regulators are based on concerns about the long-term consequences of e-cigarette consumption. Going forward, I plan to explore the long-run effects of such a ban.

Figure 12: Observed and Counterfactual Demand for Cigarettes in Louisville and Lexington KY



8 Conclusions and Future Work

To my knowledge, this paper is the first to empirically analyze the effects of e-cigarette advertising on demand for traditional cigarettes and e-cigarettes. Using both descriptive and structural methods, I show that e-cigarette advertising *decreases* demand for cigarettes. My research contributes to the ongoing policy debate as to whether e-cigarette TV advertising should be banned and suggests that a ban on e-cigarette advertising may have unintended consequences. More generally, my approach contributes to the study of advertising in categories with state dependence and to the analysis of substitution and complementarities in demand across categories.

Although this paper takes an important first step towards better understanding the role of e-cigarette advertising in the market, my analysis thus far is limited by the availability of data that would allow me to study additional questions that are of considerable interest to academics and policy makers. First, I hope to further explore the mechanism by which e-cigarette advertising affects demand. I have recently updated my descriptive analysis with newly obtained data from 2014. Going forward, I plan to re-estimate the structural model using data from 2013–2014. With the additional years of data, I will be able to include e-cigarettes as an explicit choice in the model. This will allow for a more flexible model in which e-cigarette advertising can decrease demand for cigarettes through a direct positive effect on demand for e-cigarettes (substitution / business stealing), while simultaneously allowing for the possibility that e-cigarette advertising makes cigarettes more attractive relative to the outside option

(renormalization of smoking). Even with the additional years of data, I will not be able to address the impact of e-cigarette advertising on teenagers' long-run demand for cigarettes and other nicotine products. This is an important area for future research that requires both data on youth consumption, which is not well covered in my dataset, as well as a long panel to track long-run consumption patterns. As individual states begin to pass new legislation concerning e-cigarette use indoors, tax policies, minimum purchase ages, and restrictions on e-cigarette advertising, new opportunities to study across-market variation in demand will likely arise.

Future work could also address the supply side of the market. In the absence of regulatory intervention, the future of e-cigarettes will be largely shaped by industry manufacturers and vendors. Initially the industry was composed of many small, independent producers who had no interest in perpetuating tobacco consumption. However, with the entry of the Big Tobacco companies into the arena in recent years, the incentives for producers have changed. The industry has been growing more concentrated with the largest emerging players being the big cigarette manufacturers. The FDA's new regulation that requires manufacturers to submit their products for approval in order to ensure health and safety standards could serve as a barrier to entry to small independent manufacturers and effectively work in Big Tobacco's favor. Rather than encourage users to quit smoking, cigarette companies are incentivized to maintain smoking as the status quo²⁵ and invest in e-cigarettes as a long-term hedge in the event that the market for tobacco cigarettes dissolves in the future. With the rapid growth of e-cigarette sales in the market, Solomon (2014) even argues that the recently approved merger between Reynolds and Lorillard, the second and third largest cigarette companies in the US, is partially motivated by fear of the rapidly growing e-cigarette market and the disruption this new technology will cause going forward.

²⁵As my analysis finds that e-cigarette advertising reduces cigarette sales, one may question the tobacco companies' short-run incentives to advertise. During the period of my data, Lorillard was the dominant cigarette company in the e-cigarette market and the third-largest tobacco cigarette company with about 12% market share. One explanation for their observed decision to advertise could be that Blu advertising increases Blu e-cigarette sales largely at the expense of other firms' cigarette brands. To explore this possibility, I check whether Blu advertising was higher in markets with lower Lorillard market share. I do not find any significant correlation to suggest that Lorillard coordinated its advertising to target markets where they had relatively less to lose.

A DMA Level Fixed Effects Regressions

As a comparison to the border strategy results, in this appendix I estimate DMA level regressions that ignore the potential endogeneity that would result if firms target advertising as a function of market and time varying unobservables. Comparing the border strategy ad elasticities in Table 6 with the DMA-level elasticities in Table 10, the elasticities from the DMA level regressions appear to have a positive bias. Relative to the border strategy analysis, the DMA level regressions estimate a larger positive effect of e-cigarette advertising on e-cigarette demand and a smaller negative effect of e-cigarette ads on cigarette demand. These patterns are consistent with firms advertising more in periods of high demand.

Table 10: Fixed Effects Regression Results

	(1)	(2)	(3)	(4)
	E-Cig Cartridges	Packs Cigs	Nicotine Patches	Nicotine Gum
E-Cig Ad GRP Stock	2.957** (1.489)	-9.202 (7.370)	0.0189 (0.0824)	3.189* (1.764)
Smoking Cessation Ad GRP Stock	0.246 (0.432)	1.990 (5.386)	- -	- -
Nicotine Patch Ad GRP Stock	- -	- -	-0.920*** (0.283)	-7.249** (3.238)
Nicotine Gum Ad GRP Stock	- -	- -	-0.173 (0.113)	-1.326 (1.782)
Price E-Cig Cartridge	-38.54 (70.52)	-290.8 (365.6)	-2.308 (4.706)	67.76 (83.78)
Price Pack Cigs	698.4 (1,145)	-15,941*** (3,635)	17.10 (66.52)	-1,476 (2,015)
Price Nicotine Patch	-392.5** (158.6)	-1,361 (1,082)	-358.5*** (96.41)	-3,679*** (1,217)
Price Nicotine Gum	-4,581 (3,005)	21,846 (21,134)	-1,246 (883.8)	-77,225*** (17,292)
DMA FE	Y	Y	Y	Y
Week FE	Y	Y	Y	Y
N Obs	20,124	20,124	20,124	20,124
E-Cig Ad Elasticity	0.05	-0.002	0.0004	0.002
% ΔQ from 1 SD $\uparrow A^e$	12.8%	-0.48%	0.12%	0.56%

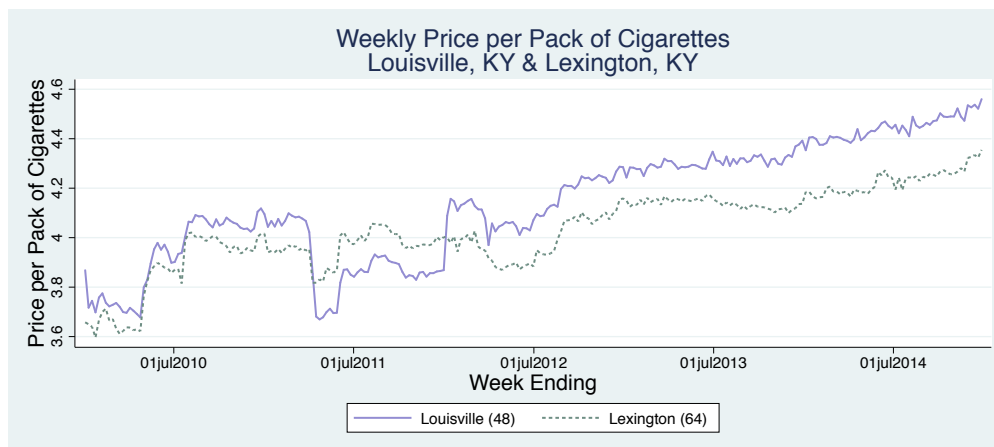
Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B Price Variation in the Border Market Sample

If prices were identical in neighboring border markets, then these prices would not be separately identified from the border-specific week fixed effects. In the border sample difference-in-differences regressions, I am able to estimate reasonable price effects suggesting that there is variation in prices across neighboring markets. Given that there appears to be significant variation in prices across neighboring border markets, it is important to consider the nature of this price variation.

For example, Figure 13 plots the weekly price of a pack of cigarettes in the Louisville and Lexington DMA border counties. While the price series seem highly correlated, there is a noticeable difference in mean price level as well as in changes in prices over time.

Figure 13: Weekly Price of Cigarettes Sold in Louisville and Lexington DMA Border Counties



There are two potential reasons for these differences in prices. The price variation could come from i) stores setting systematically different prices for the same UPCs in neighboring markets or ii) prices for the same UPC could be identical within the same retail chain across borders, and the observed differences in prices could be due to differences in the composition of cigarettes purchased. Figures 14 and 15 plot the price of a pack of Marlboro cigarettes – the UPC with the highest market share in the data – at each of the stores in the Louisville and Lexington DMA border markets. These figures show that stores within the same retail chain offer nearly identical prices for the same UPC, suggesting that the differences in observed market-level prices are coming from differences in the composition of packs purchased, as opposed to systematically different pricing behavior by stores.

Figure 14: Weekly Price of Marlboro Cigarettes in Louisville DMA Border Counties

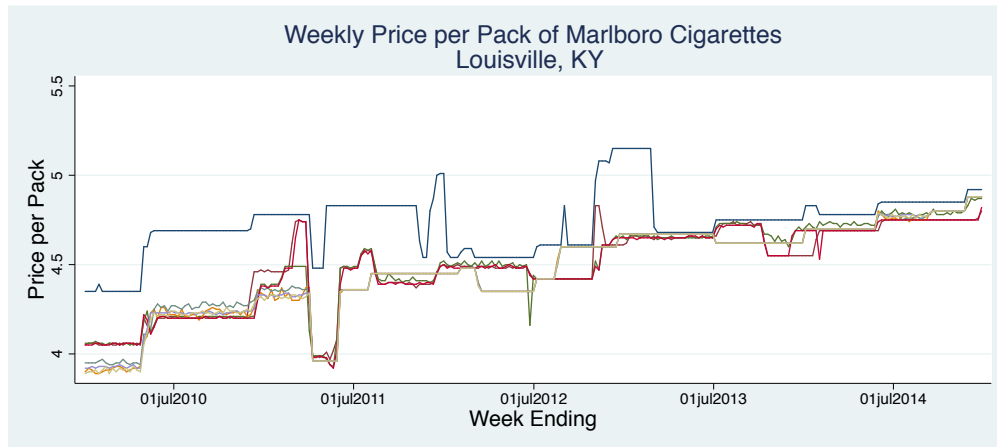
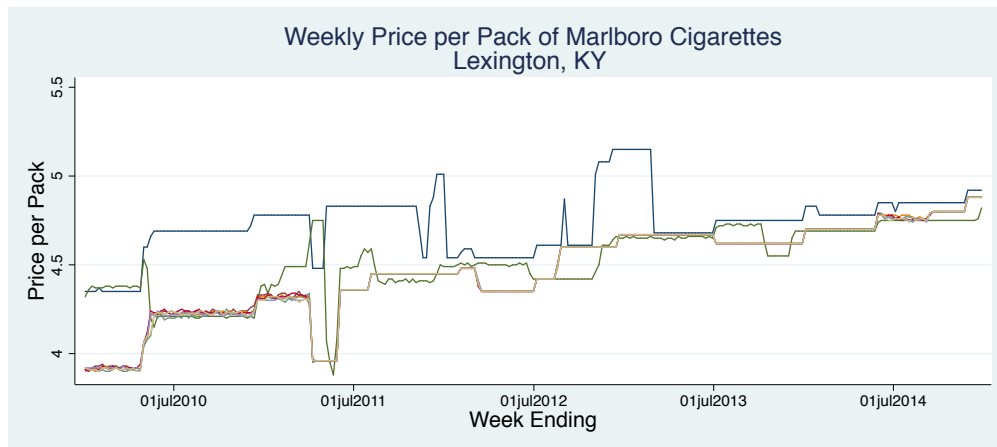


Figure 15: Weekly Price of Marlboro Cigarettes in Lexington DMA Border Counties



This sort of price variation is good because it seems to suggest that posted prices are not endogenous – i.e. stores on one side of the border are not coordinating their prices (and potentially other unobserved marketing activity) with the intensity of advertising in their local DMA.

C Sensitivities to Advertising Stock Depreciation Rate

Table 11: E-Cigarette Border Counties Regressions by Ad Stock Depreciation Rate δ

	(1)	(2)	(3)	(4)
	E-Cig	E-Cig	E-Cig	E-Cig
	Cartridges	Cartridges	Cartridges	Cartridges
	($\delta = 0.9$)	($\delta = 0.6$)	($\delta = 0.3$)	($\delta = 0$)
E-Cig Ad Stock	0.191*** (0.0351)	0.295*** (0.0885)	0.369*** (0.134)	0.428** (0.174)
Smoking Cessation Ad Stock	-0.0472*** (0.0128)	-0.0999*** (0.0289)	-0.111*** (0.0393)	-0.107** (0.0466)
Price E-Cig Cartridge	-6.774*** (1.097)	-6.780*** (1.090)	-6.784*** (1.088)	-6.785*** (1.087)
Price Pack Cigs	163.2*** (18.09)	162.6*** (18.16)	162.4*** (18.16)	162.3*** (18.16)
Price Nicotine Patch	10.49*** (2.693)	10.47*** (2.692)	10.49*** (2.690)	10.49*** (2.689)
Price Nicotine Gum	-5.691 (17.50)	-13.29 (17.51)	-14.90 (17.51)	-15.60 (17.51)
Observations	52,236	52,236	52,236	52,236
Market FE	Y	Y	Y	Y
Week-Border FE	Y	Y	Y	Y

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Cigarette Border Counties Regressions by Ad Stock Depreciation Rate δ

	(1)	(2)	(3)	(4)
	Packs Cigs ($\delta = 0.9$)	Packs Cigs ($\delta = 0.6$)	Packs Cigs ($\delta = 0.3$)	Packs Cigs ($\delta = 0$)
E-Cig Ad Stock	-2.811*** (0.806)	-4.121** (1.700)	-5.695** (2.564)	-6.940** (3.331)
Smoking Cessation Ad Stock	-0.478 (0.315)	-0.576 (0.649)	-0.840 (0.851)	-1.023 (1.005)
Price E-Cig Cartridge	68.48*** (10.56)	68.88*** (10.64)	69.10*** (10.65)	69.24*** (10.65)
Price Pack Cigs	-6,698*** (393.3)	-6,673*** (393.4)	-6,671*** (393.4)	-6,669*** (393.3)
Price Nicotine Patch	-57.25 (43.59)	-59.46 (43.63)	-59.99 (43.60)	-60.12 (43.59)
Price Nicotine Gum	-204.9 (295.0)	-129.5 (291.9)	-121.1 (291.8)	-115.0 (291.6)
Observations	52,236	52,236	52,236	52,236
Market FE	Y	Y	Y	Y
Week-Border FE	Y	Y	Y	Y
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

D Common Trends Sensitivities

Recall that the differences-in-differences identification strategy relies on the assumption that sales in bordering markets would follow a parallel trend in the absence of differences in treatment. In this section, I re-estimate the descriptive differences-in-differences regressions, restricting to the subsample of markets that have a correlation in weekly cigarette sales in 2010 above $\rho = 0.5$. This is the set of border markets that most closely satisfy the parallel trends assumption in the year before e-cigarettes were first advertised on TV. As shown in Table 13, the effect of e-cigarette advertising is directionally consistent and the magnitude of the effect increases relative to the estimates for the full sample.

Table 13: Difference in Differences Regression Results for the Restricted Sample

	(1)	(2)
	Cartridges E-Cigs	Packs Cigs
E-Cig Ad GRP Stock	0.452*** (0.060)	-7.041*** (1.543)
Smoking Cessation Ad GRP Stock	-0.082*** (0.023)	1.047 (0.674)
Price E-Cig Cartridge	-19.93*** (2.418)	-10.92 (28.95)
Price Pack Cigs	246.7*** (26.18)	-9,231*** (670.8)
Price Nicotine Patch	0.507 (4.585)	118.4 (97.79)
Price Nicotine Gum	-27.37 (29.70)	-533.7 (659.2)
DMA-Border FE	Y	Y
Week-Border FE	Y	Y
N Obs	25,407	25,407
E-Cig Ad Elasticity	0.03	-0.007
% ΔQ from 1 SD $\uparrow A^e$	8.65%	-1.68%

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

E Border Sample Demographics

Two questions arise with respect to the profile of border markets. First, are bordering markets similar on observed demographics? Market fixed effects in the model control for any time invariant differences across bordering markets, but to the extent that ad-sensitivity could be a function of demographics, it is informative to compare demographics for bordering markets. Second, how do border counties compare to the larger DMAs in which they are located? This second question relates to the generalizability or external validity of the estimates. If the demographics of the individuals living in border markets are similar to the general population, then it may be reasonable to think that the casual effects of e-cigarette advertising estimated on the border samples can be extrapolated when making policy decisions.

E.1 Comparison of Bordering Markets

In order to check whether neighboring markets are similar on observed demographics, I calculate border market level demographics by taking the population-weighted average of county-level US census data. For each characteristic I calculate the absolute deviation for each pair of bordering markets and normalize this statistic by the standard deviation of that characteristic across all 300 border markets.²⁶ The resulting statistic measures the distance in standard deviations between bordering markets. The distributions of these statistics are reported in Table 14. The median pair of bordering markets is within less than half of a standard deviation of each other for most characteristics.

Table 14: Normalized Absolute Deviations in Demographics Across Bordering Markets

	N	Min	Median	Mean	Max
Percent Female	150	0.00	0.57	0.87	5.59
Percent Population Under 18	150	0.00	0.58	0.79	3.59
Percent HS Diploma	150	0.01	0.46	0.61	3.88
Percent White	150	0.00	0.30	0.48	2.38
Percent Black	150	0	0.17	0.36	2.49
Per Capita Income	150	0.00	0.41	0.64	4.47
Population Per Square Mile	150	0.00	0.17	0.48	4.81

E.2 Comparison of Border Markets to Non-Border Markets

I compare county-level demographics for border counties to the demographics of non-border counties. The results in Table 15 show that the population of border counties is on average slightly older, less educated, and lower income. Border counties have a lower share of black residents and a lower population density than non-border counties.

²⁶Absolute deviation in characteristic x for markets i and $j = |x_i - x_j|$. Normalized absolute deviation calculated as $\frac{|x_i - x_j|}{\sigma_x}$.

Table 15: Average Characteristics in Border and Non-Border Markets

	Border Counties	Non-Border Counties	<i>p</i> value
Percent Female	50.14	50.16	0.764
Percent Population Under 18	22.22	22.74	0.000
Percent HS Diploma	83.31	85.16	0.000
Percent White	86.08	85.08	0.148
Percent Black	8.99	10.10	0.085
Per Capita Income	23,228	24,380	0.000
Population Per Square Mile	169.4	502.1	0.001
N Counties	772	1,202	

F Model Simulations

I carry out a simulation exercise to illustrate the model’s ability to recover the parameters of interest. The steps of the simulation are described below.

In each period consumers decide whether to smoke cigarettes ($c = 1$) or not ($c = 0$). Addiction is captured by allowing today’s consumption decision to be related to the consumption state in the previous period through the parameter γ . I assume the following data generating process at the individual level.

$$u_{ict} = \beta + \alpha_i p_t + \gamma 1(c_{it-1} = 1) + \xi_t + \varepsilon_{ict} \quad (20)$$

$$u_{i0t} = 0 + \varepsilon_{i0t} \quad (21)$$

Consumers are assumed to be heterogenous in their sensitivity to price. The distribution of price coefficients α_i is assumed to be normal, with mean $\bar{\alpha}$ and variance σ^2 . The parameters of interest are the “linear” parameters $\theta_1 = (\beta, \bar{\alpha})$ and “non-linear” parameters $\theta_2 = (\sigma, \gamma)$. Consistent with the full model, I include unobserved aggregate demand shocks in the simulation. In a first simulation, I assume that ξ_t is normally distributed and prices are uncorrelated with the aggregate demand shocks. In a second simulation, I assume $\xi_t = \beta_t + \eta_t$ can be decomposed into a component β_t that varies systematically over time and a component η_t that is normally distributed. In order to illustrate the joint model’s ability to account for endogeneity using the aggregate data, I assume that demand for cigarettes is increasing over time ($\beta_t \leq \beta_{t+1}$) and prices are decreasing over time such that $Corr(p_t, \xi_t) < 0$ making price endogenous. Finally,

I assume the ϵ shocks are distributed type 1 extreme value. The model-predicted aggregate market share of cigarettes is given by equation 22.

$$s_{ct} = \int_{\Theta \times \{0,1\}} Pr(c = 1 | \theta_i, c_{t-1}) dF_{\theta_i \times c} \quad (22)$$

In estimation, I approximate the distribution of heterogeneity with $R = 100$ draws from the standard normal distribution $v_r \sim N(0, 1)$ s.t. $\alpha_r = \bar{\alpha} + \sigma v_r \sim N(\bar{\alpha}, \sigma^2)$. Using Monte Carlo integration, equation 22 becomes:

$$\begin{aligned} s_{ct} &= \sum_{r=1}^R [Pr(c_t = 1 | \theta_r, c_{t-1} = 1) Pr(\theta_r, c_{t-1} = 1) + Pr(c_t = 1 | \theta_r, c_{t-1} = 0) Pr(\theta_r, c_{t-1} = 0)] \\ &= \frac{\exp[\beta + \alpha_r p_t + \gamma + \xi_t]}{1 + \exp[\beta + \alpha_r p_t + \gamma + \xi_t]} Pr(\theta_r, c_{t-1} = 1) + \frac{\exp[\beta + \alpha_r p_t + \xi_t]}{1 + \exp[\beta + \alpha_r p_t + \xi_t]} Pr(\theta_r, c_{t-1} = 0) \end{aligned} \quad (23)$$

I simulate purchase decisions for 10,000 consumers in each of $T = 150$ periods. Aggregate market shares in each period are calculated using the full set of households. A 1% random sample of households makes up the household-level dataset used for estimation. I estimate the model parameters (i) via maximum likelihood using only the household data and (ii) using the joint estimation procedure and both the aggregate and household datasets. I include time fixed effects that control for the endogeneity of price in the final linear regression step in the joint estimation procedure. Because of the parameter proliferation problem, including these fixed effects in the household model is intractable. I carry out the simulation $NS = 1,000$ times and compare the results across models.

As shown in Table 16 and Figure 17, both estimation procedures perform quite well in recovering the “non-linear” model parameters $\theta_2 = (\sigma, \gamma)$. In the simulation with exogenous prices, the joint procedure is more efficient because it incorporates the full information contained in the aggregate data. In the simulation with endogenous prices, the joint procedure recovers an unbiased estimate of the price coefficient, while the model using only household data recovers biased estimates because of the persisting price endogeneity.

Table 16: Model Simulation Results

	True Values	Exogenous Price		Endogenous Price	
		HH ML	Joint Est	HH ML	Joint Est
β	-0.5	-0.4982 (0.1843)	-0.4970 (0.1641)	-0.2120 (0.1793)	-0.4979 (0.1635)
$\bar{\alpha}$	-0.6	-0.6115 (0.0766)	-0.5967 (0.0569)	-0.6700 (0.0744)	-0.5964 (0.0568)
σ	0.1	0.1051 (0.0139)	0.1065 (0.0139)	0.1039 (0.0131)	0.1066 (0.0132)
γ	1.75	1.7357 (0.0491)	1.7228 (0.0531)	1.7481 (0.0467)	1.7237 (0.0505)

Figure 16: Distribution of Estimates in Heterogenous Simulation w/ Exogenous Prices

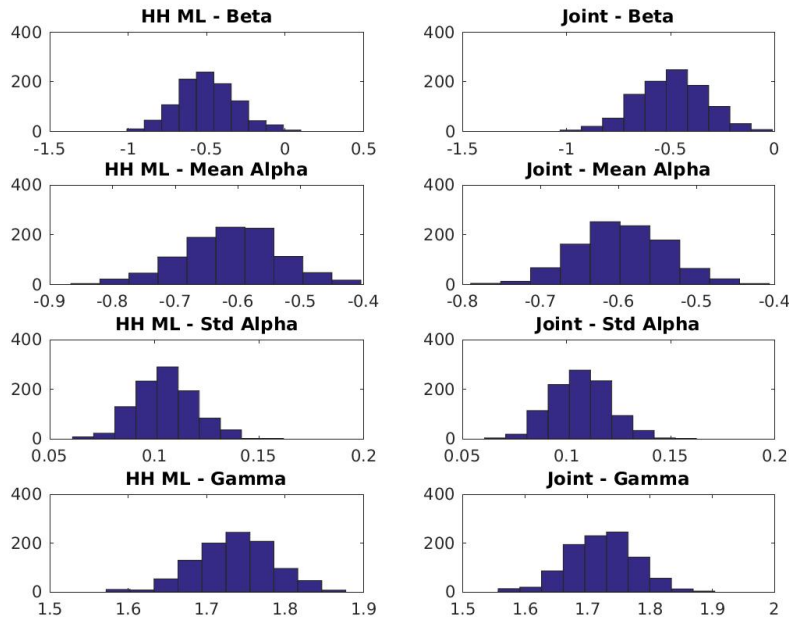
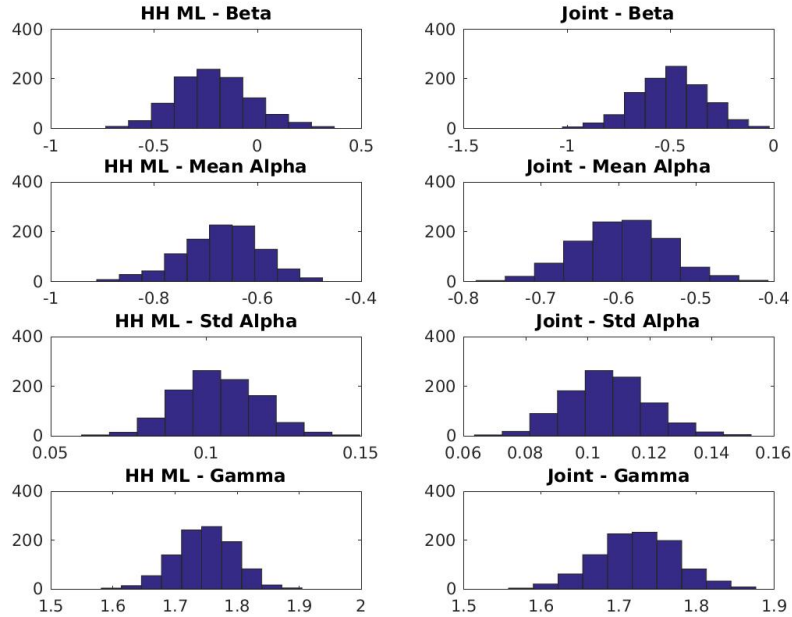


Figure 17: Distribution of Estimates in Heterogenous Simulation w/ Endogenous Prices



G Data Appendix

G.1 Household Sample Construction

All households who buy at least one of the inside goods should be included in the household sample. For the initial model estimation, I restrict to only the set of households who ever bought an e-cigarette product.

G.2 Rationalizing Multiple Purchases with Discrete Choice

In some cases a household will buy multiple units of a given product or multiple different products from the choice set in a given day (or week after aggregation). This observed behavior is inconsistent with the discrete choice assumption of the model. For the former, I ignore quantity and focus only on whether at least one unit was purchased. Looking at weekly HH data, a single carton (pack) is purchased in 57% (18%) of weeks in which at least one carton (pack) was purchased. In the latter case, I create duplicate entries for that day, and ensure that the addiction dummy variable takes a value of 1 if at least one purchase from the previous day

is for a cigarette product.

G.3 Household Price Series Construction

In order to estimate the model, I need to fill in missing prices for days in which households did not make a purchase and products that were not purchased. Rather than use the same price series as the aggregate data (average price across all stores in the market), I fill in missing prices using the last price paid by the household. Average price will capture variations in prices that last price paid wouldn't capture, but last price paid by a household is consistent if households tend to buy different products. I.e. a \$6 pack of expensive cigs relative to a \$5 average price/pack. For days before the first purchase was made, I fill in the price of the first purchase. If a household never purchased the product, I use the average price in stores in the household's county. Some households report a price per pack larger than \$20+. I drop all observations for purchases of packs over \$17.

G.4 Aggregate Price Series Construction

A market-level price series is constructed for packs of cigarettes, cartons of cigarettes, and refill cartridges and disposable e-cigarettes. The price series is calculated as the quantity-weighted price of products sold in each week across all stores in a given market.

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