How Much Do Consumers Value Single-cup Coffee Brew Technology? Assessing Market Impacts of Single-cup Brew Technology on the US Brew-At-Home Coffee Market

Philip G. Gayle* and Ying Lin+

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Abstract

The introduction of single-cup coffee brew technology in the late 2000s has not only changed the way many brew-at-home coffee drinkers brew and consume coffee in daily life, i.e. a change from brewing one "pot" at a time to making one cup at a time, but also altered the overall landscape of the brew-at-home coffee market in the U.S. This paper analyses the economic impacts in the US brew-at-home coffee market associated with the introduction and growing presence of single-cup coffee brew technology. We find that a typical coffee drinker is willing to pay up to ¢2.52 extra per fluid ounce to consume brewed coffee from the single-cup brewing method instead of using the traditional auto-drip brewing method, and this marginal willingness to pay gap increases with consumers' income level. Second, we find that both the demand and profitability of traditional auto-drip brew coffee products are substantially lower owing to the presence of single-cup brew technology coffee products. Last, our analysis reveals that consumers enjoy substantially higher welfare owing to the presence of single-cup brewing technology coffee products.

Keywords: Single-cup coffee, Willingness to pay, Brew-at-home coffee market

JEL Classification: L13, D12, L66

* Kansas State University, Department of Economics, 322 Waters Hall, Manhattan, KS, 66506; Voice: 785-532-4581; Fax: 785-532-6919; Email: gaylep@ksu.edu; **Corresponding Author**.

+ Kansas State University, Department of Economics, 327 Waters Hall, Manhattan, KS, 66506; Voice: 615-717-5090; Email: ly281044@ksu.edu

1. Introduction

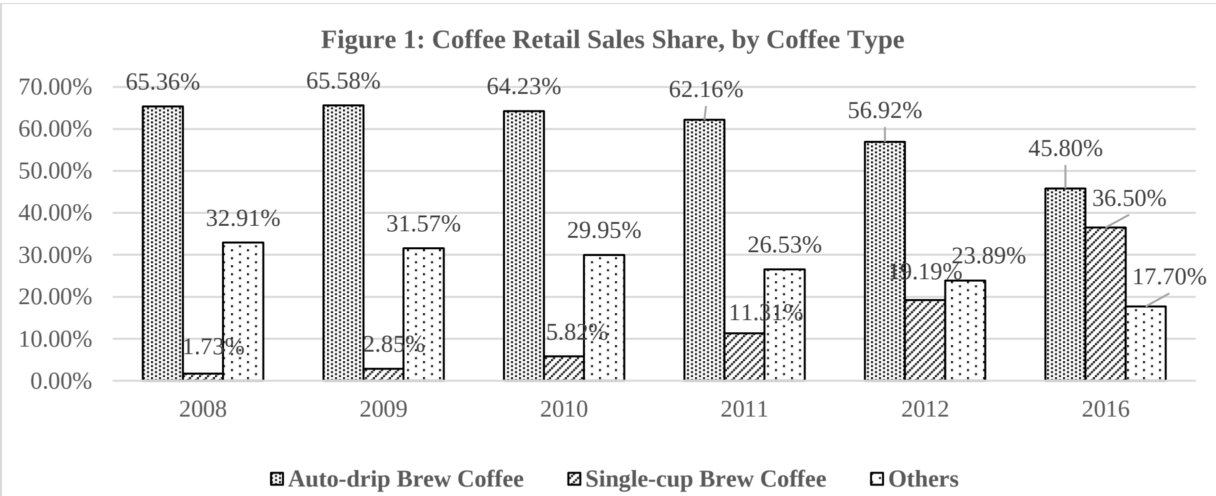
New product introduction, which often incorporates new and improved technology, has long played a critical role in influencing not only consumers' tastes and welfare but also firms' profitability and even the overall market structure. According to industry analysts, the single-cup coffee brewing technology has been considered the most-disruptive development in the business since Starbucks Corp began the coffee-shop boom in the late 1980s[1] and even the biggest thing since Luigi Bezzera patented the espresso machine in 1901.[2] K-Cup technology, a single-cup coffee brewing technology pioneered by the American firm Keurig, quickly gained popularity since the late 2000s, driving widespread adoption of the single-cup brewing systems in the United States (US) brew-at-home coffee market.[3] Adoption of the single-cup brewing systems in the US brew-at-home coffee market accelerated further in 2012 when K-Cup patent expired. The rapid rise of single-cup technology fueled sales of single-cup coffee pods. US consumers bought $3.1 billion worth of coffee pods in year 2013 versus $132 million in year 2008.[4] There is little doubt that the introduction of single-cup coffee technology, with a single-serve brewing machine and a portion-packed coffee pod, has not only changed the way many brew-at-home coffee drinkers brew and consume coffee in daily life, i.e. a change from brewing one "pot" at a time to making one cup at a time, but also altered the overall landscape of the US brew-at-home coffee market.

The key objective of this paper is to examine impacts in the US brew-at-home coffee market associated with the introduction and growing presence of single-cup coffee brewing technology. Specifically, we are interested in measuring changes in prices, consumer demand, firm profitability and overall consumer welfare associated with the introduction and growing presence of single-cup coffee brewing technology.

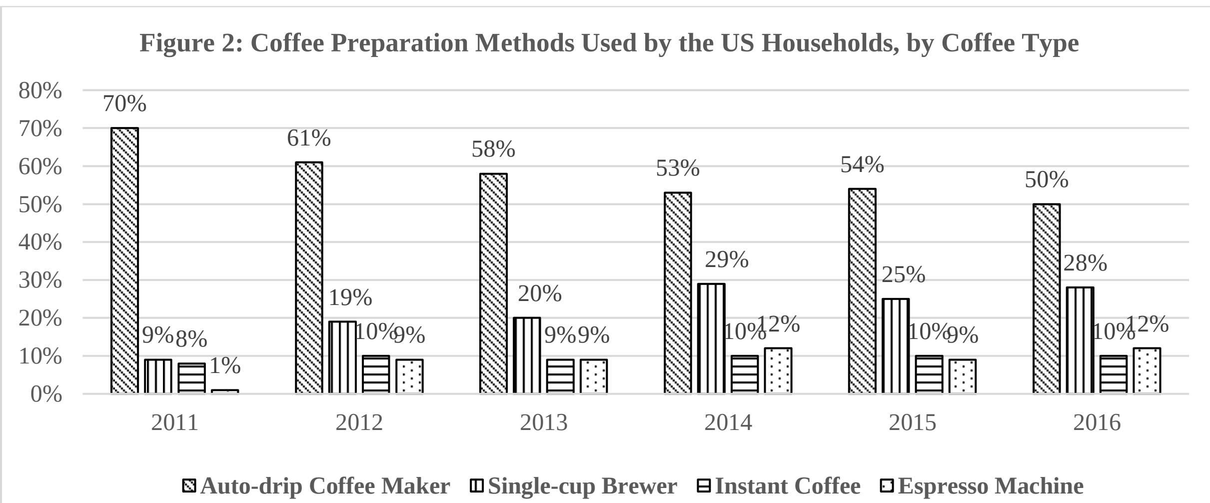
According to data from Information Resources Inc. (IRI) and Statista, the share of single-cup coffee pods sales among all brewing method coffee types at the retail level rose tremendously from 1.73% in 2008 to 36.5% in 2016, whereas the share of traditional auto-drip brew ground coffee sales experienced a significant decline from over 65% in 2008 to 45.8% in 2016 (See Figure

1 https://www.theguardian.com/cities/2015/may/14/the-first-starbucks-coffee-shop-seattle-a-history-of-cities-in-50-buildings-day-36
2 https://en.wikipedia.org/wiki/Espresso_machine
3 In fact, during the time period when Keurig single-serve systems were widely accepted by the US household, there were many other competitors, such as Salton, Sara Lee and Procter & Gamble, that introduced their own one-cup systems. (https://en.wikipedia.org/wiki/Keurig)
4 https://www.seattletimes.com/business/single-serve-coffee-revolution-brews-industry-change/

1[5]). What's more, a survey conducted by National Coffee Association (NCA) in 2016 reveals that 28% of the US population reported drinking coffee prepared with single-cup coffee pods in 2016, an increase from 19% in 2012 and 7% in 2011;[6] whereas, in 2016, 50% of the population reported drinking coffee prepared using the traditional auto-drip brewing method, a decline from 70% of the population in 2011, and 61% of the population in 2012 (See Figure 2). The fast growth of single-cup coffee sales makes the single-cup technology the second most popular brewing method after the traditional auto-drip technology, far surpassing instant coffee, espresso machines, and all other methods of brewing coffee.



Source: IRI data for 2008 to 2012. Statista.com for 2016.



Source: NCA survey (2016)

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[5] The category of "Others" includes instant (decaf) coffee, whole bean (decaf) coffee and other coffee substitutes.

[6] The increasing penetration of single-cup coffee consumption in the US households from 2011 to 2012 partially can be explained by the Keurig's K-Cup patent expiration in 2012, leading to an explosion of competitors into the single-cup pods market. (http://time.com/2913062/k-cups-war/)

The analysis in this paper is twofold. First, we examine how much consumers value their coffee consumption experience using the single-cup brewing technology relative to the traditional auto-drip brewing method. Indeed, the paper is motivated by the fact that single-cup brew coffee consumption was soaring since 2012 and substantially cannibalizing the sales of traditional auto-drip brew coffee products. To accomplish the objective of the first part of the analysis we adopt a random coefficients logit demand model [Berry (1994); Berry, Levinsohn, and Pakes (1995); Nevo (2000a, b, 2001); Petrin (2002) etc.] to obtain estimates of consumers' dollar value willingness to pay (WTP) for the single-cup technology brewing method coffee consumption experience relative to their consumption experience from using traditional auto-drip ground coffee brewing method.

The second part of the analysis is designed to better understand the economic impacts of the single-cup technology brewing method on consumer coffee demand, firm profitability, and consumer welfare. To obtain estimates of firm profitability we specify an oligopoly model based on an assumed strategic price-setting behavior of firms. Specifically, we assume that coffee manufactures set coffee product prices according to a static Nash equilibrium price-setting game. We accomplish the objectives of this part of the analysis by using the estimated coffee demand model along with the specified oligopoly model to perform a counterfactual experiment. The counterfactual experiment asks how equilibrium market outcomes of interest (prices, consumer demand, firm profits, and consumer welfare) are predicted to change if consumers equally value the single-cup technology brewing coffee consumption experience and the traditional auto-drip brewing coffee consumption experience.

Our findings suggest that, on average, a typical coffee drinker is willing to pay up to ¢2.52 extra per equivalent fl oz to consume brewed coffee from the single-cup brewing method and thereby avoid using the traditional auto-drip brewing method. Everything else equal, this WTP estimate implies that, on average, a coffee drinker is willing to pay a price per equivalent fl oz that is 2.57 times the average price per equivalent fl oz of traditional auto-drip brewed coffee products just to enjoy the attribute of single-cup brewing technology as part of the consumption experience instead of the attribute of traditional auto-drip brewing method. Furthermore, our demand model estimates suggest that this relative consumer willingness to pay gap increases with consumer income level, that is, higher income consumers tend to have greater marginal utilities from consuming coffee with the single-cup brewing technology. Our estimated model reveals that the counterfactual removal of consumer preference for coffee consumption experience with the single-cup brewing technology is predicted to result in an increase in consumer demand for traditional auto-drip brew coffee products and a significant decrease in consumer demand for single-cup brew coffee products. Specifically, such counterfactual preference change is predicted to result in demand for traditional auto-drip brew coffee products at levels that are on average 3.88% greater than the actual demand levels for these products; whereas consumer demand for single-cup brew coffee products decreased by 98.5%. The counterfactual preference change is predicted to result in a typical consumer benefiting from the introduction and growing presence of single-cup brew technology by having a mean increase in individual consumer surplus of 2% from the initial level.

On the supply side, our model estimates suggest that a typical auto-drip brew coffee product has considerably greater margin (price markup over marginal cost as a percent of price) of 55%, compared to the margin of a typical single-cup brew product of 13.6%; whereas the marginal cost for a typical single-cup brew coffee product is about 5 times greater than that of a typical auto-drip brew coffee product. These estimates suggest that single-cup brew coffee products, at least at the early stage of their product life cycle in 2012, are very costly to produce at the margin with relatively small price-cost margins. The counterfactual experiment provides evidence that a typical auto-drip brew ground coffee product in a market is predicted to experience an increase in its variable profit by 4.6% during a month. This predicted impact on variable profit of auto-drip brew coffee products suggests cannibalizing effects associated with the introduction, and growing penetration, of single-cup brewing technology products on traditional auto-drip brew ground coffee products. In other words, a traditional auto-drip ground coffee product could have had a much greater demand and profitability if consumers did not have relatively higher preference for new single-cup brewing technology products.

The rest of this paper is organized as follows. Section 2 reviews relevant literature. Section 3 discusses data sources and variables used in the analysis. Section 4 describes the empirical model, as well as the estimation method. Section 5 presents and discusses the empirical results. Section 6 describes the counterfactual procedure and analyzes findings from the counterfactual experiment. Section 7 concludes the paper.

2. Related Literature

Previous studies have paid particular attention to traditional auto-drip ground coffee and/or instant coffee categories. A number of studies focus on the response of traditional auto-drip ground coffee prices to input cost shocks (e.g. changes in raw coffee bean price or exchange rates) [Leibtag et al. (2007); Nakamura and Zerom (2010); Bonnet et al. (2013); and Bonnet and Villas-Boas (2016)]. These papers investigate factors that contribute to incomplete pass-through of cost shocks to prices in the coffee market for the traditional auto-drip ground coffee category.[7] Nakamura and Zerom (2010), for example, estimates long-run cost pass-through rates within a dynamic structural framework using retail and wholesale level price data in the US coffee market. Some studies, such as Draganska and Klapper (2007), Draganska, Klapper, and Villas-Boas (2008), Villas-Boas (2007b), and Villas-Boas (2009), focus on vertical relationships between coffee manufacturers and retailers in the traditional auto-drip ground coffee market segment. Villas-Boas (2007b), for example, assesses welfare effects of mergers at the coffee manufacturer level under various assumptions of vertical structure using retail level scanner data for the traditional auto-drip ground coffee category in Germany. Among studies that focus on vertical relationships between firms in the coffee industry, Noton and Elberg (2016) model bargaining power between coffee manufacturers and retailers in the traditional auto-drip ground and instant coffee categories in Chile.

However, there are only a few research papers studying the single-cup brew coffee category. Chintagunta et al. (2018) study the Portugal coffee market and develop a structural model of demand and supply for the coffee system of single-serve coffee machines and pods as tied-goods. The paper examines the impact of licensing decisions of manufacturers on pricing and profits of firms in the system. Kong et al. (2016) also focuses on coffee brewing machines and pods as tied goods. Their study proposes a static demand system of Keurig single-cup brewing machines and K-Cups partnered with some national coffee brands that are well-known in the mature ground coffee segment, such as Starbucks, Folgers, Maxwell House, etc. The paper performs counterfactual exercises that illustrate the role of partnering and licensing K-Cups with national brands in driving the growth of the overall Keurig single-serve coffee system. Lin (2017) is another similar work that studies the network effect of third-party brands' partnering with K-

[7] Leibtag et al. (2007) and Nakamura and Zerom (2010) study the ground coffee price-cost pass-through in the US and the other two papers focus on the German ground coffee market.

Cups on the adoption of Keurig brewing systems (the platform) in a two-sided market framework using individual household purchase data. Last, Ellickson et al. (2017) uses a structural model of demand and supply-side bargaining to examine how retailers and manufacturers behave in the absence of private label branded single-serve coffee pods before Keurig patent expired in 2012, and how their strategies adapt when entry occurs after patent expiration in the US single-cup coffee sector.

The above papers focus their empirical analyses uniquely on the single-serve coffee system. Our study, instead, is interested in understanding the potential impact of the growing penetration of single-cup coffee products on traditional auto-drip ground coffee products. Specifically, this paper aims to assess how much consumers value the current quickly growing single-cup market segment relative to the traditional auto-drip ground coffee market segment, and the extent to which key market outcomes of traditional auto-drip ground coffee products, such as demand, prices, and profitability, are impacted by the growing presence of single-cup coffee products. Our research objectives and methodology are related to the literature estimating the economic effects of newly introduced products or technology.

Researchers have studied extensively the economic effects of new products in various industries. A few well-known papers in this literature include Hausman (1996), Hausman and Leonard (2002), Petrin (2002), and Goolsbee and Petrin (2004).[8] The often used research methodology in this literature is to first estimate demand in the presence of the new product, and then use the estimated model to simulate changes in equilibrium market outcomes driven by counterfactual absence of the new product from consumers' choice set. For example, Petrin (2002) measures welfare effects of the minivan introduction in the 1980s and finds that consumers overall benefit from the new product introduction. Our research methodology has similarities to the methodology in Petrin (2002). However, instead of assessing changes in market outcomes driven by the counterfactual removal of the new product from consumers' choice set as done in Petrin (2002), we assess changes in market outcomes driven by a counterfactual change in consumers' preference for new products relative to other products in the market. In doing so in our setting, we effectively evaluate the economic effects of changes in consumers' preference for the coffee brewing technology. To the best of our knowledge, this present paper is the first to evaluate the

[8] Hausman (1996) studies the effect of Apple Cinnamon Cheerios. Hausman and Leonard (2002) looks at the effect of Kimberly-Clark bath tissue product 'Kleenex Bath Tissue'. Petrin (2002) focuses on the effect of minivans and Goolsbee and Petrin (2004) on the effect of direct broadcast satellites.

economic importance of consumers' valuation of single-cup coffee brewing technology, and the first to assess the extent to which traditional auto-drip ground coffee product sales and profitability are influenced by the introduction and growing presence of single-cup coffee products.

3. Data

The primary data used in our empirical analysis are retail-level scanner data on consumer purchases of traditional auto-drip ground coffee products and single-cup brewing technology coffee products. These scanner data are sourced from the Information Resources Inc. (IRI) academic database [Bronnenberg et al. (2008)], which spans 1795 supermarkets across 50 IRI defined geographical areas in the continental United States. In this study, markets are defined by unique combinations of time periods and IRI defined geographical areas. The IRI defined geographical areas span almost the entire continental US. The data include weekly coffee product unit sales, revenue from these unit sales, and various characteristics of the coffee products. We use data in year 2012.[9] Detailed information for each weekly observation includes: total dollars received by retailers; unit of packages sold; net weight of dry coffee (in ounces) contained in each package, and other product attributes such as coffee type[10] and form;[11] packaging information;[12] organic information;[13] caffeine content;[14] brewing method;[15] and promotional information[16]. A

[9] Data on single-cup brewing technology coffee products are available from 2008 to 2012. A reason why 2012 is a good year for the analysis we do is that it is the year when single-cup coffee products become the second most popular coffee category according to the 2016 NCA survey. It is thus an important transition year in which the single-cup coffee category started growing quickly in the US.

[10] We focus only on two coffee categories: traditional auto-drip technology ground coffee products; and single-cup brewing technology coffee products. All other categories are characterized into "others" including: instant; whole bean; ground decaffeinated; instant decaffeinated; and other coffee substitutes. As you will observe later once we have described the demand model, the "others" category constitutes the "outside" option for consumer choice.

[11] Coffee forms for regular ground coffee include regular grind and fine grind; single-cup coffee products include K-Cups that are trademarked by Keurig, other cups that are compatible with single-serve brewing systems other than Keurig, and single pods that are wrapped with filter papers. (http://www.coffeeteawarehouse.com/coffee-k-cup-vs-pod.html)

[12] Product packages for ground coffee including laminated bags (e.g. foil bags or film bags), paper bags/boxes, plastic containers, and light metal tins. (https://plastics.americanchemistry.com/LCI-Summary-for-8-Coffee-Packaging-Systems/)

[13] All observations due to coding error are removed. Observations with missing organic information are supplemented with information provided by online sources (if they are able to be identified from online resources). All other un-identified observations from any available resources are eliminated.

[14] Caffeine content is approximated using information from USDA National Nutrient Database for Standard Reference Release 27, "Basic Report 14209, Coffee, brewed from grounds, prepared with tap water". On average, 0.61 gram of ground coffee contains 40 mg caffeine, equivalently, 1.86 gram caffeine per ounce of dry coffee.

[15] Brewing methods for all ground coffee are using auto-drip coffee makers, but for single-cup products are either Keurig brewing systems or other one-cup systems such as Nespresso and Tassimo etc. (Euromonitor International).

[16] These data contain information related to promotional activities such as feature, display, and temporary price cut.

product within a market is defined as a unique combination of brand name, and non-price product attributes, which include the particular retail store. These weekly observations are aggregated to monthly data based on defined products and markets. The monthly aggregation reduces the 10 million weekly observations to 1.4 million monthly observations. Each observation is a uniquely defined product. With 12 months and 50 IRI defined geographic areas, we have 600 markets in total.

3.1 Construction of price and quantity variables

To prepare the dataset for the empirical analysis, we create the price and quantity variables for defined products. To analyze consumer taste variation across single-cup brew and traditional auto-drip brew ground coffee products, we need a comparable quantity measure. Previous literature studying the coffee market focus on traditional auto-drip brew ground coffee and/or instant coffee products, and the measure of coffee demand/consumption is universally in terms of mass weight of dry coffee grounds in ounces[17] [Villas-Boas (2007a, 2007b), Leibtag et al. (2007), Nakamura and Zerom (2010), Bonnet et al. (2013), Bonnet and Villas-Boas (2016)]. However, the demand for single-cup brew coffee pods, given their distinct brewing method from the traditional auto-drip ground coffee, cannot be simply measured by the mass weight of dry coffee grounds contained in coffee pods.

In order to construct prices that are comparable across the two coffee segments, we first define an equivalent serving size for each segment, namely, the mass weight of coffee grounds in ounces (oz) to make a standard cup of brewed coffee, 10 fluid ounces (fl oz). This standard cup size is a product of the NCA survey in 2016.[18] For single-cup coffee products in our data, an individual coffee pod contains coffee grounds of 0.3 – 0.4 oz varying by brands, with an average of 0.35 oz in a typical coffee pod. We assume each pod makes a standard cup of 10 fl oz of freshly brewed coffee regardless of how much coffee grounds each pod contains. For traditional auto-drip brew coffee products, we apply a universal serving size of 0.317 oz coffee grounds per standard 10 fl oz cup of coffee.[19] Given these assumptions, we convert the product quantity measured in

[17] There are several exceptions that focus on the single-cup coffee market. For example, Ellickson et al. (2017) adopt a similar conversion method as in our paper. Chintagunta et al. (2018) focus uniquely on single-cup coffee, thus the price variable measures the per pod price.

[18] This survey also reports that the average number of cups drank per-day per capita is 1.98. This implies a coffee drinker consumes 594 fl oz per month, on average.

[19] The coffee-to-water ratio suggested by NCA is one to two tablespoons of ground coffee for every six fluid ounces of water. (http://www.ncausa.org/About-Coffee/How-to-Brew-Coffee) The two largest ground coffee brands, Folgers

ounces of dry coffee grounds in the original IRI data to equivalent fluid ounce measure across traditional auto-drip brew coffee products and single-cup brew coffee products. Therefore, consumer quantity demanded is measured by how much fluid ounces of brewed coffee can be potentially made from each product given the product's equivalent serving size.

For each weekly observation in the data, we have information on total dollars received by the retailer for multiple packages sold during a week, the number of packages as well as the net weight (in ounces) of coffee grounds in a package. Before collapsing the weekly data to monthly, we compute the total quantity sold in equivalent fluid ounces for each weekly observation of single-cup brew products by multiplying the number of pods in a package with the number of packages sold in a week and then multiply by the standard cup size of 10 fl oz. For traditional auto-drip brew coffee products, we first compute the total ounces of ground coffee sold in each week by multiplying the net weight of coffee grounds in a package with the number of packages sold in a week. Assuming a typical consumer utilizes a typical coffee-water ratio of "0.317 oz/10 fl oz" to make a "pot" of brewed ground coffee, we compute the total quantity sold in equivalent fluid ounces in a week by dividing the total ounces of coffee grounds sold by this ratio. We then calculate the weekly average price for each weekly product observation using the ratio of total dollars from sales to total equivalent fluid ounces sold in a week. When collapsing the data to monthly frequency, the "price" variable for a product is the mean of those weekly average prices for a product sold during a month, and the "quantity" variable for a product is the sum of total equivalent fluid ounces sold in a month.

Within the framework of a discrete choice demand model, to calculate the market share of each product in a market that allows for outside goods option, one needs a measure of potential market size that is larger than the actual aggregate consumption of products in the market. Potential market size (later denoted M_t) is computed as the total equivalent fluid ounces of brewed coffee that could be consumed in a market during a month if all adult males and females in the market consumed coffee at the typical per capita consumption rates for males and females

and Maxwell House, both suggest a recipe of one tablespoon ground coffee (about 0.19 ounces) per six fluid ounces of water for regular strength, and two tablespoon ground coffee (about 0.38 ounces) per six fluid ounces of water for strong coffee. (https://www.folgerscoffee.com/coffee-how-to/how-to-measure-coffee) We consider an average coffee drinker follows a regular strength brewed coffee recipe, i.e. 0.0317 oz ground coffee makes 1 fl oz brewed coffee. Using this ratio, we then compute the total fluid ounces for each ground coffee product.

respectively.[20] The observed product share (later denoted S_{jt}) is computed by dividing the quantity sold of a product in equivalent fluid ounces by the above defined potential market size, while the share of the outside goods option, denoted as S_{0t}, is computed as $S_{0t} = 1 - \sum_{j \epsilon J} S_{jt}$, where J represents the set of coffee products in market t of our data. The outside good share is a measure of the proportion of the potential market size who did not consume any of the J coffee products in market t.

The summary statistics of price, quantity, and market size are presented in Table 1. In the collapsed dataset, there are 1,394,455 unique products sold in 600 markets according to our product and market definitions. These coffee products sold in 2012 have an average coffee price of ¢2.93 per equivalent fl oz, with a mean monthly quantity sold in a market of 10,982 equivalent fl oz. The table also reveals that coffee products that require using the single-cup brewing technology are on average more expensive than traditional auto-drip brew coffee products. In particular, mean product price among single-cup brewing technology coffee products is ¢6.40 per equivalent fl oz, while mean product price among traditional auto-drip brewing method coffee products is ¢1.61 per equivalent fl oz. Last, the measure of potential market sizes described above yields a mean of product shares equal to 8.82E-06.

3.2 Other variables

Other variables that characterize product attributes are reported in Table 1. To evaluate consumer preference for the coffee brewing technology consumption experience, we include a coffee type dummy variable, *Single-cup Brew*. Dummy variable, *Single-cup Brew*, equals to 1 if a coffee product is designed to use the single-cup brewing technology, and 0 if the product is designed to use the traditional auto-drip brewing technology. On average, 27.5% of products in our data set are single-cup brew coffee products, while the other products in our data set are traditional auto-drip brew coffee products.

Consumers normally show varying tastes between organic and non-organic food and beverage items. To capture the potential impact that the organic feature of coffee products have on

[20] Based on the NCA survey, we calculate the total equivalent fluid ounces of brewed coffee consumed by a female and a male per month respectively. On average, a female drinks 1.85 cups per day and a male drinks 2.11 cups per day, with each standard cup being 10 fl oz. The female and male adult populations in a market are obtained from the American Community Survey estimates in 2012. (https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_5YR_DP05&src=pt)

consumer demand, we consider a dummy variable, *Organic*, equal to 1 if a product is organic coffee and 0 otherwise. As Table 1 reveals, most coffee products in the data sample are non-organic.

Table 1: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Price ($/fl oz across all coffee product types)	0.029	0.024	9.04E-06	0.179
Price ($/fl oz across traditional auto-drip brew coffee products)	0.016	0.007	9.04E-06	0.114
Price ($/fl oz across single-cup brew coffee products)	0.064	0.019	0.000082	0.179
Quantity (fl oz)	10982	31226	39.42	2510784
Single-cup Brew dummy (Single-cup brew coffee products = 1)	0.275	0.447	0	1
Organic dummy (organic coffee products = 1)	0.063	0.243	0	1
Deal_cnt (No. of weeks per month a product was promoted)	0.846	1.154	0	5
Caffeine (gram per ounce)	1.685	0.477	0	2.23
Large package dummy (>16 ounces in a package=1)	0.205	0.404	0	1
Product market shares (all inside goods)	8.82E-06	0.00009	4.60E-09	0.035
Market shares of outside goods	0.982	0.014	0.738	0.997
IRI geographical areas	50			
No. of retailers	1795			
No. of manufacturers	240			
No. of brands	317			
No. of defined markets	600			
No. of defined products	1,394,455			

* All prices are adjusted to 2012 dollars.

Many studies analyze the extent to which marketing strategies used by retailers, such as whether the product is featured in the retail store, specially displayed in the retail store, and/or have a temporary retail price cut, affect consumer brand choice and brand loyalty [Hwang and Thomadsen (2017), Bronnenberg et al. (2012) and Boatwright, Dhar and Rossi (2004)]. To capture the potential impact of retailer marketing activities on consumer demand, we construct a variable, *Deal_cnt*, which counts the number of weeks in a month that a product is on feature, display, or has a temporary price cut. The summary statistics in Table 1 shows that on average, the typical product is promoted 0.84 weeks within a month.[21] We expect a positive effect of promotional activities on consumer demand.

The caffeine content for a typical product is 1.68 grams per ounce with a minimum of 0 for a decaffeinated coffee product. Caffeine is a major pharmacologically active compound in coffee beans, and it is a mild central nervous system stimulant [de Mejia and Ramirez-Mares (2014)].

[21] Coffee is one of the most frequently promoted consumer packaged goods (CPGs) (Boatwright et al. (2004)).

Coffee, like other caffeinated soft drinks, acts as a stimulant beverage. As such, we expect a positive impact of caffeine content on consumer demand.

Last, we consider the demand impact of package size, which is captured by dummy variable, *Large*, equal to 1 if a product has a net weight of coffee grounds in a package greater than the standard package size of 16 oz [Guadagni and Little (1998); and Ansari, Bawa, and Ghosh (1995)], 0 otherwise. The demand model coefficient estimate on dummy variable, *Large*, is expected to be positive according to the similar estimate in previous literature.

There are 240 coffee manufacturers and 317 brands in the data sample. It will be too large of a table to report summary statistics by all coffee manufacturers. Therefore, for the data reported in Table 2, we select ten coffee manufacturers that have the largest shares of total revenue during the sample period. In the table, we also include a firm that is the only firm in the data that solely produces single-cup coffee, TREEHOUSE FOODS INC. Table 2 presents summary revenue information of eleven firms. We distinguish the type of firms based on whether a firm produces both traditional auto-drip brew coffee products and single-cup brew coffee products or only one of the two coffee categories. Among these firms, there are six, defined as multi-coffee-type-product firms, that produce both traditional auto-drip brew coffee products and single-cup brew pods. The largest multi-coffee-type-product firm is THE JM SMUCKER CO, with the largest total coffee revenue share of 30.58% during 2012. This firm also has the largest dollar sales of auto-drip brew coffee products, accounting for 34.02% of total dollar sales of all auto-drip brew coffee products across all firms during the sample period. KEURIG GREEN MOUNTAIN is the second largest multi-coffee-type-product firm in terms of total coffee dollar sales, with 19.02% total coffee sales and the largest single-cup brew coffee producer, with single-cup pods dollar sales of 71.55% among single-cup pods revenue across all firms during 2012.

4. The Model

In this section, we outline the analytical framework used to perform the empirical analysis. The analytical framework is to estimate structural parameters that govern US domestic brew-at-home coffee markets demand and supply, and then use the estimated structural parameters to simulate new market equilibrium outcomes based on specific assumed counterfactual changes. The counterfactual change we analyze is to assume that consumers are indifferent between coffee consumption with the single-cup brewing technology and with the traditional auto-drip brewing technology.

Table 2: A Sample of Coffee Manufacturers with Annual Revenue Share >1% in 2012

		All Products		**Auto-drip Brew Coffee Products**		**Single-cup Brew Coffee Products**	
		$	%	$	%	$	%
Multi-coffee-type-product Firms	THE J M SMUCKER CO	72,700,000	30.58%	60,900,000	34.02%	11,800,000	20.10%
	KEURIG GREEN MOUNTAIN	45,200,000	19.02%	3,139,717	1.75%	42,000,000	71.55%
	KRAFT FOODS GROUP INC	34,800,000	14.64%	33,700,000	18.83%	1,046,781	1.78%
	PRIVATE LABEL	24,100,000	10.14%	22,400,000	12.51%	1,668,879	2.84%
	STARBUCKS COFFEE CO	19,700,000	8.29%	19,600,000	10.95%	80,215	0.14%
	THE REILY COMPANIES	4,257,153	1.79%	4,236,401	2.37%	20,752	0.04%
Single-coffee-type-product Firms	MASSIMO ZANETTI BEVERAGE USA	8,022,678	3.38%	8,022,678	4.48%		
	JOH A BENCKISER (JAB)	6,867,266	2.89%	6,867,266	3.84%		
	TATA TEA LTD	4,719,001	1.99%	4,719,001	2.64%		
	F GAVINA & SONS INC	2,438,692	1.03%	2,438,692	1.36%		
	TREEHOUSE FOODS INC	336,113	0.14%			336,113	0.57%
Total Coffee $ Sales in 2012		**$ 237,700,000**		**$ 179,000,000**		**$ 58,700,000**	

Our empirical procedure contains two steps. First, we specify and estimate a random coefficients logit demand model that allows consumers' heterogeneous preferences to affect coffee demand [see, e.g., McFadden (1984), Berry (1994), Berry, Levinsohn and Pakes (1995), Nevo (2000a, b, 2001), Petrin (2002) and many others]. Particularly, we follow the method described in Nevo (2000a) and Berry, Levinsohn and Pakes (1995) that uses market-level price and quantity data for each product in a series of markets to estimate the demand model, taking into account that product prices are likely correlated with shocks to demand embodied in the demand error term. Compared to standard logit and nested logit demand models, the random coefficients logit model allows for considerable flexibility in the specification of heterogeneous consumer preferences and potentially yield consumer substitution patterns across products that are difficult, and sometimes impossible, to obtain from the standard logit or nested logit models. Of particular interest are estimates of demand parameters that capture consumers' relative taste preference for their coffee consumption experience with the single-cup brewing technology compared to their coffee consumption experience with the traditional auto-drip brewing technology.

The second step of the empirical procedure requires specification of an oligopolistic model of competition between firms that supply coffee products. The oligopolistic model we use assumes coffee firms set coffee product prices according to a static Nash equilibrium price-setting game. Optimal price-setting behavior of firms in the oligopoly model implies a set of equations that depend on demand parameter estimates and allows us to compute product-level markups and recover estimates of product-level marginal costs. With the product-level marginal costs in hand along with demand parameter estimates, we again use the optimal price-setting behavioral equations implied by the oligopoly model to perform a counterfactual experiment. The counterfactual experiment asks how equilibrium market outcomes of interest (prices, consumer demand, firm profits, and consumer welfare) are predicted to change if consumers equally value the single-cup technology brewing coffee consumption experience and the traditional auto-drip brewing coffee consumption experience. Operationalizing the counterfactual experiment simply requires us setting to zero estimates of demand parameters that capture consumers' relative taste preference for their coffee consumption experience with the single-cup brewing technology compared to their coffee consumption experience with the traditional auto-drip brewing technology. Since these demand parameters are embedded into the optimizing equations implied by the oligopoly model, we simply use these equations to facilitate computation of new counterfactual market equilibrium outcomes of interest.

4.1 Demand

We model consumers' coffee product choices with a random utility discrete choice model. Suppose there are T distinct markets for coffee products, and markets are indexed by $t = 1, \dots, T$. Each market is populated with I_t potential coffee consumers, and consumers are indexed by $i = 1, \dots, I_t$. Consumers in each market are faced with J_t distinct coffee product choices, in addition to the alternative of not to purchase one of the J_t distinct coffee products in our data sample. Therefore, in each market consumers are effectively faced with $J_t + 1$ alternatives, which are indexed by $j = 0, \dots, J_t$, where $j = 0$ represents consumers' outside option of not purchasing one of the coffee products in our data sample. In our analysis, consumers' outside option is a composite of several possibilities such as buying other coffee substitutes (e.g. instant coffee, whole bean coffee, ready-to-drink coffee beverages, etc.) or simply not buying.

The conditional indirect utility consumer i obtains from choosing product j in market t is:

$$U_{ijt} = x_{jt}\beta_i + \phi_i Single - Cup\ Brew_{jt} + \alpha_i p_{jt} + a_t + a_s + a_b + \xi_{jt} + \varepsilon_{ijt} \qquad (1)$$

where x_{jt} is a vector of K observed product characteristics that vary across products and markets; and β_i is a $K+1$ vector of consumer-specific taste parameters i.e., marginal utilities, associated with the corresponding product characteristic variables in x_{jt}. $Single - Cup\ Brew_{jt}$ is a zero-one dummy variable that equals to one only if consumption of coffee product *j* in market *t* requires using single-cup brewing technology; and ϕ_i is the associated consumer-specific taste parameter. Since consumption of the coffee products in our data sample either requires using traditional auto-drip brewing technology, or using single-cup brewing technology, this implies that parameter ϕ_i measures consumer $i's$ preference for the single-cup brewing technology consumption experience compared to the traditional auto-drip brewing technology consumption experience. p_{jt} is the price of product j in market t, assumed common to all consumers; and α_i is the consumer-specific taste parameter that measures the consumer's marginal utility of price. a_t captures market-specific shocks to consumers' preferences for coffee products; a_s captures retail store-specific shocks to consumers' preferences for coffee products; and a_b captures brand-specific differences in consumers' preferences for coffee products. In estimation, we control for fixed effects captured by a_t, a_s, and a_b using relevant zero-one dummy variables. Finally, ξ_{jt} is a composite of product characteristics that are observed by consumers and firms, but unobserved by us the researchers; and ε_{ijt} is a mean-zero stochastic error term.

The distribution of consumers' taste parameters, β_i, ϕ_i and α_i, is specified as:

$$\begin{pmatrix} \beta_i \\ \phi_i \\ \alpha_i \end{pmatrix} = \begin{pmatrix} \beta \\ \phi \\ \alpha \end{pmatrix} + \Gamma D_i + \Sigma v_i, \quad v_i \sim N(0, I_{K+3}) \qquad (2)$$

where D_i is a $m \times 1$ vector of observed consumer demographic variables with mean of zero and variance of one across all markets; and Γ is a $(K+3) \times m$ matrix of parameters that measures how consumers' taste for attributes of coffee products vary by observed demographics. In the actual demand estimation, we include income in D_i in the form of deviation from its market mean, to allow an individual's marginal utility of specific product attributes to vary with his or her income level. Unobserved shocks to consumers' taste for various product attributes are contained in v_i, which is assumed to follow a standard normal distribution. Σ is a diagonal matrix, where the elements on the main diagonal are parameters which measure variation in taste across consumers for various product attributes. Given the zero mean of elements in v_i and D_i, the vector of parameters $\begin{pmatrix}\beta\\ \phi\\ \alpha\end{pmatrix}$, measures the mean of the random coefficients.

Based on equations (1) and (2) above, the conditional indirect utility consumer i obtains from the purchase of product j in market t can be re-written as:

$$U_{ijt} = \delta_{jt}\left(x_{jt}, Single - Cup\ Brew_{jt}, p_{jt}, a_t, a_s, a_b, \xi_{jt}; \beta, \phi, \alpha\right) + \mu_{ijt}\left(x_{jt}, Single - Cup\ Brew_{jt}, p_{jt}, D_i, v_i; \Gamma, \Sigma\right) + \varepsilon_{ijt} \quad (3)$$

where $\delta_{jt} = x_{jt}\beta + \phi Single - Cup\ Brew_{jt} + \alpha p_{jt} + a_t + a_s + a_b + \xi_{jt}$ is the mean utility (across consumers) obtained from consuming product j ; and $\mu_{ijt} = [\ x_{jt}, Single - Cup\ Brew_{jt}, p_{jt}](\Gamma D_i + \Sigma v_i)$ is a consumer-specific deviation from the mean utility level. The outside option, denoted good 0, yields mean utility that is normalized to be zero. For computational tractability, the idiosyncratic error term ε_{ijt} is assumed to be governed by an independent and identically distributed extreme value density.[22] The probability that product j is chosen, or equivalently the *predicted* (by the model) market share of product j is therefore:

$$s_{jt}\left(x_{jt}, p_{jt}, \xi_{jt}; \beta, \phi, \alpha, \Gamma, \Sigma\right) = \int \frac{e^{\delta_{jt}+\mu_{ijt}}}{1 + \sum_{l=1}^{J} e^{\delta_{lt}+\mu_{ilt}}} d\widehat{F(D)} dF(v) \quad (4)$$

where $\widehat{F(D)}$ and $F(v)$ are population distribution functions for consumer demographics and random taste shocks assumed to be independently distributed. As is well-known in the empirical industrial organization literature, there is no closed-form solution for the integral in equation (4), and thus it must be approximated numerically using random draws from $\widehat{F(D)}$ and $F(v)$.[23]

Finally, the demand for product j is given by:

$$d_{jt} = M_t \times s_{jt}\left(x_{jt}, p_{jt}, \xi_{jt}; \beta, \phi, \alpha, \Gamma, \Sigma\right) \quad (5)$$

where M_t is a measure of the potential size of market *t*; $s_{jt}\left(x_{jt}, p_{jt}, \xi_{jt}; \beta, \phi, \alpha, \Gamma, \Sigma\right)$ is the predicted product share function from equation (4); and $(\beta, \phi, \alpha, \Gamma, \Sigma)$ is the set of demand parameters to be estimated. The potential market size measure M_t, as previously described, is the

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[22] For notational convenience, from this point onwards we let x_{jt} represents all the measured non-price product characteristics in our data, including variable, $Single - cup\ Brew_{jt}$.

[23] In the actual demand estimation, we use 200 random draws from $F(\cdot)$ for the numerical approximation of $s_{jt}(\cdot)$.

total equivalent fluid ounces of brewed coffee that could be consumed in a market during a month if all adult males and females in the market consumed coffee at the typical per capita consumption rates for males and females respectively.

4.2 Supply

The supply side of our structural econometric model can be designed to capture both the horizontal and vertical relationships between coffee manufacturers and retailers [Bonnet and Dubois (2010); Bonnet et.al. (2013); and Bonnet and Villas-Boas (2016)]. However, in this paper, it is not our focus to explore which supply model best represents the vertical structure of the US coffee industry. Instead, we make the simplifying assumption that retailers do not play a strategic role in setting retail prices of the coffee products in our analysis, and simply set retail prices just high enough to cover their economic retailing costs and costs to obtain coffee products from coffee manufacturers. We do assume coffee manufacturers play a strategic role in setting prices of their coffee products to non-cooperatively maximize firm-level profit. As such, we consider a supply model of the coffee industry in which coffee manufacturers effectively determine coffee product prices according to a static Nash equilibrium price-setting game.

Suppose each coffee manufacturer f offers a set of coffee products in market t, F_{ft}, and sets the prices of these products to maximize the firm's variable profit:

$$\max_{p_{jt}\forall j\in F_{ft}} VP_{ft} = \max_{p_{jt}\forall j\in F_{ft}} \sum_{j\in F_{ft}} (p_{jt} - mc_{jt})q_{jt} = \max_{p_{jt}\forall j\in F_{ft}} \sum_{j\in F_{ft}} (p_{jt} - mc_{jt}) \times M_t \times s_{jt}(\boldsymbol{p}) \tag{6}$$

where in equilibrium the quantity of coffee product j that gets sold in market t, q_{jt}, is exactly equal to the market demand of this product, i.e. $q_{jt} = M_t \times s_{jt}(\boldsymbol{p})$. Recall that M_t is a measure of potential market size; $s_{jt}(\boldsymbol{p})$ is the *predicted* market share function for product j; and $\boldsymbol{p}$ is a vector of the prices for the J products in market t. Last, mc_{jt} represents the marginal cost incurred by the firm to provide product j in market t.

The first-order conditions generated from the optimization problem in equation (6) for all competing firms are a set of J equations, one for each product. Following expositions in Nevo (2000a), the set of J first-order conditions imply the following product markup equation expressed in matrix notation:

$$\boldsymbol{p} - \boldsymbol{mc} = -(\boldsymbol{\Omega} * \boldsymbol{\Delta})^{-1} \times \boldsymbol{s}(\boldsymbol{p}) \tag{7}$$

where $\boldsymbol{s}(\cdot), \boldsymbol{p}, \boldsymbol{mc}$ are $J \times 1$ vectors of product shares, prices, and marginal costs, respectively; $\boldsymbol{\Omega}$ is a $J \times J$ matrix of appropriately positioned zeros and ones based on the manufacturers' ownership structure of the J products; $\boldsymbol{\Delta}$ is a $J \times J$ matrix of first-order derivatives of predicted product shares with respect to prices; and $\boldsymbol{\Omega} * \boldsymbol{\Delta}$ is an element-by-element multiplication of the two matrices.

Equation (7) above implies product-level markup estimates, i.e. $\boldsymbol{mkup}(\boldsymbol{x}, \boldsymbol{p}, \boldsymbol{\xi}; \hat{\beta}, \hat{\phi}, \hat{\alpha}, \hat{\Gamma}, \hat{\Sigma}) = -(\boldsymbol{\Omega} * \boldsymbol{\Delta})^{-\mathbf{1}} \times \boldsymbol{s}(\boldsymbol{p})$, which depend exclusively on the demand-side variables and parameter estimates. Using computed product-level markups and product prices, product-level marginal cost estimates can be recovered as follows:

$$\widehat{\boldsymbol{mc}} = \boldsymbol{p} - [-(\boldsymbol{\Omega} * \boldsymbol{\Delta})^{-\mathbf{1}} \boldsymbol{s}(\boldsymbol{p})] \tag{8}$$

Last, with the estimated markups given by equation (7), manufacturers' variable profits can be computed using:

$$\widehat{VP}_{ft} = \sum_{j \in F_{ft}} mkup_{jt}(\boldsymbol{x}, \boldsymbol{p}, \boldsymbol{\xi}; \hat{\beta}, \hat{\phi}, \hat{\alpha}, \hat{\Gamma}, \hat{\Sigma}) \times M_t \times s_{jt}\big(\boldsymbol{x}, \boldsymbol{p}, \boldsymbol{\xi}; \hat{\beta}, \hat{\phi}, \hat{\alpha}, \hat{\Gamma}, \hat{\Sigma}\big) \tag{9}$$

4.3 Estimation and Identification of Demand

To estimate the set of demand parameters, we use generalized method of moments (GMM) following the previous literature [Berry (1994), Berry, Levinsohn and Pakes (1995), Nevo (2000a) and Petrin (2002)]. The general strategy is to derive parameter estimates such that the *observed* product shares S_{jt} are equal to the *predicted* product shares s_{jt}.[24]

Instruments

The classic econometric problem in logit demand estimation is the endogeneity of prices. Obtaining consistent demand parameter estimates relies heavily on the selection of instrument variables for the endogenous product prices. Consumers make purchase decisions among different coffee products, where a product is perceived as a bundle of product attributes. Product attributes unobserved by researchers, which are contained in ξ_{jt}, are likely correlated with prices. Hence, it

[24] The predicted product share integral is approximated by using the following simulator given by: $s_{jt} = \frac{1}{ns}\sum_i^{ns} \frac{e^{\delta_{jt}+[x_{jt}, p_{jt}](\Gamma D_i + \Sigma v_i)}}{1+\sum_l^J e^{\delta_{lt}+[x_{lt}, p_{lt}](\Gamma D_i + \Sigma v_i)}}$, where ns is the number of random draws from the distribution of D and v; $ns = 200$ in the actual demand estimation. The 200 individual draws are obtained from Public Use Microdata Sample (PUMS) datasets.

is important to select appropriate instrument variables for prices. One way to cope with the endogeneity of prices is to account for fixed differences in ξ_{jt} in a flexible manner by introducing dummy variables [Nevo (2001)]. These dummies control for constant differences in consumer utility across products as well as regional differences in the mean utility of products. As such, to help mitigate the endogeneity problem we include in the mean utility function time dummies, store dummies, brand dummies, and geographic region dummies (i.e. IRI geographical areas) to account for some product characteristics in ξ_{jt}.

To further mitigate the endogeneity problem, we construct instruments for products prices using direct components of marginal cost interacted with brand fixed effects as in Villas-Boas (2007a, 2007b) and Nakamura and Zerom (2010). Firms set coffee product prices by taking into account exogenous cost-side variables, such as coffee bean prices, energy prices, and exchange rates. Due to the exogeneity of these input markets from the perspective of coffee markets, it is likely that these input prices are uncorrelated with shocks to coffee demand contained in ξ_{jt}. For example, a firm's changes how coffee products are displayed in a store, which likely influence demand and prices for its products due to such changes being captured in ξ_{jt}, are unlikely to be correlated with exchange rate changes between Brazil and US. However, exchange rate changes between Brazil and US are likely to influence the prices of several coffee products.

When estimating demand, we include three types of instruments for prices. The first is time-varying exchange rates between Brazilian real and US dollar interacted with brand dummies.[25] Raw coffee beans, like any other exchange-traded commodities, are traded in commodity exchange markets, such as the New York Stock Exchange (NYSE). Changes in exchange rates often impact raw coffee bean trade flows and trading prices. The largest raw coffee bean exporting country is Brazil, which is also the main source of coffee bean imports for the US coffee industry in 2012, according to International Coffee Organization (ICO).[26] Therefore, changes in exchange rates between Brazil real and US dollar are likely important in explaining variations in coffee products' production costs. By using the interactions between exchange rates and brand dummies as instrument variables, we allow exchange rates to influence coffee products' production costs differently across brands. As in Nakamura and Zerom (2010), we consider lagged

[25] Exchange rate between Brazil and US is obtained from the website of the Federal Reserve Bank of St. Louis. (https://fred.stlouisfed.org/series/DEXBZUS)
[26] Global coffee trade statistics can be found at the ICO website: http://www.ico.org/new_historical.asp

exchange rates to capture the potential lagged response in coffee products' production costs and its transmission to influence coffee product prices.

For the second set of instruments, we interact the national average electricity prices[27] with the dummy variables for four different packaging materials for coffee products. The packaging materials are: (1) paper bags/boxes; (2) laminated (foil) bags; (3) plastic canisters; and (4) light metal tins. By interacting electricity price with zero-one dummy variables that correspond to the four different packaging materials, we allow these four instrument variables to capture the likelihood that changes in electricity prices affect coffee products' production costs differently across different packaging processes. Furthermore, in principle this set of instruments is valid since changes in electricity price are unlikely to be driven by changes in coffee markets, making this set of instruments exogenous to coffee markets.

Last, we include the mean of *Deal_cnt* across all products for each coffee producer as additional instrument for product price. The first-order conditions associated with firms' optimal choice of prices to maximize their variable profit reveal that a product's equilibrium price is a function of markup and marginal cost. As such, a change in a product's markup is likely to affect its price. The idea is that the average markup that a producer is able to charge is related to the characteristics of its products.

5. Empirical Results

5.1 Demand

The demand model estimates can be found in Table 3. The first column reports parameter estimates from the standard logit model using the ordinary least squares (OLS) estimator without instrumenting for price; the second column reports standard logit model parameter estimates where we have instrumented for prices using the set of instrument variables discussed in the previous section. Parameter estimates from the random coefficients logit demand model are reported in the last three columns. In the last three columns of estimates, consumer heterogeneity is considered by allowing the coefficient on coffee product price and other product characteristics to vary across individual consumers.

[27] Electricity price is from the US Energy Information Administration (EIA) website: (https://www.eia.gov/electricity/data/browser/#/topic/7?agg=0,1&geo=00fvvvvvvvvo&endsec=vg&freq=M&start=201201&end=201212&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0)

Comparing OLS estimates, which are obtained without using instruments for price, with the other columns of estimates (two-stage least squares (2SLS) and generalized method of moments (GMM)) when price instruments are used, one notices that the coefficient estimate for price increases tremendously in absolute value with instrumentation. As stated in the model section, price is an endogenous variable that is likely correlated with product attributes in ξ_{jt} since these product attributes are observed by decision-making consumers and firms, even though they are not observed by us the researchers. The Wu-Hausman endogeneity test statistics of 33392.11 confirms the endogeneity of price by rejecting the exogeneity of price at 1% level. It suggests that the OLS estimation produces biased and inconsistent estimates of the price coefficient. Moreover, the weak instrument test using Stock and Yogo's (2005) test yields a test statistic of 112.22, which is statistically significant at 1% level, and thus rejects the null hypothesis that the instruments used for price are weak. We focus the remainder of our analysis on demand estimates obtained from the random coefficients model.

Among the last three columns, the first column of estimates reports means of the distribution of marginal utilities ($\beta's$). The second column of estimates labeled "Standard Deviations" measures taste variation of select product attributes driven by unobserved consumer characteristics, v_i. The last column of estimates represents the effect of consumer income on consumers' marginal utilities of select product attributes.

We find the mean coefficient estimate for price is negative and statistically significant at 1% level, indicating coffee price, on average, has a negative impact on consumers' mean utility. All else equal, an increase in a product's price reduces the probability that a typical coffee drinker chooses the product. The coefficient estimate on the interaction between price and consumer income level is statistically significant at conventional levels of statistical significance. The positive coefficient estimate suggests an intuitively appealing result that higher income consumers tend to be less price sensitive. The parameter estimate that measures the variation of price sensitivity across consumers, which is located in the column labeled "Standard Deviations", is statistically significant, providing evidence that consumers are heterogeneous with respect to their sensitivity to price changes of coffee products.

Table 3: Demand Estimates

	Standard Logit Model ($\mu_{ij} = 0$)		**Random Coefficients Model ($\mu_{ij} \neq 0$)**		
	(1) OLS	(2) 2SLS	(3) GMM		
Variables	Mean Coef ($\alpha, \beta's$)	Mean Coef ($\alpha, \beta's$)	Mean Coef ($\alpha, \beta's$)	Standard Deviations (Σ)	Interactions with Income (Γ)
Price ($/fl oz)	-14.236***	-146.975***	-163.61***	-11.8986***	10.8184***
	(0.117)	(1.021)	(2.663)	(0.312)	(2.068)
Constant	-14.776***	-7.637***	-34.0554***	9.0402***	
	(0.337)	(0.470)	(0.870)	(1.795)	
Single-cup Brew	-0.709***	4.297***	4.0616***	-0.044	1.9357***
	(0.006)	(0.039)	(0.124)	(0.177)	(0.152)
Organic	-0.9696***	-0.510***	-0.4861***		
	(0.006)	(0.009)	(0.017)		
Deal_cnt	0.153***	0.015***	0.0051*		
	(0.0008)	(0.0016)	(0.003)		
Caffeine	0.613***	0.652***	0.6624***		
	(0.002)	(0.0031)	(0.006)		
Large	0.858***	0.450***	0.3757***		
	(0.003)	(0.005)	(0.012)		
Time Fixed Effects	Yes	Yes	Yes		
IRI Market Fixed Effects	Yes	Yes	Yes		
Store Fixed Effects	Yes	Yes	Yes		
Brand Fixed Effects	Yes	Yes	Yes		
R-sq	0.615				
Wu-Hausman (Chi-sq)		33392.1***			
Stock and Yogo Weak Instrument Test (F)		112.22***			
			GMM Objective	0.0329	
No. of Observations	1,394,455	1,394,455	1,394,455		

***p<0.01; **p<0.05; *p<0.1. Standard errors are in parentheses.

To assess how much consumers value their coffee consumption experience using the single-cup brewing technology relative to the traditional auto-drip brewing method, we focus on the parameter estimates for the dummy variable, *Single-cup Brew*. The mean coefficient estimate, 4.0616, is positive and significant at 1%, providing evidence that the average consumer obtains more utility from the coffee consumption experience that uses single-cup brewing technology compared to the coffee consumption experience that uses auto-drip brewing method. In other words, a cup of freshly brewed coffee using the single-cup brewing technology is associated with higher levels of consumer satisfaction relative to levels of satisfaction associated with coffee consumption using the traditional auto-drip brewed method of ground coffee.

The parameter estimate that measures variation across consumers of utility differences obtained from the single-cup brewing technology consumption experience relative to traditional auto-drip brewing method consumption experience, which is located in the column labeled "Standard Deviations", is not statistically significant, suggesting that taste heterogeneity for the brewing method product attribute is mostly explained by the included demographics.[28] We find evidence that an important driver of consumers' heterogeneity with respect to their preference for the single-cup brewing technology consumption experience relative to traditional auto-drip brewing method consumption experience is their level of income. In particular, the positive and statistically significant coefficient estimate for the interaction between the *Single-cup Brew* dummy variable and consumer income, 1.9357, suggests that higher income consumers have a greater gain of utility from the coffee consumption experience using single-cup brewing technology compared to the coffee consumption experience that uses auto-drip brewing method. In other words, evidence from the demand estimation suggests that, relative to lower income consumers, higher income consumers obtain an even greater satisfaction from the single-cup brewing technology consumption experience compared to their satisfaction obtained from traditional auto-drip brewing method consumption experience. Perhaps this finding is in part due to higher income households being better able to afford more expensive single-serve coffee brewing systems, which often cost $100 to $200 compared with an average price of $35 for many auto-drip coffee makers.[29]

[28] Nevo (2000a) provides detailed discussions about the interpretation of the estimates of the standard deviations for the random coefficients.
[29] http://time.com/money/3733586/k-cups-price-cost-comparison-coffee/

The structural demand model allows us to obtain estimates of consumers' willingness to pay (WTP) for various measured product attributes. For example, the average WTP for the coffee consumption experience which uses single-cup brewing technology is given by the mean of the 200 individuals' marginal utility coefficient estimates on dummy variable, *Single-cup Brew*, ($\widehat{\phi_i}$) divided by their respective marginal utility coefficient estimate on price ($\widehat{\alpha_i}$) across all markets. The resulting mean WTP estimate is ¢2.52 per equivalent fl oz,[30] indicating that a typical coffee drinker is willing to pay up to ¢2.52 extra per equivalent fl oz to consume brewed coffee from the single-cup brewing method and thereby avoid using the traditional auto-drip brewing method. This is equivalently saying a typical coffee drinker is willing to pay ¢25 extra per standard 10 fl oz cup of brewed coffee using the single-cup technology rather than the traditional auto-drip method. We now better contextualize this WTP estimate of ¢2.52 per equivalent fl oz for the single-cup brewing method attribute.

From the previously discussed summary statistics in Table 1, we saw that the mean price across traditional auto-drip brewed coffee products in our sample is ¢1.61 per equivalent fl oz, while the mean price across single-cup brewed coffee products in our sample is ¢6.40 per equivalent fl oz. In other words, in terms of price per equivalent fl oz, the data reveal that, on average, single-cup brewed coffee products are 3.98 times as expensive as traditional auto-drip brewed coffee products. However, not all of this price difference is attributable to the difference in consumers' valuation of the single-cup brewing technology consumption experience versus the traditional auto-drip brewing technology consumption experience since the products across the two sets of product types may differ along several non-price product attribute dimensions. As we reported above, relevant parameter estimates from our demand model reveal that consumers are willing to pay ¢2.52 extra per equivalent fl oz just for the single-cup brewing technology consumption experience instead of the traditional auto-drip brewing method consumption experience. Assuming all other product attributes are equivalent to the average of said attributes for traditional auto-drip brewing method products, our WTP estimate also implies that, on average, a coffee drinker is willing to pay a price per equivalent fl oz that is 2.57 times the average price per equivalent fl oz of traditional auto-drip brewed coffee products just to enjoy the attribute of single-cup brewing technology as part of the consumption experience instead of the attribute of traditional auto-drip brewing method.

[30] We convert the dollar value to cents for illustration.

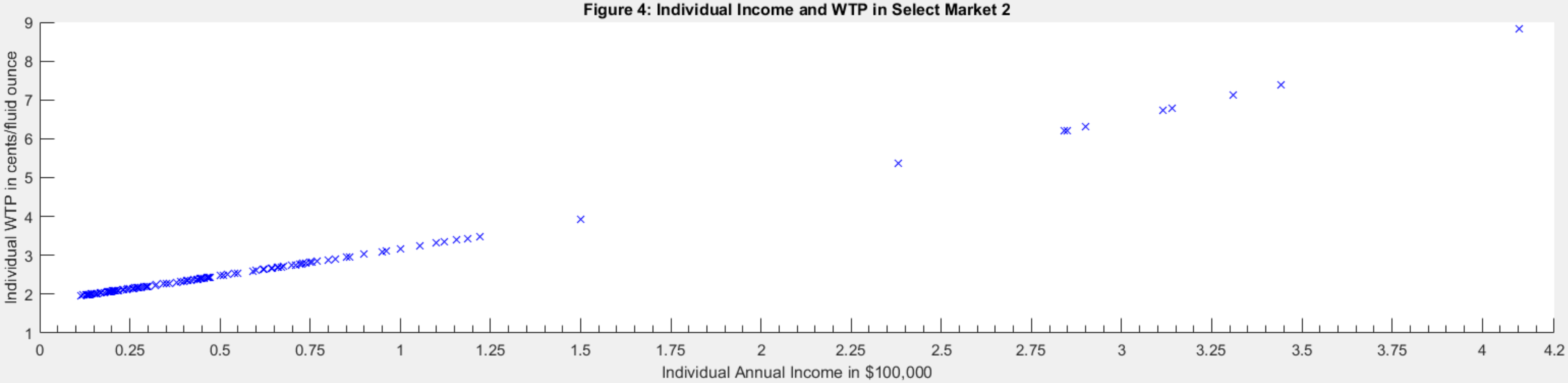
To present a picture of the relationship between individual-specific income level and the estimates of their marginal willingness to pay for the single-cup brewing technology product attribute, we plot the 200 individuals' annual income (in $100,000) and their respective estimates of willingness to pay (in cents/fluid ounce) from two select markets. These plots are shown in Figure 3 and Figure 4. It is clear that higher (lower) income individuals are willing to pay more (less) to have brewed coffee made from the single-cup coffee machines instead of the traditional auto-drip coffee makers. Similar results are found in other markets.

We now turn to discuss estimates for other product characteristics that affect consumer choice. For an average coffee drinker, organic coffee produces a negative marginal utility, suggesting that organic coffee products are less favorable than non-organic coffee during the sample period. This is an unexpected estimated demand impact of the organic attribute of coffee products. The other demand shifters all have expected demand impacts and are consistent with findings in previous studies. For example, the variable capturing the extent of promotional activities a product received during a month, *Deal_cnt*, has a positive and statistically significant coefficient estimate, suggesting that firms' promotional activities for a given coffee product serve to increase consumers' demand for the product. This finding is consistent with similar estimates in some previous work such as Guadadni and Little (1998), Gupta (1988), Lattin and Bucklin (1989), Grover and Srinivasan (1992), Boatwright, Dhar and Rossi (2004), Ansari, Bawa and Ghosh (1995). These studies all provide empirical evidence that promotional activities have a positive impact on coffee demand. Gupta (1988), for example, argues that promotion enhances a brand's value, which in turn enhances the probability of products of this brand being selected by consumers.

The coefficient estimate associated with the caffeine content variable is positive and statistically significant, suggesting that, holding all other coffee demand factors constant, consumers prefer coffee products that have higher caffeine content. A similar result is found in Bonnet and Villas-Boas (2016). The authors find consumers have significant and negative preference for caffeine-free products; thereby, a typical coffee drinker prefers coffee products that are not decaffeinated.

Figure 3: Individual Income and WTP in Select Market 1

Figure 4: Individual Income and WTP in Select Market 2



The coefficient estimate associated with the zero-one dummy package size variable, *Large*, is positive and statistically significant, suggesting that coffee products that are presented to consumers in large packages (greater than 16 oz) have a higher demand relative to coffee products in smaller size packaging. This result is similar to findings in Guadagni and Little (1998) and Ansari, Bawa, and Ghosh (1995). Prendergast and Marr (1997) argue that larger packaged consumer goods normally reflect better value to average consumers, and consumers tend to choose larger packaged products as they are more likely to stand out on the shelf.

We use our demand model estimates to compute both own- and cross-price demand elasticities for products in the data sample. We then compute the mean of own-price demand elasticities at the coffee manufacturer level and report estimates of eleven select firms in Table 4. Mean cross-price demand elasticity estimates within and across the two coffee product types are reported in Table 5.

Own-price Elasticity of Demand Estimates

In Table 4, we report the average own-price elasticities for the eleven select coffee manufacturers broken down by coffee types. The last row in the table shows average own-price elasticities across all firms in the sample. Our demand model yields an average own-price elasticity of -4.57 across all products in the sample; an average own-price elasticity of -2.63 across all traditional auto-drip brewing method coffee products; and an average own-price elasticity of -9.69 across all single-cup brewing technology coffee products. The own-price elasticity estimate suggests that a 1% reduction in the price of a traditional auto-drip brew coffee product will, on average, result in a 2.63% increase in the quantity demanded for that product, while a 1% reduction in the price of a single-cup brew coffee product will, on average, result in a 9.69% increase in the quantity demanded for that product.

The own-price elasticity of traditional auto-drip brewing method coffee products in absolute magnitude, 2.63, is slightly smaller than analogous estimates obtained in previous studies: Krishnamurthi and Raj (1991) (own-price elasticity estimates ranging from 3.6 to 8.2); Broda and Weinstein (2006) (own-price elasticity estimate of 3.1); Foster, Haltiwanger and Syverson (2008) (own-price elasticity estimate of 3.65); Villas-Boas (2007b) (own-price elasticity estimates ranging from 5.6 to 6.8); and Nakamura and Zerom (2010) (own-price elasticity estimate of 3.96). We find Chintagunta et al. (2018) is the only work that provides an own-price elasticity estimate for single-cup brew coffee products in coffee markets in Portugal, with an estimate of 3.6 in absolute magnitude, which is smaller than our mean own-price elasticity estimate for single-cup brew coffee products in US markets.

The average own-price elasticity estimates reveal that consumer demand for single-cup coffee products is more sensitive to price changes of these products compared to the sensitivity of consumer demand for traditional auto-drip coffee products to price changes of these products. The difference in price sensitivity of consumer demand across these two coffee product types may in part be driven by consumers' broad perception of these two types of coffee products. Specifically, we previously discussed the result produced by our demand model suggesting that, relative to lower income consumers, higher income consumers have a greater preference for single-cup brewing technology coffee products compared to traditional auto-drip coffee products. This result further suggests that in classifying coffee products along a spectrum ranging from necessities to luxuries, single-cup brewing technology coffee products are likely to be closer to luxuries on the spectrum compared to traditional auto-drip coffee products. It is a well-established principle in microeconomics that luxury products tend to have higher elasticities of demand compared to necessity products. As such, where the two types of coffee products lie on the product classification spectrum ranging from necessities to luxuries in part may explain why single-cup brewing technology coffee products have a higher own-price elasticity of demand compared to traditional auto-drip brew coffee products.

Among the eleven coffee manufacturers, consumers are most price sensitive to products of KEURIG GREEN MOUNTAIN (with an estimate of -10.029) and least price sensitive to PRIVATE LABEL products (with an estimate of -2.618). Among traditional auto-drip brewing method coffee products, products of JOH A BENCKISER (JAB) have the most elastic demand (-3.952) while among single-cup brewing technology products, products of STARBUCKS COFFEE CO have the most elastic demand (-11.78).

Table 4: Break-down of Own-price Elasticities, by Coffee Type, Select Coffee Manufacturers with Share of Total Coffee $ Sales >1% in 2012

		All Products		Auto-drip Brew Coffee Products		Single-cup Brew Coffee Products	
		Mean	Std. err.	Mean	Std. err.	Mean	Std. err.
Multi-coffee-type-product Firms	THE J M SMUCKER CO	-3.880	0.0050	-2.507	0.0018	-8.410	0.0098
	KEURIG GREEN MOUNTAIN	-10.029	0.0057	-3.811	0.0046	-10.700	0.0045
	KRAFT FOODS GROUP INC	-2.896	0.0057	-2.136	0.0019	-8.641	0.0277
	PRIVATE LABEL	-2.618	0.0044	-2.115	0.0024	-5.959	0.0160
	STARBUCKS COFFEE CO	-3.676	0.0047	-3.512	0.0022	-11.780	0.0471
	THE REILY COMPANIES	-2.666	0.0060	-2.582	0.0036	-10.232	0.0916
Single-coffee-type-product Firms	MASSIMO ZANETTI BEVERAGE USA			-1.939	0.0022		
	JOH A BENCKISER (JAB)			-3.952	0.0032		
	TATA TEA LTD			-2.508	0.0029		
	F GAVINA & SONS INC			-2.579	0.0042		
	TREEHOUSE FOODS INC					-7.620	0.0280
Mean Elasticities across all products in the sample		-4.570	0.0031	-2.626	0.0011	-9.692	0.0048

Table 5: Mean Cross-price Elasticities by Coffee Type

i \ ***j***	**Single-cup Brew Coffee Products**	**Auto-drip Brew Coffee Products**
Single-cup Brew Coffee Products	0.00118 (3.23e-06)	0.0007 (1.11e-06)
Auto-drip Brew Coffee Products	0.0005 (4.11e-07)	0.00085 (7.50e-07)

Cell entries *i*, *j*, where *i* indexes row and *j* column, given the percent change in market share of product *i* with a 1% change in price of product *j*. Each entry represents the mean of the elasticities from the 600 markets. Standard errors are in parentheses.

Cross-price Elasticity of Demand Estimates

Cross-price elasticity of demand estimates in Table 5 are relatively small in magnitude, but all estimates are positive and statistically different from zero, suggesting that consumers do perceive the coffee products in our sample as substitutable both within and across the two product types. It is also notable that the mean cross-elasticity estimates reveal the following intuitively appealing result: Coffee product pairs within any one of the two coffee product types, on average, have larger cross-elasticities (intra-product-type cross-elasticities) and therefore more substitutable compared to cross-elasticities among product pairs where products in the pair are in different product types (inter-product-type cross-elasticities), i.e., intra-product-type cross-elasticities are on average larger than inter-product-type cross-elasticities. Specifically, we see that among single-cup coffee products the mean cross-elasticity estimate is 0.00118, and among auto-drip coffee products the mean cross-elasticity estimate is 0.00085. These cross-elasticity estimates suggest that a 1% increase in the price of a single-cup coffee product, on average, results in a 0.00118% increase in the demand of another single-cup coffee product, while a 1% increase in the price of an auto-drip coffee product, on average, results in a 0.00085% increase in the demand of another auto-drip coffee product. However, mean cross-elasticity estimates between single-cup coffee products and auto-drip coffee products are 0.0007 and 0.0005, which are smaller in magnitude than the within product type mean cross-elasticity estimates. These mean cross-product type cross-elasticity estimates suggest that a 1% increase in the price of a single-cup coffee product, on average, results in a 0.0005% increase in the demand for an auto-drip product, while a 1% increase in the price of an auto-drip coffee product, on average, results in a 0.0007% increase in the demand for a single-cup product.

5.2 Markups and Marginal Costs

We report in Table 6 summary statistics of prices, price-cost margins, and marginal costs broken down by coffee types.[31] There is a total of 1,010,947 traditional auto-drip brewing method coffee products and 383,508 single-cup brewing technology coffee products in the sample. As previously reported in Table 1, and now again in Table 6, the average price per equivalent fluid ounce of single-cup brew coffee products is ¢6.4/fl oz, whereas the average price per equivalent fluid ounce of traditional auto-drip brew coffee products is only ¢1.6/ fl oz. The price difference

[31] The model generates 3% of observations that have negative marginal cost estimate.

suggests that, on average, it is more expensive for consumers to enjoy a cup of freshly brewed coffee using the single-cup brewing technology. In fact, using Keurig K-Cups to make brewed coffee may cost consumers up to 5 times more than brewing coffee from a pot using the traditional auto-drip method.[32]

Table 6: Summary Statistics of Price, Markup and Marginal Cost, by Coffee Type

	Traditional Auto-drip Brew Coffee Products			
	Price	Markup		Marginal Cost
Statistics	¢/fl oz	¢/ fl oz	% of Price	¢/fl oz
Mean	1.609	0.719	55.36	0.890
Median	1.509	0.692	46.87	0.792
10%	0.850	0.612	26.81	0.103
90%	2.461	0.850	87.96	1.761
Std. Dev.	0.673	0.137	285.79	0.706
No. of Products	1,010,947			
	Single-cup Brew Coffee Products			
	Price	Markup		Marginal Cost
Statistics	¢/fl oz	¢/fl oz	% of Price	¢/fl oz
Mean	6.399	0.763	13.64	5.636
Median	6.573	0.711	11.23	5.827
10%	3.296	0.630	8.07	2.522
90%	8.316	0.920	23.49	7.608
Std. Dev.	1.911	0.217	14.82	1.935
No. of Products	383,508			

Markups measured in cents per equivalent fluid ounce are positive for all products in the sample. A typical single-cup brew coffee product has a markup estimate of ¢0.76/fl oz, which is similar in magnitude to the average markup of a typical auto-drip brew coffee product of ¢0.72/fl oz. Consequently, with prices being very different across the two product types, the model predicts a considerably greater price-cost markup as a percent of price (price-cost margin or Lerner index) for a typical auto-drip coffee product, 55.4%, than that for a typical single-cup product, 13.6%. The table shows that only 10% of single-cup products have markups greater than 23.5%. The median price-cost margin among auto-drip coffee products in our data is 46.9%, which is close in magnitude to what others have found in the literature: Nakamura and Zerom (2010), 36.8%; Villas-Boas (2007b), 40.4%; and Bonnet and Villas-Boas (2016), 38.67%.

[32] https://www.businessinsider.com/keurig-cups-are-expensive-2015-3

Finally, subtracting estimated markup from the observed price for each product yields implied marginal cost. Summary statistics on implied marginal cost estimates are reported in the last column of Table 6. Auto-drip brew coffee products are estimated to have mean marginal cost of ¢0.89/fl oz, whereas single-cup coffee products are estimated to have mean marginal cost of ¢5.6/fl oz, suggesting that single-cup pods production is more costly at the margin. Product-level marginal cost in the context of our analysis is the cost to the coffee manufacturer of producing the equivalent serving size in ounces of coffee grounds that makes one fluid ounce of brewed coffee. Single-cup coffee products are individually portion-packed ground coffee pods packed in either bags or cans; whereas traditional auto-drip brew coffee products are simply ground coffee packed in bulk either in bags or cans. This difference in how ground coffee is packaged across these two coffee product types may in part explain the difference in marginal costs across the product types.

6. Counterfactual Analysis

Using the estimated product-level marginal costs, estimated structural parameters, and first-order condition equations resulting from Nash price-setting behavior of firms, we simulate the resulting market equilibrium from imposing the counterfactual assumption that consumers are indifferent between coffee consumption that uses single-cup brewing technology and coffee consumption that uses traditional auto-drip brewing method. Imposing the counterfactual assumption that consumers are indifferent between the two types of brewing methods is achieved by setting to zero coefficient estimates associated dummy variable, *Single-cup Brew*, in the utility function, i.e., based on demand parameter estimates reported in Table 3, we would set 4.0616, -0.044 and 1.9357 to 0. The counterfactual experiment is performed to investigate how equilibrium market outcomes of interests (prices, consumer demand, firm profits and consumer welfare) are predicted to change if consumers equally value the single-cup brewing technology coffee consumption experience and the traditional auto-drip brewing method consumption experience.

The new equilibrium price vector, $\boldsymbol{p}^{*}$, is obtained by numerically searching for the vector of prices that satisfy the following equation:

$$\boldsymbol{p}^{*} = \widehat{\boldsymbol{mc}} - [\boldsymbol{\Omega} * \boldsymbol{\Delta}(\boldsymbol{p}^{*})]^{-\mathbf{1}} \boldsymbol{s}(\boldsymbol{p}^{*}) \qquad (10)$$

where $\widehat{\boldsymbol{mc}}$ is the vector of recovered product-level marginal cost estimates based on all demand parameter estimates in Table 3. However, the demand parameter estimates used for constructing matrix $\boldsymbol{\Delta}(\boldsymbol{p}^*)$ and vector $\boldsymbol{s}(\boldsymbol{p}^*)$ are the estimates in Table 3, with the exception that all coefficient estimates associated with the dummy variable, *Single-cup Brew*, in the utility function are set equal to zero. A comparison of the actual observed price vector $\boldsymbol{p}$ from the data with the model predicted new equilibrium price vector $\boldsymbol{p}^*$ reveals how equilibrium price would be affected if consumers' preference for the single-cup brewing technology coffee consumption experience were to be removed.

We next discuss how the new equilibrium price vector $\boldsymbol{p}^*$ is used to recover other equilibrium market outcomes of interest. The discussion begins with predicted changes in coffee demand and firm variable profits, and then turn to the analysis of predicted changes in equilibrium product prices and markups. We leave for last, discussing predicted changes in consumer welfare.

6.1 Predicted Changes in Coffee Demand, Markup and Variable Profits

We use the following equations to compute counterfactual coffee demand and manufacturers' variable profits respectively:

$$\boldsymbol{q}^* = M \times \boldsymbol{s}\left(\boldsymbol{p}^*; \hat{\beta}, \hat{\phi} = 0, \hat{\alpha}, \hat{\Gamma}, \hat{\Sigma}\right) \tag{11}$$

$$\widehat{VP}_f^* = \sum_{j \in F_f} \left(p_j^* - \widehat{mc}_j\right) \times q_j^* \tag{12}$$

where $\boldsymbol{q}^*$ is a vector of counterfactual product demand levels measured in equivalent fluid ounces; and $\boldsymbol{p}^*$ is the previously obtained vector of counterfactual equilibrium prices predicted by the model. A comparison of the actual demand $\boldsymbol{q}$ with the counterfactual demand $\boldsymbol{q}^*$ reveals how much consumer coffee demand would be affected assuming coffee drinkers are indifferent between the two brewing methods. $\widehat{VP}_f^*$ represents manufacturer f's counterfactual variable profit. For each individual product, variable profit is computed by multiplying the counterfactual product markup $(p_j^* - \widehat{mc})$ and counterfactual product demand q_j^*. $\widehat{VP}_f^*$ is the sum of variable profits across the menu of products of firm f in a given market. We compare factual and counterfactual variable profits to evaluate changes in profitability at the product level as well as at the manufacturers' level. The above variable profit function implies that firm f's variable profit depends both on its product markups and demand levels. Therefore, we are able to decompose changes in variable profits by changes in markups and demand levels, and examine how these components drive the changes in variable profits.

In Table 7, we summarize changes in monthly market demand, markup and variable profit for traditional auto-drip brew coffee products as well as single-cup brew coffee products. Among traditional auto-drip brew coffee products in a market, we find predicted increases in consumer demand, with a mean predicted increase of 3.88%. In contrast, consumer demand for single-cup coffee products in a market is predicted to decline by a mean 98.5%.[33] Consistent with intuition, almost all auto-drip coffee products in the data are predicted to have a positive change in demand, whereas each single-cup coffee product is predicted to have a negative change in demand.

In terms of predicted changes in product markups, we find that across markets, a subset of auto-drip brew coffee products would experience increases in markup, with increases as high as 52%, while the remainder of auto-drip products would experience decreases in markup, with decreases as low as 5%. The predicted mean change in markup for auto-drip products is positive and equal to 0.55%. Similarly, a subset of single-cup brew products are predicted to experience increases in markup, with increases as high as 51%, while the remainder of single-cup products are predicted to experience deceases in markup, with decreases as low as 67%. The predicted mean change in markup for single-cup products is negative, i.e., there is a mean decline (5.8%) in markups of single-cup products. On average, the predicted changes in markups are small in magnitude relative to the predicted changes in product demand levels. As such, the predicted change in variable profit for each coffee product is often predominantly driven by the change in the product's demand rather than the change in its markup.

Auto-drip brew coffee products in a market show a mean predicted increase in variable profit of 4.6%, with increases as high as 117%. However, single-cup brew coffee products are predicted to experience reductions in variable profits, with a mean reduction of 98.6%. The predicted changes in auto-drip brew coffee products' demand levels and variable profits suggest significant cannibalizing effects associated with the introduction and growing presence of single-

[33] We summarize the quantity change for all auto-drip brew ground coffee products and all single-cup brew coffee products in the whole data sample before and after the simulation. We find 99.2% auto-drip brew ground coffee products have an increase in demand with the min of 0.00009% and the max of 73%, only 0.8% has demand reduced in the counterfactual. All single-cup brew coffee products experience reduction in demand in the simulation. At the market level, the model predicts a mean increase in auto-drip brew coffee demand in 599 out of total 600 markets. We believe the model predicts quite well the change in product demand for both coffee types, even though a few auto-drip brew coffee products have negative counterfactual demand changes.

cup brew technology coffee products. Put differently, suppose consumers no longer have a preference for the single-cup brew coffee consumption experience, a typical auto-drip brew coffee product could have had much greater demand and profitability in such a counterfactual world. The counterfactual removal of consumers' preference for the single-cup brew technology also implies a substantial decline in profitability of a typical single-cup brew coffee product.

6.2 Predicted Changes in Prices and Markups

Results in Table 7 reveal that counterfactual removal of consumer preference for the single-cup brewing technology may have a positive or negative impact on the markup of any coffee product. Predicted changes in product markups underlie counterfactual impacts on equilibrium price levels based on the assumption that product-level marginal costs are unchanged. In what follows, we discuss how the introduction and growing presence of the single-cup brew coffee products affect market equilibrium price levels.

Before we examine the counterfactual change in equilibrium prices, it is useful to discuss the potential forces at play in the market equilibrium analysis. Put differently, should we expect equilibrium prices of auto-drip brew coffee products to rise, decline or remain unchanged, and what should we expect about equilibrium price changes for single-cup brew coffee products?

Table 7: Summary Statistics on Counterfactual Changes in Demand, Markup and Variable Profit for Coffee Products in a Market

		Auto-drip Brew Coffee Products				Single-cup Brew Coffee Products			
		Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Demand	Market Mean Initial Levels (fl oz)	15410	5865.99	6936.63	36622.69	2219.29	1182.89	444.4	6536.91
	Market Mean Counterfactual Levels (fl oz)	15977	6143.04	7116.89	39255.29	31.48	26.7813	0.0001	167.33
	Change (fl oz)	567.33	496.62	-659.23	3096.93	-2187.81	1168.83	-6419.36	-438.17
	% Change (%)	3.88	2.84	-3.33	31.22	-98.54	0.92	-99.99	-96.36
Markup	Market Mean Initial Levels (¢/fl oz)	0. 73	0.07	0.61	1.70	0.76	0.15	0.61	2.82
	Market Mean Counterfactual Levels (¢/fl oz)	0. 74	0.07	0. 61	1.46	0.71	0.07	0. 59	1.51
	Change (¢/fl oz)	0. 0039	0.04	-0.57	0.59	-0.05	0.13	-2.11	0.63
	% Change (%)	0.55	2.36	-5.15	52.31	-5.81	8.58	-66.96	51.09
Variable Profit (monthly)	Market Mean Initial Levels ($)	122.42	54.90	50.74	422.2	17.51	12.21	2.96	163.38
	Market Mean Counterfactual Levels ($)	127.86	57.82	51.94	431.32	0.22	0.18	1.02e-06	1.13
	Change ($)	5.44	9.50	-110.55	129.65	-17.29	12.16	-163.38	-2.92
	% Change (%)	4.59	6.07	-7.98	117.69	-98.57	0.93	-99.99	-95.68

The counterfactual exercise causes shifts in product demands. In particular, by imposing the preference change that the preferred single-cup brew consumption experience becomes equally satisfying to the auto-drip brew consumption experience, the model predicts a reduction in demand for single-cup brew coffee products, but a rise in demand for auto-drip brew coffee products. The increase in demand for auto-drip brew coffee products will put an upward pressure on prices of these products owing to a direct demand effect. Higher prices for auto-drip brew coffee products will in turn put upward pressure on prices of single-cup brew coffee products owing to strategic Nash equilibrium price-setting behavior of firms. In other words, the increase in demand for auto-drip coffee products puts upward pressure on prices of both types of coffee products. In contrast, the decrease in demand for single-cup brew coffee products will put a downward pressure on prices of these products owing to a direct demand effect. Lower prices for single-cup brew coffee products will in turn put downward pressure on prices of auto-drip brew coffee products owing to strategic Nash equilibrium price-setting behavior of firms. In other words, the decrease in demand for single-cup brew coffee products puts downward pressure on prices of both types of coffee products. In summary, everything else being unchanged, the simultaneous increase in demand for auto-drip brew coffee products but decrease in demand for single-cup brew coffee products can result in equilibrium prices of both product types to either rise or fall.

In Table 8, we show summary results of the counterfactual changes in prices of auto-drip brew coffee products and single-cup brew coffee products. The mean counterfactual change in prices of auto-drip brew coffee products is positive and the mean counterfactual change in prices of single-cup brew coffee products is negative, even though some products of either coffee type have both positive and negative counterfactual price changes. In particular, under the counterfactual scenario in which the preferred single-cup brew consumption experience becomes equally satisfying to the auto-drip brew consumption experience, our model predicts that, on average, prices of auto-drip brew coffee products will rise by 0.4%, even though prices of a subset of these products will fall, with declines as large as 17.6%, and prices of the remainder of these products will rise, with increases as large as 116%. Similarly, the counterfactual change in consumers' preference for coffee brewing technology also predicts that, on average, prices of single-cup brew coffee products will fall by 0.02%, even though prices of some of these products will rise, with increases as large as 68%, and prices of some of these products will fall, with declines as large as 11%. In summary, since counterfactual removal of consumers' preference for the single-cup brew consumption experience is predicted to increase auto-drip brew coffee product prices on average, then we can reasonably infer that the introduction of the consumer-preferred single-cup brewing technology resulted in auto-drip brew coffee product prices being lower, on average, than would otherwise be the case.

Table 8: Summary Statistics on Counterfactual Change in Prices by Coffee Type

	Auto-drip Brew Coffee Products				Single-cup Brew Coffee Products			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Market Mean Initial Levels (¢/fl oz)	1.593	0.109	1.310	1.947	6.410	0.317	5.352	7.620
Market Mean Counterfactual Levels (¢/fl oz)	1.598	0.133	1.285	3.426	6.410	0.487	5.351	11.032
Change (¢/fl oz)	0.005	0.071	-0.217	1.698	-0.0006	0.384	-0.636	4.834
% Change (%)	0.368	4.875	-17.6	116.31	-0.019	5.658	-10.6	67.7

6.3 Welfare Analysis

The estimated random coefficients logit demand model permits us to analyze the change in welfare associated with imposing the counterfactual assumption that consumers are indifferent between coffee consumption that uses single-cup brewing technology and coffee consumption that uses traditional auto-drip brewing method. Following Nevo (2001), McFadden (1984), Small and Rosen (1981), Petrin (2002), Train (2009), and many others, the consumer surplus for consumer i is given by:

$$CS_i = \frac{\ln\left(\sum_{j=0}^{J} e^{V_{ij}}\right)}{\alpha_i} \qquad (13)$$

where α_i is the random coefficient for price and $V_{ij} = \delta_j + \mu_{ij}$. The change in consumer surplus due to the counterfactual change in consumer preference for the coffee type is given by:

$$\Delta CS_i = \frac{\ln\left(\sum_{j=0}^{J} e^{V_{ij}^{*}}\right) - \ln\left(\sum_{j=0}^{J} e^{V_{ij}}\right)}{\alpha_i} \qquad (14)$$

where V_{ij}^{*} is evaluated at the new counterfactual equilibrium price vector p^{*} and when the coefficient estimates associated with the *Single-cup Brew* dummy variable are set to zero, while V_{ij} is evaluated at actual price vector, $\boldsymbol{p}$, and the coefficient estimates reported in Table 3.

Table 9 presents summary statistics of the average consumer surplus obtained from consuming one fluid ounce of brewed coffee by a typical coffee drinker in a sample of 200 individuals in each market from the Public Use Microdata Sample (PUMS) data. As the price of a product is measured by dollar(s) per fluid ounce, an individual's consumer surplus measure is interpreted as their net benefit in dollar amount from consuming one fluid ounce of brewed coffee. We convert the dollar(s) to cent(s) in the table. In Table 9, a typical consumer in a market is predicted to have a mean decrease in welfare of 2%. In other words, if consumers' preference for the single-cup brew technology is counterfactually removed, then a typical coffee drinker's net benefit from consuming one fluid ounce of brewed coffee is predicted to decrease by 2%. This result in turn suggests that the introduction of the consumer-preferred single-cup brewing technology resulted in an increase in consumer surplus.

Table 9: Summary Statistics on Counterfactual Change in an Individual Consumer Surplus in a Market

		Mean	Std. err.	Min	Max
Consumer Surplus for a typical individual ($\widehat{CS}_i$)	Initial Levels (¢/fl oz)	0.056	0.004	0.002	1.230
	Counterfactual Levels (¢/fl oz)	0.055	0.004	0.002	1.223
	Change (¢/fl oz)	-0.001	0.00005	-0.012	0.008
	% Change (%)	-2.013	0.093	-9.619	28.078

7. Conclusion

The introduction of the single-cup brewing technology in the late 2000s has not only changed the way many brew-at-home coffee drinkers brew and consume coffee in daily life, a change from brewing one "pot" at a time to making one cup at a time, but also altered the overall landscape of the US brew-at-home coffee market. This paper is motivated by the fact that sales of coffee products that require the single-cup brewing technology rose quickly, while sales of coffee products that use the traditional auto-drip brewing method were substantially cannibalized with the introduction and growing presence of the single-cup brewing technology. To the best of our knowledge, this paper constitutes the first formal study of the economic effects of the introduction and growing presence of the single-cup brewing technology on the US brew-at-home coffee market.

The empirical analysis is conducted using IRI retail-level scanner data on sales of coffee products during year 2012. We find consumers, on average, prefer consuming brewed coffee products using the single-cup brewing method instead of the traditional auto-drip brewing method. In particular, a typical coffee drinker is willing to pay up to ¢2.52 extra per equivalent fluid ounce to consume brewed coffee using the single-cup brewing technology instead of using the traditional auto-drip brewing method. This relative gap in consumers' willingness to pay for the two distinct coffee brewing method technologies increases with consumer income, that is, higher income consumers obtain an even greater satisfaction from coffee consumption with the single-cup brewing technology.

To investigate the market effects associated with the presence of single-cup brewing technology on the US brew-at-coffee market, we use the estimated model to perform a counterfactual experiment. The counterfactual experiment involves removing consumers' relative preference for using the single-cup brewing technology instead of the traditional auto-drip brewing method, and simulating new equilibrium market outcomes based on consumers' counterfactual preferences. The counterfactual preference change yields a mean increase in consumer demand for traditional auto-drip brew coffee products of 3.88%, and a substantial mean decrease in demand for single-cup brew coffee products of 98.5%. Second, auto-drip brew coffee products are predicted to have a mean increase in variable profit of 4.6%, with increases as high as 117%, suggesting, at least in some markets, there exist substantial cannibalizing effects associated with the introduction and growing presence of single-cup brewing technology coffee products on traditional auto-drip brew coffee products. Third, the counterfactual experiment also predicts a mean increase in prices of auto-drip brew coffee products and a mean decrease in prices of single-cup brew coffee products, suggesting that the introduction of the consumer-preferred single-cup brewing technology resulted in auto-drip coffee product prices being lower, on average, than would otherwise be the case.

Last, the consumer welfare analysis suggests that consumers enjoy net benefits from the presence of single-cup coffee brew technology. The introduction and growing presence of single-cup brewing technology is predicted to increase a typical coffee drinker's welfare by 2%.

It is worth pointing out some limitations of our analysis. We simplify modeling the supply side of the market by assuming retailers play a passive role in the price-setting game. Other vertical relationships between coffee manufacturers and retailers can be examined as a potential extension of this current work [see Villas-Boas (2007b) and Hellerstein and Villas-Boas (2010)]. It may be interesting to investigate whether or not various vertical contracts between manufacturers and retailers influence predicted changes in market outcomes given the counterfactual change in consumer preference we consider.

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