The Added Caffeine, Health Concerns and Potential Regulations: The Case of Energy Drinks

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The Added Caffeine, Health Concerns and Potential Regulations: The Case of Energy Drinks

[Xuan Chen, Yizao Liu, Edward Jaenicke and Adam N. Rabinowitz]

Abstract

The introduction of energy drinks and related products, coupled with somewhat inconsistent labeling practices, has generated health concerns from possible excessive caffeine consumption. In this paper, we model demand for energy-drink brands as a function of price and product characteristics that include both caffeine levels and the presence of labeled caffeine content. Using our demand estimation results, we then construct simulations to analyze the potential policies that would mandate labels, restrict advertising, and cap caffeine. Results indicate that mandatory labeling and advertising restrictions would reduce overall sales in the energy drinks sector, while a caffeine cap’s impact on sales would vary depending on precisely how the policy would be implemented. Caffeine consumption from energy drinks would decrease, but sugar intake would increase under a caffeine cap because a demand increase of energy drinks without sugar concentration change. Therefore, policy makers should be cautious to caffeine cap regulations if considering the sugar consumption as well.

Key Words: Caffeine Consumption, Label, Regulation, Energy Drinks
1. Introduction

As a component of the human diet for many centuries, caffeine is generally considered safe if consumed moderately. Moderate caffeine consumption can improve mental alertness, concentration, fatigue, and athletic performance (Mitchell et al, 2014), but excessive caffeine intakes could cause anxiety, headaches, nausea, restlessness, and an increase in the risk of hypertension and cardiovascular disease (Nurminen et al., 1999; Nawrot et al., 2003; Heckman, 2010; Mesas et al., 2011). According to the U.S. Food and Drug Administration (FDA) and U.S. Department of Agriculture (USDA), the recommended caffeine intake level is no more than 400 mg a day for healthy adults.

The traditional dietary sources of caffeine, such as coffee and soda, are either naturally caffeinated or commercially added at moderate levels, but the market changed when a new type of beverage, energy drinks, entered. Energy drinks generated a new dietary source of caffeine but increased the added caffeine to a high level. For instance, a typical 16 oz. can of energy drink product contains 140-200mg caffeine, which is comparable to the amount of caffeine in 3-4 cans of soda. Energy drinks have become popular with teenagers and young adults, which is a different target customer from the naturally caffeinated beverages. Males between the age of 18 and 34 years old consume the most energy drinks, and nearly one-third of teens between 12 and 17 years drink them regularly. The volume of energy drinks consumed skyrocketed with an average annual growth rate of 13.3% between 2008 and 2015.

The rapid growth, however, has generated serious health concerns. The high levels of caffeine in energy drinks can make excessive caffeine intake easier. Moreover, if consumed with alcohol and tobacco, which is unfortunately a popular teenage behavior, energy drinks can pose a greater risk for depression, alcohol-related injury, and cardiac and psychiatric conditions. According to
The National Center for Complementary and Integrative Health (NCCIH), the overall number of energy-drink-related visits to emergency departments doubled between 2007 and 2011. The FDA Adverse Event Reporting System (FAERS) also shows there were more than 300 reports that claim “adverse events” possibly tied to energy drinks or energy shots between 2004 and 2012, including more than 20 extreme cases of death. To date, the FDA has not implemented any specific regulations or labeling requirements of caffeine for energy drinks. However, a number of consumer groups are proposing for regulating energy drinks, especially in terms of explicitly labeling the caffeine amount, a caffeine cap and an advertising restriction.

Given the special health concerns for energy drinks about excessive caffeine intake and the regulation proposals, this paper investigates the impacts of potential energy-drink regulations or restrictions. We measure the consumer demand responses to a variety of potential policies, with a special focus on showing how consumption responds to labeling caffeine amounts. Specifically, we first model demand for energy-drink brands as a function of price and product characteristics that include both caffeine levels and the presence of labeled caffeine content following the approach of Berry, Levinsohn, and Pakes (1995). The presence of labeled caffeine content could have both direct and indirect effect on the demand because of the signal of the label and the possible reduction of search costs of caffeine information. With the demand estimates, we then construct simulations to analyze the potential policies that would mandate labels, restrict advertising, and cap caffeine. Results indicate that mandatory labeling and advertising restrictions would reduce overall sales in the energy drinks sector, while a caffeine cap’s impact on sales would vary depending on precisely how the policy would be implemented. If the regulation set a cap on the total amount of caffeine per can and firms react to stop offering large sizes, the overall share of the energy drinks would decline. In contrast, if firms decided to reformulate or if, instead, the
regulation directly limits the concentration of caffeine, then the overall market share of energy drinks will increase because consumers may think the products are safer to consume. Caffeine consumption from energy drinks would decrease, but sugar intake would increase under a caffeine cap because demand for energy drinks would increase and there is no change in sugar concentration. Therefore, policymakers should be cautious to caffeine cap regulations if considering the sugar consumption as well.

Agricultural economists have contributed to addressing issues related to public health by estimating consumer preferences and providing insights of the efficiency of alternative food policies (Lusk and McCluskey, 2018). Examples include studies about sugar and fat taxes (e.g. Zhen et al, 2013; Zhen et al, 2011; Kuchler et al, 2005), calorie and nutrition labeling (e.g. Zhu et al, 2015; Liu et al, 2014, Kiesel et al, 2011), food subsidies (e.g. Gundersen et al, 2017; Meyerhoefer et al, 2011), restrictions on advertising and health claims (e.g. Liu et al, 2014; Streletskaia et al, 2013; Lusk et al, 2006), and information based health and diet education (e.g. Dillaway et al, 2011; Piggott and Marsh, 2004; Lusk et al, 2004). However, caffeine consumption and related policies are insufficiently studied from the food economics view. Dharmasena et al. (2011) is one of the few studies focusing on caffeine consumption, especially on the factors influencing caffeine consumption. They found that race, age, the presence of children, and gender of household head were primary determinants of daily caffeine intake per person. In addition, they found that 2000 USDA Dietary Guidelines have been successful in reducing caloric and caffeine intake derived from nonalcoholic beverage consumption at home. However, their data does not contain this new dietary source of added caffeine, the energy drinks. Among those limited research that includes energy drinks, Zhen et al (2011, 2013) clearly list energy drinks as an independent category of non-alcoholic beverages and estimate the demand and elasticity of them. However,
they focus on the fact of high sugar of the energy drinks and did not pay attention to the health concerns generated by the high level of caffeine in them.

This paper contributes to the literature by quantifying the impacts of potential regulations regarding caffeine consumption from food economics view. Besides energy drinks, caffeine is being added to a growing number of products and the caffeine level is deliberately enhanced to obtain the stimulant effect. This trend draws the reconsideration of the safety of caffeine consumption because consumers now have a higher probability to exceed the safety level of caffeine by consuming several caffeine-added products together, sometimes even without the awareness. By simulating the possible interventions of government, this paper provides the consumers as well as policymakers the insights of regulating the caffeine-added products. To the best of the authors’ knowledge, this paper is the first one that quantifies the impacts. Therefore, consumers would have healthier choices facing the growing number of artificially caffeinated foods and beverages.

2. Background on Caffeine and Energy-Drink Policies

Caffeine has been added to a variety of products, including certain foods, beverages, dietary supplements, and medications, and it is subject to different regulations when it is added to different products (Rosenfeld et al, 2014). As an ingredient in food, FDA focused on its use in cola-type beverages, where caffeine is listed as a substance that is generally recognized as safe by experts at levels not exceed 200 parts per million. This is equivalent to 71mg of caffeine in a 12-oz serving of cola (Rosenfeld et al, 2014). However, there is no specific regulation on caffeine in other types of food. In terms of the labeling caffeine, FDA does not require the amount of either natural or added caffeine to be labeled on the food products because caffeine is not a nutrient content (Rosenfeld et al, 2014). If caffeine is an ingredient in dietary supplements, the amount of caffeine
must be listed. But if caffeine is part of a proprietary blend, only the total amount of the blend is required to be listed (Rosenfeld et al, 2014).

The manufacturers can decide whether their products belong to conventional foods or dietary supplements. Therefore, they would be subject to different regulations of caffeine even though they produce the same kind of products. Most energy drinks were positioned by their manufacturers as dietary supplements but many of them have shifted to position their energy drinks as conventional foods. The caffeine in energy drinks is part of a proprietary blend, so manufacturers of energy drinks did not list the caffeine amount but just listed the total amount of the blend even though they were dietary supplements. However, more and more manufacturers have started to voluntarily label the caffeine amount on their products’ package. For example, Red Bull shifted to marketing their products in the category of convention food with caffeine amount labels on the back of their products around 2009. In 2013, the Monster energy drinks, another major firm in this industry, changed their products to the category of beverages and started to label caffeine amount on their products. The 5-Hour energy, the main brand for energy shot, did not label the caffeine amount until 2015. Until now, there are still several energy drinks do not clearly label the caffeine amount. Figure 1 shows the number of brands labeling caffeine amount in our sample. Therefore, the U.S. FDA has not implemented any specific regulations for energy drinks but regulate the caffeine in energy drinks as discussed above.

However, the health concerns of energy drinks drive the proposing for regulating the energy drinks. There are three main aspects: proper labeling of caffeine amount, limiting the caffeine content, and advertising restriction. As mentioned earlier, some energy drinks have not labeled their product with the amount of caffeine so consumers may be completely unaware of the amount of caffeine they are ingesting (Reissig et al, 2009). Moreover, energy drinks contain much more
caffeine than soda and energy drinks are aggressively marketed with advertising and sponsorship targeting primarily towards teenagers and young adults. Therefore, labeling the caffeine amount and restrictions of caffeine content and advertising become the main focus of the regulatory proposals. In fact, some of them have been implemented in other countries. In 2011, Health Canada announced its decision to begin regulating most energy drinks, including: (a) composition requirements such as the maximum limit of caffeine of 180 mg per single-serving container, (b) labelling requirements such as labeling the amount of caffeine and the health warning of high source of caffeine, and (c) monitoring requirements with research on the long-term health effects of energy drinks. In the U.K. in March 2018, several chain supermarkets stopped selling energy drinks to customers under 16 years old because of the potential risk of the high caffeine level in energy drinks.

3. Empirical Framework

3.1 Model

To investigate the impacts of potential energy-drink regulations or restrictions, we estimate the demand of energy drinks following the approach of Berry, Levinsohn, and Pakes (1995; hereafter BLP).

Assume consumer $i$ choose an energy drink product $j$ among all available alternatives $\{1, \ldots, J\}$ or not purchase $\{J=0\}$ in market $m$ to maximize utility driven by product characteristics as well as the consumers’ specific tastes. The indirect utility is given by:

$$U_{ijm} = \alpha_i p_{jm} + X'_i \beta_i + \text{Caffeine}_j (\gamma_{1,i} + \gamma_{2,i} \text{Label}_{jm}) + \text{Label}_{jm} (\varphi_{1,i} + \varphi_{2,i} \text{Trend}) + \xi_{jm} + \varepsilon_{ijm} \quad (1)$$
where an energy drink product \( j \) is defined as a combination of its brand and container size. For example, an 8.4oz. Red Bull Regular and a 16oz. Red Bull Regular are treated as different products. The reason of differentiating between container sizes from the same energy brand is that larger sizes typically contain more caffeine than smaller ones and consumers may be sensitive to the difference in caffeine amount when making a purchase decision. In addition, the market is defined as city-month combination.

\( Caffeine_j \) is the caffeine amount of product \( j \) measured at the per ounce base, and \( Label_{jm} \) is a dummy variable indicating the caffeine labeling status of product \( j \) at market \( m \), where \( Label_{jm} = 1 \) means the energy drink product labels the caffeine amount on their package at market \( m \). As mentioned earlier, some energy drinks started to voluntarily label the caffeine amount so the labeling varies across both brands and time.

The label could influence consumers’ utility directly. This is because, in general, there is information asymmetry between firms and consumers about products (Kiesel et al, 2011). By voluntarily disclosing more information on the package of their products, firms could signal some good features of products and receive premium. In another word, label caffeine amount is voluntary so it may highlight the performance-enhancing functions of caffeine and thereby have a positive influence on consumer choices. Therefore, \( Label_{jm} \) enters the utility function directly. Moreover, to capture how the impact of caffeine labeling changes over time, we introduce the interaction term of label and time trend (\( Trend \)). Therefore, \( \varphi_{1,1} + \varphi_{2,1}Trend \) indicates the direct effect of labeling caffeine on consumers’ choices of energy drinks products, which reflects how consumers interpret the signal send by the labeling.
On the other hand, the label could influence consumers’ utility indirectly. This is because in the energy drinks market, consumers still have difficulty to fully observe caffeine content information of all energy drink brands. Labeling caffeine content on the package could help consumers get access to the caffeine information easily and therefore reduce consumers’ search costs. According to Zhu et al (2015), reducing the information search cost with a simplified labeling system, on average, increases the probability of consumers choosing healthier foods, and decreases the probability that they will choose a less healthy option. To capture the effect of reducing search cost with labeling, an interaction term of label with caffeine, $Caffeine_j * Label_{jm}$, is incorporated. Therefore, $\gamma_{2,t}$ represent how the caffeine amount label affects the impact of caffeine on consumers’ choice. In another word, whether getting easier access to the information of caffeine level would influence their preference for caffeine in energy drinks.

Variable $p_{jm}$ is the price of product $j$ in market $m$. $X_{jm}$ is a vector containing other product characteristics including sugar, sodium, container size, whether if the product belongs to the energy shot, and advertising. Nutritional information such as sugar and sodium is measured at per-ounce base so it is the same for each brand regardless of packaging size. As for the container size, we notice that there is a variety of sizes offered across brands. For example, Red Bull Regular has four major container sizes: 8.4-ounce, 12-ounce, 16-ounce, and 20-ounce, which all possess non-trivial market shares. The most popular sizes for Monster Regular, however, are 12-ounce, 16-ounce, and 24-ounce Therefore, creating dummy variables for each container sizes will drastically increase the dimensionality of the model. In addition, even though container sizes are quite different across brands, most brands offer three major types: small, medium and large. Thus, we aggregate container sizes to these three types. Small indicates all containers with sizes less than 12 ounces, medium is sizes between 12 and 20 ounces and large is sizes greater than 20 ounces.
Energy drinks are known for their aggressive advertising strategies, especially among teenagers. In this analysis, we distinguish between TV advertising and sponsorship because some major energy drinks companies rely heavily on event and extreme sports sponsorship to express the “fast, cool, and energetic” lifestyle to targeted consumer groups. To capture the carryover effect of TV advertising and sponsorship on consumer demand. We model advertising as

\[
Ad_{jt} = \sum_{k=0}^{K} \lambda^k \Psi(A_{j,t-k})
\]

\[
Sponsor_{jt} = \sum_{k=0}^{K} \lambda^k \Psi(S_{j,t-k})
\]

where \(\Psi(.)\) is a non-linear goodwill production function and \(Ad_{jt}\) and \(Sponsor_{jt}\) are advertising and sponsorship expenditures for brand \(j\) at time \(t\). \(\xi_{jm}\) is unobserved product characteristics and \(\varepsilon_{ijm}\) is a stochastic term with zero mean and is distributed independently and identically as a Type I extreme value distribution.

Consumers may exhibit heterogeneous preferences for product characteristics, especially for the caffeine and labeling. To capture the heterogeneity, we use individual-specific coefficients in our model. Let \(\theta_i = (\alpha_i, \beta_i, \gamma_i, \varphi_i)\) denotes the vector of consumer-specific taste parameters for product characteristics, which is distributed as multivariate normal. Therefore,

\[
\theta_i = \theta + \Sigma v_i
\]

where \(\Sigma\) is a scaling matrix and the unobserved consumer characteristics, \(v_i\), follows a standard multivariate normal distribution. Then the indirect utility can be decomposed into three parts written as

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1 In this paper, we define \(\Psi(A_{jt}) = \log(A_{jt} + 1)\) and \(\lambda = 0.8\). Following Dubé et al. (2005), we use six lags.
\[ U_{ijm} = \delta_{jm} + \mu_{ijm} + \epsilon_{ijm} \]
\[ \delta_{jm} = \alpha p_{jm} + X_j' \beta + Caffeome_j (\gamma_1 + \gamma_2 * Label_{jm}) + Label_{jm} (\varphi_1 + \varphi_2 * Trend) \]
\[ \mu_{ijm} = (p_{jm}, X_j, Caffeine, Caffeine_j \times Label_{jm}, Label_{jm}, Label_{jm} \times Trend) \times \Sigma v_i \quad (5) \]

where \( \delta_{jm} \) is the mean utility term, \( \mu_{ijm} \) is the deviations from the mean utility generated by interaction between consumer and product characteristics, and \( \epsilon_{ijm} \) is the stochastic term with zero mean and is distributed independently and identically as a Type I extreme value distribution.

Therefore, the probability that consumer \( i \) choose product \( j \) in market \( m \) is
\[ s_{ijm} = \frac{\exp(\delta_{jm}+\mu_{ijm})}{1+\sum_{r=1}^{J} \exp(\delta_{rm}+\mu_{irm})} \quad (6) \]

Aggregated over consumers, the market share of product \( j \) in in market \( m \) is corresponding to the probability of product \( j \) chosen in market \( m \), which is
\[ s_{jm} = \int \frac{\exp(\delta_{jm}+\mu_{ijm})}{1+\sum_{r=1}^{J} \exp(\delta_{rm}+\mu_{irm})} dP_v(v) \quad (7) \]

Following BLP, we matched the predicted market share with observed shares and solve the model using the generalized moment method (GMM). The estimated coefficients can reveal the consumer’s preferences towards the energy drinks.

3.2 Identification Strategy, Endogeneity and Instruments

The key assumption to identify the parameters is the moment conditions in the generalized moment method, which requires a set of exogenous variables that are not correlated with the error term we used in GMM, the unobservable product characteristics (\( \xi \)). Price is potentially endogenous because producers may know the value of the unobservable product characteristics (\( \xi \)), but it is unknown to
researchers. Therefore, this is analogous to the classic simultaneity problem in analysis of demand and supply. To control for this endogeneity issue, we need to find instruments which are correlated with price but uncorrelated with unobservable product characteristics. Specifically, we use two sets of instruments that are often used by researchers: the cost shifters and the Hausman (1994) type instruments. The cost shifters are PPI for raw sugar and aluminum, which are major inputs of the production and packaging. Lastly, the Hausman type instruments are average price of the same brand in other markets, which are correlated with the price in one market because of common production costs but are uncorrelated with unobservable market-specific demand shocks.

In addition to the price, the labeling decision could also be endogenous because this is a voluntary behavior of firms, which is potentially correlated with unobserved factors influencing demand. Therefore, we incorporate two sets of instruments: the number of rival brands that label the caffeine content in a specific year and the interest of the public about caffeine content in one specific brand, which is captured by the consumer search data on Google trend. The assumption behind them is that firms made the labeling decisions based on competitors’ behaviors and public demand for caffeine information for their own brand. Rival firms’ labeling decisions may affect one brand’s labeling choices but are less likely to affect the demand of its product directly. In addition, the public’s interest on caffeine content in one product will certainly affect the labeling decisions but not the demand directly. Both of the instruments capture the time and brand differences. While the first instrument mainly captures the changes with respect to time and the difference between the labeling and non-labeling group, the second instrument captures the differences across brands. Take Red Bull and Monster as an example (shown in Figure 3). The number of rival brands that label caffeine exhibits a similar increasing trend for both brands. However, Monster faces slightly more competitors with labels from 2009 to 2012 because it was
in the non-labeling group. The public’s interest of caffeine amount contained in Monster was much lower than Red Bull before 2010 but had grown rapidly between 2011 and 2012.

4. Data

We use market-level Nielsen Retail Scanner data to collect sales and products information of energy drinks, including brand names, prices, sale volume, and package sizes. The Nielsen Retail Scanner data collects information from grocery stores, drug stores, mass merchandiser, and other stores with annual sales greater than two million dollars. Our data sample covers the sales information from January 1, 2006 to December 31, 2015 in seven designated market areas (DMAs).\(^2\) We restrict our analysis to the top 17 brands which belong to 7 firms and account for around 80% of total energy drinks sales nationally. Among all products, two brands (5-Hour Energy and 5-Hour Energy Extra) are energy shots. A detailed list of all brands is given by Table 1.

Table 1 also provides the descriptive statistics of the several product characteristics in \(X_{jm}\). We aggregate the sale-weighted average retail price to monthly-DMA level for each product. Among all products, 5-Hour Energy shot and Red Bull price relatively high on average. The potential market size for each period and DMA is defined as the population of the DMA times the combined per capita consumption (in volume) of energy drinks per month plus other beverages, including, coffee, tea, sport drinks and soda. The market share for each energy drinks product is then calculated as its sales volume divided by the potential market size. In general, market shares vary across brands, ranging from 0.0002 to 0.0204. The leading firms in the energy drinks market are Monster, Red Bull, Rockstar and Living Essentials (the firm producing 5-Hour Energy Shot).

\(^2\) The seven DMAs are Chicago, Dallas, Los Angeles, New York, Philadelphia, San Francisco, and Washington DC.
Monster Regular and Red Bull Regular are top selling brands, followed by their diet versions, Rockstar, and 5-Hour Energy shot.

Labeling and other nutrition information are collected from multiple sources including instore presentation, media coverage, government reports and firms’ own websites. In terms of caffeine, a number of consumer groups have published the caffeine content of many products and therefore, it is reasonable to assume that some consumers may have already obtained certain information of caffeine content even before the companies officially label it. Thus, caffeine content in energy drinks can be thought of being at least partially observed. The caffeine content of each energy drink exhibits a great variation across products. The energy shots are much more concentrated than all other energy drinks with caffeine content reaching as much as 115 mg per ounce. The average caffeine amount for all other energy drinks is generally around 10 mg per ounce, with the lowest one being 8.75 mg per ounce, which is still much higher than the average caffeine level in soda.³

Advertising and sponsorship expenditures are collected from Kantar Media Ad$pender database and we aggregate the expenditure to a monthly-brand level. In general, the total advertising expenditure increased dramatically during the past 10 years, as shown in Figure 2. There has been a slight decrease in TV advertising after 2012, while the total sponsorship expenditures have been stable after a huge jump after 2008. As a comparison, the total volume sold in energy drinks is also plotted in Figure 2, which expresses a similar trend.

5. Empirical Results

³ For example, Coca-Cola regular has 2.8 mg of caffeine per ounce.
We first tested the endogeneity of price and labelling, and then the validity of the instrumental variables with the first-stage Shea's partial $R^2$ statistics and a Hansen J-test. The results are reported in the second panel of Table 2. The p-value of the endogeneity test is 0.00, which allows us to reject the null hypothesis that price and label are exogenous. The p-value of the Hansen J-statistic is 0.276, which indicates that we cannot reject the null hypothesis of zero expected moments. Therefore, the instruments are uncorrelated with error term. However, as for the relevance of these instruments, the Shea's partial $R^2$ statistics is relative low for labelling, which is potentially caused by the data structure. The endogenous variable, label, is a dummy variable while the instruments are continuous variables. Therefore, it is not surprising that we get a relative low Shea's partial $R^2$ statistics. If we regress Label on instruments with a logit regression, the google trend and numbers of rival firms labeling significantly influence the labelling decisions of firms. Therefore, it is reasonable to believe that two variables as valid instruments. After the validity tests of the instrument, we estimate the full model.

The first panel of Table 2 shows the estimation results of demand for energy drinks specified in equation (1). The coefficient for price is negative (-22.230) and is significant at 0.1% confidence level. As for nutrition characteristics, the coefficients of mean preference for sugar is positive and significant with no much differences across consumers. This is similar to the findings in the literature on the demand of carbonated soft drinks (e.g. Liu et al, 2014): consumers have a positive valuation for calories and sugar on average. The mean preference for sodium is significantly positive with significant heterogeneity across consumers, which might be because many consumers use energy drinks in conjunction with exercise or sports activity to boost their energy level.
The coefficient of caffeine alone, however, is negative and significant, which indicates that among all high-caffeine energy drinks on the market, consumers prefer those with slightly less caffeine content. This suggests that although energy drinks are high in caffeine in general, caffeine content is not the most important factors when consumers are choosing among energy drinks products. To some extent, this is consistent with the descriptive statistics in Table 1. The two most popular energy drinks, Red Bull Regular and Monster Regular, are not those with the highest caffeine content, compared to other products on the market. However, consumers show strong heterogeneity in their preference for caffeine, which would lead some consumers to choose higher or lower caffeinated energy drinks.

To capture the effect of caffeine labeling on consumers’ preference for caffeine, the interaction term of labeling and caffeine is also included in the analysis. The coefficient of the interaction terms is estimated to be negative and significant, indicating that, on average, consumers prefer less caffeine when they are informed by a label on the package explaining the caffeine content in a product. In another word, the label can reduce the search cost for the caffeine information, which affects the marginal effect of caffeine on demand and thereby, reduces the consumers’ probability of choosing this product. Therefore, labeling caffeine content has a negative impact on the demand indirectly through the preference of caffeine.

On the other hand, caffeine labeling also enters consumers’ utility directly and it has a significantly positive direct impact on consumer’s demand in the base year of 2006. This could be explained by the voluntary behaviors of firms and the labeling signals the good function of boosting energy at the very beginning of our sample period. We further include an interaction term of label and trend to capture how consumer’ preference for caffeine labeling may have changed over time. The coefficient is negative and significant, suggesting that the mean preference of the
labeling is decreasing over time and caffeine labeling starts to have a negative impact on consumers’ choices after 2 years. Figure 4(a) shows how the impact of labeling evolves over time. Moreover, the deviation is significant, reflecting there is a strong heterogeneity in consumers’ attitudes to the labeling at that time.

The change of the attitude towards labeling might be explained by a number of reasons. When first introduced to the U.S. market, energy drinks were known for producing feelings of alertness, wakefulness, and productivity, which could provide fast recovery after exercise. With overall positive attitude towards the fast caffeine delivery by energy drinks, the caffeine label on several few brands signals the good quality of the products and therefore has a positive impact on consumer demand in earlier years. However, one of the significant changes happened in the market is the increasing attention from the public on the health risks of energy drinks. This is reflected by the rapidly growing media coverage, which has increased by five times from 2012 to 2015. These media coverage includes not only the reports about the adverse consequences potentially related to energy drinks consumption such as the hospital visits, but also the discussion about the safety of ingredients used in energy drinks, with a special focus on caffeine. Because only a few number of firms label caffeine content explicitly at the early stage, consumers would think firms choose to label caffeine content in later years because they are partially forced by the public’s urges to regulate energy drinks, which could be the prelude to a formal regulation. Therefore, consumers may interpret the caffeine label as a health warning, causing a negative impact of label on demand over time. Figure 4(a) and (b) plots the negative relationship between consumers’ preference for caffeine label and the number of media coverage across years. When media coverage on energy

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4 Canada has implemented the mandatory disclosure of caffeine amount in energy drinks and the caffeine amount cap after the proposition for regulation.
drinks’ risks is low, at the beginning our sample periods, the estimated preferences remain positive but start to decline as consumers are more aware of the health risks.

In terms of other product characteristics, compared with small size energy drinks, consumer prefer the medium size products. While the large size energy drinks are less preferable than the small size, the significant deviations implies that some consumers may like the bigger one instead. Energy shot exhibits a significant positive impact on consumers’ demand, so does the goodwill generated by the advertising and sponsorship. There is also a positive coefficient associated with the trend term, capturing other time-varying factors influencing the sales of energy drinks.

6. **Policy Interventions and Simulations**

Facing the potential problem of excessive intake of caffeine through the consumption of energy drinks and the uncertainty of the safety of added caffeine, policy interventions are proposed by the public health advocates. In 2016, the Food and Drug Administration (FDA) has announced that the agency will investigate the safety of caffeine in food products, particularly its effects on children and adolescents. The estimated parameters in our demand model allow us to simulate the effects of the possible interventions. Specifically, we performed three sets of policy simulations in the energy drinks industry. Using the demand estimates, we recalculate the new market shares for all products and evaluate how energy drinks demand will be influenced and how caffeine and sugar consumption will be affected under each of the three scenarios: (1) mandatory labeling of caffeine content; (2) caffeine cap; and (3) advertising restriction.

6.1 **Mandatory Labeling of Caffeine content**
One mostly discussed regulation is mandating caffeine content labels in energy drinks. Consumers and scientific groups have urged the FDA to make companies disclose and highlight caffeine levels, which will help eliminate the confusion consumers may encounter. Under this scenario, we assume all firms are required to label caffeine content on their products. Specifically, we simulate the impact on all brands after 2008.

Table 3 presents the simulation results, which are aggregated to the firm level. With the mandatory labeling, the overall energy drinks sector’s sales will be decreased by 22.08% and consumers’ will switch to other outside options such as soda, tea, or sports drinks. Among all products, 5-Hour Energy and Monster were hit the most, losing 83% and 51% of sales, respectively. For 5-Hour energy, this is mainly due to the high caffeine content in this energy shot. The 5-hour energy shot contains 100-115 mg of caffeine per ounce while other brands typically contain around 10 mg of caffeine per ounce. Further, 5-Hour energy and Monster are very late in labeling their caffeine content voluntarily, compared to their competitors. In fact, Monster starts to label caffeine content in 2013, after FDA investigated several deaths and incidents of adverse effects linked to Monster Energy Drinks.

6.2 Caffeine Cap

The second set of the policy scenario is caffeine cap. Our simulations resemble the regulation implemented in Canada in 2011, which requires that the caffeine content in energy drinks cannot exceed 180mg per container and the concentration of caffeine should not be more than 400 ppm (11.83mg per ounce.). The energy shot has not been regulated in Canada, but it is under discussion

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that the caffeine content should be limited to 200mg per can. Therefore, we simulate a caffeine cap in energy shot of 200mg per container or 100mg per ounce. Further, facing the total caffeine amount restriction in one container, firms could have two potential responses. First, firms can simply stop offering the large size if it exceeds the cap of 180 mg per can and withdraw the product from the market. Second, if the firm wants to keep the large size container, they can choose to reformulate their product and reduce the caffeine content, so that the largest package would follow the requirement and stay on the shelf. Therefore, in this section, we simulate three specific cases:

1. Firms react to the total amount regulation by withdrawing large-size products from the market.
2. Firm react to the total amount regulation by product reformulation to lower the caffeine content.
3. Firms react to the caffeine concentration regulation by product reformulation.

The results are described in the second panel of Table 3. If firms decide to stop offering the large-size products, consumers would then substitute to the same brand with a smaller size. However, the overall sales of the energy drinks sector will still decline by 12.52%. Among all products, Rockstar’s sales drop the most because most of its popular products are offered in large size (24 ounce). When cut the 24-ounce can from the market, Rockstar loses almost 50% of sales. 5-Hour energy will also experience a decrease in sales by around 20% because it will lose one of its two products with extra higher caffeine content, 5-Hour Energy Extra.

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If firms decide to reformulate their products to fulfil the total amount cap in order to keep the large-size drinks on the market, the overall market share will increase by 11.24% because most brands lower their concentration and consumers may think the products are safer to consume. It is worth to mention that, in this analysis, we do not consider the potential costs increase and thus the price changes due to the product reformulation process. Therefore, our results provide an upper bound of the market responses.

Lastly, if regulation directly limit the concentration, most brands have already met the requirement except for some brands produced by Rockstar and Monster. Therefore, after reformulation, as Rockstar and Monster becomes safer, they will enjoy a growth in sales while other brands would face a slightly decrease in sales. However, the overall consumption will increase a little bit, with a change of 0.46%. For all cases of caffeine cap, 5-Hour Energy have to cut its extra caffeine shot so it faces a drop around 20% under all scenarios.

6.3 Advertising Restriction

The third set of the policy intervention focuses on the firms’ two major marketing strategies, the advertising and sponsorship. Similar to carbonated soft drinks, energy drinks are also blamed for targeting young children and teenagers in advertising, which poses even greater risks. We simulate the cases that the advertising sponsorship expenditures are all restricted to 50% of the current level. The results are presented in the third panel of Table 3. If advertising expenditures are cut by 50%, all firms would experience a loss in terms of the market shares with bigger drops for 5-Hour Energy, Red Bull and PepsiCo. The overall consumption would decline by -21.99% which are replaced by the outside choices, including the soda, coffee, tea, and sport drinks. The effect is similar for decreasing the sponsorship expenditure except for that the Monster would also face a
dramatic decline in market share. The overall consumption drop are less than that in the advertising case.

6.4 Consumption of Caffeine and Sugar

We then translate the changes in market shares of energy drinks to the consumption of caffeine. In addition, we calculated the consumption changes in sugar because energy drinks are very high in sugar content (e.g. Zhen et al, 2011), which has also raised increasing concerns by nutritionist. The popularity of the high sugar energy drinks may also contribute to the growing obesity epidemic, like other carbonated soft drinks. Table 4 shows the consumption changes in caffeine and sugar.

Mandatory labeling will be the most effective in reducing caffeine consumption, followed by TV advertising restrictions. The most interesting point to mention is the impact of the caffeine cap regulations. As we mentioned in the discussion of market share changes, if firms choose to reformulate in response to the total caffeine amount cap or the direct concentration restriction, consumers would consume more energy drinks because the lower caffeine level is safer. Then the total effect on caffeine consumption is influenced by three factors: the increased consumption of energy drinks, the decreased concentration of caffeine, as well as the substitution between brands. According to our results, overall, the net caffeine intake drops -12.93% and -4.91% in react to caffeine amount cap and concentration restriction.

For consumption of sugar, mandatory labeling will still be the most effective policy, as it will reduce sugar consumption by over 27%. It is worth to mention that, when energy drinks reformulate their products in order to comply with the caffeine cap, the overall sales of energy drinks will actually grow. However, due to no changes in sugar content, these two policies would
increase the sugar intake corresponding to the demand changes of energy drinks. Therefore, policymakers should be prudent to the caffeine cap type of regulation and also take the sugar consumption into account.

7. Conclusion and Discussions

As a human diet for centuries, caffeine is generally considered safe with moderate consumption. However, the introduction of energy drinks and other caffeinated food and beverages give rise to new concerns about the caffeine consumption generated by the high level caffeine in some products and the increased probability of excessive intake. This paper evaluates the impacts of potential regulatory policies on energy drinks consumption. We analyze the demand for energy drinks with a special focus on the effect of labeling caffeine amounts on energy drinks’ consumption. Specifically, we estimate the direct and indirect effect of labeling caffeine amounts on energy drinks’ consumption through labeling itself and its possible reduction of search costs of caffeine information for consumers when they make the purchase choice. We further simulate the policy effects of imposing a list of possible regulations on energy drinks consumptions, including mandatory labeling of caffeine content, advertising restriction, and caffeine cap.

The results indicate that on average, consumers prefer energy drinks with slight less caffeine content but there is a significant taste heterogeneity among consumers. While labeling itself has a positive impact on demand in the early years, the effect became negative later on. As for the indirect effect, the labeling significantly reduces the consumers’ search cost for caffeine information, therefore, decreasing the consumption of caffeine. Simulation results show that the mandatory labeling and advertising restrictions would decrease the overall sales in the energy drinks sector. The influence of the caffeine cap varies depending on the implementation of the regulation as well as firms’ reactions. If the regulation set a cap on the total amount of caffeine per
can and firms react to stop offering large sizes, the overall share of the energy drinks would decline. However, if firms decided to reformulate or if, instead, directly limits the concentration of caffeine, then the overall market share of energy drinks will increase because consumers may think the products are safer to consume. As for the caffeine and sugar consumption, all regulation scenarios mentioned above would decrease caffeine consumption. However, because there is no sugar concentration change, caffeine cap regulation would lead to an increase in sugar intake corresponding to the demand increase of energy drinks. Therefore, policy makers should be cautious to caffeine cap regulations if considering the caffeine and sugar consumption simultaneously.

The policy implication of this paper extends beyond just energy drinks. In fact, there exhibits a trend recently in which caffeine is being added to a growing number of products, which draws the reconsideration of the safety of caffeine consumption. Specifically, the added caffeine barley appeared in soda in food category in the last century, but it has extended in a range of food products recently, including energy drinks, gum, peanut butter, jelly beans, marshmallows, sunflower seeds and other food and beverages for its stimulant effect. This increases the probability of exceeding the safety level of caffeine by consuming several caffeine added products together, sometimes even without the awareness. Therefore, it is important for policy makers to consider the possibility and potential methods to regulate these new caffeinated food and beverages. This paper simulates the several potential choices for government interventions and compare the effectiveness of different regulations, which sheds light on the further actions of policy makers if they decide to regulate the caffeinated food and beverages. In addition, this paper also draws the attention of policy makers to the implement of the potential regulations by considering sugar consumption

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7 [https://www.fda.gov/forconsumers/consumerupdates/ucm350570.htm](https://www.fda.gov/forconsumers/consumerupdates/ucm350570.htm)
together. In the energy drinks case, high sugar level also contributes to the obesity epidemic so when considering the food policy, the objective should be based on the overall healthfulness of a food product rather than one nutrition or ingredient.

This paper also has some limitations. Although this paper simulates the new market share of potential policies, we do not model the supply side, that is, we do not conduct an equilibrium analysis. Instead, we consider the influence of potential policies to consumers’ choice set by considering product offering choices of firms under these policies. In another word, the availability of some products would be influenced by the regulations but we do not consider the potential costs increase and the price changes associated with it. Therefore, the simulations are based on demand responses. Moreover, we assume consumers believe the truthfulness of the information revealed by the firms so we do not involve the credence problem of product label in this paper. However, as few papers pay attention to the new concern of caffeine consumption from food economics view, understanding the market and the demand responses would be the first step in the analysis of the caffeine consumption. Therefore, even without considering the supply side and alternative consumer behavior assumptions, this paper is important for policy makers because it sheds light on the possible initial attempts to address the new concerns for caffeine consumption. Moreover, it is also important in drawing attention of researchers in agricultural economics to focus on the new concern of the caffeine consumption as well as other health issues or economic questions associated with the introduction of energy drinks and other new caffeinated food and beverages.
References


Figure 1. Number of brands labeling the Caffeine Content in the Sample
Figure 2. Total Advertising and Sponsorship Expenditure
Figure 3. Examples of Instruments for Labeling: The Case of Red Bull and Monster
Figure 4. The Attitude to Labeling and Its Relationship to the Number of Media Coverage

Figure 4(a) Preference for Labeling

- Preference for Labeling
- Year

Figure 4(b) Media Coverage for Risk of Energy Drinks

- Number of News
- Year
<table>
<thead>
<tr>
<th>Brand</th>
<th>Sugar g/oz.</th>
<th>Sodium mg/oz.</th>
<th>Caffeine mg/oz.</th>
<th>Size oz.</th>
<th>Shot</th>
<th>Price $/oz.</th>
<th>Market Share %</th>
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<td><strong>Red Bull</strong></td>
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<td></td>
</tr>
<tr>
<td>Red Bull Regular</td>
<td>3.10</td>
<td>12.50</td>
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<td>8.4, 12, 16, 20</td>
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<td>8.4, 12, 16, 20</td>
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<td>12, 16, 24</td>
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<tr>
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<td>8.88</td>
<td>8.4, 16, 24</td>
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<td>Full Throttle Regular</td>
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<td>Nos Regular</td>
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<td>10.00</td>
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Table 2. Demand Estimation Results for Energy Drinks

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<td>Label</td>
<td>3.339***</td>
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<td>Caffeine × Label</td>
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<td>Sugar</td>
<td>0.246***</td>
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<td>Sodium</td>
<td>0.062***</td>
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<td>Energy shot</td>
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<td>Advertising</td>
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<td>Sponsorship</td>
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<td>Trend</td>
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<td>Constant</td>
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DMA fixed effects: yes
Season fixed effects: yes
Firm fixed effects: yes
Observations: 21149
GMM C statistic: 117.373
p-value: 0.00
Shea's partial R-squared: Price: 0.411, Label: 0.169
Hansen J statistic: 2.579
p-value: 0.276

* p<0.05; ** p<0.01; *** p<0.001
Table 3. Percentage Changes in Sales under All Simulated Scenarios

<table>
<thead>
<tr>
<th>Firm</th>
<th>Mandatory Labeling</th>
<th>Caffeine Cap: Total Amount</th>
<th>Firm Response: No Large Size</th>
<th>Firm Response: Reformulation</th>
<th>Caffeine Cap: Concentration</th>
<th>Restrict Advertising by 50%</th>
<th>Restrict Sponsorship by 50%</th>
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<td>(3)</td>
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<td>Total</td>
<td>-22.08</td>
<td>-12.52</td>
<td>11.24</td>
<td>0.46</td>
<td>-21.99</td>
<td>-8.19</td>
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</table>
Table 4. Percentage Change in Caffeine and Sugar Consumption under All Simulation Scenarios

| Firm          | Caffeine Cap Total Amount |  |  |  |  |  |  
|---------------|---------------------------|---|---|---|---|---|---|
|               | Mandatory Labeling        | Firm Response: No Large Size | Firm Response: Reformulation | Caffeine Cap Concentration | Restrict Advertising by 50% | Restrict Sponsorship by 50% |
| 5-Hour Energy | -84.01                    | -22.53                     | -22.50                     | -22.61                     | -53.96                     | -0.17                      |
| Coca-Cola     | 0.08                      | -4.88                      | -16.43                     | -0.12                      | -18.32                     | 0.52                       |
| Dr. Pepper    | 0.07                      | 1.16                       | -1.53                      | -0.15                      | -3.55                      | 0.30                       |
| Monster       | -53.06                    | -7.74                      | -13.88                     | -0.14                      | -6.24                      | -8.69                      |
| PepsiCo       | 0.10                      | -1.62                      | -10.20                     | -0.09                      | -22.00                     | -0.81                      |
| Red Bull      | -8.39                     | -1.55                      | -3.90                      | -0.15                      | -40.25                     | -12.04                     |
| Total         | -30.31                    | -17.40                     | -12.93                     | -4.91                      | -25.58                     | -6.97                      |

Sugar Consumption Change

| Firm          | Caffeine Consumption Change |  |  |  |  |  |  
|---------------|-----------------------------|---|---|---|---|---|---|
| 5-Hour Energy | NA                         | NA | NA | NA | NA | NA | NA |
| Coca-Cola     | 0.08                       | -4.67                     | 7.27 | -0.11                     | -18.19                     | 0.51                       |
| Dr. Pepper    | 0.07                       | 1.16                       | -1.53 | -0.15                      | -3.55                      | 0.30                       |
| Monster       | -55.96                     | -8.25                      | 13.73 | -0.10                      | -6.23                      | -8.61                      |
| PepsiCo       | 0.10                       | -1.62                      | 6.27 | -0.09                      | -22.00                     | -0.81                      |
| Red Bull      | -8.51                      | -1.80                      | 0.98 | -0.15                      | -40.30                     | -12.06                     |
| Rockstar      | 0.08                       | -15.67                     | 11.06 | 1.81                       | -10.45                     | -3.02                      |
| Total         | -27.11                     | -6.53                      | 8.43 | 0.13                       | -19.48                     | -8.13                      |

* All Products from 5-Hour Energy contain no sugar.