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Methodology Report for Applying Elasticity Estimates in CPSC Regulatory Analyses

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INDUSTRIAL ECONOMICS, INCORPORATED

Prepared for:

Consumer Product Safety Commission
Directorate for Economic Analysis
4330 East West Highway
Bethesda, MD 20814

Prepared by:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140

With support from:

Dr. Chen Zhen
Department of Agricultural & Applied Economics
University of Georgia

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Background

The Consumer Product Safety Commission (CPSC) is an independent Federal agency that protects the public against unreasonable risk of injury or death from consumer products. A legislative mandate gives CPSC regulatory authority and enforcement powers over a wide range of consumer products. For those regulations under the purview of section 7 and/or section 9 of the Consumer Product Safety Act (CPSA), CPSC is statutorily obligated to provide a "preliminary description of the potential benefits and potential costs of the proposed rule, including any benefits or costs that cannot be quantified in monetary terms, and an identification of those likely to receive the benefits and bear the costs." Further, the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), requires CPSC to consider the economic impact of its rules on small entities.

Pursuant to these requirements, CPSC develops cost-benefit analyses for all section 7 and 9 rules and RFA/SBREFA analyses for some of its rules. CPSC includes these economic analyses as part of the rule briefing package and makes them available on CPSC's website as well as through the Federal Register. Developing thoroughly researched, accurate, and logically sound economic analyses is an important part of informing decision-makers and the general public about the likely impacts of a proposed rule as well as the distributional implications.

Some CPSC rulemakings result in benefits and costs that relate to consumer surplus, producer surplus, or deadweight loss. Estimation of these benefits and costs requires characterization of the supply and demand curves for regulated products, including elasticity estimates. Elasticity refers generally to the responsiveness of one economic measure to another, and here specifically to changes in quantities demanded or supplied as a result of changes in the market price of a regulated product. In this report, we summarize efforts to inform CPSC's economic analyses by reviewing examples of elasticities applied in regulatory impact analyses and reviewing relevant elasticity estimates in the peer-reviewed literature.

The need for elasticity estimates

Many CPSC rulemakings establish voluntary or mandatory product safety standards aimed at reducing the risks of injury or death resulting from the product. Examples of rulemakings include limits on the strength of small magnet products posing ingestion-related risks; limits on the length and use of window covering cords posing risks of strangulation to children; and carbon monoxide emissions limits for portable generators.[1] In many cases, product safety standards increase the price of regulated goods as manufacturers are required to add safety features or otherwise amend product design to achieve compliance.

As the price of available products change, consumer purchasing behavior can change in response. Consumer surplus, defined as the difference between (a) what consumers are willing to pay for a good and (b) the actual market price of the good, is lessened as market prices increase. In addition, total consumption generally declines as prices increase, impacting producers as well. The extent of these impacts is determined, in part, by the responsiveness of consumption to changing prices, known as consumers' own-price elasticity of demand, and the responsiveness of production, known as the supply elasticity.

Elasticities can vary substantially across products. Price elasticity of demand is influenced by many factors, including availability and prices of substitutes (i.e., alternative products) and whether the good is a necessity or luxury. In addition, elasticities may be lower in the short-run relative to longer time horizons, reflecting consumer adaptation or

[1] For the Safety Standard for Magnets final rule, see https://www.regulations.gov/document/CPSC-2021-0037-0721.

For the Safety Standard for Operating Cords on Custom Window Coverings final rule, see https://www.regulations.gov/document/CPSC-2013-0028-3672.

For the Safety Standard for Portable Generators proposed rule, see https://www.regulations.gov/document/CPSC-2006-0057-0032.

introduction of additional alternatives. There is also variation in empirical estimates that arises from alternative modeling approaches and/or data sources.[2]

Given the many factors influencing price elasticities, and the impracticality of developing primary estimates for individual product rulemakings, this report aims to provide CPSC with: 1) an overview of key concepts, elasticity estimation, and product and market considerations that may influence analysts' selection of empirical estimates and application in welfare calculations; 2) a review of elasticity applications in regulatory analyses and summary of associated approaches to estimating benefits and costs; 3) a current survey of relevant elasticity estimates and their attributes based on literature searches and defined screening and study evaluation criteria..

Report organization

The remainder of this report is organized as follows:

- In Chapter 2, we provide a conceptual overview of basic welfare economic concepts related to elasticities, including consumer and producer surplus. We introduce stylized depictions of supply and demand for unregulated and regulated markets.
- In Chapter 3, we provide three general approaches to estimating changes in consumer surplus, producer surplus, and compliance costs. For each approach, we summarize our review of regulatory impact analyses conducted by various federal agencies, including details on their application of elasticity estimates and comparisons with recent CPSC practices.
- In Chapter 4, we detail our search for elasticity estimates in the peer-reviewed literature.
- In Chapter 5, we summarize the results from our literature review. Key studies relevant to CPSC are summarized in an accompanying Excel database.
- In Appendix A, we describe how analysts can derive elasticities for broad product classifications from finer-scale estimates (e.g., those available by brand or by model).
- In Appendix B, we provide a list of high-quality studies that estimate elasticities and that analysts can consult for citation reviews.

[2] Meta-analyses of own and cross-price elasticity estimates conducted by Bijmolt et al. (2005) and Auer and Papies (2020), respectively, demonstrate the influence of market and methodological characteristics. These studies are described in Chapter 4.

CHAPTER 2 | Conceptual Overview

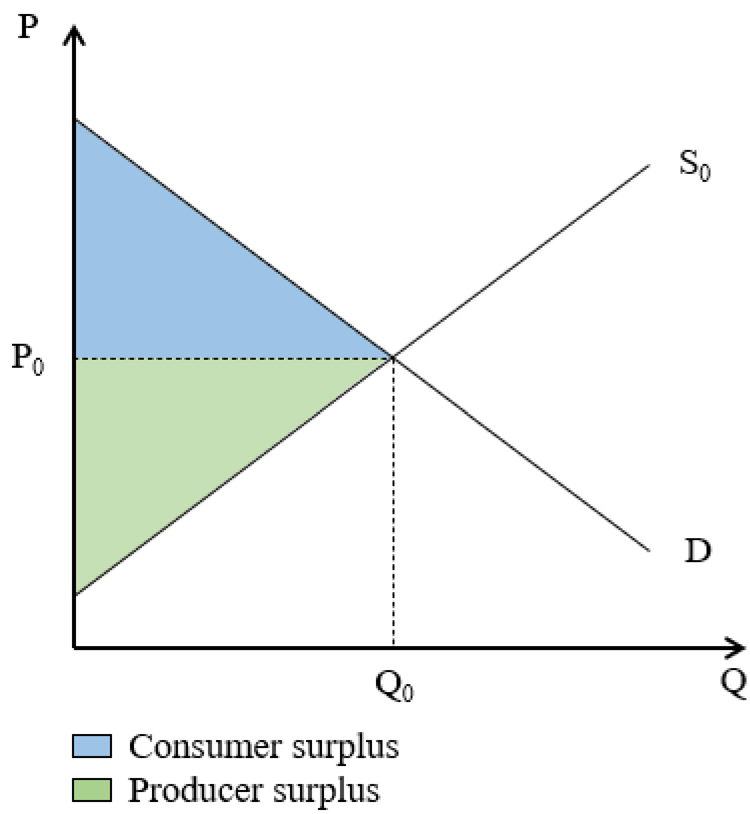
In this chapter, we provide a basic framework for assessing changes in consumer and/or producer surplus resulting from regulation. We introduce and define related terms and concepts and discuss when these frameworks may require alterations, as in the case of imperfect competition (e.g., monopolies). We present approaches consistent with partial equilibrium analysis, or assessment of individual markets (e.g., for a specific consumer product).[3]

Consumer and producer surplus in an unregulated market

Consumer and producer surplus are commonly evaluated in partial equilibrium analyses of the anticipated costs of rulemakings. Exhibit 2-1 provides a simple depiction of market equilibrium prior to a rule being implemented, with the horizontal axis representing the quantity of the good (Q), and the vertical axis representing its price (P). The market demand curve (D) indicates how much consumers will purchase at each price. This curve is constructed by aggregating consumers' willingness to pay for the product. For normal goods, individuals will consume more of a good at lower prices. The supply curve (S_0) indicates the quantity that will be supplied at each price. All else equal, supply will increase at higher prices. The equilibrium market price (P_0) is determined by the intersection of the supply and demand curves.

[3] In instances where a regulation may have impacts beyond the market for the regulated good, analysts should consider input-output modeling or computable general equilibrium modeling. These approaches consider impacts in related markets and on broader economic indicators such as personal consumption and gross domestic product.

Exhibit 2-1. Market equilibrium before rule



At the market equilibrium, consumers and producers experience welfare gains known as consumer surplus and producer surplus. Consumer surplus is depicted as the area in **blue** and producer surplus is shown in **green**.

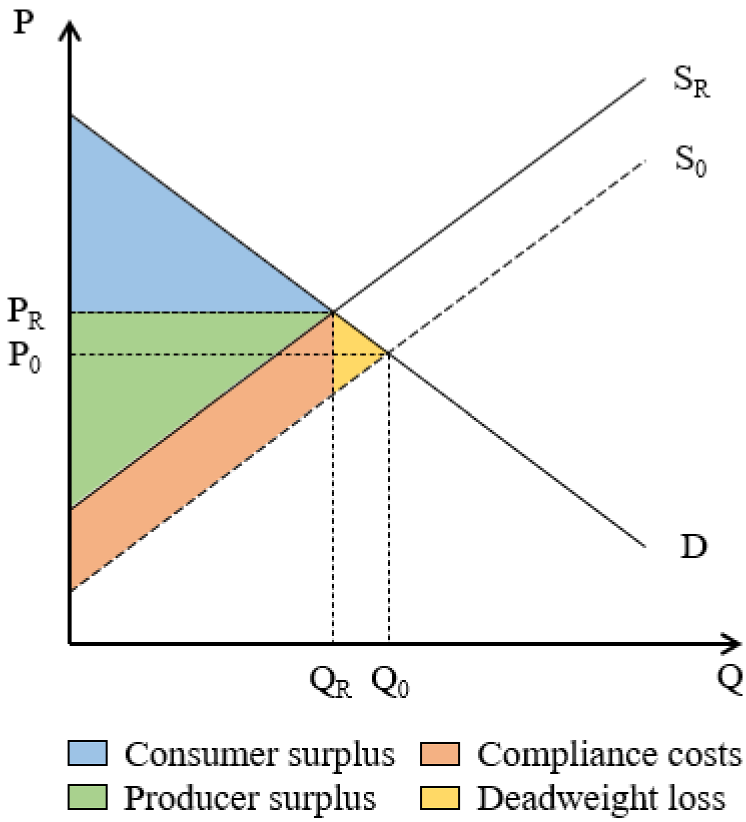
Consumer surplus is the benefit individuals experience from consuming a good. Consumer surplus is measured as the area between the demand curve and the market price of the good. In other words, it is the amount consumers would be willing to pay beyond the price they do pay.

Producer surplus is the benefit to producers from selling a good. Producer surplus is measured as the area between the supply curve and the market price of the good. This area represents the amount by which the price paid by consumers exceeds the marginal costs of production.

Consumer and producer surplus in a regulated market

Regulation can induce changes in the market equilibrium price and quantity, as depicted in Exhibit 2-2. In instances where a regulation imposes costs on producers—as may be the case when product safety standards are introduced—the supply curve shifts (from S_0 to S_R) to reflect the added marginal cost of supplying the newly regulated good. Due to the higher costs, consumers respond by purchasing less of the good. The result is a new market equilibrium with a higher price (P_R) and reduced quantity (Q_R).

Exhibit 2-2. Market equilibrium after rule



At the new market equilibrium (Q_R, P_R), consumer and producer surplus are lessened relative to an unregulated market. These changes are classified as costs in regulatory analyses. Regulatory costs are comprised of two elements: compliance costs and deadweight loss. Together, these factors sum to the loss in consumer and producer surplus relative to the unregulated market.

Compliance costs are represented in Exhibit 2-2 as the area in **orange**. These are calculated by multiplying the new market quantity (Q_R) by the unit cost of complying with the regulation. Finally, deadweight loss is depicted in **yellow** and reflects consumer and producer surplus that is no longer experienced due to the shift towards a lower market equilibrium quantity. While deadweight losses may be minor for small changes in price (and quantity), they comprise an important share of surplus losses for more significant shifts in market equilibria. Together, deadweight loss and compliance costs represent the full surplus losses from regulation.

Elasticities

We rarely observe many of the key components labeled in Exhibits 2-1 and 2-2. Even characterizing the market equilibrium requires detailed and accurate data on pricing and consumption. Market prices may be observed on retailer websites; however, they may fluctuate across time, location, and by brand and/or vendor. Sales data are often needed to accurately assess the price paid by consumers for goods. Other factors, such as the exact shapes and slopes of the demand and supply curves are generally less understood (and the subject of this report).

Elasticities refer to the sensitivity of one parameter to a change in another parameter. In the context of supply and demand, elasticities describe how quantity demanded and supplied are impacted by changes in price. These are represented visually as the slope of the two curves. In Exhibits 2-1 and 2-2 where price is measured on the vertical axis, steeper curves (i.e., higher slopes) correspond with lower (in absolute value) elasticities. Two additional commonly referenced (though of less direct relevance to CPSC regulatory analyses) elasticity measures are cross-price and income elasticity of demand.

Own-price elasticity of demand is the extent to which consumers' quantity consumed is influenced by the price of the consumed good. Often referred to as "demand elasticity" or "price elasticity," it is typically measured as the ratio of the percentage change in demand to the percentage change in price. An elasticity of one (1) is observed when the percentage change in consumers' demand is perfectly proportional to the percentage change in the price of a good. Goods with higher elasticities (>1 in absolute value) are sometimes labeled as "elastic" while lower elasticities (<1 in absolute value) may be deemed "inelastic." Essential goods such as food, water, and home heating fuel, which consumers are unwilling (or are unable) to eliminate from their budgets, are generally considered inelastic. Higher demand elasticities are associated with products for which consumers are highly sensitive to price, such as airplane tickets, electronics, jewelry, new cars, and other non-essential or luxury goods.

Cross-price elasticity of demand is the extent to which consumers' quantity consumed for one good is influenced by the price of another good. Positive cross-price elasticities are observed for substitutes, or goods that are demanded more when another good's price increases. For example, consumers may consume more Pepsi when the price of Coca Cola increases. Negative cross-price elasticities are observed for complements, or goods that are frequently consumed together. For example, the demand for gasoline powered vehicles may decrease when the price of gasoline increases.

Supply elasticity measures how responsive producers are to changes in market price. It is typically measured as the ratio of the percentage change in supply to the percentage change in price. As prices increase, economic theory suggests producers will typically ramp up production to sell at the higher price—or new producers will enter the market if the market price exceeds their marginal cost of production.

Income elasticity of demand is the extent to which consumers' consumption is impacted by changes in their real income. "Normal" goods are products for which demand increases as consumer income rises. For example, households with higher income may purchase more vehicles. "Inferior" goods are those for which demand decreases as consumer income rises. For example, cheaper foods such as canned vegetables or store-brand groceries may be consumed less at higher income levels.

There are a variety of approaches to estimating elasticities found in the peer-reviewed literature and elsewhere. Broadly speaking, empirical demand studies can be classified into two groups, reduced-form models and structural models, based on the degree to which the functional form of the regression model is derived from a consumer optimization problem. Reduced-form demand models are ad hoc specifications of consumer demand as a function of product prices, consumer demographics, income and other covariates that are hypothesized to shift demand. Most reduced-form demand models are single-equation linear, log-linear or log-log regressions. The coefficients of a reduced-form demand regression do not correspond to parameters of a consumer utility function, hence the name of this group of models. Any study of consumer demand in which the functional form of the regression is not explicitly derived from an assumed preference structure is considered a reduced-form approach (see e.g., Lichtman-Sadot, 2016; and Li, Finkelstein and Zhen, 2022).

In contrast, structural demand models are derived explicitly from an assumed consumer preference structure, whether it is the utility function or the expenditure function (Deaton and Muellbauer 1980a). By design, the estimated coefficients correspond to parameters of the function and these "structural" coefficients in turn facilitate post-estimation welfare analysis, such as calculating the compensating variation (one of several measures of consumer surplus) associated with a regulation-induced price increase. There are several classes of structural demand models that are popular in the empirical literature. First, flexible demand systems such as the Almost Ideal Demand (Deaton and Muellbauer 1980b) and its variants and the Exact Affine Stone Index Demand (Lewbel and Pendakur 2009) are widely applied to estimate price elasticities for nondurable goods and services. The most important advantage of flexible demand systems is its ability to approximate any consumer preference to the second degree. This means little a priori restriction is placed on the own- and cross-price elasticities. That is, the magnitude and the sign of each price elasticity is left for the data to decide. The cost of this flexibility is the large number of coefficients that have to be estimated, which require the data to be of high quality. Most importantly, there should be enough variation in relative prices to identify the cross-price elasticities. The second class of structural models are discrete-choice models (Berry, Levinsohn and Pakes 1995; Train 2003) that place the restriction that all modeled products be pure substitutes (i.e., positive cross-price elasticities). By this and a few other assumptions, the discrete-choice models are able to include a larger number of products than flexible demand systems can, without placing implausible requirements on data quality. The discrete-choice models are a popular choice in the industrial organization literature where brand-level price elasticities are of interest to infer market power (Nevo 2001), predict impacts of mergers (Houde 2012), and estimate the welfare effect of new products (Petrin 2002).

Compared to reduced-form models, structural demand models are usually more difficult to estimate. Because of the nonlinearity in most structural demand regressions, it is difficult to include many covariates as control variables. For example, it is not practical to include household fixed effects to the nonlinear flexible demand systems and the random-coefficient discrete-choice models. By contrast, household fixed effects can be easily included in linear reduced-form demand models. The decision of which group of models to use depends on the specific research question and data available.

Other considerations for estimating consumer and producer surplus

Additional considerations for CPSC analysts may include the competitive nature of the regulated market, potential shifts in demand, the time horizon considered, whether some products already comply with the regulation, and assumptions about the linearity of supply and demand. The simplistic figures depicting unregulated and regulated markets (Exhibits 2-1, 2-2) do not capture important elements of some markets being regulated. These factors include:

- **Imperfect competition.** For many CPSC rulemakings, assuming a perfectly competitive market is a reasonable representation of affected markets for the purposes of estimating changes in surplus. The assumptions of this model include homogeneity in the good produced by firms, no barriers to market entry, multiple producers, no transaction costs, and perfect information. While many markets do not strictly adhere to these assumptions, the market dynamics represented in perfectly competitive models are generally consistent with the responses of producers and consumers across a wide range of markets. For this reason, this is the standard approach for most partial equilibrium analyses in regulatory analysis.

  In some cases, a market may be dominated by one or few suppliers (monopoly and oligopoly, respectively). For example, such conditions may arise in the context of a patented safety technology such as SawStop. Under monopolistic and oligopolistic market conditions, the supplier(s) are not "price takers" but rather can influence the equilibrium price depending on their market share. According to economic theory, a monopolist will sell at a reduced quantity corresponding with the point where marginal costs are equal to marginal revenues. And, monopolists will price the good higher than in a competitive equilibrium. Relative to a perfectly competitive market, concentrated markets have greater producer surplus and reduced consumer surplus. As such, the typical calculations for consumer and producer surplus may not apply in a concentrated market for a regulated good. Analysts will need to consider additional parameters, such as deriving a marginal revenue curve.

To better understand market structure, we recommend CPSC consider whether a given market is characterized by oligopolistic competition. To make such determinations, CPSC may use metrics of market concentration, such as the Herfindahl-Hirschman index (HHI).[4,5] Notably, these calculations are data intensive. CPSC may consider the data from the U.S. Census Bureau Annual Survey of Manufacturers or Economic Census.

In addition, imperfect competition may reference instances where a market is driven by one (or few) buyers. This is known as a monopsony (or oligopsony). Monopsony is most frequently studied in the context of labor markets, such as when a large factory or company is looking to employ workers and can, in a free market with few other employers, effectively set wage rates. In contrast to monopolistic competition, monopsonistic competition results in *higher* consumer surplus, *lower* producer surplus, and *lower* total surplus. The buyer maximizes its welfare by equating its marginal willingness to pay (demand curve), with the marginal expenditure for the good.[6] The resulting price and quantity fall below the efficient market equilibrium. As with monopolistic competition, we recommend CPSC consider whether a given market has one or few buyers through available data or market research.

- **Shifts in demand.** In some cases, regulation may induce changes in consumer demand. Examples include regulations addressing imperfect information, such as consumer's risk perceptions, or instances where regulations materially change the attributes of the regulated good. Labeling requirements for products may inform users of consumption-related risks, resulting in a change in their willingness to pay for a product. Further, some product standards are accompanied by "nuisance" costs, or undesired outcomes associated with the regulated good, such as reduced performance of fuel-efficient vehicles. Due to challenges associated with quantifying demand for both the unregulated and regulated goods, agencies rarely model shifts in the demand curve.

- **Time horizon.** Supply and demand may be more (or less) elastic depending upon the time frame considered. Conventionally, demand elasticities are thought to be lower in the short-run (concurrent with the onset of a permanent price change) relative to the long-run, the length of which depends on how long it takes the consumer to fully adjust to a permanent price change. For example, daily commuters in gasoline-powered vehicles may be unable to significantly reduce their gasoline consumption in the short-run; however,

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[4] The HHI is calculated by (1) squaring the market share of each firm in a given market and (2) summing the resulting values. For example, for a market consisting of three firms with shares of 50 percent, 30 percent, and 20 percent, the HHI is 3,800 ($50^2 + 30^2 + 20^2 = 3,800$). The HHI approaches zero when a market is made up of a large number of firms that are relatively equal in size and reaches its maximum of 10,000 when a market is controlled by a single firm. The U.S. Department of Justice and the Federal Trade Commission reference the HHI in their Horizontal Merger Guidelines (U.D. DOJ and FTC 2010), which designate an HHI below 1500 as an unconcentrated market, an HHI between 1500 and 2500 as a moderately concentrated market, and an HHI above 2500 as a highly concentrated market. See https://www.justice.gov/atr/herfindahl-hirschman-index and https://www.justice.gov/atr/horizontal-merger-guidelines-08192010#5c.

[5] Other metrics include the four-firm concentration ratio, or the proportion of total output in an industry produced by the four largest firms in that industry. While a low value is indicative of a competitive industry and a high value is indicative of a less competitive industry, there is no general consensus among economists on the interpretation of intermediate concentrations. In general, however, a four-firm concentration ratio of less than 0.4 is considered very competitive. The four-firm concentration ratio and other concentration ratios (e.g., the eight-firm concentration ratio) were frequently used measures of concentration prior to the widespread adoption of the HHI. Because concertation ratios fail to capture the market structure within an industry and therefore provide a less complete assessment of concentration, the HHI is more widely used today. To illustrate the limitations of concentration ratios, a market in which each of the four largest firms accounts for 20 percent of the market has the same four-firm concentration ratio as another market in which the top four firms have shares of 55 percent, 20 percent, 4 percent, and 1 percent. The difference between these two scenarios, however, is captured by the HHI, which has a value of 1,600 under the first scenario and 3,442 under the second.

[6] Brennan (2009, working paper) includes useful discussion of the economic theory for monopoly and monopsony: https://economics.umbc.edu/wp-content/uploads/sites/243/2014/09/wp_09_110.pdf.

sustained periods of elevated fuel prices may incentivize these commuters to consider more fuel-efficient (or electric powered) vehicles later on.

For CPSC regulatory analyses, which typically model 10 or more years of costs and benefits, we recommend use of long-run elasticities for both supply and demand. Short-run estimates may understate or overstate changes in consumer and producer surplus; however, CPSC may consider supplementing a long-run partial equilibrium analysis with discussion of short-term impacts if they are potentially important for the regulated product market.[7]

- **Instances where some existing products comply with proposed regulations (and some do not).** In some cases, a subset of products may already comply with proposed rulemaking proposed by CPSC. In these cases, producers of the compliant goods will not incur additional costs while other producers (of noncompliant goods) will. If this is the case, contraction in supply (and changes in price) may be less pronounced than scenarios where all producers incur costs to comply with the regulation.

- **Linear demand and supply.** In lieu of directly estimating a demand model and a supply model to study the regulatory impact of a proposed safety standard, most analyses will rely upon existing demand and supply elasticities from the literature. In this case, the analyst needs to assume locally linear demand and supply at the observed market equilibrium. While demand and supply may be nonlinear across the full quantity domain, regulatory-induced shifts typically change quantities consumed by a marginal extent.

[7] Differences between short-run and long-run estimates may be less pronounced for durable goods relative to other types of products, such as addictive goods or those involving adjustment costs (e.g., shifting transportation).

CHAPTER 3 | Review of Elasticity Applications in Regulatory Analyses

In this chapter, we discuss our review of CPSC's and other federal agencies' Regulatory Impact Analyses (RIAs) that apply the concepts outlined in Chapter 2. We identified three main approaches that agencies have used to assess regulation-induced costs and benefits to consumers and producers. We present the approaches in descending order of sophistication. The first approach estimates changes in consumer surplus, producer surplus, compliance costs, and deadweight loss. Absent information about the elasticity of supply and thus producer surplus, the second approach is used to estimate changes in consumer surplus and compliance costs. Finally, if there are not sufficient data available for both supply and demand elasticities, analysts can adopt a third approach to only estimate direct compliance costs.

In addition to CPSC's own analyses, the Environmental Protection Agency (EPA)[8] and the National Highway Traffic Safety Administration (NHTSA) have produced RIAs that may serve as useful examples to CPSC analysts on the application of elasticities.[9] Table 3-1 below presents the RIAs we primarily relied on for this chapter's discussion of estimating consumer surplus and producer surplus. The "Elasticity Description" column indicates which type(s) of elasticity the agency uses in the RIA and from which market these elasticity estimates are drawn or derived.

Table 3-1. Review of Regulatory Impact Analyses

Agency	RIA Title	Elasticity Description	Elasticity Sources Cited
Approach 1: Full estimation of consumer surplus, producer surplus, compliance costs, and deadweight loss			
CPSC	Adult Portable Bed Rails (2022)	Automobiles, own-price elasticity of demand, elasticity of supply	Goldberg (1995)
CPSC	Recreational Off-Highway Vehicles and Utility Task/Terrain Vehicles (2022)	Automobiles, own-price elasticity of demand, elasticity of supply	Goldberg (1995)
EPA	NESHAP Gasoline Distribution Technology and Bulk Gasoline Terminals (2022)	Gasoline, short-run own-price elasticity of demand, short-run elasticity of supply	Davis et al. (2016); Lewis et al. (2017); Coyle and Prisinzano (2012)
EPA	NESHAP Commercial/Institutional Boilers and Process Heaters (2022)	Paper and wood products, own-price elasticity of demand, elasticity of supply	ICF International (2013); US International Trade Commission (2017)

[8] Many of EPA's RIAs are associated with the agency's National Emission Standards for Hazardous Air Pollutants (NESHAP).

[9] We focus on EPA and NHTSA since these agencies regulate similar consumer products and conduct analytically sound and sophisticated RIAs that can serve as useful examples to CPSC staff. We also reviewed RIAs produced by the Customs and Border Protection Agency, the Food and Drug Administration, the Fish and Wildlife Service, and Health Canada.

Agency	RIA Title	Elasticity Description	Elasticity Sources Cited
EPA	Oil and Natural Gas Sector Climate Review (2021)	Crude oil and natural gas, own-price elasticity of demand, elasticity of supply	Hausman and Kellogg (2015); Coglianese et al. (2017); Newell and Prest (2019)
EPA	NESHAP Pulp and Paper Industry (2016)	Paper and paperboard products, own-price elasticity of demand, elasticity of supply	US Forest Service (2007); EPA's previous RIA (1993)
EPA	NESHAP Brick and Structural Clay Products (2015)	Brick and structural clay products, own-price elasticity of demand, elasticity of supply	Rutherford (2002); Shih (2008)
EPA	NESHAP Spark Ignition and Reciprocating Internal Combustion Engines (2013)	Energy, agriculture, and construction markets, own-price elasticity of demand, elasticity of supply	Wade (2003); National Energy Modeling System; previous EPA RIAs
EPA	Emissions from Non- Road Diesel Engines (2004)	Multiple application markets, own-price elasticity of demand, elasticity of supply	Elasticity estimates are derived econometrically using price data
Approach 2: Estimation of consumer surplus and compliance costs			
CPSC	Window Coverings (2022)	Household goods, own-price elasticity of demand	Houthakker and Taylor (2010)
CPSC	Table Saws (2017)	Household goods, own-price elasticity of demand	Houthakker and Taylor (2010)
CPSC	Portable Generators (2016)	Household goods, own-price elasticity of demand	Houthakker and Taylor (2010)
EPA	NESHAP Automobile and Light Duty Vehicles (2004)	Automobiles, own-price elasticity of demand	Trandel (1991); Goldberg (1995); Berry et al. (1995); McDaniel et al. (2000)
NHTSA	Model Years 2024-2026 Light-Duty Vehicle Corporate Average Fuel Economy Standards (2022)	Automobiles, own-price elasticity of demand	Gately (1990); Fischer (2007); Leard et al. (2021); additional input from stakeholders during comments period on NHTSA dockets

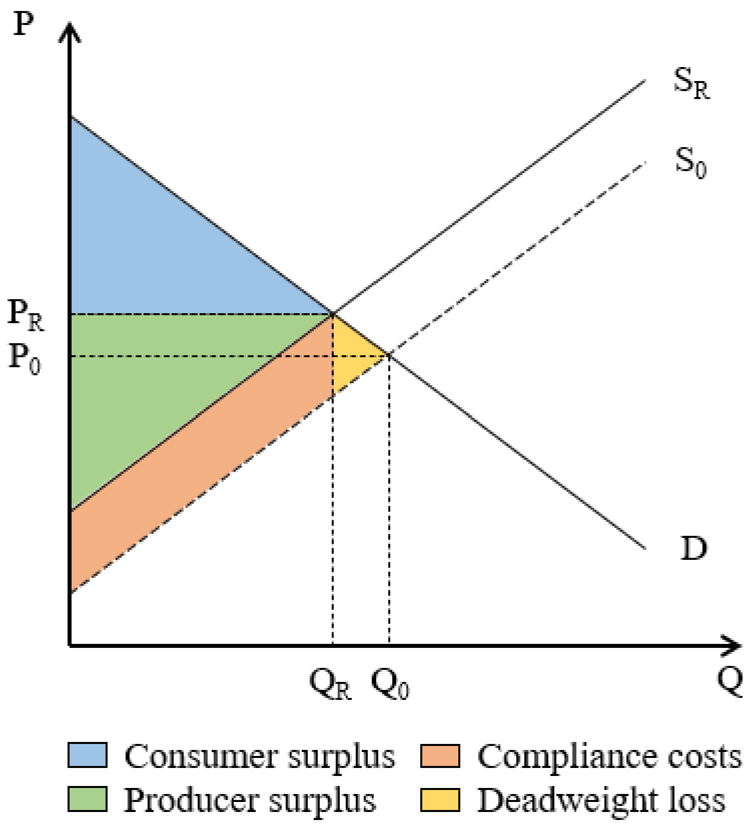
Agency	RIA Title	Elasticity Description	Elasticity Sources Cited
NHTSA	Heavy Duty Vehicles GHG Emissions and Fuel Efficiency Standards (2016)	Vehicle miles traveled rebound effect	Energy and Environmental Research Associates (2015); Leard et al. (2015); Winebrake et al. (2015); previous NHTSA RIAs
NHTSA	Electronic Stability Control Systems on Heavy Duty Vehicles 2012)	Commercial freight services, own-price elasticity of demand	Naughton et al. (2005); Leard et al. (2015); Wadud (2016)
Approach 3: Estimation of compliance costs			
CPSC	Magnets (2022)	None (analysis provides hypothetical examples of elasticities)	None
CPSC	Safety Standards for Clothing Storage Units (2021)	None	None
CPSC	Amendments to Fireworks Regulations (2018)	None	None
CPSC	Standard for the Flammability of Residential Upholstered Furniture (2007)	None	None
NHTSA	Occupant Protection for Vehicles Equipped with Automated Driving Systems (2022)	None	None
NHTSA	Side Impact Test for Child Restraints (2014)	None	None
NHTSA	Minimum Sound Requirements for Hybrid and Electric Vehicles (2013)	None	None
NHTSA	Tire Pressure Monitoring System (2005)	None	None
NHTSA	Upgrade Roof Crush Resistance (2005)	None	None

Approach 1: Full parameterization of demand and supply

The first approach is a full parameterization of demand and supply to estimate changes in consumer surplus, producer surplus and compliance costs. Analysts should choose this option whenever possible, as it provides the most sophisticated and complete assessment of regulation-induced changes in economic welfare. At the same time, this approach requires the most data, including estimates of both the price elasticity of demand and the elasticity of supply.

Exhibit 3-1 provides a graphical representation of market equilibrium after a federal rule takes effect. Approach 1 solves for the post-rule equilibrium market price (P_R) and quantity (Q_R). First, analysts need to know the market equilibrium price (P_0) and quantity (Q_0). Analysts also need sufficient data about regulatory compliance costs and elasticities to model the demand and supply curves.

Exhibit 3-1. Market equilibrium after rule



Generally, a new regulation raises the cost of production for suppliers. Determining how much the supply curve shifts from S_0 to S_R in response requires knowledge of the incremental unit costs of the regulation and of firms' ability and willingness to adjust production given these costs. A key determinant of the price elasticity of supply is the length of time over which product choices can be made. Within the general framework of Approach 1, agencies have employed varying assumptions about short-run vs. long-run supply elasticities and firms' ability to adjust production. Ideally, producers hope to pass on all regulatory costs to consumers in the form of higher prices but generally cannot sufficiently increase supply to do so because of short-term production constraints.

As regulatory costs increase market prices, consumers will demand less of the regulated product. To calculate P_R and Q_R, analysts need an estimate of the own-price elasticity of demand for the regulated product. If there are insuffcent data available for the reuglated product itself, agenices typically use proxies and rely on existing data of elasticities of goods that are simlar to the regulated product. Notably, Approach 1 allows analysts to estimate cost passthrough, or the amount of the added compliance costs that are borne by consumers. Cost passthrough is calculated as ($P_R - P_0$) divided by the unit compliance cost.

CPSC has adopted Approach 1 in RIAs of proposed regulations affecting Adult Portable Bed Rails and Recreational Off-Highway Vehicles and Utility Task/Terrain Vehicles. In both cases, CPSC relied on estimates of own-price elasticity of demand and the elasticity of supply for automobiles (Goldberg 1995) to calculate the deadweight loss resulting from the regulation.[10,11] There is limited discussion of the rationale for choosing the automobile market as a proxy for the regulated products or of alternatives CPSC considered.

EPA has implemented Approach 1 extensively in economic analyses of clean air standards, notably the National Emissions Standards for Hazardous Air Pollutants (NESHAP). These examples are indicated in the "Elasticity Description" column of Table 3-1 by RIAs that apply own-price elasticity of demand and elasticities of supply. For example, EPA assesses changes in both supply and demand in markets such as natural gas (Gasoline Distribution Technology and Bulk Gasoline Terminals, Oil and Natural Gas Sector Climate Review RIAs), wood and paper products (Commercial/Institutional Boilers and Process Heaters, Pulp and Paper Industry RIAs), and the Brick and Structural Clay Products. Clean air standards affect a range of markets and industries that rely on the regulated industry (e.g., fossil fuels), which increases the complexity of modeling changes in economic behavior. Changes in one market – not always the regulated market – influences change in other markets. In other words, the regulations necessitate that EPA move beyond the partial equilibrium framework and adopt a general equilibrium model. For example, EPA's 2004 Control of Emissions from Nonroad Diesel Engines RIA models interactions between 62 regulated markets and other nonregulated stemming from the costs of complying with the rule.

Approach 2: Flat supply curve

Approach 2 assumes that the total cost of regulation is borne by consumers in the form of higher prices. Effectively, this assumes that firms are price takers under perfect competition and that the supply curve is flat. As a result, no producer surplus exists, but analysts can still estimate compliance costs and changes in consumer surplus given estimates of equilibrium market quantity and price, regulatory-induced unit costs, and the own-price elasticity of demand for the regulated product. This approach, shown graphically in Exhibit 3-2 below, represents an upper bound on the potential economic welfare impact on consumers.

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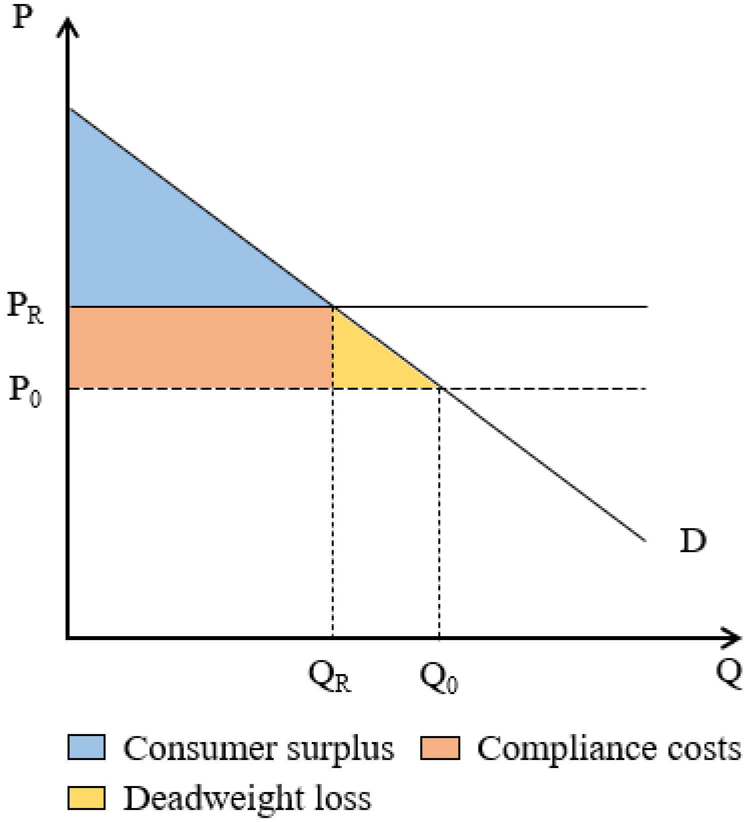
[10] The RIAs calculate deadweight loss as the sum of consumer surplus and producer surplus, but do not report results split by its component parts.

[11] Goldberg, Pinelopi Koujianou. "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry." Econometrica, vol. 63, no. 4, 1995, pp. 891–951. JSTOR, https://doi.org/10.2307/2171803.

Exhibit 3-2. Stylized market equilibrium after rule (flat supply curve)



The implicit economic assumptions underlying Approach 2 may not always be appropriate to apply to the regulated product or market. However, for many products, estimates of the elasticity of supply simply do not exist and data are not always readily available for analysts to calculate their own estimates. EPA's ability to employ Approach 1 is mainly due to the fact that markets within their oversight, such as energy and automobiles, are extensively researched by industry groups, regulators and academics. There is considerably less research conducted on the elasticity of supply for the types of consumer goods that CPSC regulates. Cost passthrough is assumed to be 100 percent in this approach – that is, producers pass on the entirety of the cost of compliance to consumers by raising prices by an amount equal to the unit compliance cost.

CPSC employs Approach 2 in RIAs of Window Coverings, Table Saws, and Portable Generators. These analyses all relied on *Consumer Demand in the United States: Prices, Income, and Consumption Behavior*, a book published by economists Lester D. Taylor and H.S. Houthakker in 2010. CPSC transfers own-price elasticity of demand estimates for household goods to the regulated consumer products.[12] Producers are assumed to pass on all regulatory costs to consumers in the form of higher prices.

NHTSA uses Approach 2 in assessments of Model Years 2024-2026 Light-Duty Vehicle Corporate Average Fuel Economy Standards and Electronic Stability Control Systems on Heavy Vehicles. The former RIA is notable for the

[12] Household goods are broadly defined to include products such as floor coverings; picture frames; mirrors; art products; portable lamps; window coverings and hardware; telephone equipment; writing equipment; and hand, power, and garden tools.

level of input regarding supply elasticity that the agency received in the comments period. The agency initially proposed that the own price elasticity of demand for these vehicles was unit elastic (i.e., -1.0). In the comments period, many argued that this value was too large and unsupported by the evidence. The deliberation was particularly complex as commentators suggested NHTSA should employ long-run instead of short-run elasticities and consider substitution effects between new and used cars. Ultimately, though NHTSA was presented with a wide range of own price elasticity of sales for the regulated vehicles, the agency chose a single value (-0.4) to evaluate in the RIA.

NHTSA's Electronic Stability Control Systems on Heavy Vehicles RIA adopts a simplified variation of Approach 2 in that the analysis is not framed in the context of consumer surplus, producer surplus, and deadweight loss. Instead, the agency uses an own-price elasticity of demand estimate for freight trucking services to calculate the regulation's impact on vehicle sales.

Approach 3: Compliance cost estimation

Without information about own demand and supply elasticities, analysts cannot model consumer and producer surplus and can only estimate the direct compliance costs of the regulation. Approach 3 requires analysts to know the pre-regulation market equilibrium quantity (Q_0 in the exhibits above) and the unit costs of compliance. Analysts can multiply Q_0 by unit costs to calculate the total compliance costs of the regulation. Approach 3 will likely overstate changes in economic welfare because it assumes the quantity of units sold remains unchanged after the regulation takes effect. Furthermore, the approach does not typically specify who will bear the costs. Producers could incur costs in the form of reduced profits, or consumers could bear the costs in the form of increased prices.

CPSC has used Approach 3 in its regulatory analyses of Magnets, Fireworks, Clothing Storage Units, and Upholstered Furniture. We also reviewed many examples of NHTSA's RIAs that use Approach 3, including the Side Impact Test for Child Restraints, Tire Pressure Monitoring System, and Upgrade Roof Crush Resistance.

Other approaches

The above discussion is not an exhaustive account of the strategies that federal agencies employ to conduct regulatory impact analyses. There is also considerable analytic variation within each of the three broad approaches we outlined. For example, EPA has analyzed regulations that affect multiple markets using general equilibrium models. We included such analyses under Approach 1, since they involve a full estimation of consumer surplus, producer surplus, compliance costs, and deadweight loss, but some analyses require considerably more data and resources than others. Agencies such as the Food and Drug Administration (FDA) regulate addictive products (e.g., tobacco) and food products, which complicates regulatory analyses by incorporating non-price decision making (addiction) and the effects of incomplete information (labeling) into welfare analyses.[13] After the Food Safety Modernization Act went into effect in 2011, the FDA conducted several RIAs since the law contains various rules that affect a range of markets.

[13] See footnote 2.

CHAPTER 4 | Literature Search for Peer-Reviewed Elasticities

Objectives

CPSC's Regulatory Agenda is continually evolving as consumer product safety risks are identified and addressed by the Commission.[14] In some instances, the agenda addresses new products (e.g., electric mobility products such as electric scooters) or new technologies (e.g., SawStop table saw blade-contact sensor). Uncertainty regarding which products CPSC may regulate in the coming years necessitates that CPSC's Directorate for Economic Analysis has access to elasticity estimates across a wide range of consumer products. To support this goal, IEc conducted a literature search for elasticity estimates in the peer-reviewed literature and created an Excel workbook containing these estimates. In the sections below, we summarize our approach we used to identify and review relevant studies and associated elasticity estimates.

Literature search

As described in Chapter 3, elasticity estimates are often unavailable for regulated goods of interest. Elasticities published in peer-reviewed journals often relate to commodities (e.g, crude oil, gasoline) and food products; however, durable goods are less commonly evaluated in academic research. Given the anticipated challenges associated with finding estimates for specific consumer goods (e.g., residential boilers), we searched for any studies related to "durable(s)" or "consumer products/goods." in two search databases, Scopus and EconLit.

Search terms

We summarize our search terms in Table 4-1. These include five economic terms (price, pricing, demand, elasticity, margins) and three terms to restrict studies to those pertaining to relevant products (durable, consumer product, consumer good). The Scopus search covers title, abstract, and keywords, while we restricted the EconLit search to abstract only. Together, these databases cover all economics, marketing, and industrial organization journals identified by IEc as likely to provide useful elasticity estimates for this effort.

Table 4-1. Literature search parameters

Database	Search Terms	Notes
Scopus	TITLE-ABS-KEY ((price OR pricing OR demand OR elasticity OR margins) AND ("consumer product" OR durable OR "consumer good"))	Restricted to "Economics, Econometrics and Finance" and "Business, Management, and Accounting" subject areas.
EconLit	AB((price OR pricing OR demand OR elasticity OR margins) AND ("consumer product" OR durable OR "consumer good"))	15 abstract searches comprised of combinations of search terms, e.g., *AB(price) AND AB(consumer good).*

In addition to literature searches in Scopus and Econlit, Dr. Chen Zhen of the University of Georgia provided us with a set of high quality, relevant, and seminal studies estimating elasticities for consumer products, which are

[14] See here for CPSC's Semiannual Regulatory Agenda published on August 8th, 2022: https://www.federalregister.gov/documents/2022/08/08/2022-14617/semiannual-regulatory-agenda

summarized in Table 4-2.[15] Analysts may also find it helpful to conduct backward and forward citation reviews for these articles, which could potentially identify additional relevant studies for CPSC. We note that our literature search likely captures many of the studies that would be identified in this exercise. We provide more information about citation reviews in Appendix B.

Table 4-2. High-quality studies included in the literature review

Citation	Description
Hendel (1999)	Own-price and cross-price elasticities of demand for personal computers.
Nevo (2001)	Own-price and cross-price elasticities of demand for cereal.
Song and Chintagunta (2003)	Own-price and cross-price elasticities of demand for digital cameras
Hendel and Nevo (2006)	Own-price and cross-price elasticities of demand for detergent.
Davis (2008)	Own price elasticity for high-efficiency washers.
Kee et al. (2008)	Own-price elasticity of (import) demand for 4,900 products classified by 6-digit harmonized tariff schedule (HTS) codes.
Gowrisankaran and Rysman (2012)	Own-price elasticity for digital camcorders.
Melnikov (2012)	Own-price elasticity of demand for computer printers.
Grennan (2013)	Own-price and cross-price elasticities of demand for medical devices (stents).
Rapson (2014)	Own-price elasticity for air conditioners.
Hiller et al. (2018)	Own-price and cross-price elasticities for smartphones.
Adams and Williams (2019)	Own-price elasticity for drywall.
Hiller and Savage (2021)	Own-price elasticity for tablet computers.

[15] While Nevo (2001) is focused on cereal, we include the study in our literature search because it is a seminal methodological piece for estimating demand for differentiated products.

Supplemental literature searches and elasticity databases

We supplemented our literature search with estimates identified within relevant meta-analyses.[16] Most notably, Auer and Papies (2019) conducted a recent meta-analysis of cross-price elasticities of demand. The authors identified 115 studies and 7,264 elasticity estimates. Auer and Papies provided IEc with a list of the 38 studies that include elasticity estimates for durable products. We also reviewed the studies cited in the RIAs that we discussed in Chapter 3; many of the studies focused on energy and transportation markets but we identified seven studies containing relevant elasticities for CPSC. In addition, we received a Microsoft Access elasticity database (the Elasticity Databank) from EPA that contains elasticities across a wide range of products. With a few exceptions, most products contained in the database are not relevant to CPSC's work.[17] We did identify relevant own-price elasticity of demand estimates for automobiles, batteries, and wooden household furniture, which we included in our elasticity database.

Review criteria

We first applied the criteria summarized in Table 4-3 to restrict the studies to a relevant subset for full-text review.

Table 4-3. Screening criteria

#	Description
1	Study is based on data from the United States.
2	Study is available in English.
3	Study published in prior 30 years (i.e., after 1992).[18]
4	Study title/abstract references durable goods or consumer products.[19]
5	Study title/abstract suggests empirical (i.e., not solely theoretical) estimation of demand and/or supply.

[16] Bijmolt et al. (2005) conducted a meta-analysis on the determinants of own-price elasticities of demand. Across 81 studies, the authors identified 1,860 price elasticities; only 33 estimates related to durables. The authors did not specify which studies contained elasticities for durable goods, and these studies are notably older. We did not receive a response from the authors for the list of durable elasticities; as such, these studies were not included in our review unless they were identified in the literature search or supplemental efforts.

[17] The database includes own-price demand and supply elasticities, cross-price elasticities, income elasticities, and trade elasticities. EPA collected the elasticities from the economic literature and its own economic or regulatory impact analyses. Similar to IEc's approach in this report, EPA uses EconLit to identify an initial list of relevant papers that may contain elasticities and then filters the list based on key search terms (e.g., "elasticity", "industry"). EPA also includes elasticities that the agency derived econometrically for other economic analyses. The Elasticity Databank provides the source of each elasticity as well as the methodology used to estimate the elasticity. Overall, the database contains 1,369 entries. The most common types of products in the database are related to the chemical manufacturing, electricity, fuel, and paper/paperboard industries.

[18] We establish a time cutoff for publications due to concerns that older elasticities may not be applicable given potential shifts in consumer preferences and changes to the products being studied.

[19] While our search terms include "durable", "consumer product", and "consumer good", the studies identified through other means may not satisfy this criterion.

Following the initial screening, we conducted a full-text review of the remaining articles to identify elasticity estimates that are relevant, high quality, and appropriate for use in CPSC regulatory analyses. Table 4-4 includes the criteria we applied in this review.

Table 4-4. Evaluation criteria

#	Description
6	Preference for peer-reviewed studies.
7	Preference for studies published more recently.
8	Preference for studies with broad geographic coverage (rather than one city or region).
9	Preference for long-run elasticity estimates.
10	Preference for aggregate category definitions rather than brand-level or SKU-level elasticity estimates.[20]
11	Preference for studies that do not use conditional demand.[21]

The evaluation criteria in Table 4-4 reflect the tradeoffs involved in reviewing available elasticity estimates. Few studies satisfied all evaluation criteria; the list provides analysts with the attributes that define more preferred study methodologies and characteristics. As we discuss below, application of these criteria requires significantly more judgment relative to the screening process, and in many cases there are gradations in quality and applicability to the CPSC context. We did not exclude studies based on the evaluation criteria. Rather, we documented these study characteristics in the elasticity database described below. 632 studies were removed following full-text review because they contained no elasticity estimates for consumer products.

[20] We note that while aggregate category-level elasticities may be most helpful to CPSC, best practice in many journals—particularly those focusing on industrial organization—involves estimating finer-scale elasticities (i.e., at the brand or SKU level). As such, higher quality estimates may be more disaggregated. However, with sufficient information on market share and own-price and cross-price elasticities for various brands, it may be possible to construct an aggregate category own-price elasticity of demand. See the Appendix for instructions on this aggregation.

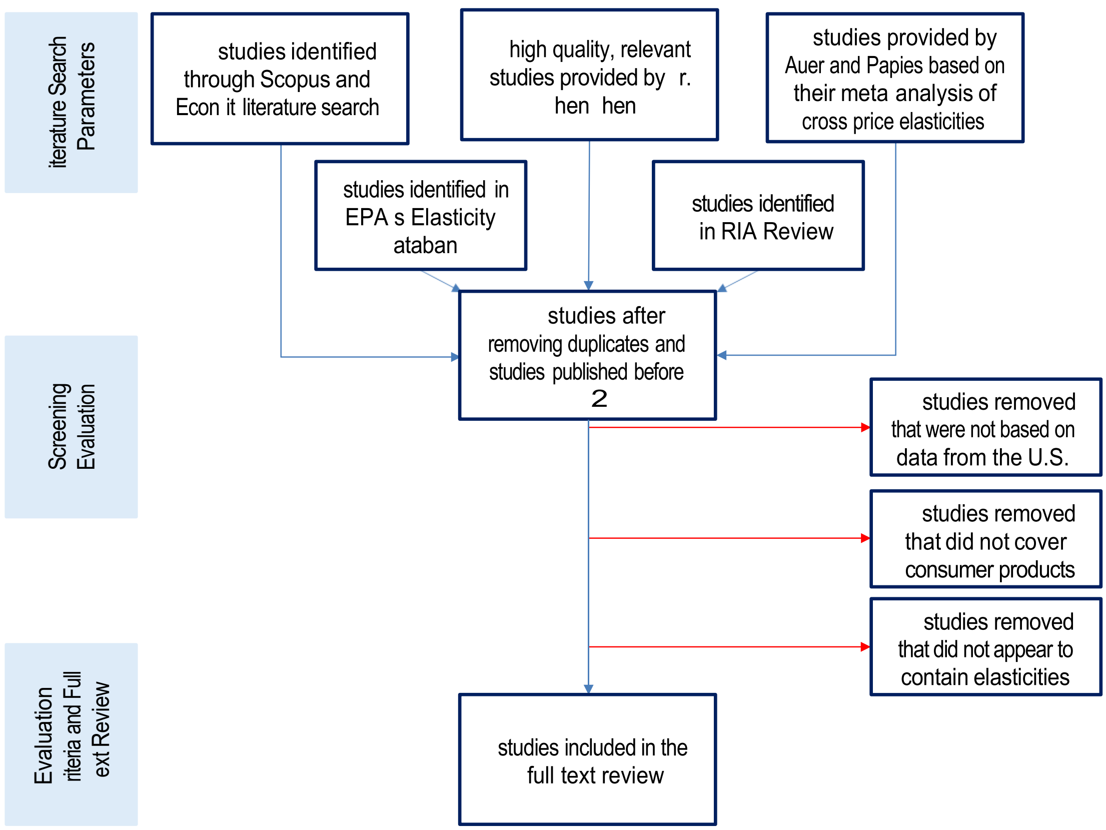
[21] A number of demand system studies estimated demand conditional on total expenditures allocated to the goods being studied. These conditional demand elasticities are not suitable for policy analysis because total expenditures are likely to change with the policy (LaFrance and Hanemann 1989; Hanemann and Morey 1992). For example, food group demand elasticities conditional on total food spending are not appropriate for simulating the effect of a policy affecting overall food price because total food spending will change as overall food price changes.

Chapter 5 | Results

Summary of Literature Review Findings

Exhibit 5-1 summarizes the literature search and screening process. In total, we reviewed 1,962 studies identified through structured and supplemental literature searches and from the citations of a relevant meta-analysis. Most studies failed to meet our screening criteria. In total, we identified 75 studies which appeared to (a) be based in the United States, (b) focus on consumer products, and (c) were likely contain elasticity estimates.

Exhibit 5-1. Summary of literature screening and review



The results of our full-text review of these 75 studies are summarized in the accompanying Excel file titled *CPSC Elasticities Database 20230608.xlsx.* Closer review of these studies eliminated additional papers that did not satisfy all screening criteria. Elasticity estimates from 46 studies are included in the database.[22,23] These estimates cover a range of consumer products, including drywall, automobiles, medical devices, laundry detergent, air conditioning units, and computers. Despite the variety in products, many products of interest to CPSC are not represented in these studies.

We also highlight that some existing research may not be well-suited for use in regulatory analysis due to the vintage of data, the limited geographic scope, and/or the methodologies employed. IEc summarized these features in the database and encourages CPSC to consider whether the estimates meet the needs of an RIA on a case-by-case basis. The database documents the elasticity estimates presented in each study, including comments on preferred specifications and differences in model estimates (e.g., short versus long run). Own-price elasticities of demand are the primary estimates contained in the database. In cases where a study reports multiple elasticities, we include the value ("Own" columns) and description ("D_Own" columns) of each estimate We did not identify any studies in our full-text review that reported elasticities of supply.[24] To maintain a manageable database, we opted to note when studies published cross-price elasticities of demand; however, these estimates are not included in the Excel file.

Consistent with the discussion in Chapter 2 regarding structural and reduced-form models, we classified authors' methodologies for estimating elasticities into three main categories:

- Discrete Choice Model: a structural model in which the parameters characterize an assumed preference structure (most commonly a direct utility function). Examples include simple logit, nested logit, and mixed (random coefficient) logit models. Products are restricted to be substitutes by assuming consumers purchase at most one unit of one product among a menu of differentiated products. This is a reasonable restriction for big-ticket durable goods but may not be ideal for less expensive multi-purchase items. The benefit of this approach is that the model can accommodate a large number of products even when there is limited variation in relative prices and consumer preference is econometrically associated with product characteristics. The latter may be especially useful to CPSC if a safety rulemaking is targeted to a product characteristic.
- Flexible-Functional Form Continuous Demand System: a structural model in which the parameters characterize an assumed preference structure (mostly commonly a cost function). Examples include the Almost Ideal Demand System (AIDS), the Translog demand, and the Exact Affine Stone Index (EASI) models. In contrast to a discrete choice model, products are not restricted to be pure substitutes, but the model requires significant exogenous relative price variation to reliably identify the true cross-price elasticities. Product characteristics are not built into the model. However, the researcher can explore the association between the estimated price elasticities and product characteristics after the demand system is estimated.
- Reduced-Form Model: a model in which the reduced-form parameters do not result directly from a preference structure but still reflect the consequence of consumer optimization. For example, in a simple ordinary least squares regression, we expect the coefficient on own price to be negative when the dependent variable is purchased quantity. But this negative coefficient is not a parameter of a utility function or cost function. Compared to the structural discrete choice models and the flexible demand systems, the reduced-

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[22] We included one analysis (from EPA's Elasticity Databank) in the database that was published in 1984: Economic Impact Analysis of Effluent Limitations and Standards for the Battery Manufacturing Industry (U.S. EPA 1984). We included the study because it provides elasticities for batteries, a relevant product for CPSC that we did not encounter elsewhere in our literature search while constructing the database.

[23] Since the book contains many elasticities that were calculated using different methodologies, we included a single row for *Consumer Demand in the United States* (Houthakker and Taylor 2010) in the database. Analysts should consult the book, which is available in CPSC's office, to find relevant elasticities. As noted in Chapter 3, CPSC has relied upon the book's elasticities for products such as household appliances and furniture in several regulatory analyses.

[24] Supply elasticities were not the main focus of our literature search and may warrant additional literature searches with different search terms.

form parameters are less useful for counterfactual policy simulations but can still provide reasonable approximations of elasticities given sufficient assumptions.

Finally, we note if a study discusses price endogeneity bias and if the authors addressed the bias. Endogeneity is common in estimating elasticities because prices, as variables set by firms, often respond to components of demand that the economist cannot directly observe. In our review, authors typically find appropriate "instruments" for price to account for endogeneity bias.

Discussion

The review described in this report presents a body of literature on the demand response to price changes for consumer goods. This literature is limited. Own-price elasticities of demand for consumer products are not of great academic interest alone. In addition, the limited amount of data on products of interest to CPSC are usually unavailable to academic researchers. Research in this area is often published to highlight new data or methods. Inclusion of resulting estimates in the accompanying database should not be interpreted as a blanket approval for use in regulatory analysis; we urge CPSC to review each study carefully prior to application in its work.

While the literature on consumer goods elasticities is limited, the database resulting from our search should not be considered exhaustive. We developed tractable search terms to find studies of consumer goods (e.g., "durables" or "consumer products"). We did not search for individual products of interest to CPSC (e.g., portable generators or off-road vehicles). Some studies focusing on these specific products may not use the terms "durable" or "consumer good" in the title or abstract, limiting our ability to identify these studies. We recommend that CPSC consider searching for product-specific elasticities during the preparation of regulatory impact analyses and that CPSC continue adding to the elasticity database accompanying this report.

Although elasticities are not currently available for many consumer products, it may be appropriate to transfer elasticities from other products if quantification is needed in the regulatory analysis. We recommended that CPSC assess the following considerations for transferring elasticities on a case-by-case basis. First, Analysts should check if own-price elasticity of demand estimates are available for complement or substitute products. These estimates may serve as suitable proxies. We note that products with few or no substitutes (e.g., tables saws or football helmets) are generally less price elastic than products with many substitutes (e.g., electric bikes/scooters, since there are alternative modes of transport such as non-electric bikes and public trains/buses). Products which are complements, such as e-scooters and their replacement batteries, may have elasticities of similar magnitude. Analysts should also consider applying an elasticity for the overarching category to which the regulated product belongs, if available. For example, e-scooters are a part of the Sporting Goods, or, more broadly, Entertainment and Leisure industries. If an elasticity for Sporting Goods is not available, analysts could use an elasticity for Entertainment and Leisure products as a lower bound for the elasticity of e-scooters. This would be a lower bound because e-scooters represent a small subset of Entertainment and Leisure products. If the constituents of the Entertainment and Leisure product universe are mostly substitutes, then the own-price elasticity of each component product is generally higher than that of the overall category.

There are other qualitative factors to consider in determining the relative elasticity of a consumer product or the appropriateness of transferring an elasticity. Luxury goods are generally more price elastic than necessities; this is a continuum, not a binary, so analysts should classify regulated products as more or less elastic depending on how essential consumers consider the product to be. As general best practice in conducting regulatory analyses, we recommend that CPSC consider presenting a range of elasticity estimates, seek input from colleagues, and clearly communicate the uncertainties and limitations of applying elasticities to calculate consumer or producer surplus.

Finally, given the paucity of relevant elasticity estimates in the peer-reviewed literature, we recommend that CPSC consider pursuing primary estimation using data on product sales and prices. The data and methods for this effort are summarized in the accompanying memorandum titled "Options for Primary Estimation of Consumer Product Elasticities."

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Appendix A: Deriving Category-Level Elasticity of Demand from Brand-Level Data

This Appendix describes the methodology for deriving the overall category-level elasticity of demand from brand-level data. In many instances, peer-reviewed articles publish detailed own-price and cross-price elasticity estimates for brand- or model-level products. For example, Hiller et al. (2018) present these values for 16 smartphone models in Table 6. While useful, these detailed elasticities may be too finely resolved for application in regulatory analysis. And, these model-level elasticities likely overstate the own-price elasticity of aggregate smartphone demand. In this Appendix and the accompanying Excel spreadsheet, we explain these calculations with step-by-step instructions. Analysts will need to collect the following input variables for each brand within the category of interest:

q_i = units sold of brand i

p_i = initial (pre-regulation) price of brand i

$d \ln p_i \approx \Delta p_i / p_i$ = expected regulation-induced percentage change in the price of brand i

w_i = revenue market share of brand i

s_i = unit market share of brand i

e_{ij} = elasticity of demand for brand i with respect to the price of brand j

The availability of the above data will vary depending on the case. The data may be publicly available or obtainable from a data vendor. Analysts may also request these data from the author(s) of a paper published in an academic journal; authors are generally obligated to respond due to publishing standards for replication of their work.

Steps to Calculate Category-Level Elasticity of Demand

Given the above inputs, analysts can derive the category-level elasticity of demand by calculating two intermediate outputs: the regulation-induced percentage change in the category-level price and the regulation-induced percentage change in the category level-quantity.

Let category units sold be $Q = \sum_{i=1}^{N} q_i$, where q_i is units sold of brand i and N is the number of brands on the market. We assume category-level price P is linked to brand-level prices p_i through the Stone price index:[25]

$$(1)\ \ln P = \sum_{i=1}^{N} w_i \ln p_i,$$

where w_i is revenue market share of brand i. The Stone price index is derived by taking the logarithm of the geometric mean of brand-level prices, weighted by w_i, i.e., $P = \prod_{i=1}^{N} p_i^{w_i}$. There are two benefits with working with the logarithm of prices rather than the level of prices, and relatedly with the geometric mean rather than the arithmetic mean (average). First, prices are often right skewed with long right tails caused by occasional price spikes and extreme values. Taking the logarithm will make the transformed price measure more normally distributed. Second, $d \ln P \approx \Delta P / P$ and $d \ln p_i \approx \Delta p_i / p_i$ for small changes in P and p_i. That is, log values are easier to work with when investigating proportional changes, which are most relevant to demand elasticities.

Total differentiation of $\ln P$ (equation 1) gives:

[25] Stone, R. The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom 1920-1938, Vol. I. London: National Institute of Economic and Social Research, 1954.

$$(2)\quad d\ln P = \sum_{i=1}^{N} w_i d\ln p_i,$$

where $d\ln P \approx \Delta P/P$ and $d\ln p_i \approx \Delta p_i/p_i$ for small changes in P and p_i. Equation (2) shows that the regulation-induced percentage change in the category-level price is equal to the sum of the percentage changes in brand-level own prices, weighted by each brand's respective revenue market share.

$d\ln p_i \approx \Delta p_i/p_i$ is the expected post-regulation change in the market (sale) price of brand i. Absent sufficient data on supply elasticities, analysts can approximate the change in brand market prices using the expected regulation-induced change in the unit cost of producing brand i. Analysts will need to estimate changes in unit costs and determine if these changes will apply uniformly across all brands.

Analysts can then calculate the percentage change in category units sold using the following equation:

$$(3)\qquad \frac{\Delta Q}{Q} = \frac{\sum_{i=1}^{N} q_i\left(\sum_{j=1}^{N} e_{ij} d\ln p_j\right)}{Q} = \sum_{i=1}^{N}\left[s_i\left(\sum_{j=1}^{N} e_{ij}\, d\ln p_j\right)\right]$$

where s_i is unit market share of brand i, and e_{ij} is elasticity of demand for brand i with respect to the price of brand j. Since $d\ln p_i \approx \Delta p_i/p_i$, the $e_{ij} d\ln p_j$ term is the percentage change in quantity demanded for brand i given a price change for brand j. The summation symbol in parentheses indicates that we repeat the calculation for every other brand and sum the results. Thus, for each brand, the calculation in brackets of equation (3) is the brand-level percentage changes in quantity demanded for brand i, given own-price and cross-price effects, weighted by brand $i's$ unit market share s_i. The outer summation symbol indicates that we repeat the calculation for every other brand and sum the results, yielding the regulation-induced percentage change in category units The category-level price elasticity of demand is recovered using:

$$(4)\qquad \varepsilon = \frac{\frac{\Delta Q}{Q}}{d\ln P}.$$

where the numerator is the percentage change in category units and the output of equation (3), and the denominator is the percentage change in category price and the output of equation (2).

To calculate ε in equation (4), analysts need information on w_i s_i, e_{ij}, p_i, and Δp_i. Revenue share w_i is required to back out the anticipated percent change in category-level price following regulation-driven brand-level price changes. This applies to regulations that are expected to increase brand prices by different proportions. For example, the mandated installation of a safety device may cost the same per unit across brands. But because brand prices vary, the proportional price increases are different between brands.

If w_i is not available, the category-level price elasticity of demand can be calculated with the assumption that the price of every brand changes by the same proportion, i.e., $d\ln p_1 = d\ln p_2 = \cdots = d\ln p_N = d\ln P$. In this case, calculation of ε simplifies to

$$(5)\qquad \varepsilon = \frac{\frac{\Delta Q}{Q}}{d\ln P} = \frac{\sum_{i=1}^{N} s_i\left(\sum_{j=1}^{N} e_{ij}\, d\ln p_j\right)}{d\ln P} = \sum_{i=1}^{N}\left[s_i\left(\sum_{j=1}^{N} e_{ij}\right)\right].$$

Using equation (5) requires only information on unit market share s_i and brand elasticities e_{ij}.

Appendix B: Citation Reviews

This Appendix lists the high-quality, relevant studies discussed in Chapter 4, including the count of publications (a) in their reference list and (b) that cite each paper. We note that studies often cite the same articles. As such, the "References" and "Cited by" columns include duplicates. Analysts may identify relevant studies with elasticity estimates by reviewing the backward and forward citations for these articles. Our literature search described Chapter 3 captured many of studies identified in further citation reviews.

Citation	Description	References	Cited by[26]
Hendel (1999)	Own-price and cross-price elasticities of demand for personal computers.	21	118
Nevo (2001)	Own-price and cross-price elasticities of demand for cereal.	43	828
Song and Chintagunta (2003)	Own-price and cross-price elasticities of demand for digital cameras	35	100
Hendel and Nevo (2006)	Own-price and cross-price elasticities of demand for detergent.	34	238
Davis (2008)	Own price elasticity for high-efficiency washers.	23	114
Kee et al. (2008)	Own-price elasticity of (import) demand for 4,900 products classified by 6-digit harmonized tariff schedule (HTS) codes.	35	203
Gowrisankaran and Rysman (2012)	Own-price elasticity for digital camcorders.	53	98
Melnikov (2012)	Own-price elasticity of demand for computer printers.	26	35
Grennan (2013)	Own-price and cross-price elasticities of demand for medical devices (stents).	37	115
Rapson (2014)	Own-price elasticity for air conditioners.	35	58
Hiller et al. (2018)	Own-price and cross-price elasticities for smartphones.	45	5

[26] The "Cited by" column includes citations appearing in the Scopus database as of January 3, 2023. Estimates may differ slightly across literature databases.

Citation	Description	References	Cited by[26]
Adams and Williams (2019)	Own-price elasticity for drywall.	41	18
Hiller and Savage (2021)	Own-price elasticity for tablet computers.	35	0