Teaching and Educational Methods

Enhancing the Teaching of Product Substitutes/Complements: A Pedagogical Note on Diversion Ratios

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Abstract
Application of diversion ratios in demand analysis has received little attention. Even microeconomic textbooks typically do not address this topic. The literature review presented here shows use of diversion ratios, along with cross-price elasticities, to study the price effects associated with mergers and acquisitions, a practice recommended to measure product substitutability/complementarity. With the aim of expanding experiential learning in the fields of applied economics, agricultural economics, and agribusiness, this article demonstrates how diversion ratios can be calculated from any uncompensated own-price and cross-price elasticity matrix derived from the analysis of demand systems, and it discusses the teaching of this concept in the classroom.

1 Introduction

In analyzing the impact of a tax on consumption or a merger on competition, it is useful to assess the degree of substitution between one good and a number of other goods. Typically, cross-price elasticities of demand are used to identify the degree of substitutability or complementarity among goods. These elasticities often relate to the closeness of substitutes. Consider a per-unit cigarette tax designed to reduce tobacco consumption. Suppose that the cross-price elasticity between cigarettes and cigars is 0.5, whereas the cross-price elasticity between cigarettes and chewing tobacco is 5.0. On the basis of the values of the aforementioned cross-price elasticities, we would conclude that chewing tobacco and cigarettes are more closely related than cigarettes and cigars. The elasticities allow us to compare percentages, but the relative magnitudes of the changes in terms of percentages can be misleading when translated to quantities as the following example suggests.

Suppose that the quantity demanded of cigars is the equivalent of 1,000 pounds of tobacco, whereas the quantity demanded of chewing tobacco is the equivalent of 10 pounds of tobacco. Given the respective cross-price elasticities, if the price of cigarettes were to increase 10 percent, the quantity demanded of cigars would increase 50 pounds, whereas the quantity demanded of chewing tobacco would increase by only 5 pounds. When actual quantities are taken into account, the better substitute for cigarettes in terms of the equivalent quantity of tobacco is cigars rather than chewing tobacco.[1] The alternative measure introduced here, the diversion ratio, allows us to make this comparison.

Alternative measures for identifying substitutes (or complements) on the basis of actual quantities, emerged from the industrial organization literature, specifically the literature on the competitive effects of mergers (a focus of antitrust enforcement) (Shapiro 1996; Werden 1998). Werden (1998, 405) provides five measures for ranking substitutes on the basis of unit diversion or dollar diversion. The unit diversion

[1] A similar argument was articulated by Ault et al. (2005) in considering the use of cross-price effects to study the effectiveness of smokeless tobacco in smoking cessation.

ratio relates the increase in unit sales of substitute product *j* relative to the decrease in unit sales of product *i*. Alternatively, the dollar diversion ratio represents the increase in dollar sales of substitute j relative to the decrease in dollar sales of product *i*. Relatively little is known about diversion ratios outside of the fields of antitrust economics or industrial organization. In fact, diversion ratios typically are not even addressed in microeconomic textbooks.

Given the proliferation of product differentiation strategies in agricultural and food markets, stakeholders are keen to understand which products are substitutes for each other. To help stakeholders better coordinate their production and marketing decisions, analysts would need to know whether or not two or more substitutes are "equally close" to a given product, that is, whether the substitutes would experience the same change in quantity or dollar sales in response to a change in the price of the base product.

If impacts of quantity-wise movement among products are of interest, we suggest the use of diversion ratios. But if impacts of percentage changes in prices of various products are of interest, the concept of cross-price elasticities would be of greater utility. Together, diversion ratios and cross-price elasticities can be used to measure product substitutability/complementarity in demand analysis.

This articles presents the concept of diversion ratios and reviews the literature on applications of the ratios in applied economic analyses. It demonstrates that diversion ratios are a natural byproduct of the estimation of demand systems, describes certain characteristics of the ratios, and shows how, using an empirical example, the concept of the ratios can be taught in the classroom.

2 The Concept of Diversion Ratio

According to Werden (1998), the term *diversion ratio* appears to have been introduced by Shapiro (1996). But the idea and its relevance were discussed five years earlier by Willig (1991). Shapiro (1996) reported that the diversion ratio was used by antitrust enforcement agencies to analyze "unilateral effects" in mergers involving differentiated products, that is, the tendency of a horizontal merger to lead to higher prices simply by virtue of the fact the merger will eliminate the direct competition between the merging firms (even if all other firms in the market continue to compete independently). The diversion ratio concept currently is considered by the Department of Justice and the Federal Trade Commission in the United States, the European Commission, and the Competition Bureau in Canada.

Diversion ratios provide a perspective different from that of conventional cross-price elasticities on identifying substitutes or complements. The *unit diversion ratio* is the change in the quantity of one good attributed to a change in the quantity of another good. If a consumer buys one less unit of a good as a result of, say, an increase in the price of that good, *ceteris paribus*, to where would that consumption be diverted? Alternatively, what happens to the consumption of other goods as a result of this increase in price? It may be of strategic value to know the quantity-wise response of one good to a change in the quantity of another good.

Consider two goods, i and j. We want to determine the change of quantity of good j attributed to the change of quantity of good i, both measured in the same units (say, gallons or ounces). Mathematically, we can describe this relationship as follows:

$$DR_{ji} = \frac{\partial q_j}{\partial q_i} \tag{1}$$

where DR_{ji} refers to the diversion ratio of good j with respect to good i, and ∂q_j is the change in the quantity of good *j* and ∂q_i is the change in the quantity of good *i*.

Let us assume that the price of the *i*th good changes (i.e., ∂p_i). It is likely to affect both good i and good j. This relationship can be captured in equation (1) by rewriting it as follows:

$$DR_{ji} = \frac{\frac{\partial q_j}{\partial p_i}}{\frac{\partial q_i}{\partial p_i}}. \quad (2)$$

Multiplying both the numerator and denominator by p_i/q_j and upon further simplification, we obtain the following:

$$DR_{ji} = \frac{\frac{\partial q_j}{\partial p_i}\frac{p_i}{q_j}}{\frac{\partial q_i}{\partial p_i}\frac{p_i}{q_j}} = \frac{e_{ji}}{\frac{\partial q_i}{\partial p_i}\frac{p_i}{q_j}\frac{q_i}{q_i}} = \frac{e_{ji}}{e_{ii}}\frac{q_j}{q_i}. \quad (3)$$

On the basis of equation (3), the diversion ratio is a function of e_{ji}, which represents the uncompensated cross-price elasticity of demand for good *j* with respect to a change in the price of good *i*, e_{ii}, which represents the own-price elasticity of demand for good *i* and the ratio of the quantity of good *j* to the quantity of good *i*. Like own-price and cross-price elasticities, diversion ratios vary, empirically, from observation to observation.

Likewise, the *dollar diversion ratio*, defined as the change in the dollar sales of product *j* relative to a change in the dollar sales of product *i*, can be expressed mathematically as follows; $e_{ji}p_jq_j/e_{ii}p_iq_i$, where p_i is the price of product *i* and p_j is the price of product *j*. This metric can be expressed as $DR_{ji} * \frac{p_j}{p_i}$. In other words, the dollar diversion ratio describes where the dollar sales are diverted, as a result of a decrease in sales of one good due to, say, a public policy measure like taxes on sugar-sweetened beverages, for example.

Finally, the relative unit (or relative dollar) diversion ratio relates the increase in unit (or dollar) sales of substitute product *j* relative to the decrease in unit sales of base product *i* proportionate to their relative quantity or dollar-sales shares, as a result of a change in the price of the base product. To arrive at this measure, the unit diversion ratio (or the dollar diversion ratio) simply is multiplied by the share of product *i* relative to the share of product *j*.

3 Applications of Diversion Ratios from the Extant Literature

To illustrate the specific use of diversion ratios, we draw examples from the economic literature with respect to industrial organization (applications to antitrust issues), new product introductions, and taxation of sugar-sweetened beverages. According to Shapiro (1996), the diversion ratio between Brand A and Brand B is a key variable in determining post-merger market competitiveness, because this metric relates the change in the consumption of Brand B attributed to a change in consumption of Brand A.

To support this contention, consider a situation in which Brands A and B each have pre-merger prices of $100 and pre-merger sales of 1,000. Suppose that a 10 percent price increase by Brand A leads to a 25 percent reduction in units sold. As the price of Brand A rises, some customers will shift from Brand A to Brand B. Prior to the merger, these customers would be lost to the firm owning Brand A. Therefore, the number of sold Brand A units is now 750. Hence, the revenue pre-merger accruing to Brand A is now $82,500, down from $100,000, as a result of the 10 percent price increase.

Now consider a merger between brands A and B. After the merger, the firm owning Brand A now also owns Brand B and thus does not lose customers for Brand B. Suppose that the diversion ratio from Brand A to Brand B is 70 percent. Consequently, of the 250 units lost by Brand A due to the price increase, 70 percent, or 175 units, are diverted to Brand B. The merged entity would take into account the additional revenue earned by Brand B when considering the price increase from $100 to $110. Assuming that the price of Brand B also rises to $110, the diverted sales of 175 units generate a revenue stream of $19,250. Adding this amount to the pre-merger revenue of $82,500 yields the post-merger revenue of $101,750. Bottom line: the merger yields additional revenue of $1,750 above the pre-merger level as a consequence of the 10 percent price increase. In this example, a 10 percent price hike will generate more revenue after the merger only if the diversion ratio is at least 63.64 percent.

Werden (1998) described the use of own-price and cross-price demand elasticities and diversion ratios in the analysis of mergers and acquisitions (antitrust analysis), although he did not provide empirical examples. In 2010, the horizontal merger guidelines issued jointly by the U.S. Department of Justice and the U.S. Federal Trade Commission were the first to explicitly incorporate the concept of diversion ratios (U.S. Department of Justice 2010).

Abere et al. (2002) used the concept of diversion ratio (unit as well as dollar diversion ratio) to investigate ex-ante market competition analysis of the acquisition of Cadbury Schweppes' carbonated soft drinks by the Coca-Cola company in Canada. In that analysis, diversion ratios were used to identify the next-best substitute products, defined as the products that would account for the largest-volume loss as a result of a reduction in price competitiveness due to the proposed acquisition. Abere et al. (2002) generated diversion ratios using own-price and cross-price elasticities obtained from the Rotterdam and linear approximated almost ideal demand system (LA/AIDS) models, hence two diversion ratios for each beverage were considered. According to the calculated diversion ratios, the next-best substitute products for Cadbury Schweppes' carbonated soft drinks were fruit juices and fruit drinks (those with the largest diversion ratios).

Yuan et al. (2009) estimated cross-price elasticities as well as unit and dollar diversion ratios in assessing the demand for functional food products. They investigated potential cannibalization in the orange juice category resulting from introduction of a new functional orange juice product, Minute Maid Heart Wise. Would sales of conventional Minute Maid products be diminished as a result of the launch of the Minute Maid Heart Wise product? The analysis using unit and dollar diversion ratios revealed that introduction of Minute Maid Heart Wise would not cannibalize sales or volumes of existing Minute Maid orange juice products. However, sales and volumes of competing brands of Minute Maid products, namely Florida's Natural and Tropicana, would be diminished. This result is indicative of decreasing quantities of Florida's Natural and Tropicana brands as a result of the introduction of Minute Maid Heart Wise. In other words, according to the calculated diversion ratios, the next-best substitute products for Minute Maid Heart Wise were, in order, Tropicana and Florida's Natural. Additionally, the sum of all diversion ratios indicated that introduction of the phytosterol-enriched Minute Maid Heart Wise product increased volumes of all orange juice category products by 0.46 units. In other words, consumers now purchase more orange juice than they did before the introduction of Minute Maid Heart Wise.

Dharmasena and Capps (2012) used the concept of unit diversion ratios and dollar diversion ratios to shed light on where the consumer is diverted when a gallon of sugar-sweetened beverages (carbonated soft drinks, sports drinks, and fruit drinks) is removed from the consumption bundle as a result of a beverage tax.[2] Details of this study are presented in the "An Applied Example" below.

4 Diversion Ratios as a Natural Byproduct of the Estimation of Demand Systems

The use of demand systems applications is widespread in the economics literature. A survey of these systems was provided by Barnett and Serletis (2008). Popular demand systems include the almost ideal demand system (AIDS) (Deaton and Muellbauer 1980), direct or indirect translog models (Christensen and Lau 1975), the Rotterdam model (Barten 1964; Theil 1965), the Barten synthetic model (Barten 1993), the quadratic almost ideal demand system (QUAIDS) (Banks, Blundell, and Lewbel 1997), and the exact affine

[2] Taxes may not necessarily remove just one unit of sugar-sweetened beverages. One unit is a representative measure used for simplicity of explanation.

stone index (EASI) inverse Marshallian demand system (Lewbel and Pendakur 2009). The calculation of unit diversion ratios or dollar diversion ratios is a natural byproduct of the estimation of any demand system.[3] From equation (3), the unit diversion ratio is related to the ratio of the cross-price elasticity of good *j* with respect to the price of good *i* relative to the own-price elasticity of good *i*.

The principal product of demand systems is the estimation of the matrix of own-price and cross-price elasticities. If attention is centered on any column of the uncompensated own-price and cross-price elasticity matrix, the calculation of diversion ratios for that column is initiated by dividing any cross-price elasticity in that column by the corresponding own-price elasticity of that column. Subsequent multiplication of the ratio of the respective quantities yields the unit diversion ratio. Consequently, given the matrix of own-price and cross-price elasticities derived through the estimation of any demand system, the calculation of diversion ratios is a straightforward exercise. Once matrices of elasticities have been produced through the estimation of demand systems, diversion ratios can be calculated with simple arithmetic.

5 Characteristics of Diversion Ratios

We draw attention to several characteristics of diversion ratios. First, the diversion ratio for any good with respect to itself is 1. Second, for substitute products, the diversion ratio is *negative*, and for complementary goods, the diversion ratio is *positive*. Third, the sum of the diversion ratios in any given column may be zero, positive, or negative. In general, the sum of diversion ratios is not equal to zero. Finally, tests of significance of any diversion ratio may be based on the use of the Delta method, a method for approximating the variance/standard error of the diversion ratio. Bootstrapping methods also may be applicable in this capacity. Any diversion ratio corresponds to a nonlinear combination of estimated coefficients of the demand system, associated prices, and associated quantities. Consequently, the statistical distribution to be used in testing the significance of any diversion ratio rests on the use of a chi-squared distribution with one degree of freedom.

6 An Applied Example

We illustrate the identification of next-best substitutes using unit diversion ratios and dollar diversion ratios for 10 non-alcoholic beverages featured in the work by Dharmasena and Capps (2012). Specific categories of non-alcoholic beverages considered were isotonics (sports drinks), regular soft drinks (non-diet soft drinks), diet soft drinks, high-fat milk (whole and 2 percent milk), low-fat milk (1 percent and skim milk), fruit drinks, fruit juices, bottled water, coffee, and tea. Policymakers' interest is in knowing where the consumer would be diverted if a gallon of regular soft drinks were removed from the consumption bundle as a result of a tax on those drinks. The set of uncompensated elasticities gleaned from the use of the linear approximated quadratic almost ideal demand system model (LA/QUAIDS) is exhibited in Table 1.

Interest is centered on sugar-sweetened beverages, namely isotonics, regular soft drinks, and fruit drinks. To calculate the unit diversion ratios with respect to regular soft drinks, for example, we initially divide all elasticities in the regular soft drinks column in Table 1 by the own-price elasticity of regular soft drinks. Second, we multiply these ratios by the respective quantity ratios to obtain diversion ratios of all beverages with respect to regular soft drinks. Negative signs associated with the unit diversion ratios delineate the decrease (increase) in the quantity of one good due to a unit increase (decrease) in the quantity of another good, hence substitutability between goods. On the other hand, a positive sign associated with the unit diversion ratios describes the decrease (increase) in the quantity of one good due

[3] The Allen elasticity of substitution is also a natural byproduct of demand systems. This notion is given by e_{ij}^{*}/w_j, where e_{ij}^{*} is the compensated cross-price elasticity of demand and w_j is the budget share of the j^{th} good. This measure provides a symmetric substitution matrix.

Table 1. Estimated uncompensated own- and cross-price elasticities generated from the linear approximated quadratic almost ideal demand system model (LA/QUAIDS) estimated by Dharmasena and Capps (2012)[a]

	Isotonics	Regular soft drinks	Diet soft drinks	High-fat milk	Low-fat milk	Fruit drinks	Fruit juices	Bottled water	Coffee	Tea
Isotonics	**-3.8650**	-0.1216	2.2073	-0.8598	0.5235	**-2.4720**	**1.9803**	0.3722	1.0631	-0.0021
	(0.8227)	(1.3177)	(1.3857)	(0.8888)	(0.7879)	(0.7470)	(1.0876)	(0.7639)	(0.7736)	(0.4210)
	[0.0000]	[0.9268]	[0.1168]	[0.3375]	[0.5092]	**[0.0016]**	**[0.0740]**	[0.6279]	[0.1749]	[0.9960]
Regular soft drinks	-0.0088	**-2.2552**	**-0.6208**	0.0424	**0.2373**	**-0.1663**	**1.0338**	-0.0543	**0.2181**	0.0555
	(0.0609)	(0.2679)	(0.1916)	(0.1153)	(0.1005)	(0.0948)	(0.1683)	(0.1071)	(0.1151)	(0.0666)
	[0.8852]	**[0.0000]**	**[0.0020]**	[0.7146]	**[0.0218]**	**[0.0847]**	**[0.0000]**	[0.6143]	**[0.0632]**	[0.4083]
Diet soft drinks	0.1509	**-0.8550**	**-1.2721**	**0.3856**	-0.1722	**0.3726**	-0.0963	**0.2475**	-0.0051	-0.0121
	(0.0957)	(0.2821)	(0.3167)	(0.1569)	(0.1363)	(0.1312)	(0.1878)	(0.1321)	(0.1371)	(0.0752)
	[0.1205]	**[0.0037]**	**[0.0002]**	**[0.0171]**	[0.2117]	**[0.0063]**	[0.6101]	**[0.0661]**	[0.9707]	[0.8727]
High-fat milk	-0.0544	0.1964	**0.4359**	**-0.7591**	0.2989	**-0.2219**	**-0.5556**	0.0173	-0.0185	**-0.1452**
	(0.0595)	(0.1708)	(0.1542)	(0.2170)	(0.1971)	(0.0803)	(0.1253)	(0.0846)	(0.0902)	(0.0504)
	[0.3641]	[0.2549]	**[0.0065]**	**[0.0009]**	[0.1350]	**[0.0077]**	**[0.0000]**	[0.8388]	[0.8378]	**[0.0056]**
Low-fat milk	0.0558	**0.6358**	-0.2009	0.4435	**-0.9237**	-0.1448	**-0.4669**	-0.1537	-0.0209	-0.0793
	(0.0806)	(0.2263)	(0.2036)	(0.2996)	(0.2942)	(0.1004)	(0.1552)	(0.1038)	(0.1101)	(0.0597)
	[0.4916]	**[0.0068]**	[0.3279]	[0.1444]	**[0.0027]**	[0.1549]	**[0.0039]**	[0.1441]	[0.8501]	[0.1894]
Fruit drinks	**-0.2934**	-0.3659	**0.6436**	**-0.4501**	**-0.2044**	**-0.6892**	0.0786	**-0.3446**	**0.4709**	-0.0912
	(0.0888)	(0.2424)	(0.2269)	(0.1406)	(0.1154)	(0.1860)	(0.1977)	(0.1602)	(0.1812)	(0.0922)
	[0.0017]	[0.1368]	**[0.0063]**	**[0.0023]**	**[0.0821]**	**[0.0005]**	[0.6925]	**[0.0358]**	**[0.0119]**	[0.3270]
Fruit juices	**0.1069**	**1.2844**	-0.0141	**-0.4326**	**-0.2370**	0.0683	**-1.1731**	-0.0769	**-0.2526**	-0.0775
	(0.0585)	(0.2006)	(0.1494)	(0.0996)	(0.0808)	(0.0910)	(0.1889)	(0.1052)	(0.1103)	(0.0658)
	[0.0730]	**[0.0000]**	[0.9250]	**[0.0000]**	**[0.0049]**	[0.4559]	**[0.0000]**	[0.4681]	**[0.0258]**	[0.2437]
Bottled water	0.0566	0.0318	**0.5864**	0.0721	-0.1784	**-0.3424**	-0.1532	**-0.7540**	-0.0455	0.1965
	(0.1027)	(0.3143)	(0.2603)	(0.1677)	(0.1337)	(0.1840)	(0.2606)	(0.2899)	(0.2144)	(0.1282)
	[0.5842]	[0.9199]	**[0.0282]**	[0.6687]	[0.1876]	**[0.0680]**	[0.5589]	**[0.0119]**	[0.8329]	[0.1310]
Coffee	0.1203	**0.6977**	0.0962	0.0166	0.0128	**0.4856**	**-0.4584**	-0.0312	**-1.6459**	**0.2442**
	(0.0839)	(0.2743)	(0.2188)	(0.1444)	(0.1157)	(0.1683)	(0.2214)	(0.1737)	(0.2456)	(0.1079)
	[0.1571]	**[0.0138]**	[0.6620]	[0.9091]	[0.9120]	**[0.0055]**	**[0.0431]**	[0.8580]	**[0.0000]**	**[0.0274]**
Tea	0.0019	0.3359	0.0117	**-0.4200**	-0.1524	-0.1192	-0.2967	0.2448	**0.3893**	**-0.9104**
	(0.0784)	(0.2713)	(0.2067)	(0.1385)	(0.1072)	(0.1462)	(0.2244)	(0.1771)	(0.1847)	(0.1540)
	[0.9804]	[0.2207]	[0.9552]	**[0.0037]**	[0.1607]	[0.4184]	[0.1915]	[0.1724]	**[0.0395]**	**[0.0000]**

Source: Dharmasena and Capps (2012).

[a] Estimated elasticities in bold font indicate statistical significance at the 0.10 level. Standard errors are shown in parentheses, and p-values are shown in square brackets.

to a unit decrease (increase) in the quantity of another good, hence complementarity between goods. Table 2 exhibits the calculated unit diversion ratios associated with the respective non-alcoholic beverage categories, and it includes calculated standard errors and *p*-values.

Let us assume the consumer is responding to the proposed tax on sugar-sweetened beverages by consuming fewer regular soft drinks. For every gallon of regular soft drinks taken away from the consumer, consumption of low-fat milk would increase by 0.11 gallons; fruit juices, by 0.29 gallons; and coffee, by 0.32 gallons. Consumption of diet soft drinks would decrease by 0.26 gallons. If, as a result of the tax, the consumption of isotonics were reduced by a gallon, the consumption of fruit drinks would decrease by 0.81 gallons. However, the consumption of fruit juices would increase by 0.50 gallons. A tax-induced decrease in the consumption of a gallon of fruit drinks would reduce the consumption of isotonics by 0.34 gallons; high-fat milk, by 0.66 gallons; and bottled water, by 0.94 gallons. On the other hand, a decrease in the consumption of fruit drinks would increase consumption of diet soft drinks and coffee by 1.26 gallons and 2.52 gallons, respectively.

The tax policy on non-alcoholic beverages is not a zero-sum game, because the calculated diversion ratios within any column do not sum to zero (see the column sum estimate reported in Table 2). The tax on regular soft drinks decreases the consumption of non-alcoholic beverages by 0.47 gallons in total, all other factors invariant. The tax on isotonics increases the consumption of non-alcoholic beverages by 0.97 gallons in total, whereas the tax on fruit drinks decreases the consumption of non-alcoholic beverages by 0.34 gallons in total, *ceteris paribus*.

Table 3 presents the calculated dollar diversion ratios for the respective non-alcoholic beverage categories. As a result of a tax on sugar-sweetened beverages, every dollar decrease in sales of regular soft drinks would increase sales of high-fat milk by 6 cents; low-fat milk, by 13 cents; fruit juices, by 51 cents; coffee, by 14 cents; and tea, by 3 cents. Consumers would spend 91 cents more on diet soft drinks, 22 cents more on fruit juices, and 80 cents more on coffee for every dollar of spending diverted from fruit drinks. Further, for every dollar diverted from isotonics as a result of tax on sugar-sweetened beverages, consumers would spend 52 cents more on diet soft drinks, 13 cents more on low-fat milk, 48 cents more on fruit juices, 28 cents more on coffee, and 9 cents more on bottled water.

To clarify further, for every dollar diverted from isotonics, consumers would spend a total of $1.51 more on diet soft drinks ($0.52), low-fat milk ($0.13), fruit juices ($0.48), bottled water ($0.09), and coffee ($0.28), see Table 3). However, consumers would spend a total of $1.83 less on isotonics ($1.00), regular soft drinks ($0.04), high-fat milk ($0.19), and fruit drinks ($0.60). Consequently, consumers would spend 32 cents less on all non-alcoholic beverages as a result of a tax on isotonics (see the column total for isotonics in Table 3). Similarly, for every dollar diverted from regular soft drinks as a result of a tax, consumers would spend 45 cents less on all beverages (see the column total for regular soft drinks in Table 3). Similarly, for every dollar diverted from fruit drinks as a result of a tax, consumers would spend $1.38 less on all beverages (see the column total for fruit drinks in Table 3).

Table 5 exhibits the next-best substitutes for the 10 respective beverage products based on compensated cross-price elasticities and unit diversion ratios. For five of these products, the next-best substitutes identified by compensated cross-price elasticities (shown in Table 4) differ from those identified by unit diversion ratios. For diet soft drinks, the next-best substitute is high-fat milk according to compensated cross-price elasticities but bottled water according to unit diversion ratios. For isotonics and fruit drinks, the next-best substitute is diet soft drinks according to cross-price elasticities but coffee according to unit diversion ratios. For regular soft drinks, the next-best substitute is fruit juices according to compensated cross-price elasticities but coffee according to unit diversion ratios. Finally, the next-best substitute for tea is regular soft drinks according to cross-price elasticities but coffee according to unit diversion ratios.

Interestingly, compensated cross-price elasticities and unit diversion ratios identify the same next-best substitutes for high-fat milk, low-fat milk, fruit juices, bottled water, and coffee. For high-fat.

Table 2. Unit diversion ratios calculated from the LA/QUAIDS model estimated by Dharmasena and Capps (2012)[a]

	Isotonics	Regular soft drinks	Diet soft drinks	High-fat milk	Low-fat milk	Fruit drinks	Fruit juices	Bottled water	Coffee	Tea
Isotonics	1	0.0015	-0.0699	0.0522	-0.0390	**0.3379**	**-0.0926**	-0.0246	-0.0170	0.0002
		(0.0161)	(0.0423)	(0.0545)	(0.0575)	(0.1466)	(0.0469)	(0.0544)	(0.0120)	(0.0316)
		[0.9267]	[0.1040]	[0.3419]	[0.5004]	**[0.0249]**	**[0.0534]**	[0.6526]	[0.1626]	[0.9960]
Regular soft drinks	0.0829	1	**0.7136**	-0.0935	**-0.6417**	0.8252	**-1.7537**	0.1302	**-0.1269**	-0.1509
	(0.5697)		(0.3330)	(0.2531)	(0.3128)	(0.5469)	(0.2669)	(0.2744)	(0.0667)	(0.1760)
	[0.8848]		**[0.0365]**	[0.7133]	**[0.0449]**	[0.1370]	**[0.0000]**	[0.6369]	**[0.0622]**	[0.3949]
Diet soft drinks	-0.9691	**0.2593**	1	**-0.5816**	0.3185	**-1.2641**	0.1117	**-0.4062**	0.0020	0.0225
	(0.5833)	(0.0911)		(0.2615)	(0.2702)	(0.4503)	(0.2227)	(0.2112)	(0.0546)	(0.1399)
	[0.1022]	**[0.0062]**		**[0.0302]**	[0.2434]	**[0.0069]**	[0.6178]	**[0.0595]**	[0.9707]	[0.8727]
High-fat milk	0.3053	-0.0520	**-0.2993**	1	**-0.4829**	**0.6576**	**0.5630**	-0.0248	0.0064	**0.2361**
	(0.3338)	(0.0432)	(0.1120)		(0.1955)	(0.3154)	(0.1561)	(0.1202)	(0.0313)	(0.0904)
	[0.3643]	[0.2341]	**[0.0098]**		**[0.0166]**	**[0.0416]**	**[0.0007]**	[0.8373]	[0.8377]	**[0.0116]**
Low-fat milk	-0.2098	**-0.1129**	0.0924	**-0.3915**	1	0.2876	**0.3170**	0.1477	0.0049	0.0864
	(0.2935)	(0.0356)	(0.0977)	(0.1832)		(0.2201)	(0.1000)	(0.1294)	(0.0256)	(0.0668)
	[0.4778]	**[0.0025]**	[0.3479]	**[0.0370]**		[0.1967]	**[0.0025]**	[0.2588]	[0.8496]	[0.2011]
Fruit drinks	**0.8058**	0.0475	**-0.2164**	**0.2904**	0.1617	1	-0.0390	**0.2419**	**-0.0801**	0.0726
	(0.3311)	(0.0325)	(0.0739)	(0.1310)	(0.0999)		(0.0979)	(0.1124)	(0.0254)	(0.0716)
	[0.0182]	[0.1494]	**[0.0049]**	[0.0308]	[0.1114]		[0.6919]	**[0.0357]**	**[0.0025]**	[0.3150]
Fruit juices	**-0.5047**	**-0.2862**	0.0082	**0.4794**	**0.3222**	-0.1703	1	0.0927	**0.0738**	0.1059
	(0.2529)	(0.0370)	(0.0865)	(0.1856)	(0.1398)	(0.2275)		(0.1423)	(0.0335)	(0.0977)
	[0.0508]	**[0.0000]**	[0.9252]	**[0.0124]**	**[0.0249]**	[0.4573]		[0.5173]	**[0.0315]**	[0.2829]
Bottled water	-0.2935	-0.0078	**-0.3725**	-0.0879	0.2666	**0.9387**	0.1437	1	0.0146	-0.2956
	(0.5608)	(0.0769)	(0.1613)	(0.2064)	(0.2281)	(0.4835)	(0.2525)		(0.0696)	(0.2037)
	[0.6028]	[0.9197]	**[0.0247]**	[0.6718]	[0.2474]	**[0.0572]**	[0.5716]		[0.8345]	[0.1524]
Coffee	-1.1799	**-0.3231**	-0.1154	-0.0382	-0.0363	**-2.5159**	**0.8120**	0.0782	1	**-0.6941**
	(0.8338)	(0.1234)	(0.2600)	(0.3332)	(0.3278)	(0.8262)	(0.4140)	(0.4456)		(0.2887)
	[0.1626]	**[0.0114]**	[0.6588]	[0.9092]	[0.9123]	**[0.0035]**	**[0.0548]**	[0.8613]		**[0.0195]**
Tea	-0.0073	-0.0601	-0.0054	**0.3739**	0.1664	0.2387	0.2031	-0.2372	**-0.0914**	1
	(0.2971)	(0.0471)	(0.0959)	(0.1516)	(0.1356)	(0.2852)	(0.1667)	(0.2016)	(0.0411)	
	[0.9804]	[0.2075]	[0.9552]	**[0.0167]**	[0.2251]	[0.4061]	[0.2280]	[0.2445]	**[0.0303]**	
Column Sum	-0.9699	**0.4663**	**0.7353**	**1.0033**	**1.0355**	0.3354	**1.2652**	**0.9980**	**0.7863**	**0.3831**
	(0.6066)	(0.1016)	(0.2632)	(0.3593)	(0.4110)	(0.5861)	(0.4361)	(0.4095)	(0.0571)	(0.2026)
	[0.1154]	**[0.0000]**	**[0.0071]**	**[0.0071]**	**[0.0146]**	[0.5693]	**[0.0053]**	**[0.0180]**	**[0.0001]**	**[0.0638]**

Source: Dharmasena and Capps (2012).

[a] Diversion ratios in bold font indicate statistical significance at the 0.10 level. Standard errors are shown in parentheses, and p-values are shown in brackets.

Table 3. Dollar diversion ratios calculated from the LA/QUAIDS model

	Isotonics	Regular soft drinks	Diet soft drinks	High-fat milk	Low-fat milk	Fruit drinks	Fruit juices	Bottled water	Coffee	Tea
Isotonics	1.0000	0.0027	-0.1292	0.0833	-0.0626	0.4512	-0.0963	-0.0805	-0.0712	0.0005
Regular soft drinks	0.0449	1.0000	0.7136	-0.0806	-0.5570	0.5962	-0.9878	0.2304	-0.2871	-0.2670
Diet soft drinks	-0.5244	0.2593	1.0000	-0.5016	0.2765	-0.9133	0.0629	-0.7187	0.0046	0.0398
High-fat milk	0.1915	-0.0603	-0.3470	1.0000	-0.4859	0.5509	0.3677	-0.0509	0.0169	0.4843
Low-fat milk	-0.1308	-0.1300	0.1065	-0.3890	1.0000	0.2394	0.2057	0.3010	0.0127	0.1761
Fruit drinks	0.6035	0.0657	-0.2995	0.3466	0.1942	1.0000	-0.0304	0.5923	-0.2509	0.1777
Fruit juices	-0.4848	-0.5081	0.0145	0.7342	0.4964	-0.2184	1.0000	0.2912	0.2966	0.3328
Bottled water	-0.0898	-0.0044	-0.2105	-0.0429	0.1308	0.3834	0.0457	1.0000	0.0187	-0.2956
Coffee	-0.2822	-0.1428	-0.0510	-0.0145	-0.0139	-0.8035	0.2022	0.0612	1.0000	-0.5428
Tea	-0.0022	-0.0340	-0.0031	0.1823	0.0816	0.0975	0.0647	-0.2371	-0.1169	1.0000
Net column sum	0.3257	0.4481				1.3834				

Source: Calculated by the authors on the basis of Dharmasena and Capps (2012).

Table 4. Estimated compensated own- and cross-price elasticities generated from the linear approximated quadratic almost ideal demand system model (LA/QUAIDS)[a]

	Isotonics	Regular soft drinks	Diet soft drinks	High-fat milk	Low-fat milk	Fruit drinks	Fruit juices	Bottled water	Coffee	Tea
Isotonics	**-3.8544**	0.1027	**2.3611**	-0.7024	0.6280	**-2.3827**	**2.1822**	0.4497	1.1617	0.0543
	(0.0000)	(0.9368)	(0.0950)	(0.4302)	(0.4331)	(0.0024)	(0.0553)	(0.5517)	(0.1421)	(0.8969)
Regular soft drinks	0.0048	**-1.9652**	**-0.4219**	**0.2459**	**0.3724**	-0.0509	**1.2950**	0.0460	**0.3457**	**0.1283**
	(0.9368)	(0.0000)	(0.0295)	(0.0388)	(0.0006)	(0.5887)	(0.0000)	(0.6645)	(0.0043)	(0.0568)
Diet soft drinks	**0.1622**	**-0.6151**	**-1.1075**	**0.5539**	-0.0604	**0.4681**	0.1198	**0.3304**	0.1005	0.0482
	(0.0950)	(0.0295)	(0.0009)	(0.0008)	(0.6625)	(0.0007)	(0.5361)	(0.0140)	(0.4699)	(0.5196)
High-fat milk	-0.0472	**0.3504**	**0.5415**	**-0.6510**	**0.3707**	**-0.1607**	**-0.4169**	0.0705	0.0492	**-0.1065**
	(0.4302)	(0.0388)	(0.0008)	(0.0039)	(0.0667)	(0.0489)	(0.0020)	(0.3996)	(0.5902)	(0.0369)
Low-fat milk	0.0635	**0.7992**	-0.0889	**0.5581**	**-0.8476**	-0.0798	**-0.3198**	-0.0973	0.0509	-0.0383
	(0.4331)	(0.0006)	(0.6625)	(0.0667)	(0.0059)	(0.4277)	(0.0497)	(0.3423)	(0.6486)	(0.5186)
Fruit drinks	**-0.2822**	-0.1280	**0.8068**	**-0.2833**	-0.0935	**-0.5945**	0.2928	-0.2624	**0.5755**	-0.0314
	(0.0024)	(0.5887)	(0.0007)	(0.0489)	(0.4277)	(0.0022)	(0.1553)	(0.1012)	(0.0027)	(0.7316)
Fruit juices	**0.1142**	**1.4380**	0.0912	**-0.3248**	**-0.1655**	0.1294	**-1.0348**	-0.0238	-0.1850	-0.0389
	(0.0553)	(0.0000)	(0.5361)	(0.0020)	(0.0497)	(0.1553)	(0.0000)	(0.8183)	(0.1015)	(0.5503)
Bottled water	0.0613	0.1330	**0.6558**	0.1432	-0.1312	-0.3021	-0.0621	**-0.7190**	-0.0009	**0.2220**
	(0.5517)	(0.6645)	(0.0140)	(0.3996)	(0.3423)	(0.1012)	(0.8183)	(0.0148)	(0.9966)	(0.0852)
Coffee	0.1245	**0.7860**	0.1567	0.0785	0.0540	**0.5207**	-0.3789	-0.0007	**-1.6071**	**0.2664**
	(0.1421)	(0.0043)	(0.4699)	(0.5902)	(0.6486)	(0.0027)	(0.1015)	(0.9966)	(0.0000)	(0.0153)
Tea	0.0102	**0.5107**	0.1315	**-0.2974**	-0.0710	-0.0497	-0.1393	**0.3052**	**0.4662**	**-0.8665**
	(0.8969)	(0.0568)	(0.5196)	(0.0369)	(0.5186)	(0.7316)	(0.5503)	(0.0852)	(0.0153)	(0.0000)

Source: Dharmasena and Capps (2012).

[a] Estimated elasticities in bold font indicate statistical significance at the 0.10 level. Standard errors are shown in parentheses.

Table 5. Identification of next-best substitutes calculated from compensated cross-price elasticities and quantity diversion ratios

Beverage category	Cross-price elasticity and diversion ratio	Isotonics	Regular soft drinks	Diet soft drinks	High-fat milk	Low-fat milk	Fruit drinks	Fruit juices	Bottled water	Coffee	Tea
Isotonics	Cross-price elasticities	-		x							
	Unit diversion ratios	-								x	
Regular soft drinks	Cross-price elasticities		-					x			
	Unit diversion ratios		-							x	
Diet soft drinks	Cross-price elasticities			-	x						
	Unit diversion ratios			-					x		
High-fat milk	Cross-price elasticities			x	-						
	Unit diversion ratios			x	-						
Low-fat milk	Cross-price elasticities		x			-					
	Unit diversion ratios		x			-					
Fruit drinks	Cross-price elasticities			x			-				
	Unit diversion ratios						-			x	
Fruit juices	Cross-price elasticities		x					-			
	Unit diversion ratios		x					-			
Bottled water	Cross-price elasticities			x					-		
	Unit diversion ratios			x					-		
Coffee	Cross-price elasticities		x							-	
	Unit diversion ratios		x							-	
Tea	Cross-price elasticities		x								-
	Unit diversion ratios									x	-

Source: Compiled by the authors on the basis of Dharmasena and Capps (2012). All the cross-price elasticities are compensated elasticities.

milk and for bottled water, the next-best substitute is diet soft drinks. For low-fat milk, fruit juices, and coffee, the next-best substitute is regular soft drinks.

7 Teaching Discussion

At what level of instruction and in what courses should the concept of diversion ratios be introduced? We advocate the teaching of diversion ratios in graduate-level microeconomics and industrial organization (IO) courses. The concept of cross-price elasticities in undergraduate classes typically poses problems for students. Consequently, introducing the concept of diversion ratios in undergraduate teaching programs is not recommended.

We have successfully taught the concept of diversion ratios in a graduate-level applied demand analysis class addressing estimation of demand systems and identification of product substitutes or complements. As noted above, calculation of unit diversion ratios or dollar diversion ratios is a natural byproduct of the estimation of any demand system, and use of diversion ratios adds measurably to discussion of unequivocal product substitutes or complements, an important topic given the proliferation of product differentiation strategies in agricultural and food markets. Given adoption of the diversion ratio concept by the Department of Justice and the Federal Trade Commission in the United States, the Competition Bureau in Canada, and the European Commission, teaching of the concept in any graduate-level IO course will enhance the marketability of graduate students, especially those seeking opportunities with these government agencies.

8 Conclusion

Diversion ratios are typically applied in industrial organization contexts and cross-price elasticities, in demand analyses. Use of diversion ratios in demand analysis has received little attention.

Unit diversion ratios and dollar diversion ratios can be calculated from the use of any uncompensated own-price and cross-price elasticity matrix derived from demand systems. Using ten beverage categories, we compared next-best substitutes identified on the basis of compensated cross-price elasticities and on the basis of unit diversion ratios. Our analysis shows that to understand the impacts of percentage changes in prices of various products, we ought to use conventional cross-price elasticities. However, to understand the impacts of quantity-wise movement among products, we ought to use diversion ratios.

We advocate increased use of the diversion ratio concept, along with Allen elasticities of substitution, to measure product substitutability/complementarity. Because calculation of diversion ratios is a natural byproduct of the application of demand systems, introduction of the diversion ratio concept in graduate-level microeconomics courses would enhance experiential learning. Given its adoption in the Horizontal Merger Guidelines in 2010, the concept should be taught in any IO graduate-level course.

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