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ARTICLE

When Can Benefit–Cost Analyses Ignore Secondary Markets?

Matthew J. Kotchen[1,2,*] and Arik Levinson[2,3]

[1]Yale University, New Haven, CT, USA
[2]National Bureau of Economic Research, Cambridge, MA, USA
[3]Georgetown University, Washington, DC, USA
*Corresponding author: e-mail: matthew.kotchen@yale.edu

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Abstract
We make four main contributions in this paper related to the theory and practice of benefit–cost analysis (BCA). First, we show that most BCAs of policy interventions do not consider the welfare consequences in secondary markets, where goods or services can be complements or substitutes to those in the directly regulated markets. Second, we provide a general theoretical analysis for examining the sign of welfare effects in secondary markets, showing how the results depend on the welfare measure of interest and on whether the goods are complements or substitutes. We conclude that the welfare effects in secondary markets will typically be negative in cases most relevant for policy analysis. Third, we develop a straightforward tool that BCA analysts can use to evaluate the potential magnitude of secondary-market effects in particular applications. The tool itself highlights how secondary markets are likely to be relatively small in most circumstances. Finally, we illustrate use of the tool in different applications that provide further evidence that secondary-market effects are likely to be small.

1. Introduction

Benefit–cost analyses (BCAs) are used around the world by governments and organizations to advocate for and evaluate policy. In the USA, BCAs have been required by executive order since 1981.[1] In principle, a good BCA should consider all of the benefits and costs resulting from a proposed policy change, including those in secondary markets that are not directly affected by the policy being evaluated. For example, an analysis of a proposed tax on sugary drinks should consider the effects on substitutes, such as drinks with less sugar or foods with more. A BCA considering a limitation on greenhouse-gas emissions from trucks

[1] An executive order during the Reagan Administration (EO 12291) established a requirement for regulatory actions whereby “the potential benefits to society for the regulation outweigh the costs to society.” To measure progress, the order required agencies considering major rule changes to produce regulatory impact analyses, effectively BCAs in most cases.

should assess what happens in the market for alternative shipping modes. And an analysis of health warning labels for cigarettes or seafood with mercury should account for what people do instead of smoking or eating fish.

In practice, however, BCAs rarely consider effects in markets other than those directly targeted by the regulations. The omission is unsurprising. Assessing secondary costs and benefits is difficult. Perhaps more surprising is that leading BCA textbooks offering practical guidance implicitly sanction the neglect of secondary markets (e.g., Gramlich, 1997; Boardman *et al.,* 2018). The rationale is based on the claim that BCA analysts will typically estimate something close to general equilibrium demand curves in primary markets, either intentionally or not, and those will account for secondary markets' effects. We show that claim does not generally hold, however, and this means that secondary-market effects remain a missing component of most BCAs.

The question of how to treat secondary markets for measuring changes in economic welfare has long been a subject of research. We focus in this paper on one particular set of secondary markets, where primary and secondary markets are linked though consumer behavior. That is, a primary market is subject to some form of regulation that affects its price, and other markets may be affected because the goods or services are complements or substitutes in consumption. We also limit our analysis to secondary markets that are undistorted by market power or externalities. Early work on this issue concentrated on cases with preexisting distortions in secondary markets, which the primary regulation either ameliorated or exacerbated (Harberger, 1964, 1971). It was subsequently generalized by Just and Hueth (1979) and Just *et al.* (1982) to the case we examine here, where secondary markets are undistorted.

The basic idea is that correct and complete welfare measures can be obtained by using a measure of surplus in the primary market alone if the demand curves used in the primary market account for price changes in secondary markets, that is, general equilibrium adjustments. With this approach, demand curves used for welfare measurement in the primary market are not textbook, all-else-equal demand curves. In particular, they do not hold constant the prices in other markets. Instead, the general equilibrium demand curves trace out the quantities of supply and demand in the primary market assuming equilibrium conditions hold across all markets. Thurman (1993) provides a relatively straightforward proof of the fundamental result and shows how complications arise with the possibility of market interactions through demand and supply simultaneously.

The value of general equilibrium welfare measurement stems from the way that researchers can examine a single market subject to a policy intervention to evaluate the benefits and costs across all affected markets. It provides the basis for analyses that carry out BCAs using general equilibrium models and focus on single-market effects. It has also influenced key guidance on how to undertake partial equilibrium analysis to estimate overall welfare effects inclusive of primary and secondary markets. Gramlich (1997) recommends that analysts ignore secondary markets and instead use computable general equilibrium (CGE) models to calculate general equilibrium demand curves in primary markets. Boardman *et al.* (2018) claim that ignoring secondary-market effects is justifiable, because typical BCAs estimate demand in primary markets by using price and quantity combinations before and after the regulatory change being analyzed. And because those changes include the effects of any price changes in secondary markets, they provide a close approximation to the general equilibrium approach for taking account of secondary-market effects, indirectly and perhaps even unintentionally. As a consequence, something close to conventional wisdom is that BCAs need not directly examine secondary markets.

An issue we highlight in this paper is that the rationale underlying this conventional wisdom does not typically apply. We show that BCAs conducted in a variety of settings do in fact ignore secondary markets, but they do not use CGE models or before-and-after prices to estimate something that approximates general equilibrium demand in primary markets. Our evidence starts with studies in three particular areas: taxes on sugary drinks, pollution emissions standards for trucks, and product warning labels. In addition, we review the BCAs contained in 56 regulatory impact analyses (RIAs) for major Clean Air Act (CAA) rules issued by U.S. regulatory agencies since 1997. With rare exceptions, these ignore secondary markets and fail to estimate general equilibrium demand in the primary market. The result is that secondary-market welfare effects are missing from the net benefit calculation of most BCAs.

A second contribution of this paper, mostly detailed in an Supplementary Material but summarized in Section 4, is a comprehensive analysis of when ignoring secondary markets will result in an over- or under-estimate of net benefits. When the relevant measure of consumer welfare is equivalent variation (EV) or consumer surplus (CS), we show why the welfare effects in the secondary market are always negative. This is true regardless of whether the goods are substitutes or complements, normal or inferior, or whether the regulatory effect increases or decreases prices in the primary market. If we assume that the good in the secondary market is normal, then the same result continues to hold so long as y is a substitute for x. If, however, y is a complement, then different outcomes are possible. Together, these results generalize the standard textbook result for the sign of secondary-market welfare effects to account for income effects. They also provide evidence that the net welfare effects in secondary markets are likely to be negative in cases most relevant for policy analysis – that is, in cases where the income effects are small or the secondary-market good is a substitute.

As a third contribution, we develop a simple tool that BCA analysts can use to assess the likely magnitude of secondary-market effects. The tool relies on a few straightforward approximations typical of most BCAs, such as linear supply and demand and welfare measures based on CS, which are close approximations when income effects are relatively small. And it requires knowing a few basic parameters: simplified demand and cross-price elasticities, and relative market sizes. We then apply the tool to illustrate its usefulness, showing two instances where secondary-market effects for BCAs are small in practice and why.

The first application is a tax on sugary drinks in Mexico, where the secondary good is milk, a substitute. The second application is a tax on residential heating oil in the USA, and the substitute is natural gas. In both cases, we show that for actual parameter estimates, the error of simply ignoring secondary markets is quite small. It is smaller even than the likely error from estimating key parameters in the primary market, such as the own-price elasticity of demand. These examples demonstrate how ignoring secondary-market effects might be defensible in practice, but not for the reasons advocated in leading BCA textbooks.

Our contribution is to render all of this as intuitively as possibly, using straightforward graphical analysis accessible to most BCA practitioners, and to provide numerical examples based on existing analyses of actual or proposed policies. In doing so, we simplify more detailed treatments of related questions in the literature. As noted previously, Just *et al.* (1982) describe how the use of general equilibrium demand curves in primary markets can

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account for secondary-market welfare effects. Bullock (1993) proves the result formally. Brännlund and Kriström (1996) describe rules of thumb for when partial equilibrium analyses capture upstream and downstream general equilibrium effects. Carbone and Smith (2013) add environmental secondary benefits. Johansson and Kriström (2019) consider an application for renewable energy subsidies. Johansson (2021) offers a version of Bullock (1993) with an application for high-speed rail. de Rus (2021) considers secondary markets with market distortions like taxes or externalities, but where prices do not change. Our analysis applies to undistorted secondary markets where prices do change.

We begin in the next section with some preliminaries. Drawing entirely on a graphical analysis, we replicate how BCA textbooks treat undistorted, secondary-market effects. Then in Section 3, we report the results of a selected literature review showing that rarely do real-world BCAs follow the textbook guidance. They almost always ignore secondary markets without using general equilibrium demand (or approximations thereof) in primary markets. In Section 4, we provide a more general analysis showing that the signs of welfare effects in secondary markets depend on the welfare measure of interest and on whether the goods are complements or substitutes. In Section 5, we develop our simple tool for assessing the magnitude of secondary-market effects, which also allows us to quantitatively evaluate the textbook guidance for omitting them and to demonstrate why secondary effects are likely to be small in theory. In Section 6, we apply our simple tool to the two cases, taxes on sugary drinks and heating oil, to illustrate how secondary-market effects are likely to be relatively small in practice. Section 7 concludes with a summary and policy implications.

2. Preliminaries

To begin providing an organizing framework, we label the primary market x and the secondary market y. The overall change in social welfare from a policy intervention, denoted ΔSW, can be written as

$$\Delta SW = \Delta SW_x + \Delta SW_{\text{nonmarket}} + \Delta SW_y \tag{1}$$

where ΔSW_x is the primary-market welfare effect, and $\Delta SW_{\text{nonmarket}}$ is the non-market welfare effect that the policy is designed to address. These first two terms are the typical focus of BCAs.[2] The third term ΔSW_y represents the welfare effect in a secondary market. How does the omission of ΔSW_y affect the qualitative and quantitative conclusions of a BCA that focuses on only the first two terms in (1)? Answering this question, both in theory and practice, is a central aim of this paper, and we begin with an overview of the simplest textbook approach for understanding secondary-market effects and justifying their omission.

2.1. Constant marginal costs in secondary markets

The simplest case to consider is one where marginal costs are constant in both the primary and secondary markets, which we treat as equivalent to perfectly elastic supply for both x

[2] Think of energy efficiency standards for buildings, designed to improve local air quality, or subsidies for electric vehicles, designed to slow climate change. In both cases, BCAs weigh costs in the regulated primary market against the non-market benefits the regulation is designed to achieve.

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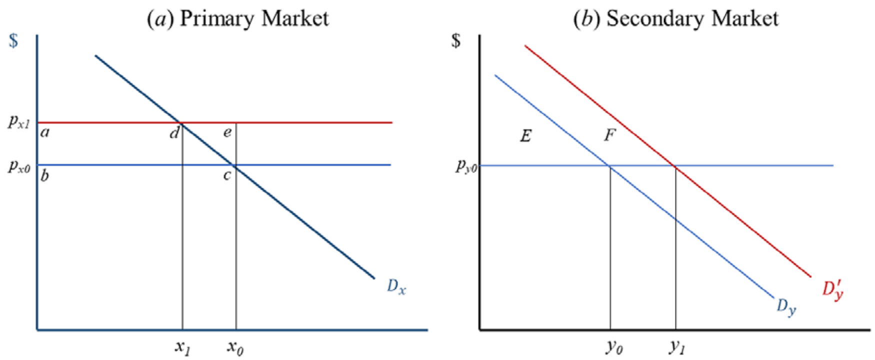

Figure 1. *Perfectly elastic supply in the secondary market. Both the primary and secondary markets have a perfectly elastic supply. The price in the primary market* (p_x) *rises, there are no market failures, no income effects, and the two goods are substitutes.*

and *y*.[3] We also assume initially no income effects on consumer demand, so we can assess consumer welfare using the standard measure of CS.

The first policy that we consider is one that increases the marginal cost of *x* from p_{x0} to p_{x1}, as depicted in Figure 1. CS in the primary market, CS_x, decreases by the area *abcd* on the left side of Figure 1, and that is the social cost of the policy in the primary market, recognizable to every Econ 101 student.[4] Assuming the two goods are substitutes, demand for *y* will shift out from D_y to D_y' on the right side of Figure 1. Perfectly elastic supply means there is no change in producer surplus in the secondary market, which is always zero.

At first glance, it appears as though CS in the secondary market CS_y increases, from area *E* to area *EF*. That is wrong, however, as noted by both Gramlich (1997) and Boardman *et al.* (2018). For intuition, suppose the primary market is coffee and the secondary-market tea. The coffee price increase causes the demand for tea to shift right from D_y to D_y'. But the coffee price change does not make tea consumers better off. The welfare effect of the coffee price change, and the fact that some coffee drinkers will switch to tea, is fully captured by the downward sloping coffee demand D_x and the loss of CS_x equal to *abcd*. That is, the marginal willingness to pay along D_x reflects the marginal utility of consuming coffee net of adjustments to the consumption of substitutes like tea. Hence, area *F* in Figure 1 does not count as a gain in surplus.

This simple illustration shows that if marginal costs are flat in the secondary market, a policy that affects price in the primary market has no effect on the secondary market's price, producer surplus, or consumer welfare. The observation is even more clear when considering compensated measures of consumer welfare, which we describe in Section 4 when generalizing the analysis to account for the possibility of income effects.

Although Figure 1 depicts the case where the price of the primary good increases and the secondary good is a substitute, the same results hold for a price decrease or for goods that are

[3] The results in this section do not rely on constant marginal costs in the primary market, but we assume that condition to focus attention on the secondary market.

[4] Of course, if there were an externality being corrected equal to the difference in marginal costs, that loss of CS would be more than offset by a decrease in external costs $\Delta SW_{nonmarket} = abce$, for a net gain of *cde*, the original deadweight loss from the externality.

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complements.[5] The key takeaway is that with perfectly elastic supply in the secondary market, BCAs can ignore secondary-market effects with no consequence.

2.2. Increasing marginal costs in secondary markets

If marginal cost (i.e., supply) is increasing in the secondary market, then the change in p_x causes a change in p_y, with consequences for producer and CS in the secondary market. Figure 2 depicts the situation, continuing to assume the case of a policy that increases price in the primary market and where the goods are substitutes. The primary market starts the same as Figure 1. The policy increases p_x and decreases CS_x by area *abcd.* But now the shift of demand in the secondary market from D_y to D_y' causes a price increase from p_{y0} to p_{y1}.

What, then, are the welfare effects of the secondary market's price change? Recall that given the initial price p_{y0} and the corresponding change in quantity demanded from y_0 to y_1, it would be incorrect to include the area between the two demand curves D_y to D_y' as a change in CS, for that welfare change is already accounted for in the primary market. Now, however, we do need to account for the welfare change from p_{y0} to p_{y1} and subsequent reduction in quantity demanded from y_1 to y_2. It follows that producer surplus, PS_y, increases by area *GH*, and consumer surplus CS_y decreases by area *GHI*, with the net effect being a welfare loss in the secondary market of ΔSW_y equal to the shaded area *I.*

A more general result – continuing to assume no income effects – is that the net effect on welfare in the secondary market is always negative. And this result holds regardless of whether p_x increases or decreases and whether the goods are complements or substitutes.

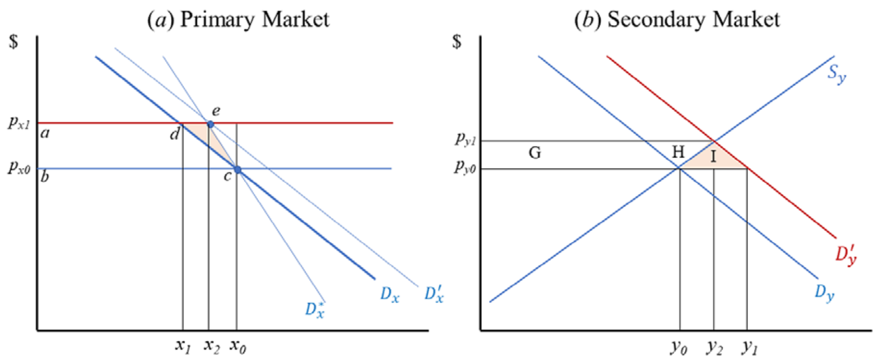

Figure 2. *Upward sloping supply in the secondary market. The secondary market has an upward sloping supply. Everything else is the same as that in Figure 1:* p_x *rises, no market failures, no income effects, and the goods are substitutes. The shaded area* I *represents the net welfare loss in the secondary market. The shaded area* cde *represents the overestimate of welfare costs in the primary market that occurs if based on* D_x^*.

[5] The case of complements is captured be reinterpreting the demand shift in the secondary market as going in reverse from D_y' to D_y, with no reduction of CS_y. Cases involving a price decrease in the primary market are also seen directly in Figure 1 where the initial price change is from p_{y1} to p_{y0}, which causes an increase in CS_x and still no changes in price or consumer surplus in the secondary market, regardless of whether the goods are complements or substitutes.

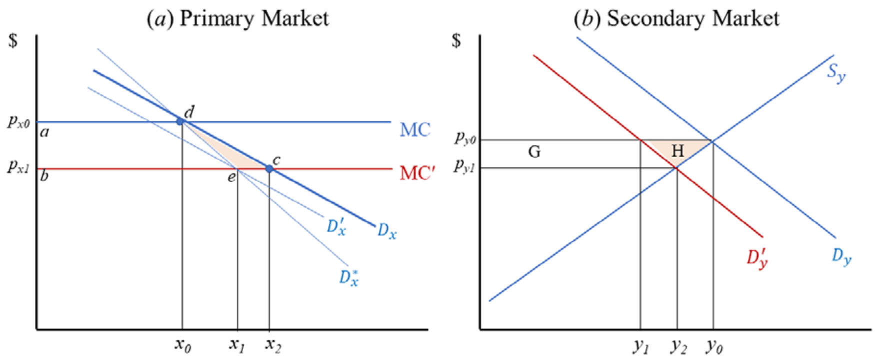

Figure 3. *A price decrease in the primary market. This is a version of Figure 2 in which the regulation causes the primary price* $\mathrm{p_x}$ *to decrease. There are no income effects, and the goods are still substitutes. Secondary-market producer surplus* $\mathrm{PS_y}$ *falls by* GH. *Secondary-market consumer surplus* $\mathrm{CS_y}$ *rises by* G. *Net welfare in the secondary market* $\mathrm{SW_y}$ *falls by* H. *The shaded area* cde *represents the underestimate of welfare benefits in the primary market that occurs if based on* $\mathrm{D_x^*}$.

Figure 3 illustrates the case of a decrease in p_x, while continuing to assume that x and y are substitutes. The net welfare effect in the secondary market is illustrated on the right hand side as a loss equal to area H. This follows because the loss in producer surplus ΔPS_y from the decrease in p_y, area GH, is greater than the gain in consumer surplus ΔCS_y, area G, where ΔCS_y is based on D'_y after the initial adjustment in the primary market. Although not shown graphically, cases involving complements also result in net losses in the secondary market, and to see this, one need only interpret the right side of Figure 2 as the response to a price decrease in the primary market, and the right side of Figure 3 as a response to a price increase in the primary market.

2.3. Implications

An implication of the preceding discussion is that ignoring the secondary-market effects can result in a miscalculation of costs in a BCA. In particular, without income effects, costs will always be underestimated. This is recognized by Gramlich (1997) and Boardman *et al.* (2018); however, both textbooks claim that BCAs can and do make an offsetting adjustment by using general equilibrium demand when analyzing the primary market.

Boardman *et al.* (2018) offer the simpler of the two solutions, claiming that typical BCAs will unintentionally estimate something close to general equilibrium demand.

> As it is frequently difficult statistically to hold the prices of secondary goods constant while estimating the relations between price and quantity demanded in a primary market, empirically estimated demand schedules – the ones actually observed and available for use in a BCA – often more closely resemble equilibrium demand schedules such as D^* than "textbook-style" demand schedules. (p.168)

In the context of Figures 2 and 3, this means that estimation of primary-market welfare changes are not based on the D_x demand curve and therefore not the standard measure of CS_x

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equal to area *abcd* in both figures. Instead, the authors claim that the measure of consumer welfare is more often based on observed data before and after prices change, thereby consistent with an approximate general equilibrium demand curve D_x^*, which yields area *abce* in Figure 2 and area *abde* in Figure 3.[6] The reason this is useful, according to Boardman *et al.* (2018), is that in the case of Figure 2, the overestimate of the partial equilibrium welfare cost in the primary market, equal to shaded area *cde*, will approximately offset the ignored welfare cost in the secondary market, equal to area *I*. Similarly, in Figure 3, the underestimate of the primary-market welfare gain equal to area *cde* will approximately offset the ignored welfare cost in the secondary market, equal to area *H*.[7] Therefore, the argument goes, analysts can reasonably ignore secondary markets in BCAs.

Similarly, Gramlich (1997) claimed, 25 years ago, that BCAs can use a new technology – "general equilibrium simulation" – to calculate general equilibrium demand in primary markets, and that those will account for secondary-market effects.

> [E]ven fledgling economists should be able to specify demand and supply functions with interactive effects …. And once this is done, the new technology allows one to plug into a microcomputer simulation disk and compute social net benefits. (p.225)

CGE models are undoubtedly better and easier to use today, and Farrow and Rose (2018) now echo Gramlich's prescription. The difference between this CGE approach and Boardman's, which we discuss more formally later in the paper, is that Boardman proposes using observed rather than simulated data. Yet both approaches yield partial equilibrium approximations to the general equilibrium effect.

2.4. Further questions

These graphical preliminaries provide an intuitive sense for how secondary-market effects depend on price changes. The simple analysis does not, however, show the complete set of secondary-market effects in the presence of income effects, and how these may differ depending on whether the goods are complements or substitutes. Researchers are also left wondering exactly what factors might reasonably affect the size of secondary-market effects and the degree to which the proposed correction based on estimating D_x^*, using actual or simulated data, approximates the true welfare cost. These are questions that we turn to more formally beginning in Section 4. But first we consider the question of how typical BCAs treat secondary markets in practice.

3. BCAs and secondary markets in practice

We have shown why textbooks claim that BCAs can ignore secondary-market effects, because of the offsetting effect that comes from using general equilibrium demand curves, or

[6] Later in the paper, we describe why we refer to D_x^* as an "approximate" general equilibrium demand curve and not simply the general equilibrium demand curve. In short, the reason is that D_x^* described in the approach here is based on a line connecting observed points, rather than the locus of points that simultaneously satisfy equilibrium conditions in both the primary and secondary markets at different levels of p_x.

[7] Similar graphs can be used show the offsetting effects for primary market price changes in both directions for complements.

approximations thereof, in primary markets. What do actual U.S. government BCAs do? Farrow and Rose (2018) point out that longstanding U.S. government guidelines for BCAs appear to offer conflicting or difficult-to-interpret guidance on whether to consider secondary-market effects. Recently, the EPA Science Advisory Board recommended that new guidelines from the EPA clarify that BCAs should include ancillary (or co-) benefits and costs.[8] Those arise in cases where secondary markets are distorted, as when they are responsible for pollution. That is not the focus here, however. We examine undistorted secondary markets for substitutes or complements, but where prices in the secondary-market change in response to the regulation in the primary market.

In practice, we find, that while typical BCAs do in fact ignore secondary markets, they do not make the offsetting general equilibrium adjustments in primary markets, either intentionally or otherwise. Rather, typical BCAs make concerted efforts to estimate welfare changes in primary markets using standard, partial equilibrium demand curves that hold other prices equal. Indeed, the focus on clear and causal identification in applied econometrics aims to estimate precisely this when estimating demand responses. As a consequence, most BCAs miss welfare effects that might arise in secondary markets. In support of this conclusion, we provide a brief review of the literature on BCAs for three prominent and very different public policies: sugary drink taxes; greenhouse-gas emissions standards for heavy-duty trucks; and product warning labels. We also provide a summary of 56 BCAs conducted by the U.S. Environmental Protection Agency (EPA) (2016) as part of major CAA rules since 1997.

3.1. Taxes on sugary drinks

Many countries and some U.S. local governments tax sugary drinks to discourage their consumption and combat diseases such as obesity and diabetes. If those taxes cause consumers to substitute other less-sugary drinks or more sugary foods, and that demand shift is sufficiently large to change prices of those goods, there will be welfare effects in secondary markets. Whether a sugary drink tax passes a BCA depends on many considerations, but we focus on the key primary-market characteristic of the elasticity of demand. Specifically, we consider whether the elasticity is typically estimated in the standard way, holding all other prices equal, or estimated as an approximate general equilibrium demand curve like D_x^* in Figure 2.

Peer-reviewed economics research on the topic is clear about the objective to estimate standard, partial equilibrium demand curves (Allcott *et al.,* 2019*a*). The challenges are well-recognized (measurement error and simultaneity) and the solutions are common (randomized control trials and instrumental variables). Indeed, two recent papers use instrumental variables precisely for the purpose of estimating *partial* equilibrium, all-else-equal demand curves (Finkelstein *et al.,* 2013; Allcott *et al.,* 2019*b*). It follows that, in principle, these studies should consider price and welfare effects in other markets. But do they? Both studies do consider substitution to other untaxed sugary foods, but only because that substitution erodes some of the health benefits of the tax. Yet neither study considers substitution to untaxed non-sugary drinks like milk or bottled water, which is the purpose of the tax. This means that potential welfare effects in the secondary markets are missing from the analyses.

[8] sab.epa.gov/ords/sab/f?p=100:12:4069866428378 (accessed May 21, 2022).

What about the BCAs in medical journals? Wilde et al. (2019) estimate the cost-effectiveness of a U.S. national tax on sugar-sweetened beverages, but they ignore secondary markets because they assume that substitution effects to water, diet soda, juice, and milk will be small. And in the primary market, they use an average, own-price elasticity taken from Roy *et al.* (2015), which is described as based on "reduced-form estimation that holds all other prices constant" (p.59). Similarly, Long et al. (2015) do not estimate price or welfare effects in secondary markets, and they use an own-price elasticity in the primary market taken from another study (Powell *et al.,* 2013) that is clearly intended as a partial equilibrium, demand elasticity, rather than a general equilibrium, before-and-after elasticity like D_x^*.

How about analyses from policy organizations? Many studies evaluate the costs and benefits of taxing sugary drinks, including ones by The Center on Budget and Policy Priorities (Marr & Brunet, 2009), The Federal Reserve Bank of Chicago (McGranahan and Shanzenbach, 2011), and the joint Urban-Brookings Tax Policy Center (Francis *et al.,* 2016). In all cases, the analyses are based on demand for sugary drinks using standard partial equilibrium demand, often borrowed from prior published studies, while ignoring price and welfare effects in related secondary markets.

3.2. Fuel economy standards for heavy-duty trucks

In 2016, the U.S. Department of Transportation (DOT) and the EPA jointly issued new fuel economy and greenhouse-gas emissions standards for heavy-duty trucks. The rule's BCA is noteworthy because of theoretical ambiguity on how the regulation was expected to alter the quantity of truck vehicle miles traveled (VMT) and the substitute transport markets. The regulation raises the cost of buying trucks but lowers the cost of driving them. If the net effect decreases overall truck VMT, some of that shipping demand could shift to substitutes like air freight or rail. If, however, the regulation increases truck traffic, that could decrease demand for substitutes like air and rail. Either way, if prices change in the secondary markets, there are welfare effects in those markets that should be considered, unless, as the textbooks prescribe, welfare in the primary market is measured using a general equilibrium approach.

The DOT/EPA RIA begins by invoking demand elasticity estimates in Winebrake *et al.* (2015*a*, *b*). Both papers use aggregate national data, regressing annual differences in the log of total U.S. truck VMT on the change in log diesel fuel prices, lagged VMT, and some macroeconomic indicators. They essentially regress quantity on price, mentioning simultaneity concerns as a justification for including lagged VMT. Moreover, they do not attempt to control for the price of substitutes, and this is potentially problematic because if national diesel fuel demand changes, which is the rule's objective, then presumably rail and air shipping costs would change as well. This means that one can reasonably question what elasticity is being estimated. It is not a true, ceteris-paribus elasticity, so it may be something more like an elasticity along an equilibrium demand curve like D_x^*. Nevertheless, both papers estimate own-price elasticities that are not statistically different from zero.

If the RIA had stopped with the Winebrake *et al.* (2015*a*, *b*) estimates, we might have concluded that it did, in fact, unintentionally estimate something approximating an equilibrium demand curve in the primary market, in which case ignoring the secondary market would be justified. But the RIA expressed reservations about those estimates and therefore turned to results from Leard *et al.* (2016). Although that paper had not been peer reviewed at the time of the rulemaking, it takes a sophisticated approach to estimate VMT demand. It

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uses data on 185,000 individual trucks, rather than aggregate national demand for fuel. It includes both local and national fuel prices. And, importantly, it accounts for shipping costs by competitors and expressly recognizes that fuel costs are likely to be endogenous for reasons of reverse causality and omitted variables. The authors account for the endogeneity using oil prices as an instrument for fuel costs.

In this case, the DTO/EPA analysts were caught between using peer-reviewed studies that it thought did not estimate demand carefully and using what they viewed as a more careful study that had not yet been peer-reviewed. As a result, the agency chose a compromise between the different estimates, placing greater weight on the peer-reviewed results in Winebrake *et al.* (2015*a*, *b*). Nevertheless, the intent to use estimates of partial equilibrium, all-else-equal demand was clear, and the RIA ignores secondary markets, such as shipping by rail or air.

3.3. Product warning labels

Product warning labels do not impose a tax or directly alter the cost of production meaningfully, but they do provide information intended to alter consumer behavior. Examples include the ever more graphic prose and pictures the U.S. Food and Drug Administration (FDA) requires on cigarette packaging (FDA, 2020), and the 2001 FDA advisory that children and pregnant women should limit consumption of fish that may be contaminated by mercury.

In this case, welfare effects in the primary market are subtly complex and depend how we evaluate pre- and post-label demand. The labels only shift demand by informing or reminding consumers of health concerns. If one believes the original, label-free demand for the primary good represented uninformed consumers or reflected an addiction that consumers would like help breaking, then the shift in primary demand may make consumers better off (Levy *et al.,* 2018). In that case, some have argued that we would not want to count any loss of consumer welfare in the primary market. On the other hand, if at least some consumers were informed and rational, enjoying the occasional cigarette or sushi dinner knowing the risks, then Cutler *et al.* (2015) show that we should use those consumers' CS to estimate the welfare gain to the uninformed or addicted consumers.

Unlike the trucking example, the effect on secondary markets is straightforward in these cases. The warning labels are designed to reduce demand in primary markets and will therefore presumably increase consumption of substitutes. No matter how we interpret welfare in the warned-about primary market, any price change in secondary markets will result in welfare changes there. If cigarette warnings increase demand for and prices of chewing gum or snack food, or if fish warnings increase demand and prices of meat, then there will be welfare effects in these markets that in principle should be accounted for in BCAs. Yet these secondary-market effects tend to be ignored. For example, Jin *et al.* (2015) conducted both a retrospective BCA of prior anti-smoking policies and a prospective BCA of future FDA regulations. They focus entirely on the substantial difficulties of estimating CS changes in the primary market. But no matter how those primary benefits are estimated, if warning labels or other anti-smoking efforts change demand in markets for substitutes or complements, then the analyses miss at least one component of the overall welfare effects.

Just like in the other examples of sugary drinks and trucks, demand estimation in this primary market also tends to focus on partial equilibrium approaches. Shimshack *et al.* (2007) and Shimshack and Ward (2010) examine the effect of the U.S. FDA's mercury

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advisories on fish consumption by targeted groups. Both papers contrast the responses to the advisory by targeted and untargeted consumers. A clear advantage of this approach is that it controls for price changes in other markets, because those other price changes would affect both groups equally. That is, if the FDA advisory indirectly caused meat prices to increase, both targeted and untargeted consumers would both be inclined to consume more fish. Therefore, by examining the difference between the two groups, the authors estimate the effect of the advisories on partial equilibrium, all-else-equal fish demand. They do not, in other words, estimate general equilibrium demand in the primary market that would account for secondary-market welfare effects.

3.4. Twenty years of EPA benefit–cost analyses

Since 1997, the EPA has conducted many dozens of BCAs for rules enacted under the CAA, in the form of RIAs done to comply with various executive orders. Supplementary Table A1 lists 56 of those RIAs, along with their features relevant for our analysis.[9] We observe whether each BCA considers secondary markets or not, and whether it aims to estimate partial or general equilibrium demand curves in the primary market. We also examine whether each BCA assesses welfare using CS, CV, or EV, an issue we will explore in theory in the next section.

Some of the RIAs do acknowledge secondary-market effects, and the few that account for them in estimation either do so in ways that differ from the approach outlined here, or appear to have done so unintentionally. For example, the 2010 RIA that examines the air pollution standards for cement manufacturers mentions that "Cement competes with other construction materials such as steel, asphalt, and lumber. Lumber is the primary substitute in the residential construction market, while steel is the primary substitute in commercial applications."[10] But beyond noting these relationships, the secondary-market effects do not enter the welfare analysis.

A few of the RIAs employ complex multimarket models – like CGE models but without national labor or capital modules – to examine effects on suppliers or downstream industries. The RIA for the EPA's 2011 rule limiting hazardous emissions from solid waste incinerators, for example, examined the consequence of raising costs for 100 industry sectors that purchase waste disposal services.[11] Those downstream industries incur welfare losses, but that is a different issue from our focus here on substitutes and complements. The RIAs account for vertically related markets, whereas we are considering horizontally related markets. Just *et al.* (1982) describe situations where the net social welfare change, including effects on final goods markets, can be measured entirely from general equilibrium demand for inputs like hazardous waste services. Importantly, however, the RIA ignores potential substitutes for solid waste incineration, such as landfills or recycling.

While we find that all RIAs ignore secondary markets in the benefits estimation, we also find that none makes the textbook adjustment by intentionally estimating general equilibrium demand in the primary market. Interestingly, two appear to do so unintentionally. The 2011 RIA for a rule limiting hazardous air emissions from industrial boilers, and the same

[9] We started with the list in Aldy *et al.* (2021), Table A1 and added more recent analyses.

[10] www.epa.gov/sites/default/files/2016-04/documents/ria_cement-2010.pdf (accessed September 16, 2021).

[11] www.regulations.gov/document/EPA-HQ-OAR-2003-0119-2493 (accessed September 16, 2021).

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year's RIA for a rule governing interstate transport of particulates and ozone, both use Ho *et al.*'s (2008) estimates of demand in their primary markets.[12] That paper uses Gramlich's approach, generating industry-specific elasticities by putting a small cost on one industry in a CGE model, running the model, and recording the resulting decline in the industry's output. Because the model adjusts for changes in all other industries' prices, the before-and-after price-quantity combinations are not on partial equilibrium, all-else-equal demand curves. Rather, they represent the equivalent of D_x^* in Figure 2. By using those general equilibrium elasticities from Ho *et al.* (2008) the EPA appears to have done precisely the correct thing for those two RIAs, yet nothing in the text of the RIAs suggests the EPA did so intentionally.

Finally, we make two observation that apply to all of the RIAs. The first relates to the Boardman *et al.* (2018) assertion that BCAs are likely to estimate demand using before-and-after prices and quantities, thereby accounting for secondary-market welfare changes. Our survey suggests that U.S. government RIAs rarely do so, and perhaps never on purpose. The reason, of course, is that RIAs are written as prospective analyses prior to policy implementation, so "after" prices and quantities are unavailable unless modeled. The second observation is that all of the RIAs that measure changes in consumer welfare do so with CS, rather than CV or EV. This follows, of course, because of the ease of estimating uncompensated rather than compensated demand curves and is to be expected.

3.5. Summary

In all three examples considered in our review – sugary drinks, truck fuel economy, and warning labels – we find that high-profile and influential BCAs estimate ceteris-paribus, partial equilibrium demand in primary markets while ignoring welfare effects in secondary markets. All may therefore omit important components of the overall net benefits of those policies. We also find a similar pattern across nearly 25 years' worth of RIAs conducted by the EPA in support of CAA regulations. Having established that secondary-market welfare effects are missing in nearly all BCAs we reviewed, we now turn to more general questions about whether those omitted effects are positive or negative, and their magnitudes.

4. The sign of welfare effects in secondary markets

All of the BCAs we examined in the previous section used consumers surplus as the measure of consumer welfare. That is appropriate, so long as demand for x and y have no income effects. In our graphical analysis in Section 2, which relied on that assumption, we replicated the claim in BCA textbooks (Gramlich, 1997; Boardman *et al.,* 2018) that the net welfare effects in secondary markets are negative. That leaves open the question of whether negative welfare effects in secondary markets is special to the case of no income effects, or is a more general result.

In the Supplementary Material we describe a straightforward, graphical approach for signing the welfare effects in secondary markets when there are income effects. In that Supplementary Material, we assume there is only one relevant secondary market in which prices change, and the welfare effects in that market are evaluated conditional on the price

[12] www.regulations.gov/document/EPA-HQ-OAR-2002-0058-3290 and www.epa.gov/csapr/regulatory-impact-analysis-final-cross-state-air-pollution-rule (accessed September 16, 2021).

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Table 1. *Summary of the sign of net welfare effects in the secondary* (y) *market for either a price increase or decrease in the primary market* (x)

Welfare measure	Neither gross substitutes nor complements	Gross substitutes	Gross complements: Net complements	Gross complements: Net substitutes
Using EV	0	–	–	–
Using CV	0	–	?	+

Notes: The secondary-market good y is presumed to be normal, although this is not necessary for the EV results, and secondary-market supply is increasing. If supply is perfectly elastic, as we showed in Section 2, there are no welfare effects no matter whether x and *y* are substitutes or complements. When y is a gross substitute for x, it must also be a net substitute, assuming it is normal.

change in the primary market. We then define the conditions under which secondary-market welfare effects will be negative, positive, or ambiguous. The answer depends on the particular welfare measure used – that is, EV or CV – and on whether the goods in the two markets are substitutes or complements. While readers interested in the details can find them in the Supplementary Material, we summarize the main findings here in Table 1.

Recall that EV holds utility constant ("equivalent") at the level after the policy change. It measures how much a consumer would pay to avoid a price increase, or to obtain a price decrease. Because EV focuses on welfare after the prices change, compensated demand curves intersect uncompensated demand curves at the new price-quantity combinations, (p_{y1}, y_2) in Figures 2(*b*) and 3(*b*). As a consequence, it does not matter whether good y is normal and the compensated demand curve is steeper than uncompensated demand, or good y is inferior and the compensated demand is flatter.

If p_y rises the lost consumer welfare, measured by EV, will exceed gained producer surplus. That is area I in Figure 2(*b*). The area will be smaller using EV if the good is normal and D_y' is steeper, and larger using EV if the good is inferior and D_y' is less steep. If p_y falls the gained consumer welfare, measured by EV, will falls short of lost producer surplus. That is area H in Figure 3(*b*). And again, the area will be smaller using EV if the good is normal and D_y' is steeper, and larger using EV if the good is inferior and D_y' is less steep.

Note that in this case we can ignore the distinction between gross and net substitutes and complements.[13] The reason also involves the definition of EV, and its reference utility being at the new price-quantity combination. EV measures do not compensate consumers for price changes, and so it is irrelevant whether, if consumers were compensated for a change in p_x, they would consume more or less y. All that matters is whether y is a gross substitute or complement. That changes when we turn to CV.

For now, however, when there are income effects and consumer welfare is measured using EV, the results parallel those in the more simple textbook case that assumes no income effects and measures welfare using CS. In these cases, there are always welfare losses in secondary markets when prices there change.

When using CV to measure welfare, however, the results do depend on whether y is a gross or net substitute or complement for x. Recall that CV holds utility constant ("compensated") at the level before the policy change. It measures how much income a

[13] In standard terminology "gross" to refer to the sign of the uncompensated or Marshallian cross-price effects, $\partial D_y/\partial p_x$, and "net" to refer to the compensated or Hicksian cross-price effects, $\partial h_y/\partial p_x$.

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consumer would need to be given to compensate for a price increase, or need to be taken away to compensate for a price decrease. As we show in the Supplementary Material, even in the simplest case when y is normal, welfare outcomes in secondary markets are complicated. Any outcome is possible: a welfare loss, a theoretically uncertain outcome, or even a welfare gain. These results are summarized in the second row of Table 1, and explained in more detail in the Supplementary Material.

Taken together, these results generalize the standard textbook discussion of secondary-market welfare effects to account for income effects. While they may appear confusing and dependent on a variety of circumstances, in most cases relevant for policy analysis, the results are relatively straightforward. We have shown that they will typically be negative, and we now turn to their magnitudes. In particular, we show in the next section how secondary-market welfare effects can be approximated with knowledge of only a few fundamental parameters.

5. A simple approach for evaluating secondary-market welfare effects

The issue of valuing welfare changes in secondary markets has a long history. Hotelling (1938) and Harberger (1971) wrote about it in the context of secondary markets with preexisting distortions. It was generalized by Just and Hueth (1979) and Just *et al.* (1982) to the case we examine here, with undistorted secondary markets. They also take a general equilibrium approach. If demand in the primary and secondary markets are substitutes or complements, then as we have shown, a regulated change in p_x can affect demand for y and its price p_y, and this in turn can bounce back to affect x and p_x, and so on ad infinitum. The idea is that multiple-market complexities can be simplified by examining only the primary market and assessing the change in welfare there using a general equilibrium demand curve that accounts for changes in the price of secondary markets.

Thurman (1993) provides a relatively straightforward proof of the proposition, and some intuition. In the context of Figure 2 he describes the area

$$\int_{p_{x0}}^{p_{x1}} D_x^*\left(p_x, p_y(p_x)\right) dp_x, \tag{2}$$

where D_x^* is the general equilibrium demand curve, capturing all the combinations of x and p_x that account for corresponding equilibrium changes to y and p_y. In this case, Thurman (1993) proves that Equation (2) captures the entire and exact welfare change from raising the price of x, including the welfare changes to consumers and producers of y. A related discussion and formal treatment can be found in Johansson (1993) in a chapter on general equilibrium benefit–cost rules.

In practice, however, BCA analysts are unlikely to know entire demand curves, let alone general equilibrium demands, or be able to integrate them with respect to prices. Analysts are likely to have just a few key pieces of information: initial prices and quantities in various markets, some measure of the price change to be considered in the primary market, and some key elasticities. If we assume D_x^* is a straight line connecting the pre- and post-regulation prices and quantities (points c and e in Figure 2), then Equation (2) is area *abce*. Boardman *et al.* (2018) then claim that this area approximates the overall welfare effect because it accounts for two partial equilibrium effects: the welfare change in the market for x (area

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abcd) plus the net welfare effect in the market for y (area I), where the latter follows because of the assertion that area *cde* is a close approximation to area I.

Using these approximations, initial prices and quantities, and a few elasticities, our aim in this section is to identify what factors affect the magnitude of welfare effects in secondary markets and to examine conditions that affect performance of the Boardman *et al.* (2018) prescription. Our analysis continues to be theoretical, but we make some simplifying assumptions: linear supply and demand, and no income effects in either the primary or secondary markets. As has long been recognized, these simplifications impose strong restrictions on underlying welfare and production functions (see LaFrance, 1985). But they also yield intuitive and easily interpreted results that are likely most relevant for real-world applications, and that can be used by BCA analysists to assess whether secondary-market effects are expected to be important.

5.1. Welfare effects in both markets

The initial prices and quantities in both markets are given by (p_{x0}, x_0) and (p_{y0}, y_0). Consider a policy that changes the marginal cost (i.e., price) in the primary market to $p_{x1} = p_{x0}(1+\alpha)$, where α can be positive or negative, and $\alpha \times 100$ is the percentage change. Assuming initially no change of price in the secondary market, consider a change in quantity demanded in the primary market to be $x_1 = x_0(1+\alpha\eta_x)$, where $\alpha\eta_x \times 100$ is the percentage change in demand for x, which can be positive or negative, but will have the opposite sign of α η_x is presumed negative due to downward-sloping demand.

The parameter η_x represents a simplified own-price elasticity of demand for x as it might be applied in a BCA, that is, a percentage quantity response relative to the baseline pre-policy quantity x_0.[14] Because we have assumed no income effects, we can use CS (equal to CV and EV) as the correct welfare measure in the primary market:

$$\begin{aligned} \Delta CS_x &= -\frac{\alpha p_{x0}(x_0 + x_1)}{2} \\ &= -\frac{\alpha p_{x0} x_0 (2 + \alpha\eta_x)}{2} \end{aligned} \tag{3}$$

Referring back to Figures 1 and 2, Equation (3) is the area *abcd* in panel (a). The sign of (3) is the opposite of α, which follows because a price increase lowers CS while a price decrease raises it.[15]

If the secondary-market price does not change, then the expression for ΔCS_x in (3) captures the complete welfare effects of the policy (ignoring any potential non-market effects). This is true even if demand shifts in the secondary market because y is a gross substitute or complement for x, so long as p_y does not change. Assuming no change in p_y for the moment, we can write the change in quantity that would occur in the secondary market as $y_1 = y_0(1+\alpha\eta_{xy})$, where following the same convention $\alpha\eta_{xy}$ denotes the percentage change in demand for y, and η_{xy} denotes a simplified cross-price elasticity, that is, a percentage change relative to the baseline price p_{x0} and quantity y_0. The new quantity y_1 can be greater or less than y_0, depending on whether the initial policy causes a price increase or decrease in the

[14] Of course η_x is not a true elasticity, which would differ along the demand curve and be different moving in the opposite direction from x_1 to x_0.

[15] To see this mathematically, note that $x_0(2+\alpha\eta_x) = x_0 + x_1 > 0$.

Table 2. *Summary of the signs of parameters*

	Policy			
	Primary-market price increase $(\alpha > 0)$		Primary-market price decrease $(\alpha < 0)$	
	Substitutes $(\eta_{xy} > 0)$	Complements $(\eta_{xy} < 0)$	Substitutes $(\eta_{xy} > 0)$	Complements $(\eta_{xy} < 0)$
Change from x_0 to x_1: $\alpha\eta_x$	−	−	+	+
Change from y_0 to y_1= sign of $\alpha\eta_{xy}$= sign of β	+	−	−	+
Change from x_1 to x_2 = sign of $\beta\eta_{xy}$	+	+	−	−

primary market and on whether the goods are gross complements or substitutes. Table 2 summarizes the four possibilities in the second row.

If the secondary-market price p_y does change, more work is needed to tally the overall change in welfare across both markets. Continuing with this reduced-form approach, we parameterize the percentage price change in the secondary market as β, where $p_{y1} = p_{y0}(1+\beta)$. It is helpful to note that β and $\alpha\eta_{xy}$ will have the same sign. (See Table 2.) This means, for example, that if the intermediate quantity of y increases ($\alpha\eta_{xy} > 0$ so that $y_0 < y_1$, holding p_y fixed), then upward sloping supply in the secondary market means that p_y must also increase. Of course, the magnitude of β will depend on the supply and demand curves in the secondary market, and with additional information about these functions, we can solve for β explicitly.

To see this, let y_2 denote the market clearing quantity in the secondary market after its price adjustment β. For example, Figure 2 depicts that market equilibrium as $\left(p_{y1}, y_2\right)$, the intersection of supply S_y and the new demand D'_y. At that equilibrium we can write

$$y_2 = y_0\left(1+\beta\sigma_y\right) = y_1\left(1+\beta\eta_y\right) \tag{4}$$

where σ_y is the simplified elasticity of supply of y (in percentage terms relative to y_0), $\beta\sigma_y$ is the percentage change in the quantity supplied from y_0 to y_2, η_y is the simplified elasticity of demand for y (relative to y_1), and $\beta\eta_y$ is the percentage change in the quantity demanded from y_1 to y_2. These percentage changes would depend on the exact equations for supply and demand, but we need not know the expressions themselves for purposes of our analysis here. Using (4) and the relationship $y_1 = y_0(1+\alpha\eta_{xy})$, we can solve explicitly for

$$\beta = \frac{-\alpha\eta_{xy}}{\eta_y\left(1+\alpha\eta_{xy}\right) - \sigma_y} \tag{5}$$

which as noted above will have the same sign as $\alpha\eta_{xy}$, owing to the fact that the denominator is negative.[16]

[16] The denominator is negative because σ_y is positive (supply slopes up), η_y is negative (demand slopes down), and $\alpha\eta_{xy}$ cannot be less that -1, because that would mean the regulatory change in the x market eliminates more than 100 percent of the market for y.

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Equation (5) reveals several insights about the potential size of price changes in the secondary market. First, the price change is decreasing in both the simplified supply and own-price elasticities in the secondary market.[17] Second, in the limit, if either the supply (σ_y) or own-price (η_y) response is perfectly elastic $(=\infty)$, there is no scope for a price change and no welfare loss in the secondary market. The scenario where supply is perfectly elastic is consistent with the case illustrated in Figure 1. Third, we can see how the scenario where the cross-price elasticity is zero $(\eta_{xy}=0)$ is another circumstance without welfare effects in the secondary market. Finally, the potential size of the price change is increasing in both the initial price change α and the cross-price elasticity η_{xy}, both of which determine the size of the demand shift in the secondary market.[18]

Returning now to the use of β itself as sufficient for characterizing the size of the secondary-market welfare effect, we can solve for the change in producer surplus, which is area GH in Figures 2 and 3:

$$\Delta PS_y = \beta p_{y0}(y_0+y_2)/2. \tag{6}$$

Similarly for CS:

$$\Delta CS_y = -\beta p_{y0}(y_1+y_2)/2. \tag{7}$$

Combining these two expressions, and the fact that $y_1 = y_0\left(1+\alpha\eta_{xy}\right)$, yields the net welfare effect in the secondary market:

$$\begin{aligned}\Delta SW_y &= \Delta PS_y + \Delta CS_y \\ &= -\frac{\beta\alpha\eta_{xy}p_{y0}y_0}{2} < 0,\end{aligned} \tag{8}$$

where it is useful to recall that β has the same sign as $\alpha\eta_{xy}$ so that $\beta\alpha\eta_{xy}>0$. (See Table 2.) The negative sign of (8) accords with the more general result we proved earlier: net welfare effects in secondary markets are always negative, assuming no income effects. Equation (8) also makes clear how, beyond the effect of parameters already discussed because of their influence on β, the size of the expenditure in the secondary market $(p_{y0}y_0)$ has a large effect on the potential size of secondary-market welfare effects.

In the context of evaluating the importance of secondary markets for a particular BCA, however, a more useful measure would scale the welfare loss in the secondary market compared to the correctly estimated partial equilibrium welfare effects in the primary market. This we examine with the ratio of (8) over (3), which after a bit of rearranging yields

$$\frac{\Delta SW_y}{\Delta CS_x} = \frac{p_{y0}y_0}{p_{x0}x_0} \times \frac{|\beta\eta_{xy}|}{2+\alpha\eta_x}. \tag{9}$$

Equation (9) reports the typically omitted welfare effects in the secondary market as a fraction of those in the primary, and we take the absolute value to keep the overall expression positive.

Several insights can be gained by examining Equation (9). First, it shows how all the terms that increase β also increase the ratio. Those terms are explicit in Equation (5), and we discussed them earlier in that context: the simplified cross-price elasticity between x and y,

[17] We refer to the parameters as elasticities, which as noted is only correct for small changes.

[18] To verify this result, let $\theta=\alpha\eta_{xy}$ and solve for $\frac{\partial\beta}{\partial\theta} = \frac{\sigma_y-\eta_y}{\left(\eta_y(1+\theta)-\sigma_y\right)^2} > 0$.

and the simplified supply and demand elasticities (percentage changes) of y. Second, the secondary-market welfare loss is larger when the initial market value (measured by total expenditure) of the secondary sector is larger relative to the primary. That's the first fraction on the left side of (9). Third, the primary-market elasticity has opposite effects, depending on whether the initial change in price α is positive or negative. If $\alpha > 0$, then a larger elasticity η_x lowers the denominator and raises the ratio. If $\alpha < 0$, then a larger elasticity η_x raises the denominator and lowers the ratio. That's because when demand is more elastic, a price increase yields a smaller decline in CS, but a price decrease yields a larger increase.

A fourth insight is that the number 2 in the denominator of (9) means that in many reasonable cases, the secondary-market effect will be small relative to the primary. Consider an extreme case in which the two markets have the same initial valuations $\left(p_{y0}y_0 = p_{x0}x_0\right)$ and the absolute values of the elasticities are both equal to 1 $(-\eta_x = |\eta_{xy}| = 1)$. In this case, Equation (9) simplifies to $|\beta|/(2+\alpha)$. Then, for example, if we assume further a price change in the primary market of 10 % and an equal percentage price change in the secondary market $(\alpha = \beta = 0.1)$, the secondary-market welfare effect is approximately 5 % of that in the primary market. This is, of course, a very special case but in many settings, more realistic values of the parameters would tend to make the secondary-market effects even smaller, including if the simplified own-price elasticity is larger than the simplified cross-price elasticity and if the direct price change in the primary market is larger than the indirect change in the secondary market.

More generally, Equation (9) can be used by BCA analysts as a sort of "multiplier" to assess how important omitted secondary markets are likely to be, relative to the primary market. All analysts need to know are estimates of the initial price change α, initial market values, proxies for the own and cross-price elasticities η_x and η_{xy}, and the price change in the secondary market β. Analysts can either make educated guesses about β (perhaps trying a range of values), or estimate it more rigorously using Equation (5) and proxies for the secondary-market supply and demand elasticities, σ_y and η_y. In Section 6 we do just that, for two real-world cases. But first we use our simple framework to evaluate the textbook suggestion for how BCAs treat secondary-market effects.

5.2. Evaluating the textbook prescription

The Boardman *et al.* (2018) textbook suggests that typical BCAs account for secondary markets by estimating demand in primary markets as a linear interpolation between before-and-after price-quantity combinations. Referring back to Figure 2, recall that area *cde* is the overestimate of the welfare costs in the primary market that comes from using D_x^*. The motivation is that this curve represents an approximation of the general equilibrium demand curve in (2) based on linearly interpolating the observed before-and-after, price-quantity observations.

Our simplified setup enables explicit expressions for this overestimate as

$$\begin{aligned} K &= \frac{(p_{x1} - p_{x0})(x_2 - x_1)}{2} \\ &= \frac{\alpha\eta_{xy}\beta p_{x0}x_0(1+\alpha\eta_x)}{2} > 0, \end{aligned} \tag{10}$$

where the first row is just the area of the triangle *cde*, and the second equality follows by substituting in the facts that $x_1 = (1+\alpha\eta_x)x_0$ and $x_2 = (1+\beta\eta_{xy})x_1$. It turns out, and is straightforward to verify, that Equation (10) applies not only to the case illustrated in

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Figure 2, where p_x increases and y is a gross substitute, but to all possible changes in p_x and for both complements or substitutes. In some cases, as shown in Figure 2, the quantity $K > 0$ represents an overestimate of costs, whereas in other cases such as in Figure 3 it represents an underestimate of benefits.

A question of immediate interest, then, is how this error of estimating costs in the primary market, K, compares to the error of ignoring welfare effects in the secondary market. Boardman *et al.* (2018) assert that the two magnitudes are approximately equal and offsetting. Recognizing that $K > 0$ is an overestimate of primary market costs or an understatement of primary-market benefits, and that $\Delta SW_y < 0$ is an underestimate of secondary costs, we can solve for the difference between the two:

$$K + \Delta SW_y = \underbrace{\frac{\alpha\eta_{xy}\beta}{2}}_{\geq 0}\left(p_{x0}x_0(1+\alpha\eta_x) - p_{y0}y_0\right). \tag{11}$$

Expression (11) equals zero, and there is no bias involved in the textbook approximation, if there is no policy $(\alpha = 0)$, there is no cross-price response $(\eta_{xy} = 0)$, or there is no price change in the secondary market $(\beta = 0)$, which could arise because of perfectly elastic supply or demand. More generally, (11) does not equal zero unless we have a knife-edge result of the expression in parentheses equal to zero. That's because, as described above, K in Equation (10) is only an approximation of the more formal and exact result based on integrating over all the values of a general equilibrium compensated demand curve, as in Equation (2) (Just *et al.,* 1982, Appendix D; Thurman, 1993).[19] The textbook approach is therefore an approximation of the true general equilibrium approach, and this explains why Equation (11) does not equal precisely zero.

The approximation in (10) might overstate or understate the true welfare costs in both markets, so (11) might be positive or negative, respectively. Regardless of its sign, the magnitude of the error increases in all the same parameters that increase β, as shown in (5). The sign of (11) also depends importantly on the relative magnitudes of the initial expenditures in the two markets. The bigger the secondary market, the more likely we are to continue underestimating total costs. But the bigger the primary market, the more likely we are to do the opposite and overestimate costs. Finally, the only part of (11) that depends on the direction of the initial policy change (the sign of α) is the term $p_{x0}x_0\alpha\eta_x$. This represents the initial change of expenditure in the primary market, before any price adjustment in the secondary market. When α is positive, a larger initial demand response makes the expression less likely to continue underestimating costs (i.e., less likely to be negative). In the examples that follow, we use Equation (11) to numerically evaluate the textbook prescription.

6. Two numerical examples

The assumptions we have made in the previous section – linearizing demand, assuming away income effects, and describing elasticities as percentage changes relative to initial

[19] To paraphrase the logic in Thurman (1993, p. 453) applied to our context, the general equilibrium demand curve of interest in the primary market traces out points of equilibrium in both markets where p_x and p_y change simultaneously. That is, p_y varies continuously along the demand curve to maintain equilibrium in the secondary market for each level of p_x.

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quantities – sacrifice some precision. But the assumptions have the benefit that we can apply what we have learned to real-world situations, where we know initial prices and quantities and where researchers often have estimates of key elasticities. In particular, the equations in the previous section provide a basis for approximating the true welfare cost of a policy, $\Delta SW_x + \Delta SW_y$, setting aside the nonmarket benefits. We can also use the equations to calculate the error from ignoring ΔSW_y, the textbook correction, K, and the difference between the two. They can all be estimated using a few parameters likely to be available to analysts constructing a BCA: initial market conditions (p_{x0}, x_o) and $\left(p_{y0}, y_o\right)$, the regulatory effect on the primary market (α), the primary-market demand elasticity (η_x), and the cross-price elasticity (η_{xy}). Moreover, with just a bit more information, the secondary-market elasticities of demand η_y and supply σ_y, we can also calculate the price change in the secondary market (β).

In this section, we examine two situations in which benefit cost analyses have been completed and for which those parameters have been estimated. The first is a tax on sugary drinks in Mexico, and the second is an increase in the price of residential heating oil in the U.S. With these examples, we are able to provide a better sense of the potential magnitudes involved when it comes to secondary markets and the performance of the partial equilibrium correction.

6.1. A 10-per cent soft drink tax in Mexico

In 2014 Mexico began taxing sugary drinks at a rate of 1 peso per liter, or approximately 10 %. The goal was to reduce Mexico's high rates of obesity and diabetes. The non-market health gains would be offset, at least in part, by consumer and producer losses in the markets for sugary drinks and their substitutes. In advance of the tax's implementation, Colchero *et al.* (2015) published an analysis containing much of the data needed to calculate those losses, and to compare the losses in the primary regulated market (sugary drinks) to losses in markets for substitutes, which typical BCAs ignore. One of the largest substitutes for sugary drinks, and one most closely associated with positive health outcomes, is milk.

Table 3 presents some key parameters taken directly from Colchero *et al.* (2015), supplemented by a few other studies, along with our calculations based on those parameters and the above equations. The key to estimating the size of the welfare losses in secondary markets is β, the secondary price increase. That calculation, in Equation (5), requires information about α,η_{xy}, η_y, and σ_y. Conchero *et al*. (2015) provide all except for σ_y, the supply elasticity. For illustrative purposes, we use an estimate of $\sigma_y = 0.066$, estimated for the U.S. by Bozic *et al.* (2012). Equation (5) then leads to an estimate of $\beta = 0.005$, reported on the first line of the *Calculations* section of column (1). A 10 % increase in the price of sugary drinks leads to a 0.5 % increase in the price of milk.

The bottom of Table 3 uses this information to display two assessments of the importance of secondary-market welfare effects. The first compares welfare changes in the two markets. Using the estimate of β, we can calculate the welfare losses in the milk market from Equation (8), and the ratio of typically-ignored secondary-market losses to the primary-market losses in Equation (3). That ratio, $\Delta SW_y/\Delta CS_x$, is in Equation (9), and the result is reported in column (1) of Table 3 as 0.032 %. The implication of this estimate is that ignoring welfare effects in the substitute milk market results in an extremely small error in comparison to the welfare effects in the primary market for sugary drinks. Moreover, changing any number of parameters can enlarge the error, but not substantially. Taking an extreme case, if

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Table 3. *Real-world examples*

	Sugary drink tax	Residential heating oil tax
	(1)	(2)
Parameters		
Primary market: x	Sugary drinks	Residential fuel oil
Secondary market: y	Milk	Residential gas
Ratio of market sizes $(p_y y_0)/(p_x x_0)$	1.12	3.71
Primary price increase (α)	0.1	0.1
Primary demand elasticity (η_x)	−1.06	−1.002
Std. error of η_x	(0.02)	(0.338)
Cross-price elasticity $\left(\eta_{xy}\right)$	0.11	0.135
Std. error of η_{xy}	(0.02)	(*0.069*)
Secondary demand elasticity (η_y)	−1.65	−0.313
Std. error of η_y	(0.02)	(0.090)
Secondary supply elasticity (σ_y)	0.534	0.79
Std. error of σ_y	(0.066)	(*0.482*)
Calculations		
Secondary price increase (β) [eq. (5)]	0.0050	0.0107
Std. deviation of $\widehat{\beta}$	(0.0009)	(0.1986)
(a) Max possible β if $\eta_y = 0$	0.0206	0.0143
(b) Max possible β if $\sigma_y = 0$	0.0066	0.0426
Share error from ignoring secondary markets		
$\Delta SW_y/\Delta CS_x$ [eq. (9)]	0.00032	0.0028
Using max of (a), (b), or $\beta + s.e.\left(\widehat{\beta}\right)$	0.00134	0.0552
Share error in primary market from η_x 95% confidence interval	0.044	0.698
Share error K from using D_x^* in primary market [eq. (10)/(3)]	0.00026	0.00068
Share error K relative to welfare costs in secondary market [eq. (10)/(8)]	0.80	0.24

Notes: Column (1) contains analysis based on Colchero *et al.* (2015). The baseline milk consumption y_0, used in the ratio of market sizes, comes from Bozic *et al.* (2012). The estimates of η_y and $SE(\eta_y)$ for milk come from Barquera *et al.* (2008) for the U.S. Column (2) is based on U.S. Department of the Interior, Bureau of Ocean Energy Management (2015), which uses elasticities from Newell and Pizer (2008) and Serletis *et al.* (2010). Prices and quantities of gas and oil in column (2) are from U.S. EIA (2015). Standard errors in italics for η_{xy} and σ_y are constructed by dividing the elasticity estimate by 1.96, so that the estimate is presumed statistically significant at precisely the 5 % level.

the secondary-market demand were completely inelastic ($\eta_y = 0$), the estimate of β would increase from 0.005 to 0.0206. Then if we plug the larger β into Equation (9), the ratio of ignored secondary welfare losses to the primary-market CS increases to 0.134 %, which is still exceedingly small.

A second assessment of the importance of secondary-market welfare changes compares those to the range of likely errors of estimated losses in the primary market. In "Consumer Surplus Without Apology," Willig (1976) showed that the errors caused by using CS to measure welfare, rather than the more technically correct EV or CV, will typically be smaller than the errors from estimating demand in the first place. In a similar spirit, we can show that the error from ignoring secondary markets will typically be smaller than that from estimating η_x, the own-price elasticity of demand in the primary market. Colchero *et al.* (2015) report the elasticity of demand for sugary drinks as $\eta_x = -1.06$, with a surprisingly small standard error of 0.02. If we calculate losses in the primary market, ΔCS_x, using Equation (8) and the two extremes of the 95 % confidence interval of η_x, we find a difference between the two extremes of 4.4 % of the central estimate of ΔCS_x.[20] While small, this range, based only on uncertainty about η_x, is still 100 times the error from ignoring secondary markets altogether from Equation (9), 0.032 %.

Both comparisons – to primary-market losses and to primary-market estimation errors – are exceedingly small. As seen in Equation (9), they depend on the ratio of the two market sizes, the cross-price and own-price elasticities, and β, which in turn depends on the elasticities of secondary-market demand η_y and supply σ_y. In this particular case, the markets are comparably sized, and the two goods are modest substitutes, but the own-price elasticity of demand for milk is quite large $\eta_y = -1.65$, which dampens the price increase β, even when we assume the supply elasticity σ_y is zero.

Finally, how does the general equilibrium approximation of the overall welfare effects, using D_x^* in Figure 2, perform in this example. It results in an overestimate of the partial equilibrium costs in the primary market of 0.026 %, which turns out to be 80 % of the welfare costs in the secondary market. Hence, the correction performs well, but as already shown, the secondary-markets effects themselves are small compared to the correctly estimated partial equilibrium welfare effects in the primary market. In this case, therefore, BCAs can safely ignore welfare effects in secondary markets like milk that are substitutes for sugary drinks. Not, as BCA textbooks suggest, because they might estimate general equilibrium demand in primary markets. But rather, because the secondary-market welfare effects are so small.

6.2. An oil price rise in the USA

We now consider an example policy that raises the price of residential fuel oil, where the secondary market is natural gas. We examine these energy sources in their use as final products, used by households for heating. Our primary source of parameters estimates for estimating primary and secondary-market effects comes from the U.S Department of the Interior. Every 5 years the Department's Bureau of Ocean Energy Management (BOEM) produces a 5-year forecast of energy markets' likely response to the offshore leases it facilitates. In its most recent report (U.S. Department of Interior, 2015) the Bureau explicitly cites the Boardman *et al.* (2018) approach for estimating welfare changes in secondary markets by using CS along general equilibrium demand curves in primary markets, such as D_x^* in Figure 2. The BOEM report also provides all of the data necessary to calculate Equations (3), and (8)–(11), plus the secondary-market elasticities of demand η_y and supply σ_y necessary to calculate β using (5). We use the BOEM report to estimate the welfare costs associated with a regulation that raises the price of residential fuel oil by 10 % $(\alpha = 0.1)$, taking into account the market for the main substitute for residential energy, natural gas.

[20] We calculate ΔCS_x using 10) and the estimate of $SD(\eta_x) = 0.02$ from Table 3, and using $\pm 1.96 \times SD(\eta_x)$. The difference between the two extremes of ΔCS_x, divided by the central estimate of ΔCS_x, is only 4.4 percent.

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This example differs from the previous one because the secondary gas market is considerably larger than the primary oil market, as shown by the different ratios of market sizes in Table 3. In this case, the secondary market is nearly four times as large. Moreover, the secondary-market own-price elasticity η_y is considerably smaller. Both of these differences leave room for a larger error if secondary-market welfare losses are ignored.

The two parameters missing from the BOEM study are the standard errors of the estimates of σ_y, the elasticity of gas supply, and η_{xy}, the cross-price elasticity between oil and gas. We assume both are estimated to be marginally statistically significant, and divide the point estimates by 1.96 to generate a proxy for their standard errors.

Because BOEM provides estimates of the elasticities of demand η_y and supply σ_y of natural gas, we can use (5) to calculate $\beta = 0.0107$. A 10 % increase in the price of fuel oil leads to a natural gas price increase that is only one-tenth as large. Plugging this estimate into Equation (9), the error from ignoring the secondary market remains small: it is only 0.28 % of the primary-market welfare loss. In this case, the reason is that the cross-price elasticity is small enough, and the elasticities of supply and demand in the secondary market are large enough, that the effect of the fuel oil tax on the price of natural gas is minimal.

To get a sense of how large β and the secondary-market losses can be, assume each of the four parameters $(\eta_x, \eta_y, \eta_{xy}, \sigma_y)$ is independently and normally distributed with means and standard errors reported in Table 3. We generate a random value of each of the four from those distributions, and use those values to calculate $\widehat{\beta}$. We repeat that 10,000 times, which gives us simulations of $\widehat{\beta}$ that have a standard deviation of 0.1986, as reported in column (2). Estimating Equation (9) using a β that is larger by one standard deviation, the share error from ignoring secondary markets is still only 5.52 %.[21] By contrast, and again in the spirit of Willig (1976), the share error using the range of the 95 % confidence interval around η_x is 69.8 %. Hence, the error from excluding the secondary market is much smaller, despite the fact that the secondary market, natural gas in this case, is relatively inelastic and nearly four times the size of the primary market for oil. In this case, as with the sugary drink example, BCAs can safely ignore secondary-market welfare effects, not because they might estimate general equilibrium primary demand but because the secondary effects are so small.

Last, the general equilibrium approximation of the overall welfare effects, using D_x^* in Figure 2, performs a bit less well in this example than in the sugary drinks case. Using D_x^* overestimates the partial equilibrium costs in the primary market by 0.068 %, which is 24 % of the welfare costs in the secondary market. Here the correction only offsets one-quarter of the error from ignoring substitutes or complements. Again, however, those secondary-market effects themselves are small relative to the partial equilibrium primary-market effects.

7. Conclusion

We have focused entirely on the case where secondary markets are linked to primary markets through consumption, as substitutes or complements. We assume throughout there are no preexisting taxes, externalities, or other distortions in the secondary markets. Textbooks are

[21] We carry out a similar analysis for the soft drink example, and these results are reported in the first column of Table 3. In that case, however, the estimate value of $\widehat{\beta}$ does not result in the most extreme case, which is why we do not discuss it.

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clear that the result discussed here does not apply in those cases. Goulder and Williams (2003), for example, study taxes in a primary market when a secondary market is much larger and distorted by preexisting taxes. Their examples are taxes on single commodities (cigarettes and energy) where the secondary market is the entire labor market, distorted by the income tax. In those cases, the secondary-market deadweight loss is a rectangle – lost revenue from the preexisting existing tax. That rectangle can easily be larger than the primary-market deadweight loss triangle. In our setting here, even when the secondary market is large, as in our example using fuel oil and natural gas, both welfare losses are triangles.

One additional caveat to keep in mind involves the geographic scope of the analysis. Throughout we have considered all welfare effects, no matter where they occur. If a domestic policy affects the prices of imports or exports, some effects will fall on foreign consumers or producers. Bullock (1993), Mohring (1993), and Johansson (2021) consider what happens if one only counts domestic benefits and costs.

Though limited to this particular case – counting all the benefits and costs of regulations affecting single markets with secondary effects on substitutes or complements – we make four main contributions. First, we show that most BCAs of policy interventions do not consider the welfare consequences in secondary markets, where goods or services can be complements or substitutes to those in the directly regulated markets. Our evidence is based on a literature review of peer-reviewed studies in three prominent and different domains – sugary drink taxes, emissions from heavy-duty trucks, and product warning labels – along with all BCAs conducted by the federal government in support of significant CAA rules since 1997. Second, we provide a general theoretical examination of the sign of welfare effects in secondary markets, showing how the results depend on the welfare measure of interest (CS, EV, or CV) and on whether the goods are complements or substitutes. The welfare effects in secondary markets will typically be negative in cases most relevant for policy analysis – that is, in cases where the income effects are likely to be small and the secondary-market good is a gross substitute. Third, we develop a straightforward tool that BCA analysts can use to evaluate the potential magnitude of secondary-market effects in particular applications. The tool itself highlights how secondary-market effects are likely to be relatively small in most circumstances. Finally, we apply our tool to two very different applications – a sugary drink tax in Mexico and a tax on U.S. residential fuel – to illustrate its value and provide further evidence in support of the conclusion that secondary-market effects are likely to be small. In particular, in these examples, the secondary-market welfare effects are smaller than the confidence intervals for welfare effects in the primary market.

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