WELFARE ANALYSIS WITH MULTIPLE MARKETS, MULTIPLE MARKET FAILURES OR SUBOPTIMAL POLICY CALIBRATION

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Abstract

One of the hallmarks of welfare analysis as a system for organizing policy-relevant evidence is that it embeds accounting standards. Every dollar of impact can, at least in theory, be included in a net benefit estimate exactly once—no more and no less. The visualization tools of partial equilibrium analysis can be powerful and elegant contributors to this goal, especially if integrated with accounting ledgers. However, only a few illustrative cases are taught in a manner that combines user-friendly analytic tools with accuracy. This paper fills in some of the resulting gaps, toward the goal of greater understanding for both students and the practitioners of policy-oriented welfare analysis they might eventually become.

Keywords: policy analysis; applied welfare economics; market failure; value of information

JEL Classifications: A20; D61

Introduction: Welfare Analysis, From Undergraduate Pedagogy to Assessment of Public Policy

Welfare analysis, as encountered by a student during a first economics course, typically begins with an introduction to consumer surplus. A single demand curve illustrates how consumer surplus is lower with a relatively high price for the relevant product than it would be if price were reduced.[2] Upon the introduction of this concept and its producer-surplus counterpart, a social welfare result can accompany a market model's price and quantity predictions. For example, the sum of consumer and producer surplus is higher with perfect competition than with a monopoly (holding equal the marginal cost schedule).

Government intervention may also receive attention in the welfare analysis introduction, especially an intervention that takes the form of an excise tax.[3] The tax drives a divergence between supply and demand, which is why the amount of the tax determines the vertical height of the tax-wedge triangle (shaded area CC+DD, as illustrated in Figure 1). Consumer surplus decreases by AA+CC, producer surplus decreases by BB+DD, and the government collects tax revenue of AA+BB. Although an excise tax analysis of this type is among the most likely policies for early economics students to encounter, Krutilla (2005, p. 867) reports that, among participants in a cost-benefit analysis class with intermediate microeconomics as a prerequisite, "it is a rare student who, at the start of the course, is able to convincingly explain the full [welfare] effects of a commodity tax." Exploration of tools that would improve pedagogy in this area is Krutilla's primary topic and will be further extended in this paper.

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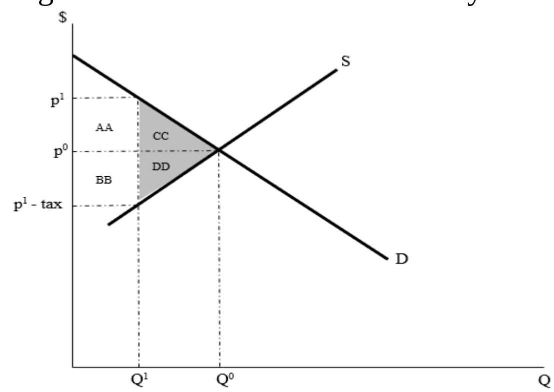
[2] Among the many examples that could be cited are: Mansfield and Yohe (2000), Figure 4.10; Mankiw (2018), sections 7-1c and 7-1d; Varian (2010), section 14.7; and Boardman et al. (2018), section 3.1.1.

[3] Examples include Varian, Figure 16.7, or Pindyck and Rubinfeld (2013), Figure 9.20.

In moving from the tax and monopoly cases to welfare analysis featuring slightly more complexity, there is no apparent consensus about which tools would promote student (or practitioner) understanding. For example, where substitution effects connect two markets, a principles textbook might only include predictive modeling of price and quantity changes, forgoing any welfare analysis; alternatively, the concepts of consumer and producer surplus may be omitted while presenting other approaches to economic efficiency that are arguably more advanced.[4]

This paper seeks to fill some of the gaps and correct several inaccuracies in the teaching and practice of welfare analysis, showing how relatively basic analytic tools—including accounting ledgers or, to use Krutilla's term, tableaux—can be applied to more than just the handful of cases that are widely taught in early and intermediate economics course.

Figure 1. Excise Tax Welfare Analysis



Precursors to Multi-Market Welfare Analysis

As discussed above in the substitute-products example, analysis involving multiple markets is commonplace in some respects but not as regards the welfare concepts that are the focus of this paper. In order to build up a sufficient analytic structure, I begin with cases that blend characteristics of single- and multi-market models.

The first such case continues the above discussion of a commodity or excise tax. The net welfare loss (deadweight loss) is traditionally identified as area CC+DD. The familiarity of the welfare-loss result can obscure that it depends, in some sense, on activity occurring *elsewhere*; the value generated by the government's expenditure of AA+BB is not generally observed in the market depicted in Figure 1. As shown in Table 1, if there is separate sub-analysis of the market (or non-market setting) where the government spending manifests its value, then appropriate accounting may necessitate that the Figure 1 sub-analysis include the full welfare effects occurring in that market—the entire area AA+BB+CC+DD.

Table 1. Excise Tax Welfare Accounting

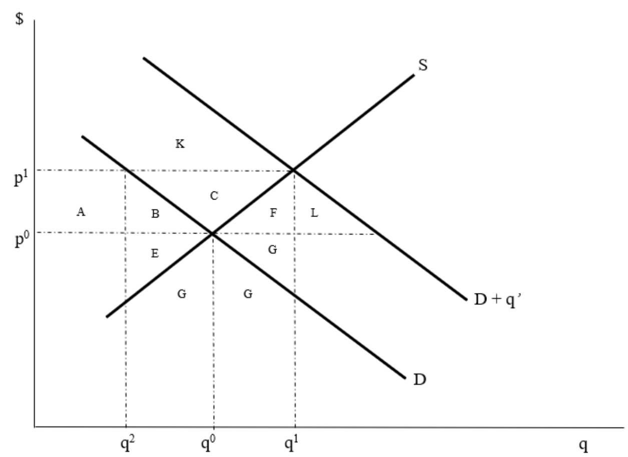
	Welfare effects, as visualized only with Figure 1	Welfare effects, if Figure 1 model augmented by broader analysis of the value (VV) of government spending
Consumers	-(AA+CC)	-(AA+CC)
Producers	-(BB+DD)	-(BB+DD)
Other	Government revenue = AA+BB	VV
Societal total	-(CC+DD)	VV - (AA+BB+CC+DD)

[4] Pindyck and Rubinfeld's Figure 16.1, "Two Interdependent Markets: (A) Movie Tickets and (B) DVD Rentals," appears in a chapter titled "General Equilibrium and Economic Efficiency" that forgoes discussion of consumer and producer surplus in favor of such tools as Edgeworth boxes.

The issue of sub-components of an analysis affecting each other's accounting will recur in the next case—that of an input market for a good or service purchased as part of a government project. As shown in Figure 2, a new demand curve (*D+q'*) would be used to predict changes in price and quantity exchanged in the market relative to what would be observed with original demand curve *D*.

The horizontal difference between the two demand curves represents government purchase activity, which has consequences for the interpretation of area K. Because this input-market case draws heavily on an example from a cost-benefit analysis textbook (Boardman et al., 2018 [5]), I assume that the government's transformation of the input purchased in the Figure 2 market will be subject to its own analysis—one using willingness-to-pay estimates relevant to the recipients or users of the government project's final output. If this separate sub-analysis is conducted, then excluding area K from Figure 2's concept of consumer surplus would be necessary for avoiding double-counting; this exclusion would have the additional advantage of clearly differentiating between government ventures and the welfare of pre-existing consumers in the Figure 2 market. Accordingly, consumer welfare effects are tracked, both here and by Boardman et al., with a visual focus on the pre-shifted demand curve (*D*), yielding a consumer surplus loss of A+B. When combined with a producer surplus gain of A+B+C and government expenditure B+C+G+E+F, the result is a welfare loss of B+G+E+F across all *direct* participants in the input market. Table 2 summarizes the preceding analysis, with one modification to the accounting ledger presented by Boardman et al.; instead of labeling the rows in a manner that implies that this market's participants encompass all of society, there is acknowledgement that the welfare results would depend on a separate sub-analysis of the output value of the government project, other input costs of the project, and deadweight loss of taxation that funds the government spending.

Figure 2. Market for an Input to a Government Project, Adapted from Boardman et al.'s Figure 6.3 (2018)



[5] As of the fall of 2022, among the benefit-cost analysis course syllabi listed on the website of Society for Benefit-Cost Analysis, Boardman et al. (2018) or its prior edition is listed several times more frequently than all other textbooks combined.

Table 2. Welfare Accounting Ledger Associated with the Input Market Modeled in Figure 2

	Gains	Losses	Net gains
Consumers		A+B	-(A+B)
Producers	A+B+C		A+B+C
Government		B+C+G+E+F	-(B+C+G+E+F)
Subtotal captured in Figure 2 *			-(B+G+E+F)
Subtotal *not* captured in Figure 2	Output value of government project	Other project input costs, if any, and deadweight loss of collecting B+C+G+E+F	
Societal total *	A+B+C + output value of government project	A+2B+C+G+E+F + other project input costs, if any, and deadweight loss of collecting B+C+G+E+F	Output value of government project - (B+G+E+F + other project input costs, if any, and deadweight loss of collecting B+C+G+E+F)

* Clarification relative to the ledger on Boardman et al.'s page 146, which labels the loss of B+G+E+F as the total societal welfare change rather than, more precisely, as the societal welfare change captured in the Figure 2 subset of a broader analysis.

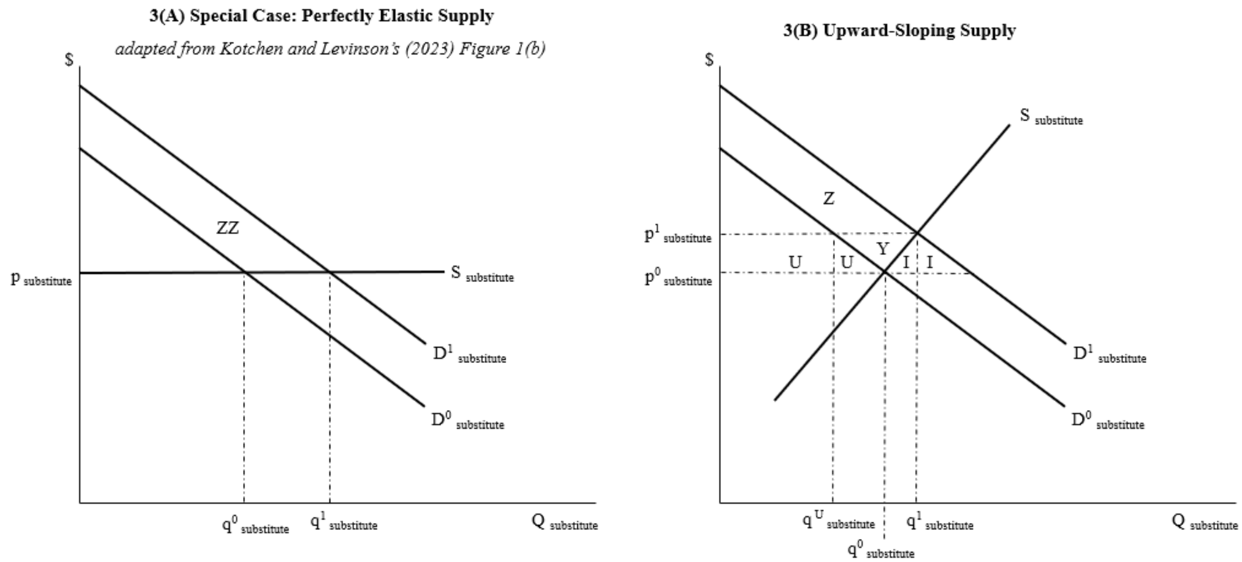
Multi-Market Welfare Analysis

I now turn from the "precursors" discussed above to more general multi-market models, with substitution and complementarity. If the price of *x* increases (or some other condition makes *x* less appealing), then demand for *y* increases if it is an *x* substitute and decreases if is it is a complement; predicting the resulting change in the price of *y* and quantity traded is relatively straightforward, as would be the associated change in producer surplus. The analysis of consumer surplus change is more challenging and generates a variety of answers, as will be discussed next.

Figure 3(A) shows a special case in which supply of a substitute product is perfectly elastic and demand for this product shifts due to consumption decreasing in a primary market. Secondary-market area ZZ has a welfare meaning; it is the amount that would be omitted from social surplus accounting in the primary market if the demand function used there is not defined over a sufficiently long time period for a new equilibrium (reflecting interactions with the secondary market) to be reached.[6] However, if long-run equilibrium welfare effects have been appropriately captured in the primary market, then ZZ has the potential to contribute to double-counting. As discussed in more detail in Boardman et al.'s Section 7.1.2, the same double-counting can arise regardless of the direction of consumption change in the primary market and for both complementarity and substitution across markets; across all these conditions, if secondary-market supply is perfectly elastic, then there is no long-run consumer welfare effect that is unique to a secondary market.

[6] Just et al.'s (2004) chapters 8 and 9 provide a technical discussion of how multi-market interactions progress across time.

Figure 3. The Market for a Substitute when Consumption of the Primary Product Decreases



In Figure 3(B), I allow the secondary-market supply curve to slope upward; otherwise, Figure 3(B) resembles Figure 3(A) in that secondary-market demand increases due to substitution for a product for which consumption is decreasing. When supply in the secondary market slopes upward, price rises from $p^0_{\text{substitute}}$ to $p^1_{\text{substitute}}$, and producer surplus increases by an amount represented by area U+Y.

The secondary-market consumer effect that has not yet been counted is the consumer surplus loss represented by area U—that is, the price increase experienced for the $q^U_{\text{substitute}}$ units that would have been consumed even in the old equilibrium (and are still consumed in the new) along with the lost surplus on units $q^U_{\text{substitute}}$ through $q^0_{\text{substitute}}$, which are no longer purchased by the market's original consumers.[7] There is a notable resonance between Figure 3(B)'s area U and Figure 2's A+B, as well as a resonance between Figure 3(A)'s area ZZ and Figure 3(B)'s area Z; in all of these cases, avoidance of multi-market double-counting is accomplished by tracking secondary-market consumer surplus effects with a visual focus on a single demand curve (in both panels of Figure 3, $D^0_{\text{substitute}}$), rather than a comparison using multiple demand curves.

Suppose, for instance, that the consumers who lost surplus area AA+CC due to the taxation modeled in Figure 1 are also potential consumers in Figure 3(B)'s substitute-product market. Area Z has, implicitly, already been netted off from long-run AA+CC, so a multi-market accounting ledger should focus on U as the only unaccounted spillover-market consumer surplus change. Table 3 depicts such a ledger, with Table 1's summary results summed with effects derived from analysis of Figure 3(B).

[7] It is not technically correct to assume that the consumers pushing demand out to $D^1_{\text{substitute}}$ are necessarily separate people from the ones captured in $D^0_{\text{substitute}}$, but the reasoning may be more intuitive if considered in this way rather than framed (more accurately) as new consumption creating a divergence between the secondary market's original consumption *activity* and its supply.

Table 3. Multi-Market Welfare Accounting, Integrating Figure 1 and Figure 3(B)

	Welfare Effects, per Table 1	Welfare Effect Uniquely Captured in Figure 3(B)'s Market for a Substitute *	Summed Welfare Effects
Consumers	-(AA+CC)	-U	-(AA+CC+U)
Producers	-(BB+DD)	U+Y	U+Y - (BB+DD)
Other	VV = value of government spending		VV
Societal total	VV - (AA+BB+CC+DD)	Y	Y + VV - (AA+BB+CC+DD)

* For a complement, signs on these results would be reversed.

As noted in Table 3, when summing producer and consumer surplus, the societal welfare result that would be uniquely captured by an analysis of the Figure 3(B) spillover market would be a welfare *gain* represented by area Y. This result serves as a corrective to Kotchen and Levinson's (2023) claim that, absent income effects, a cost-imposing regulation's "net effect on welfare *in the secondary market* is always negative" (emphasis added).[8] Kotchen and Levinson reach this conclusion by inappropriately focusing on area I, rather than area Y (area Y in this paper's Figure 3(B) being equivalent to area H in their Figure 2(b)).[9]

These inaccurate results in the literature, especially the quoted statements, reflect the pitfalls of overgeneralization. Relatedly, although the topics covered in this paper tend to be more suitable for advanced undergraduates (and beyond) than for earlier stages of economics education, a takeaway message that could be applied even to teaching microeconomic principles is that general statements should be avoided in the assessment of consumer surplus when demand curves shift and in the assessment of producer surplus when supply curves shift.

Distortion Wedges for Public Policy-Focused Benefit-Cost Analysis

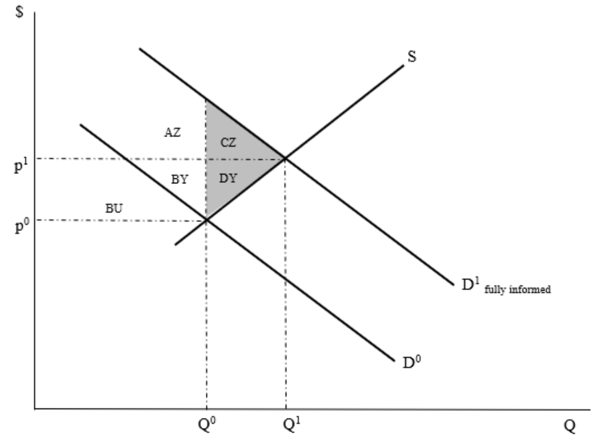
The just-noted lack of generality can generate other pitfalls for welfare analysis, as will be discussed next. Imagine, for instance, that a new scientific discovery increases demand for some product. Although the details of a model of the relevant market would differ from what appears in Figure 2 or either panel of Figure 3, there would be a visual commonality, with demand shifting to the right in all cases. Would it then be correct to attribute to the scientific discovery a consumer surplus increase that is akin to Figure 2's area K, Figure 3(A)'s area ZZ, or Figure 3(B)'s area Z? Alternatively, would these areas be revealed to represent double-counting with some other welfare amount, along the lines of was discussed in this paper's preceding sections? Consistent with a running theme of this paper, the answer to these questions will depend on what occurs across various markets.

[8] Boardman et al. assert that "demand shifts in undistorted secondary markets that cause price changes always involve losses in social surplus" in those secondary markets (p. 181). Kotchen and Levinson frame their paper as proving the universality of this statement made by Boardman et al. However, both the paper and the textbook overgeneralize their conclusions.

[9] Analysis can similarly go awry for the case of secondary-market *supply* increase in response to a primary-market shock, as discussed in more detail by the U.S. Department of Agriculture (2022). Analogous to the demand cases above, secondary producer surplus effects should be tracked with a visual focus on one supply curve; the resulting producer surplus loss (in the case of a secondary-market price reduction) can fall short of consumer surplus gain.

If Figure 4 depicts demand being affected by the hypothetical new scientific discovery, then the vertical distance between D^0 and D^1 could provide evidence on consumers' willingness-to-pay for the information revealed by the scientific investigations; however, the cost savings resulting from the scientific discovery will probably be more observable elsewhere, such as in an information-provision market.[10] The multi-market analysis, including effects in both the information-provision market (cost savings) and the Figure 4 market (spillover effects, if any), should proceed using the tools discussed in "Multi-Market Welfare Analysis," above.

Figure 4. Welfare Effect of a Scientific Discovery Revealing Current Underconsumption



By contrast, if consumers' information-search activity and general spillovers across markets are negligible, then a welfare analysis can focus on the single market shown in Figure 4. In the absence of the hypothetical scientific discovery, only Q^0 units of Figure 4's product are consumed, at price p^0, leading to underconsumption-related deadweight loss of CZ+DY. When the discovery eliminates this deadweight loss, area DY accrues to producers, as part of an overall gain for them of BU+BY+DY, and area CZ accrues to consumers, as part of their overall welfare change of CZ-(BU+BY). Although it might be tempting to identify AZ as part of consumers' welfare improvement, it would be incorrect to do so because that welfare already accrues to them in the original equilibrium (without the accompanying search costs of the type that distinguish the previous case from this one).

Figure 4 bears more than a passing resemblance to Figure 1, which illustrates the comparative statics of taxation. If one or many distortions—such as the lack of information underlying Figure 4 (the latter case, without search costs) or the tax introduced in Figure 1—combine to cause underconsumption, the deadweight loss can be visualized with a triangular wedge to the left of the intersection of the supply curve and the undistorted demand curve. Figure 5(a)'s shaded area (G+H) illustrates an analogous overconsumption wedge. As a tool for generating a net societal welfare result—and overcoming the types of student confusion reported by Sewell (2018) and Interis (2019)—the wedge visualization deserves emphasis broadly.[11] Indeed, a key recommendation of this section will be that distortions wedges be established first, with subsequent tracing and disaggregation of sub-population effects such as consumer or producer surplus changes.

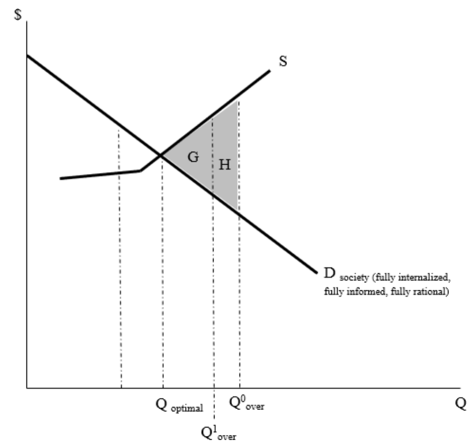
[10] Gathering evidence of information search activity has the additional advantage of distinguishing, at least somewhat, between substantive information and manipulative effects of advertising. Even when the latter induces demand shifts, its value may be spurious.

[11] In the context of a public policy benefit-cost analysis, this wedge structure provides specificity about the quantitative extent to which the policy outcome has the potential to generate positive net benefits.

Multiple types of market failure, government failure or incomplete rationality may be layered together in a distortion wedge; indeed, many types of distortions are likely to occur in tandem or, as noted by Nardinelli (2018), may be difficult to distinguish from each other. For instance, an internality—in which individuals impose suboptimally high costs on their future selves—may exist alongside a more traditional market failure or government failure. In such a case, the internality would be responsible for part of the consumption difference between Figure 5(a)'s Q^0_{over} and $Q_{optimal}$, with the other distortion(s) responsible for the remainder.

As a further example, consider the multiple externalities associated with conversion of wetlands to commercial or residential use. Downstream areas may be more prone to flooding and other adverse environmental consequences post-conversion, so the amount of wetland conversion may be suboptimally high. This tendency may be exacerbated if subsidized insurance incentivizes even more conversion of wetland areas; this type of pecuniary externality is discussed by Taylor and Druckenmiller (2022).

Figure 5(a). Reduction in Societal Distortion Wedge, Due to Policy Intervention



If a government policy addresses only one of multiple distortions, then the resulting welfare gain would be represented by quadrilateral H. Similarly, even if there is just one underlying distortion, an under-correcting policy would generate welfare improvement that is smaller than the original (shaded) deadweight loss triangle. (An over-correcting policy would yield a welfare gain equal to the difference in area between Figure 5(a)'s shaded triangle and an underconsumption wedge to the left of the supply-demand intersection.)

Returning to the wetland over-conversion example introduced earlier, suppose two distortion-reducing policies are being compared. In the first, the government would identify the units of wetland conversion between Q^0_{over} and Q^1_{over} and make them ineligible for participation in the subsidy program.[12] The second possible intervention would revise subsidy rates, also yielding a decrease in wetland conversion down to Q^1_{over}. The reduction in deadweight loss attributable to either one of these policies would be represented by area H.

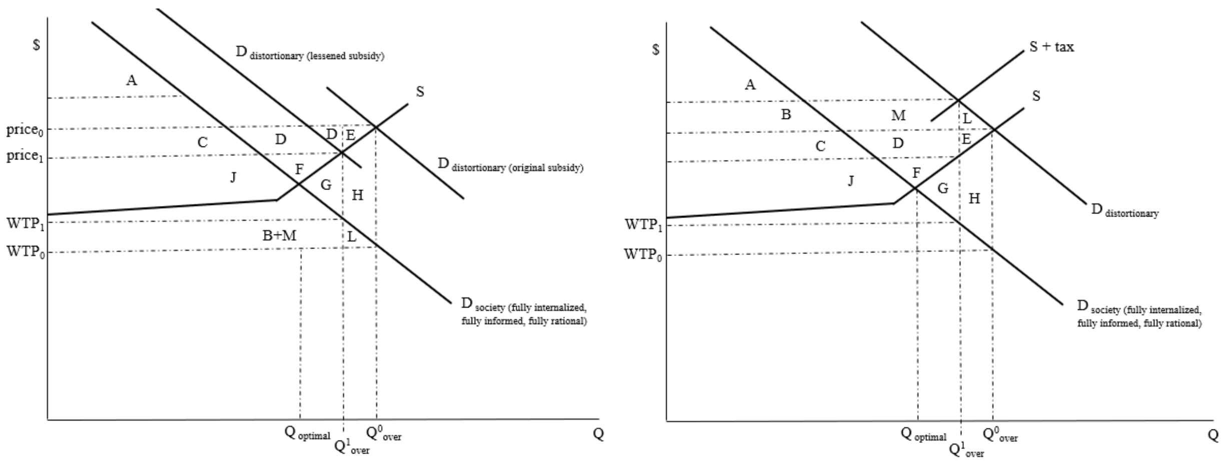
There are, however, differences between the analyses of the two policies, and one such difference involves the comparison of area H to aggregate reduced subsidy payments. To facilitate this comparison (and eventual tracking of consumer and producer surplus changes), Figure 5(b) adds detail to the same market diagram depicted in Figure 5(a).[13] If subsidies are no longer paid on units between Q^0_{over} and Q^1_{over} but unchanged for the remaining Q^1_{over} units, then the aggregate payment reduction is E+H+L, which is an amount that only slightly overstates the societal welfare gain of H. By contrast, if subsidy rates are changed more broadly, aggregate payments decrease

[12] To simplify the examples discussed in this paragraph, I will assume that the underlying wetland-conversion subsidies are direct, rather than taking the form of subsidized *insurance*, where risk-protection value would be another welfare effect to include in benefit-cost accounting.

[13] The two panels of Figure 5(b) are mostly interchangeable. Subsidy reductions (left-hand panel) and tax increases (right-hand panel) generate equivalent welfare consequences, but observed market prices would differ.

by (E+H+L)+(B+M+C+D), and this amount would make a much worse proxy for net welfare change (H) across various segments of society.

Figure 5(b). Consistency Between Figure 5(a)'s Societal Distortion Wedge and Summation Across Disaggregated Welfare Tracking



Welfare effects that are disaggregated by type of market participant may also be of interest. The producer surplus change is a straightforward decrease of C+D+E. The welfare change for consumers and other affected individuals (such as non-participants in the market affected by a negative externality) depends on the policy change being analyzed, but in many cases may be most reliably assessed by process of elimination. For instance, with the hypothetical change in wetland-conversion subsidy rates, it has already been established that overall social welfare gain is H, producer surplus loss is C+D+E, and government gain is E+H+L+B+M+C+D; the remainder, B+M+L, is loss borne by consumers.

Table 5 summarizes welfare results for various other cases, including a suboptimally calibrated Pigovian tax and non-tax policies that either do or do not increase the marginal cost of consumption.

Table 5. Welfare Effects of Various Undercorrecting Policies

	(i)	(ii)	(iii)	(iv)
	Initial Equilibrium	New Equilibrium with Under-correcting Policy That Does Not Raise Marginal Cost (MC) of Consumption	New Equilibrium with Under-correcting Tax Policy	New Equilibrium with Under-correcting Non-Tax Policy That Raises MC of Consumption
Consumer Surplus and Other Non-Producer, Non-Tax-Revenue Welfare [a]	A+B - (D+E+F+G+H)	A+B+C-(F+G) [b] gain: C+D+E+H [b]	A-(D+F+G+M) gain: E+H-(B+M)	A-(D+F+G+M) gain: E+H-(B+M)
Producer Surplus	C+D+E+F+J	F+J loss: C+D+E	F+J loss: C+D+E	F+J [c] loss: C+D+E
Government Tax Revenue	0 (zero)	0 (zero) change: 0 (zero)	B+C+D+M gain: B+C+D+M	0 (zero) change: 0 (zero)
Society (sub-total to be combined with administrative costs or other effects that do not depend on consumption quantity)	A+B+C+J – (G+H)	A+B+C+J - G [b] gain: H [b]	A+B+C+J - G gain: H	A+J - (D+G+M) gain: H-(B+C+D+M) [d]

[a] In the case of an externality, the portion of policy-induced welfare change that consists of gain to individuals not directly participating in this market is E+H+L, with consumer surplus gain of C+D-L (for a non-MC-raising policy) or loss of B+M+L (for a tax or other MC-raising policy).
[b] Welfare results may be upper bounds.
[c] For simplicity of the illustration, there is an implicit assumption here that the marginal cost increase is equal for any produced unit; otherwise, the producer surplus after policy implementation would be some subset of B+C+D+F+J+M that, because its lower border is not parallel with the original supply curve, does not precisely equal F+J.
[d] The B+C+D+M portion of the welfare change is not triangular—nor would it be in the analysis of a fully corrective policy, as incorrectly claimed by the U.S. Food and Drug Administration (2011) in the righthand panel of their Figure 1.

It is important to mention that the net welfare impacts just described only reflect what can be captured in marginal utility (demand) and marginal cost (supply) schedules. If, for instance, a policy intervention involves a government administrative cost (or a benefit, as discussed in relation to Figure 2 and Tables 2 and 3, earlier in the paper) that does not depend on the amount that consumption changes, then the diagrammed welfare changes are sub-components of overall welfare gain or loss.

As a further caveat, the welfare gain areas listed in Table 5 may be misidentified if the policy under consideration does not affect behavior at the margin in the same manner as a tax. Suppose that the modeled intervention is a label change that causes consumers to partially overcome an internality. There is no guarantee that it is the units of consumption for which willingness-to-pay is between WTP_0 and WTP_1 (out of the wider range of irrational consumption) that are newly forgone. A lesser reduction in irrational consumer behavior would produce smaller welfare gains than what is shown in Table 5's column (ii).

Conclusion

Some of the most used and useful tools in economics are visual in nature, and this truism for economics generally is also valid for benefit-cost analysis. Words alone can be slippery when performing key steps of such an analysis—such as the basic step of categorizing effects as benefits or costs—and market visualizations can provide needed solidity for the relevant thought processes. However, although a supply-demand diagram is simple, its accurate and appropriate use is not always obvious.

For example, time is of fundamental importance—both in terms of defining a market and, relatedly, using comparative statics over a sufficiently long period that a new equilibrium could be reached—but a relatively recent publication has gone awry on this score.[14] Policy issues are likely to continue raising questions about which economic tools are most important to establish firmly for students and practitioners.

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[14] DeCicca et al. (2017) offer further critiques of Cutler et al. (2015), but a succinct starter observation is that Cutler et al.'s Figure 2 features demand curves that are short-run and health costs that are primarily long-run.

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