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# Teaching Undergraduate Economics: Emphasize Early the Meaning of Vertical Distances and of Their Summation Over Quantities

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**Abstract**
Many important economic concepts—for example, deadweight losses, market surplus measures, and concepts preceded by the word "total"—are graphically depicted as areas. Although many students can identify areas like total surplus appropriately in simple circumstances such as when a market is in equilibrium, many struggle to do so when the circumstances are even slightly more complex, such as when a market is not in equilibrium. The reason may be that many students do not understand how these areas are graphically derived. In this commentary, I discuss simple adjustments instructors can make to emphasize the economic meaning of vertical distances and of their summation over quantities so that students can better identify graphical representations of economic concepts even in more complex circumstances.

I teach an introductory environmental economics course for which a class in principles of microeconomics or its equivalent is a prerequisite. Many students in the course have already taken intermediate microeconomics as well. If students struggle in my course, certainly one of the leading reasons is because they are not accustomed to thinking about the economic meaning of vertical distances in graphs that measure dollars on the vertical axis and quantity of a good on the horizontal axis.

A common error is illustrated by Figure 1, which depicts a market in which there is a negative externality, as indicated by a marginal social cost (MSC) curve above the supply curve. When students are asked to depict the deadweight loss in surplus when the market is in equilibrium, many indicate the horizontally shaded triangle instead of the vertically shaded triangle. I suspect that many students make this mistake because they do not understand how deadweight losses in general are graphically derived (i.e., that they are a series of appropriate vertical distances added over quantities). Instead, they have learned in microeconomic principles class that a per-unit tax leads to a deadweight loss that looks like a triangle "pointing" to the right. In this commentary, I discuss these and other potential reasons that many undergraduate economics students likely struggle with the meaning of vertical distances. I also present ways that instructors can reinforce marginal analysis concepts.

One reason that students might struggle with the economic meaning of vertical distances is that some instructors introduce them to the "supply and demand" diagram before introducing them to the "marginal cost and marginal benefit" diagram, which of course is the same diagram. A demand curve (D) is an ordering of consumers from highest to lowest marginal benefit of consumption, and a supply curve (S) is an ordering of producers from lowest to highest marginal cost of production. Thinking about the curves in these two respective ways emphasizes different spatial relationships. Consider the "D" curve in demand terms: if you tell me a price, I can tell you the quantity demanded at that price, which is graphically a horizontal distance. Now consider the "D" curve in marginal benefit terms: if you tell me a quantity, I can

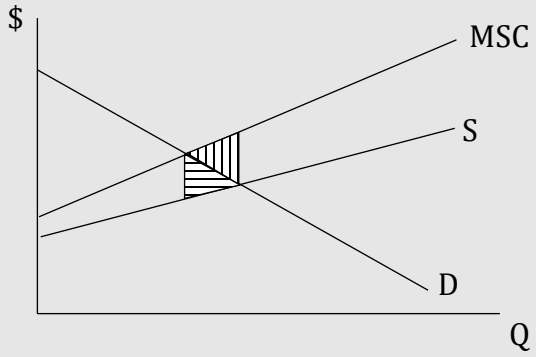



**Figure 1. Which triangle is the deadweight loss when the market is at equilibrium?**

tell you the marginal benefit of the last unit consumed, which is graphically a vertical distance.[1]

Perhaps some instructors explain supply and demand curves before marginal cost and marginal benefit curves because they want to quickly introduce students to the concept of market equilibrium. Equilibrium is much more straightforwardly explained by thinking of the diagram in supply and demand terms. When a good's price is too high, a quantity surplus results, so some bright seller gets the idea to reduce the price in order to sell the surplus and get it off the shelves. When a good's price is too low, another bright seller gets the idea to raise it because she can do so and still make a sale. This dynamic plays out until equilibrium is reached. Instructors frequently follow up this lesson by introducing elasticities.

However, in many cases, instructors could better serve student learning by using marginal cost and marginal benefit curves instead of supply and demand curves. These cases include those in which students are asked to consider whether a market makes people best off (as measured by total surplus), the conditions under which it fails to make them best off, and the policies that could improve or worsen market outcomes. In judging whether an action makes people better off—in this case, by deciding whether to produce and consume one more unit of a good—marginal benefits and costs are measured as vertical distances in the graph, not as horizontal distances. While experienced instructors naturally think this way, I believe there are three ways we can more effectively help our students to do the same.

First, we can ensure that definitions correspond with the vertical distances that are useful. For example, the microeconomics principles textbook by Mankiw (2015) defines *consumer surplus* as "the amount a buyer is willing to pay for a good minus the amount the buyer actually pays" (p. 137). Graphically this amount is the vertical distance between the marginal benefit curve and the price line at a particular unit. On the next page, consumer surplus is used to refer to an area in the graph: "The area below the demand curve and above the price measures the consumer surplus in a market" (p. 138). Mankiw explains that the area called consumer surplus is calculated by adding together the consumer surplus on each unit consumed, but he uses the same term to describe both the vertical distance relevant to a given single unit consumed and the area relevant to all units consumed. If, instead, we were to use a term such as *marginal consumer surplus* to describe the consumer surplus gained from consumption of a single unit (we use the word *marginal* to emphasize one unit in other economic situations, so why not here?), that surplus might be better established as an important unique concept. Indeed, marginal consumer surplus is arguably the more important concept because consumer surplus (the area) is just the summation of a bunch of marginal consumer surplus values. If a student forgets that relationship, he or she will have difficulty when the circumstances of the problem change.

[1] Relatedly, I find it easy to forget to remind students that it is assumed that each previous unit was allocated to the consumer who values it most. The parallel assumption applies to marginal cost.

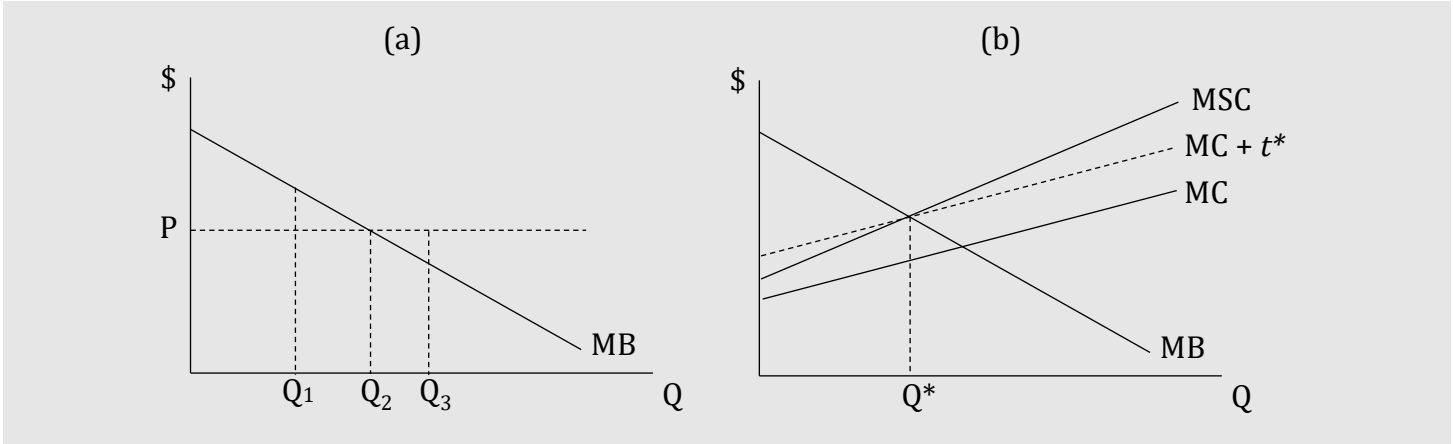
Second, as touched on above, we can consider the order in which we teach concepts. One possibility might be to first discuss market welfare impacts of different quantities of a good consumed and produced using a marginal cost and marginal benefit diagram and then to teach equilibrium using a supply and demand diagram. This order of presentation would seem to be preferable if there are more contexts in which it is natural to think of the curves as marginal cost and marginal benefit curves than contexts in which it is natural to think of them as supply and demand curves. The lesson of equilibrium might also then be more impactful because students should immediately recognize that the equilibrium maximizes total surplus (under the typical assumptions).

Third, we can label the curves to reflect how we would like students to think about them. In Figure 1 for instance, the supply and demand curves could instead be labeled MC and MB. Doing so may help reinforce for students that a curve with a label that starts with M likely signals that vertical distances will be important in the diagram.

Consider panel (a) of Figure 2, which depicts a marginal benefit (MB) curve, a given price, and three quantities of the good. Given the price, the area depicting consumer surplus is either a trapezoid (under $Q_1$), a triangle ($Q_2$), or a "bowtie" shape ($Q_3$), where the left side of the bowtie is positive consumer surplus and the right side is negative consumer surplus. Once the student has mastered the idea that consumer surplus is the sum of the marginal consumer surpluses for each unit—that is, a set of vertical distances—he or she will never get the area representing consumer surplus incorrect for a given Q. When the idea of adding vertical distances over quantities has not been mastered, students tend to rely on other means of determining the answer, like remembering that it was a triangle in the previous class example.

It is especially critical that students understand the economic meaning of vertical distances and of their summation over quantities in comparatively complex diagrams. One of the more complex graphs from an introductory course in environmental economics depicts an optimal Pigouvian tax in the presence of a negative externality, as in panel (b) of Figure 2. A vertical distance of central importance is the "marginal external cost," that is, the cost of the pollution from a given unit of the good, imposed on people external to the market transaction. The marginal social cost (MSC) curve simply sums, for each unit, the marginal cost of producing the unit (MC) and the marginal external cost of that unit. So, by algebra, the marginal external cost of a given unit is the vertical distance between the MSC and MC curves.

In a simple graph that depicts only a MB curve, a MC curve, and a MSC curve (i.e., panel (b) but without the dashed lines), students should be able to identify the economically efficient quantity of the good (the quantity at which the MB and the MSC are equal and therefore have the same vertical distance) and the optimal Pigouvian tax, $t^*$ (equal to the vertical distance between the MSC and MC curves at the efficient quantity[2]), which maximizes total surplus. Table 1 lists several other important concepts relevant to this example, all of which are graphically derived by adding vertical distances over quantities.




[2] Tip: emphasize *which* vertical distance between MSC and MC is the optimal one for determining the tax. If the MSC and MC curves are drawn parallel, this point is lost.

**Table 1. Concepts that are vertical distances added up over quantities**

| Concept | Relevant Vertical Distance | Geometric Shape[a] |
|---|---|---|
| consumer surplus | MB - P | triangle |
| producer surplus (under tax) | P - (MC + *t*) | triangle |
| total external cost | MSC - MC | trapezoid |
| total tax revenue | *t* | parallelogram (or rectangle) |
| deadweight loss if market *isn't* at Q* | MB - MSC (or MSC - MB) | N/A |
| total surplus | MB - MSC | triangle |

*Note:* Each listed concept is an area that is found by adding up the relevant vertical distance over the appropriate number of units.

[a] The corresponding geometric shape in panel (b) assumes the market is at efficient quantity, Q*, but may be different under a different Q.

**Figure 2. Consumer surplus at different quantities (a), taxing under a negative externality (b).**

Students would have a much easier time graphically depicting these and other concepts in different economic contexts if they understood the economic meaning of vertical distances. In most introductory microeconomics textbooks, vertical distances on graphs (and their summation across units) are important in understanding numerous topics: market efficiency, the costs of taxation, international trade and tariffs, externalities, public goods and common resources, production and associated costs, profit maximization, deadweight losses from monopolies, and markets for factors of production, among others.

As a final argument for encouraging students to understand the economic meaning of vertical distances, consider the connection of those distances to integration, which students learn as they advance in the study of economics.[3] Adding up a bunch of vertical distances over a quantity is integration, so undergraduates who have learned integration and have been trained from the start to think of many economic concepts as summations of vertical distances over quantities can easily grasp the connection between economics and the mathematical tools we use to express it.

Table 2 lists an incomplete but reasonably representative assortment of introductory-level microeconomics textbooks, some more general and some with greater focus on agricultural contexts. The table is not intended to be a critique of the overall quality of these books, some of which are excellent; instead, it highlights each book's approach to the three ideas presented above to help students better relate marginal thinking to vertical distances. Clearly, the books in general do not adopt all the suggestions. However, a blanket recommendation to implement all the suggestions should not be inferred by the reader. For example, teaching students market welfare concepts graphically before teaching equilibrium may not suit many instructors, and even if it does, it might introduce other problems, for example, by not matching the order of presentation in the instructor's otherwise preferred textbook. On the other hand, using different terms to differentiate "marginal" consumer or producer surplus from "total" consumer or producer surplus would seem to be fairly innocuous. We generally will not accept students failing to distinguish between marginal cost and total cost just by using the word *cost*, so we should probably hold ourselves to the same standard when discussing surplus measures and other concepts when the distinction is useful.

My overall point is this: by thinking carefully about how our teaching—from what we say to what we write to what we draw—might affect students' thinking, we can adjust our teaching styles to best serve that thinking. For example, even when supply and demand curves are first introduced as such, instructors

[3] In my own department, undergraduate students are not required to learn integration as part of the major curriculum, but many do learn it if they take advanced calculus courses, and of course integration is necessary at the graduate level.

**Table 2. What do microeconomic principles textbooks do?**

| Textbook authors | Does not use "consumer surplus" to refer to both a vertical distance and an area? | Market welfare covered graphically[a] before equilibrium? | Curves labeled "MC" and "MB" when discussing market-level welfare? |
|---|---|---|---|
| Acemoglu et al. (2015) | No | No | Yes and No[b] |
| Arnold (2019) | No | No[c] | No |
| Bade and Parkin (2015) | No[d] | No | Yes |
| Barkley and Barkley (2016) | No | No | No |
| Mankiw (2015) | No | No | No |
| Penson et al. (2015) | No | Yes | No |

[a] Several books cover marginal thinking and analysis before equilibrium, just not graphically.
[b] Does so when covering producer surplus but not when covering consumer or total surplus.
[c] Does illustrate efficiency at the individual level (not market level) very early on (p. 7).
[d] Is careful to define market surpluses as summations of MB and MC over quantities.

can label them MC and MB when contextually appropriate rather than continuing to label them S and D. I emphasize to my students the importance of first determining, for a single unit of the good, the vertical distances that correspond to the concept under examination. Only after having ascertained those distances should they add them together (i.e., shade them in) until they get to the relevant quantity. I have found that students who master this way of thinking are much less likely to go wrong, and they end up with a strong understanding of economic concepts and their various portrayals in verbal, algebraic, and graphical forms.

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