Demand, Elasticity, and Consumer Surplus

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When evaluating the effects of changes to the transportation system, it is useful to understanding how one might measure the total economic cost of travel, to predict how demand changes in response to changes in cost, and to quantify how the benefits people get from the transportation system change when the cost of travel changes.

Cost of travel

The total cost of travel includes both *monetary* and *non-monetary* costs.

Monetary costs include things like transit fares, tolls, and the cost of fuel and vehicle maintenance.

Non-monetary costs include things like travel time, discomfort, and risk of death, injury, or property damage. In many common circumstances, travel time represents most of the total cost of travel. Risk of death or injury may also be an important factor.

In order to combine monetary and non-monetary costs, we need to be able to express them with a common unit of measurement. One way to do this is to assign a monetary value to non-monetary costs.

Demand for travel

We can observe the demand for travel as the total amount of travel at the existing price. The units of measurement for travel demand should be consistent with with the data we have on prices. If we have data on the price per trip, then our measure of travel demand should be the number of trips. If we have data on the price per distance traveled (e.g. the cost per mile or the cost per kilometer), then our measure of travel demand should be the total distance traveled.

Demand curves

If the price of travel changes, it is possible that the demand for travel will change as well.

A demand curve like the one shown in Figure 1 illustrates the relationship between demand and price, with price shown on the y-axis and demand shown on the x-axis. We typically plot independent variables on the x-axis and dependent variables on the y-axis. If we understand demand changes to be in response to price changes, this convention of plotting price on the y-axis will seem backwards (or sideways).

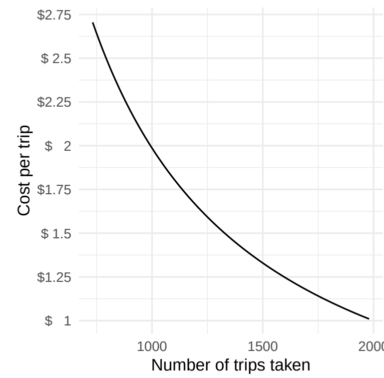


Figure 1: Example of a demand curve

Elasticity

The *elasticity* of demand refers to the steepness of the demand curve or how responsive people are to price changes. If people always use a particular transportation system the same amount, no matter how much it costs, then we would say that demand is *perfectly inelastic* and the demand curve would be a vertical line like the one in Figure 2, indicating that demand is the same at all prices.

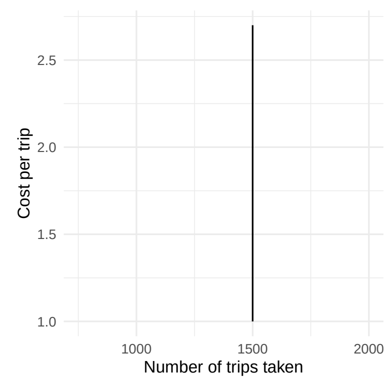


Figure 2: Perfectly inelastic demand curve

Inelastic demand would suggest that there are *no* alternatives to travel on a particular system, and this is never the case (staying home is often a reasonable alternative). However, when there are very few alternatives, a demand curve would be very steep. Figure 3 shows a demand curve for gasoline in the United States between 2004 and 2014[1].

[1] **Source:** Based on quarterly data from Eliana Eitches and Vera Crain , "Using gasoline data to explain inelasticity ," Beyond the Numbers: Prices & Spending, vol. 5, no. 5 (U.S. Bureau of Labor Statistics, March 2016), https://www.bls.gov/opub/btn/volume-5/using-gasoline-data-to-explain-inelasticity.htm

Between 2004 and 2014, gas prices fluctuated between $3.91 per gallon (in the third quarter of 2008) and $1.72 per gallon (in the first quarter of 2004). During the first quarter of 2004, when gas cost about $1.72 per gallon, the average household consumed about 210.7 gallons of gasoline. During the the third quarter of 2008, when gas prices were 127 percent higher, the average household consumed 180.5 gallons of gasoline: an reduction of just 14 percent.

We can calculate elasticity as the ratio of an observed change in demand to the associated observed change in price, or the reduction in demand that would be associated with a one-percent increase in price.

In the above example, the elasticity of demand for gasoline would be:

$$\frac{14\%}{127\%} = 0.11$$

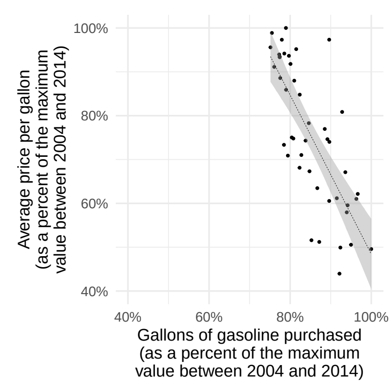


Figure 3: Demand curve for gasoline in the United States

It's worth noting that, while $3.91 is 127% higher than $1.72, $1.72 is 56% lower than $3.91. Likewise, 180.5 gallons is 14% lower than 210.7 gallons, but 210.7 gallons is 17% higher than 180.5 gallons. This means that if we were talking about a decrease in gas prices rather than an increase, we'd get an elasticity of:

$$\frac{17\%}{56\%} = 0.30$$

It doesn't really make sense that price elasticities would be different for price increases than decreases. A common way to bring them into alignment is to calculate the percent change as a symmeterical percent change:

$$change = \frac{difference}{average}$$

So the symmetrical percent change in gas prices would be:

$$\frac{3.91 - 1.72}{\frac{1}{2}(3.91 + 1.75)} = 77\%$$

The symmetrical percent change in fuel consumption would be:

$$\frac{210.7 - 180.5}{\frac{1}{2}(210.7 + 180.5)} = 15\%$$

And the elasticity (for a price increase or decrease) would be:

$$\frac{15\%}{77\%} = 0.19$$

When you are setting prices for something, having a guess as to how elastic the demand for that thing is can be really useful. When there is inelastic demand, you can expect revenue to increase by the same amount that the price increases. If demand is elastic, small increases in price can lead to large increases in demand, so changes in revenue might be modest (or even negative).

Consumer surplus

You can think of the downward sloping demand curve as implying that each person has a price they would be willing to pay for a given service or good (this is a simplification).

In the demand curve shown in Figure 1, at a price of $2 per trip, there are about 990 people who would be willing to make a trip. At a price of a $1.99 per trip, 1000 people would be willing to make a trip. These additional ten people who are willing to pay $1.99 for a trip (but not $2) are satisfied with a price of $1.99: They are paying exactly as much for the trip as the trip is worth to them.

The other 990 people who would have still made a trip at a price of $2 per trip are even happier because they are paying less for the trip than they were willing to pay. Some of them would have been willing to pay more than $2.50 per trip, so those folks are very happy with the price of $1.99. Others would have been willing to pay up to $2, so they happy about the price being $1.99, but not as happy as those who would have been willing to pay up to $1.

The total difference between the actual price of something and how much everyone who purchases at that price would have been willing to pay is the *consumer surplus*. You can picture it as the area below the demand curve and above the price level, as shown in Figure 4.

Consumer surplus is most useful for thinking about the total benefit (or loss) to consumers that comes with a change in price. Figure 5 illustrates the increase in consumer surplus that comes from reducing the price per trip from $2 per trip to $1.75 per trip. The dark-gray area is the consumer surplus when the price is $2 and the light-gray area is the additional consumer surplus that is gained when the price drops to $1.75.

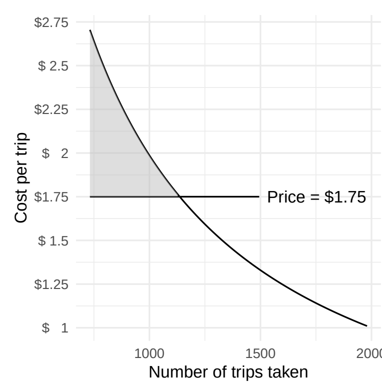
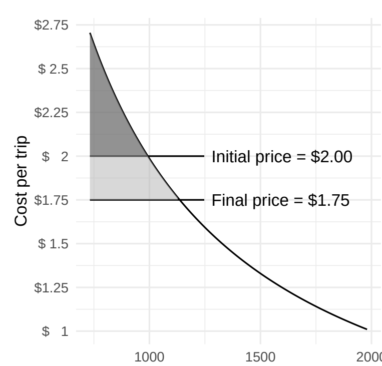


Figure 4: Illustration of consumer surplus



We can quantify the benefit of this price change to consumers by calculating the area of the light-gray area, which we can approximate as a rectangle plus a triangle - as illustrated in in Figure 6.

The area of the rectangle is the demand at the initial price times the change in price. The area of the triangle is one half the difference in the price times the difference in demand.

Dividing the area into a rectangle and a triangle isn't just a trick for calculating the area. It also has a direct interpretation. The area of the rectangle represents the benefit to existing travelers, and the area of the triangle represents the benefit to new travelers.

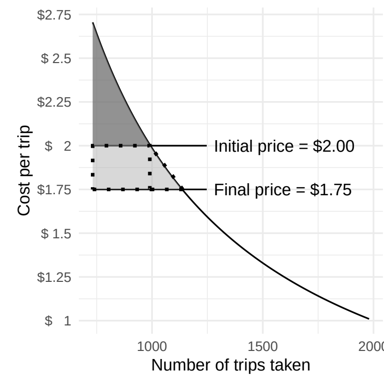


Figure 6: Parts of consumer surplus