Appendix 3.1. Supply, Demand, and Welfare Analysis

Environmental and Natural Resource Economics: A Contemporary Approach presupposes that you have had an introductory economics course. But if you have not, or if your basic economic theory is a little rusty, this appendix provides you with the background microeconomic knowledge you will need for the text.

Economists use models to help them explain complex phenomena. A model is a scientific tool that helps us understand something by focusing on certain aspects of reality yet ignoring others. No model can consider every possible factor that might be relevant, so scientists make simplifying assumptions. One of the most powerful and widely used models in economics concerns the interaction of supply and demand. Based on several simplifying assumptions, this model provides us with insights about the changes we can expect when certain things happen, as well as what types of economic policies are the most appropriate in different circumstances.

The Theory of Demand

The theory of demand considers how consumer demand for goods and services changes as a result of changes in prices and other relevant variables. In this appendix, we use the market for gasoline as an example. Obviously, many factors affect consumer demand for gasoline, so we start by making a simplifying assumption. For now, let us consider only how consumer demand for gas changes when the price of gas changes—all other relevant factors are assumed to be held constant. Economists use the Latin term *ceteris paribus*, meaning "all other things equal," to isolate the influence of only one or a few variables.

How will the quantity of gas demanded by consumers change as the price of gas changes? The **law of demand** states that as the price of something increases, consumers will demand less of it, *ceteris paribus*. Or we could conversely say that consumers demand more of something when the price of it falls. This inverse relationship between the price of something and the quantity demanded can be expressed in a couple of ways. One way is through a demand schedule—a table showing the quantity of a specific good or service demanded at different prices. The other way is

to use a graph to illustrate a demand curve—just the graphical representation of a demand schedule. The convention among economists is to put the quantity demanded on the horizontal axis (the *x*-axis) and price on the vertical axis (the *y*-axis).

law of demand: the economic theory that the quantity of a good or service demanded will decrease as the price increases.

Suppose that we have collected some data about how much gasoline consumers in a particular metropolitan area demand at different prices. This hypothetical demand schedule is presented in Table 1. We can see that as the price of gas rises, people demand less of it. The data in Table 1 are expressed graphically, as a demand curve, in Figure 1. Notice that the demand curve slopes down as we move to the right, as we would expect according to the law of demand.

Table 1. Demand Schedule for Gasoline

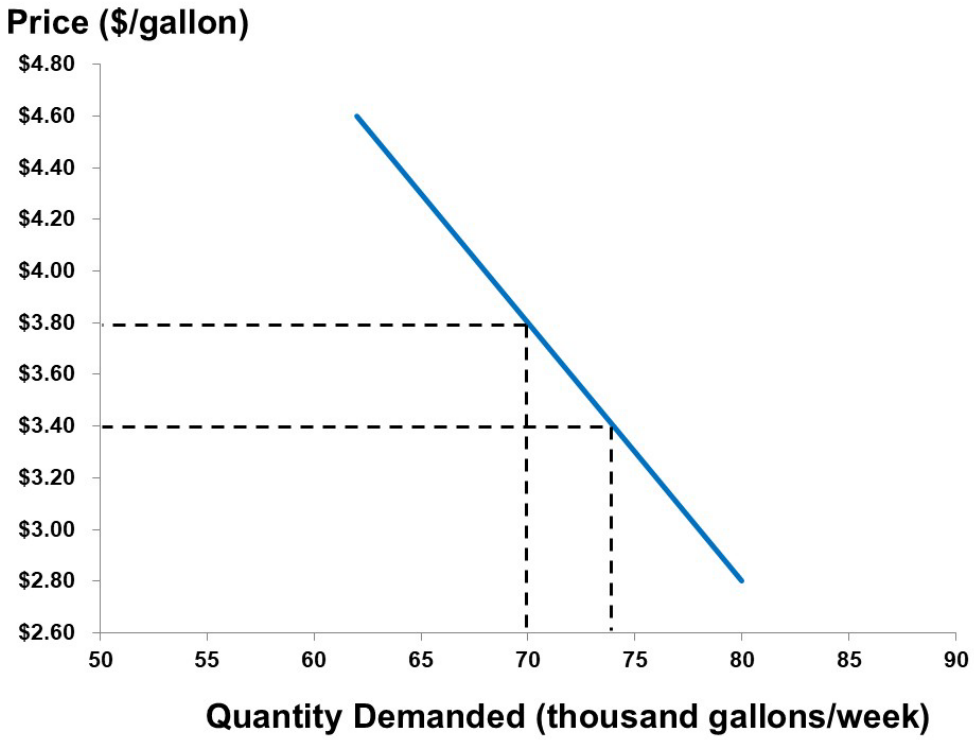
Price ($/gal.)	$2.80	$3.00	$3.20	$3.40	$3.60	$3.80	$4.00	$4.20	$4.40	$4.60
Quantity demanded (thousand gal/week)	80	78	76	74	72	70	68	66	64	62

We can see in Figure 1 that at a price of $3.40 per gallon, consumers in the area will purchase 74,000 gallons of gas per week. Suppose that the price rises to $3.80 per gallon. At the higher price, we see that consumers decide to purchase less gas, 70,000 gallons per week. We call this movement along a demand curve at different prices a *change in the quantity demanded*. This is different from what economists call a *change in demand*. A change in demand occurs when the entire demand curve shifts.

What would cause the entire demand curve to shift? First, we need to realize that a change in the price of gasoline will *not* cause the demand curve to shift; it will only cause consumers to move along the demand curve in Figure 1 (i.e., a change in the quantity demanded). Our demand curve in Figure 1 is stable as long as we assume that no other relevant factors are changing—the *ceteris paribus* assumption. To expand our model, let us consider several factors that would cause

the entire demand curve to shift. One factor is income. If the consumers' incomes were to rise, many would decide to purchase more gas at the same price. Higher incomes would result in a change in demand. This is shown in Figure 2, where the entire demand curve shifts to the right.[1]

Figure 1. Demand Curve for Gasoline

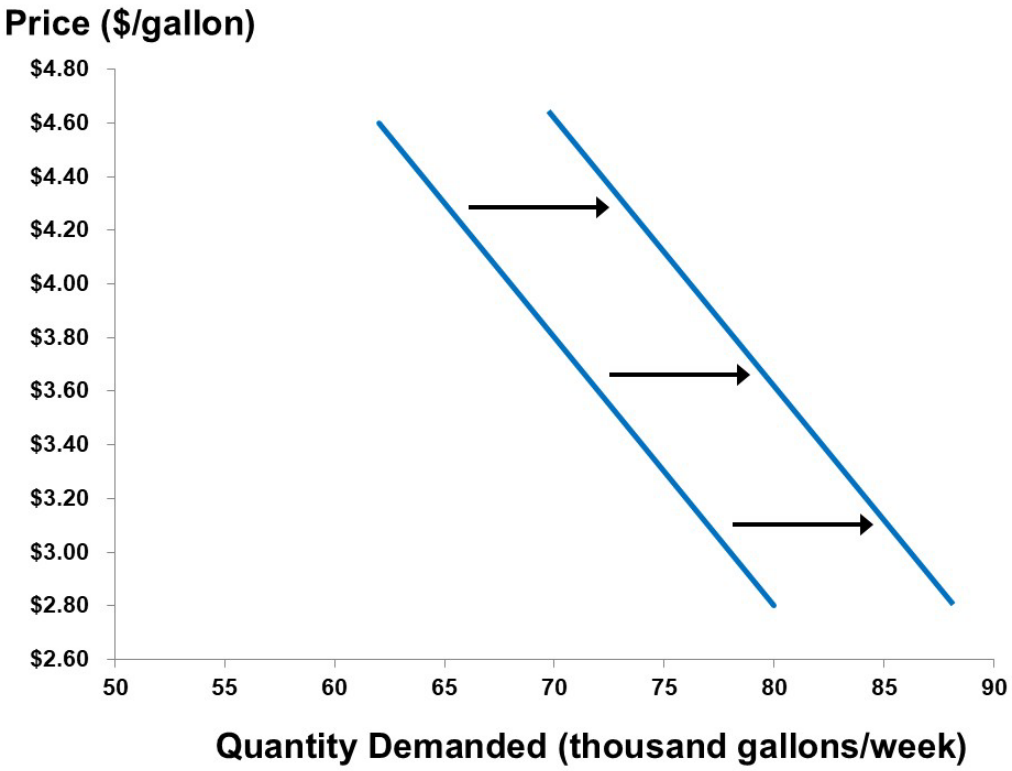


Another factor that would cause a change in demand is a change in the price of related goods. In our example of the demand for gas, suppose that the price of public transportation increases significantly. This would cause the demand for gas to increase (shift to the right) as some people decide to drive their own vehicles because public transportation is now too expensive for them. A change in consumer preferences could also cause the demand curve for gas to shift. For example, if more consumers purchase electric vehicles, this would cause a decrease in the demand

[1] Economists generally describe demand curves as shifting to "the right" or "the left," not up or down. This is because it makes more intuitive sense to say that at a given price consumers will demand more or less than to say that consumers will purchase a given quantity at a higher or lower price.

for gas. A significant change in the number of people driving would also cause a change in the demand for gas. In what direction do you think the demand curve for gas would shift if the population of our metropolitan area were to decrease by 20%? Can you think of any other factors that would also cause a demand curve to shift?

Figure 2. A Change in Demand



The Theory of Supply

The next step in our analysis is to consider the other side of the market. The theory of supply considers how suppliers respond to changes in the price of a good or service they offer, or changes in other relevant factors. While low prices appeal to consumers looking for a bargain, high prices appeal to suppliers looking to make profits. As you might expect, the **law of supply** is the opposite of the law of demand. The law of supply states that as the price of something increases, suppliers

will choose to offer more of it, *ceteris paribus*. According to the law of supply, price and the quantity supplied change in the same direction.

law of supply: the economic theory that the quantity of a good or service supplied will increase as the price increases.

Once again, we can express the relationship between price and the quantity supplied using both tables and graphs. Table 2 illustrates a supply schedule for gas, with the quantity supplied increasing as the price of gas increases. Figure 3 simply converts the data in Table 2 into a graph. Notice that the supply curve slopes upward as we move to the right.

Table 2. Supply Schedule for Gasoline

Price ($/gal.)	$2.80	$3.00	$3.20	$3.40	$3.60	$3.80	$4.00	$4.20	$4.40	$4.60
Quantity demanded (thousand gal/week)	52	57	62	67	72	77	82	87	92	97

There is also a distinction between a *change in the quantity supplied* and a *change in supply*. A change in the quantity supplied occurs when we move along a supply curve as the price of something changes. This is shown in Figure 3. We see that at a price of $3.40, suppliers are willing to supply 67,000 gallons of gas. But if the price were to increase to $3.80, the quantity supplied would increase to 77,000 gallons per week.

A change in supply occurs when the entire supply curve shifts. Again, several different factors might cause a supply curve to shift. One is a change in the price of input goods and services. For example, an increase in the wages paid to gasoline company employees would cause suppliers to raise the price that they charge for gas, meaning a shift in the supply curve to the left (meaning a decrease in supply), as illustrated in Figure 4. Another factor that would cause a change in supply is a change in production technology. Suppose that an innovation reduces the costs of gasoline refining. In which direction would the supply curve shift in this case? Can you think of other factors which would cause a change in supply?

Figure 3. Supply Curve for Gasoline

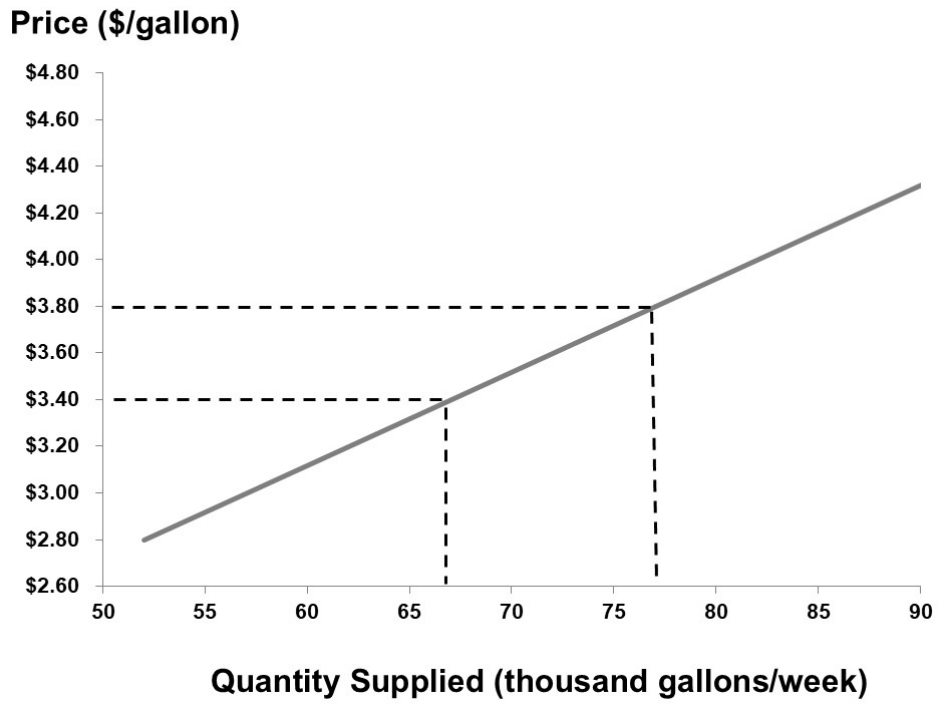
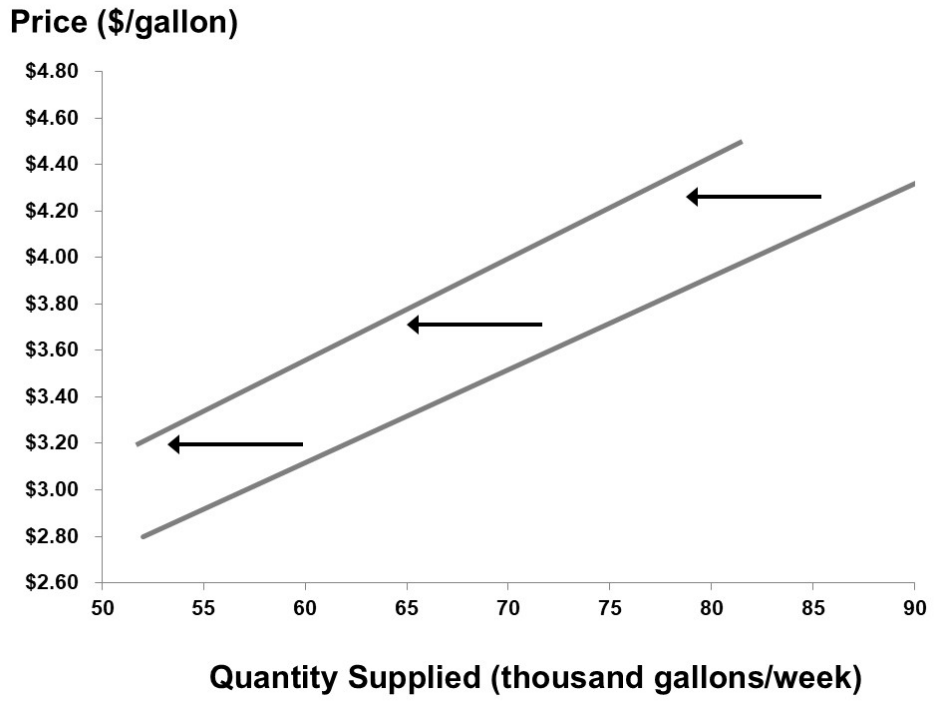


Figure 4. A Change in Supply

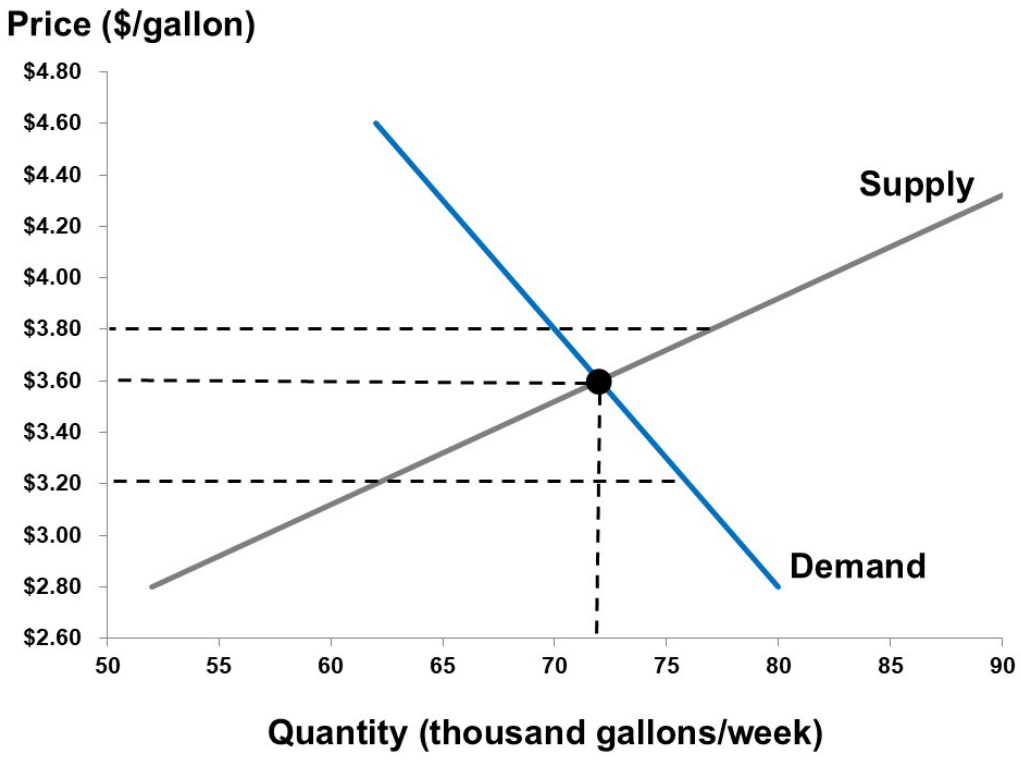


Market Analysis

We can now bring together both sides of the gasoline market. The price of gasoline is determined by the interaction of consumers and suppliers. We can illustrate this interaction by putting our demand and supply curves on the same graph, as shown in Figure 5. We can use this figure to determine what the price of gas will be and how much will be sold. First, suppose the price of gas was initially $3.80 per gallon. We see in Figure 5 that at this price the quantity supplied exceeds the quantity demanded. We call this situation a **surplus** because suppliers have more gas than consumers are willing to buy at that price. Rather than dumping the excess gas, suppliers will lower their price in order to attract more customers. Thus, in the case of a surplus, we expect downward pressure on prices.

surplus: a market situation in which the quantity supplied exceeds the quantity demanded.

Figure 5. Equilibrium in the Market for Gasoline



What if the initial price were instead $3.20 per gallon? We see in Figure 5 that at this price the quantity demanded exceeds the quantity suppliers are willing to supply. Suppliers will notice this excess demand and realize they can raise their prices. Thus, in the case of a **shortage**, there will be upward pressure on prices.

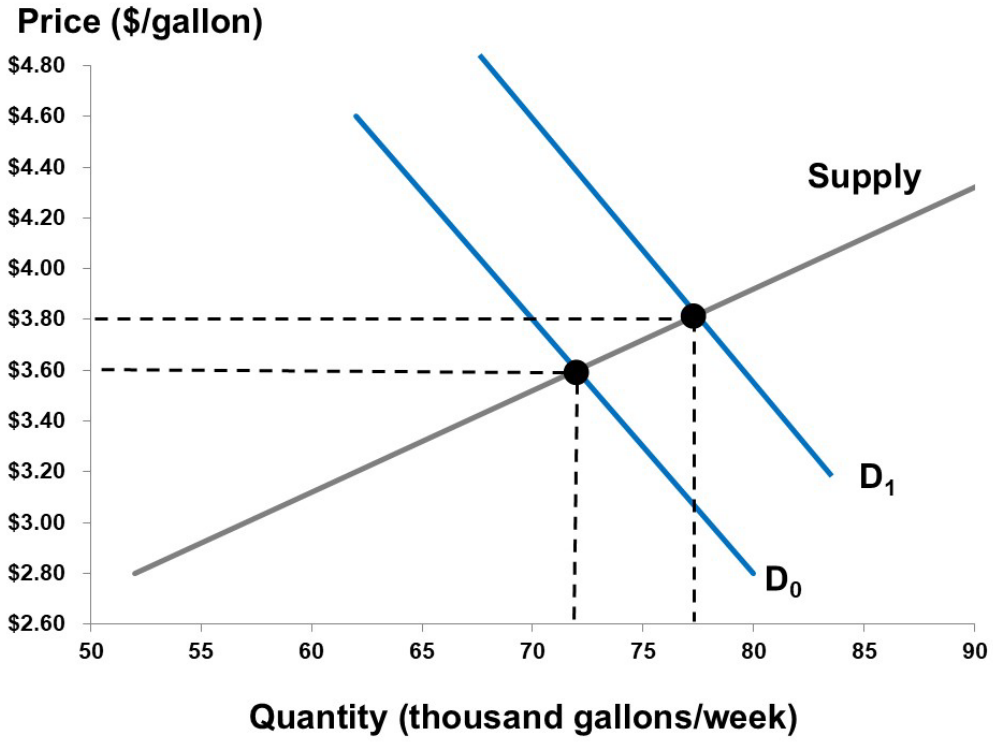
shortage: a market situation in which the quantity demanded exceeds the quantity supplied.

When a surplus or shortage exists, the market will adjust, attempting to eliminate the excess supply or excess demand. This adjustment will continue until we reach a price where the quantity demanded equals the quantity supplied. Only at this price is there no pressure for further market adjustment, *ceteris paribus*. We see in Figure 5 that this occurs at a price of $3.60 per gallon. At this price, both the quantity demanded and the quantity supplied are 72,000 gallons per week. Economists use the term **market equilibrium** to describe a market that has reached this stable situation.

market equilibrium: the market outcome where the quantity demanded equals the quantity supplied.

A market in equilibrium is stable as long as all other relevant factors stay the same, such as consumer incomes, the prices of related goods, and production technology. Changes in these variables will cause one (or both) curve(s) to shift and result in a new equilibrium, as illustrated in Figure 6. Assume that an increase in consumer income causes the demand curve for gas to shift from D_0 to D_1. This results in a new market equilibrium with a higher price and an increase in the quantity of gas sold. You can test yourself by figuring out what happens to the equilibrium price and quantity when the demand curve shifts in the opposite direction and when the supply curve shifts.

Figure 6. A New Equilibrium with a Change in Demand for Gasoline



Elasticity of Demand and Supply

Demand and supply curves also tell us how responsive consumers and suppliers are to changes in price. Consider again how consumers would respond to an increase in the price of gasoline. Consumers would buy less gas but, at least in the short term, probably not that much less because they generally have fixed commutes to work, cannot easily buy a new vehicle, and so on. The degree of consumer responsiveness to a change in the price of something is determined by the **price elasticity of demand**.

price elasticity of demand: the responsiveness of the quantity demanded to price, equal to the percentage change in quantity demanded divided by the percentage change in price.

The demand for a good is relatively *price inelastic* if the quantity demanded changes little as the price changes. This can be illustrated graphically by a relatively steep demand curve. The formal expression of demand elasticity in mathematical terms is:

$$\text{elasticity of demand} = \frac{\text{percent change in quantity demanded}}{\text{percent change in price}}$$

Because the quantity demanded moves in the opposite direction of the price, demand elasticity is a negative number. Gasoline is an example of a good that is price inelastic. But the demand for a good is relatively *price elastic* if the quantity demanded changes a great deal as the price changes (the demand curve would be relatively flat). Can you think of some goods which have relatively elastic demand curves?

We can also talk about the price elasticity of supply. The supply of a good is considered price inelastic if the quantity supplied changes little as the price changes. A price-elastic supply curve would indicate a relatively large change in the quantity supplied with a change in the price. The mathematical expression for elasticity of supply is the same as for elasticity of demand, but because quantity and price move in the same direction, supply elasticity is positive.

Notice that the price elasticity of demand and supply can change as we consider a longer period. In the short term, the demand and supply curves for gasoline are relatively inelastic. But when we consider a longer time frame, consumers can respond to an increase in gas prices by moving closer to work or buying a more fuel-efficient vehicle, and suppliers can build new refineries or drill more oil wells. So the price elasticity of demand and supply for gasoline will be more elastic over a longer period.

Welfare Analysis

The final topic we consider in this appendix is welfare analysis. Welfare analysis looks at the benefits that consumers and suppliers obtain from economic transactions. Using welfare analysis, our supply-and-demand model becomes a powerful tool for policy analysis. Our understanding of welfare analysis begins with a more detailed look at demand and supply curves.

Why do people buy things? Economists assume that people will not purchase something unless the benefits that they obtain from the purchase exceed what they have to pay for it. While the cost of something is expressed in dollars, quantifying benefits in dollar terms is not obvious. Economists define the net benefits a consumer obtains from a purchase as their maximum **willingness to pay** less the price they actually have to pay. For example, if someone is willing to spend a maximum of $30 for a particular shirt yet the actual price is $24, then he or she obtains a net benefit of $6 by buying it. This net benefit is called **consumer surplus**.

willingness to pay (WTP): the maximum amount of money people are willing to pay for a good or service that increases their well-being.
consumer surplus: the net benefit to a consumer from a purchase; equal to their maximum willingness to pay minus price.

Note that if the price of the shirt were instead $32, the consumer would not purchase it because the costs are greater than the perceived benefits. When we observe people purchasing goods or services, we conclude that they are doing so because the benefits that they obtain exceed their costs. If the price of a particular item rises, some people will decide not to purchase it—buying other things instead or saving their money. If the price rises further, more people will drop out of the market because the cost exceeds their maximum willingness to pay. In other words, a demand curve can also be viewed as a maximum willingness-to-pay curve.

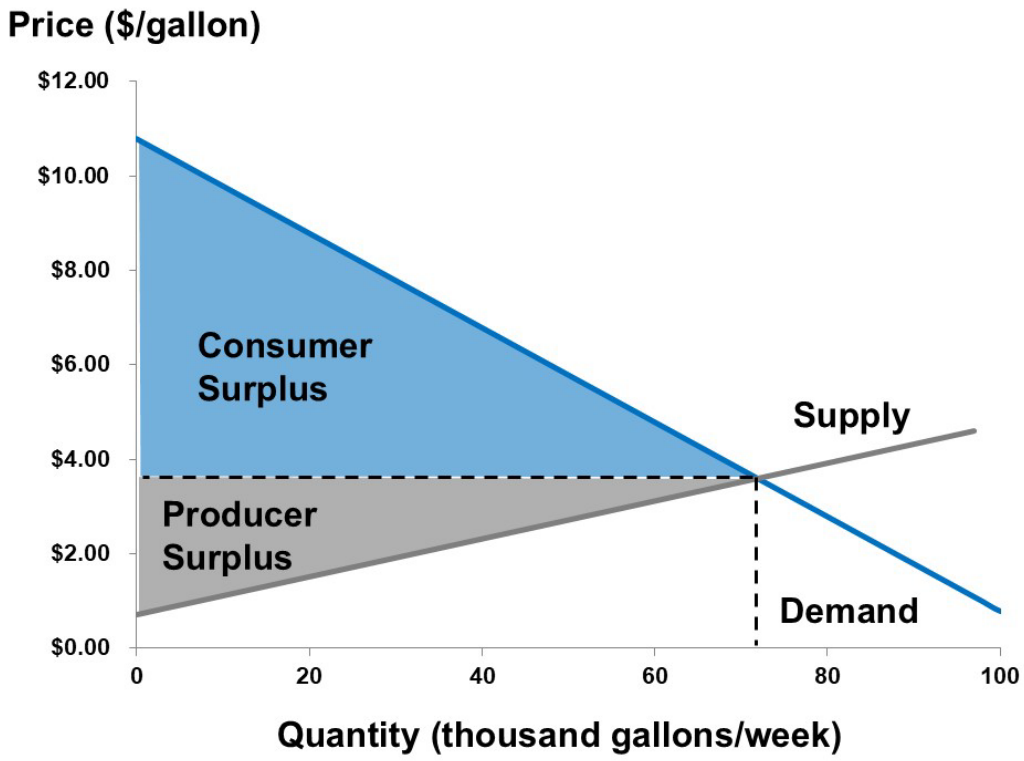
We now look at Figure 7, which shows the demand and supply curves for gasoline. The equilibrium values are the same as before ($3.60 per gal. and 72,000 gallons sold), but the demand and supply curves have been extended to the *y*-axis. Given that the demand curve is a maximum willingness-to-pay curve, the vertical difference between the demand curve and the equilibrium price is consumer surplus. Total consumer surplus in the gasoline market is indicated by the blue triangle in Figure 7.

We can also look at the supply curve in more detail. Economists assume that suppliers will supply an item only if the price exceeds their costs of production—in other words, if they can obtain a profit. The supply curve shows how much is needed to cover production costs. This explains the upward slope; as production increases, costs tend to rise. (At low levels of production, costs might fall as production increases due to increased input productivity, a phenomenon known

as **economies of scale**. But eventually, costs are likely to rise as raw materials run short, workers are paid overtime, and so forth.) In effect, the supply curve tells us how much it costs to supply each additional unit of an item. The cost to supply *one more* unit of a good is called the marginal cost. In other words, a supply curve is a marginal cost curve.

economies of scale: an expanded level of output increases returns per unit of input.

Figure 7. Consumer and Producer Surplus



Economists define the benefits that producers obtain from selling an item as **producer surplus**. Producer surplus is calculated as the selling price minus the cost of production. Once again, we can look at our supply-and-demand graph to visualize producer surplus. We see in Figure 7 that producer surplus is the lower triangle between the supply curve and the equilibrium price. The total net benefits in a market are simply the sum of consumer and producer surplus.

producer surplus: the net benefits of a market transaction to producers, equal to the selling price minus production costs (i.e., profits).

We can use welfare analysis to determine the impacts of various government policies, such as taxes and price controls. While welfare analysis can indicate whether a policy increases or decreases net benefits, it normally does not tell us about the distribution of costs and benefits or the broader social and ecological impacts. Clearly, other impacts must be considered if we want to conduct a complete policy analysis.