Chapter 3
Elasticities

Elasticity is a measure of the responsiveness of a variable to changes in price or any of the variable's determinants. In this chapter we will examine four kinds of elasticities, with numerous applications to important economic problems.

3.1 Price elasticity of demand (*PED*)

Price elasticity of demand

- Explain the concept of price elasticity of demand, understanding that it involves responsiveness of quantity demanded to a change in price, along a given demand curve.

Understanding price elasticity of demand (*PED*)

According to the law of demand, there is a negative relationship between price and quantity demanded: the higher the price, the lower the quantity demanded, and vice versa, all other things equal. We now want to know *by how much* quantity responds to change in price.

Price elasticity of demand (*PED*) is a measure of the responsiveness of the quantity of a good demanded to changes in its price. *PED* is calculated along a given demand curve. In general, if there is a large responsiveness of quantity demanded, demand is referred to as being *price elastic*; if there is a small responsiveness, demand is *price inelastic*.

The formula for *PED*

- Calculate PED using the following equation.

$$PED = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in price}}$$

Suppose we are considering price elasticity of demand (*PED*) for good *X*. The formula used to measure its *PED* is:

$$\text{price elasticity of demand} = PED = \frac{\text{percentage change in quantity of good } X \text{ demanded}}{\text{percentage change in price of good } X}$$

If we abbreviate 'change in' by the Greek letter Δ, this formula can be rewritten as:

$$PED = \frac{\%\Delta Q_x}{\%\Delta P_x}$$

Simplifying, the above formula can be rewritten as:

$$PED = \frac{\frac{\Delta Q_x}{Q_x} \times 100}{\frac{\Delta P_x}{P_x} \times 100} = \frac{\frac{\Delta Q_x}{Q_x}}{\frac{\Delta P_x}{P_x}}$$

The sign of *PED*

- State that the PED value is treated as if it were positive although its mathematical value is usually negative.

Since price and quantity demanded are negatively (indirectly) related, the *PED* is a negative number. For any percentage increase in price (a positive denominator), there results a percentage decrease in quantity demand (a negative numerator), leading to a negative *PED*. Similarly, for a percentage price decrease the result will be a percentage price increase, again leading to a negative *PED*. However, *the common practice is to drop the minus sign and consider PED as a positive number*. (In mathematics this is called taking the absolute value.) This is done to avoid confusion when making comparisons between different values of *PED*. Using positive numbers, we can say, for example, that a *PED* of 3 is larger than a *PED* of 2. (Had we been using the minus sign, –2 would be larger than –3.)

The use of percentages

Elasticity is measured in terms of percentages for two reasons:

- We need a measure of responsiveness that is independent of units. First, we want to be able to compare the responsiveness of quantity demanded of different goods; it makes little sense to compare units of oranges with units of computers or cars. Secondly, we want to be able to compare responsiveness across countries that have different currencies; an elasticity measured in terms of euros will not be comparable with an elasticity measured in yen or pounds. By computing changes in quantity and changes in price as percentages, we express them in common terms, thereby making it possible to compare responsiveness for different goods and across countries.
- It is meaningless to think of changes in prices or quantities in absolute terms (for example, a $15 increase in price or a 20 unit decrease in quantity) because this tells us nothing about the relative size of the change. For example, a $15 price increase means something very different for a good whose original price is $100 than for a good whose original price is $5000. In the first case there is a 15% increase, and in the second there is a 0.3% increase. Using percentages to measure price and quantity changes allows us to put responsiveness into perspective.

The same arguments apply to all other elasticities we will consider.

Calculating *PED*

♦ Calculate PED between two designated points on a demand curve using the PED equation above.

We can now use the formula above to calculate *PED*. Suppose consumers buy 6000 DVD players when the price is $255 per unit, and they buy 5000 DVD players when the price is $300.

$$PED = \frac{\frac{6000-5000}{5000}}{\frac{255-300}{300}} = \frac{\frac{1000}{5000}}{\frac{-45}{300}} = \frac{0.20}{-0.15} = -1.33 \text{ or } 1.33$$

since we drop the minus sign. Therefore *PED* for DVD players is 1.33.[1]

Test your understanding 3.1

1 **(a)** Explain the meaning of price elasticity of demand. **(b)** Why do we say it measures responsiveness of quantity *along a given demand curve*?

2 Why do we treat *PED* as if it were positive, even though it is usually negative?

3 It is observed that when the price of pizzas is $16 per pizza, 100 pizzas are sold; when the price falls to $12 per pizza, 120 pizzas are sold. Calculate price elasticity of demand.

4 A 10% increase in the price of a particular good gives rise to an 8% decrease in quantity bought. What is the price elasticity of demand?

The range of values for *PED*

♦ Explain, using diagrams and PED values, the concepts of price elastic demand, price inelastic demand, unit elastic demand, perfectly elastic demand and perfectly inelastic demand.

The value of *PED* involves a comparison of two numbers: the percentage change in quantity demanded (the numerator in the *PED* formula) and the percentage change in price (the denominator). This comparison yields several possible values and range of values for *PED*. These are illustrated in Figure 3.1 and summarised in Table 3.1.

[1] You may note that the value of this elasticity of demand depends on the choice of the initial price–quantity combination. In the calculation above, this was taken to be 300, 5000. If we had taken 255, 6000 as the initial price–quantity combination, we would get a *PED* value of 0.94. (You could calculate this as an exercise.) This difficulty can be overcome by use of the 'midpoint formula':

$$PED = \frac{\frac{\Delta Q_x}{\text{average } Q_x}}{\frac{\Delta P_x}{\text{average } P_x}}.$$

In the previous example,

$$PED = \frac{\frac{1000}{5500}}{\frac{45}{277.5}} = 1.12, \text{ where } 5500 = \frac{(5000+6000)}{2} \text{ and } 277.5 = \frac{(255+300)}{2}$$

i.e. we use the average of the two Q_x values and the average of the two P_x values instead of the initial Q_x and initial P_x.

- **Demand is price inelastic when *PED* < 1 (but greater than zero).** The percentage change in quantity demanded is smaller than the percentage change in price, so the value of *PED* is less than one; quantity demanded is relatively unresponsive to changes in price, and demand is **price inelastic**. Figure 3.1(a) illustrates price inelastic demand: the percentage change in quantity demanded (a 5% decrease) is smaller than the percentage change in price (a 10% increase), therefore *PED* is less than one.

Value of *PED*	Classification	Interpretation
Frequently encountered cases		
$0 < PED < 1$ (greater than zero and less than one)	inelastic demand	quantity demanded is relatively unresponsive to price
$1 < PED < \infty$ (greater than 1 and less than infinity)	elastic demand	quantity demanded is relatively responsive to price
Special cases		
$PED = 1$	unit elastic demand	percentage change in quantity demanded equals percentage change in price
$PED = 0$	perfectly inelastic demand	quantity demanded is completely unresponsive to price
$PED = \infty$	perfectly elastic demand	quantity demanded is infinitely responsive to price

Table 3.1 Characteristics of price elasticity of demand

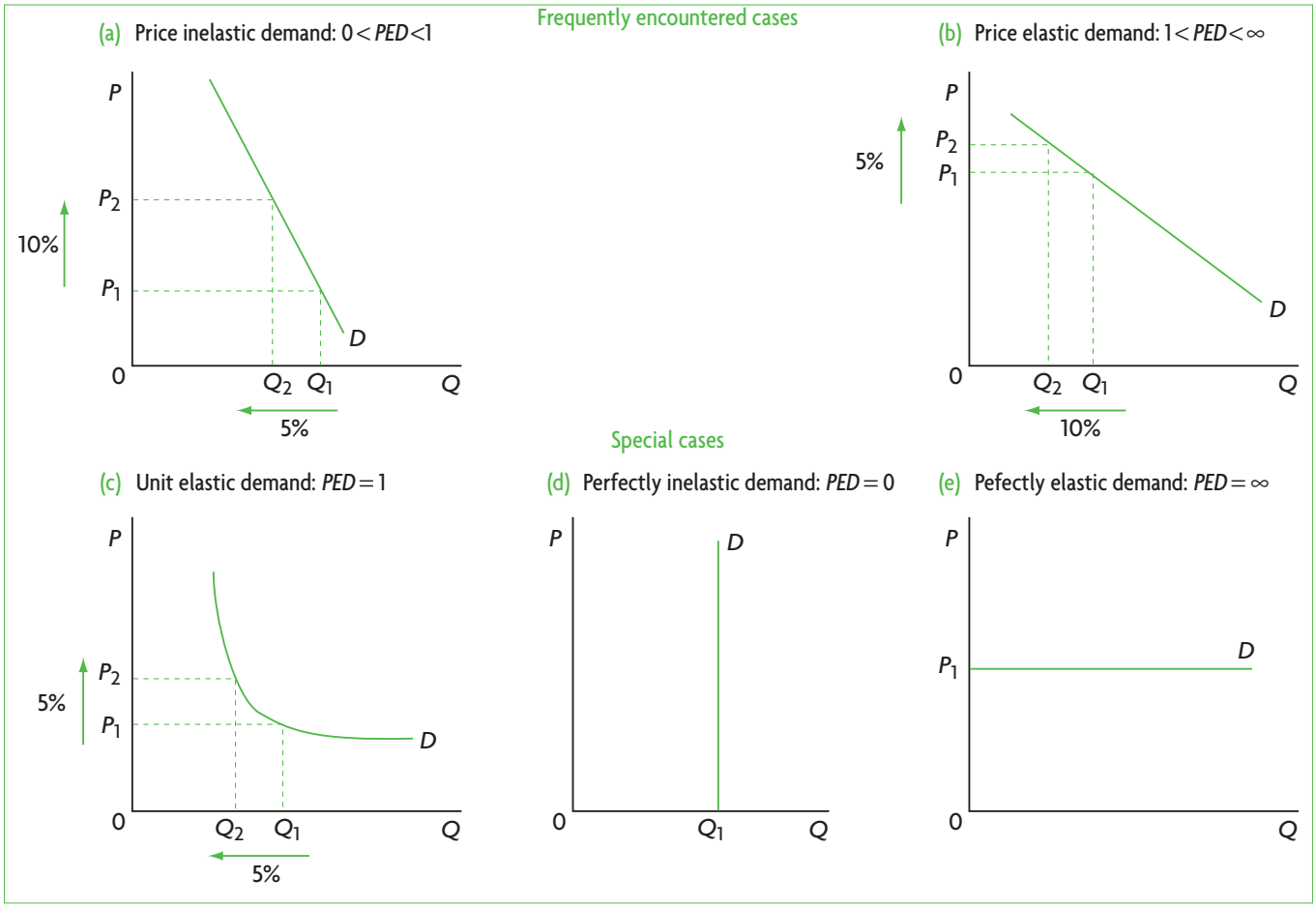

Figure 3.1 Demand curves and *PED*

- **Demand is price elastic when *PED* > 1 (but less than infinity).** The percentage change in quantity demanded is larger than the percentage change in price, so the value of *PED* is greater than one; quantity demanded is relatively responsive to price changes, and demand is **price elastic**. In Figure 3.1(b) the percentage change in quantity demanded (–10%) is larger than the percentage change in price (5%), therefore *PED* is greater than one.

In addition, there are three special cases:

- **Demand is unit elastic when *PED* = 1.** The percentage change in quantity demanded is equal to the percentage change in price, so *PED* is equal to one; demand is then **unit elastic**. Figure 3.1(c) shows a unit elastic demand curve, where the percentage change in quantity demanded (–5%) is equal to the percentage change in price (5%).
- **Demand is perfectly inelastic when *PED* = 0.** The percentage change in quantity demanded is zero; there is no change in quantity demanded, which remains constant at Q_1 no matter what happens to price; *PED* is then equal to zero and demand is **perfectly inelastic**. For example, a heroin addict's quantity of heroin demanded is unresponsive to changes in the price of heroin. Figure 3.1(d) shows that a perfectly inelastic demand curve is vertical.
- **Demand is perfectly elastic when *PED* = infinity.** When a change in price results in an infinitely large response in quantity demanded, demand is **perfectly elastic**. As shown in Figure 3.1(e) the perfectly elastic demand curve is horizontal. At price P_1, consumers will buy any quantity that is available. If price falls, buyers will buy all they can (an infinitely large response); if there is an increase in price, quantity demanded drops to zero. This apparently strange kind of demand will be considered in Chapter 7 (at higher level).

The numerical value of *PED* can therefore vary from zero to infinity. In general, the larger the value of *PED*, the greater the responsiveness of quantity demanded. *PED* for most goods and services is greater than zero and less than infinite, and other than exactly one. The cases of unit elastic, perfectly inelastic and perfectly elastic demand are rarely encountered in practice; however, they have important applications in economic theory.

Variable *PED* and the straight-line demand curve versus the slope

♦ Explain why PED varies along a straight line demand curve and is not represented by the slope of the demand curve.

When PED varies

Along any *downward-sloping, straight-line demand curve*, the *PED* varies (changes) as we move along the curve. This applies to all demand curves of the types shown in Figure 3.1 (a) and (b). It excludes unit elastic, perfectly inelastic and perfectly elastic demand curves (where *PED* = 1, *PED* = 0 and *PED* = infinity, respectively, and does not vary). We can see in Figure 3.2 that when price is low and quantity is high, demand is inelastic; as we move up the demand curve towards higher prices and lower quantities, demand becomes more and more elastic. The figure shows the *PED* values along different parts of the demand curve (you will be asked to do the PED calculations as an exercise – see Test your understanding 3.2).

The reason behind the changing *PED* along a straight-line demand curve has to do with how *PED* is calculated. At high prices and low quantities, the percentage change in *Q* is relatively large (since the denominator of $\Delta Q/Q$ is small), while the percentage change in *P* is relatively small (because the denominator of $\Delta P/P$ is large). Therefore the value of *PED*, given by a large percentage change in *Q* divided by a small percentage change in *P* results in a large *PED* (elastic demand). At low prices and high quantities the opposite holds. The value of *PED* is

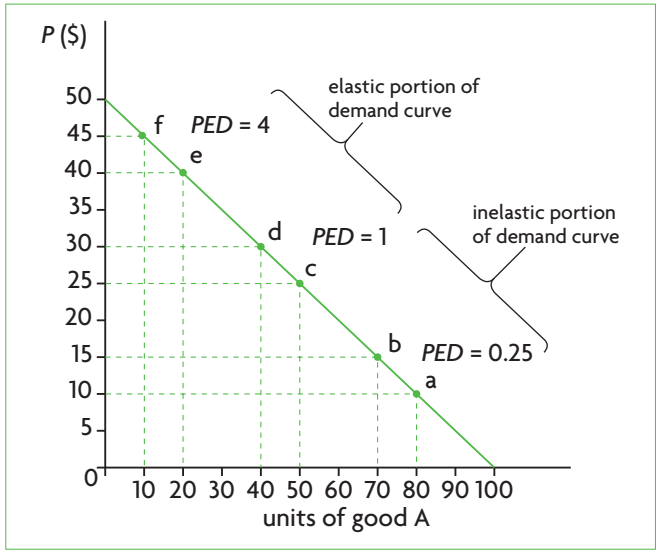

Figure 3.2 Variability of *PED* along a straight-line demand curve

given by a low percentage change in Q divided by a high percentage change in P, resulting in a low *PED* (elastic demand).

On any downward-sloping, straight-line demand curve, demand is price-elastic at high prices and low quantities, and price-inelastic at low price and large quantities. At the midpoint of the demand curve, there is unit elastic demand.

Therefore, the terms 'elastic' and 'inelastic' should not be used to refer to an entire demand curve (with the exception of the three special cases where *PED* is constant throughout the entire demand curve). Instead, they should be used to refer to a portion of the demand curve that corresponds to a particular price or price range.

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The relationship between PED and the slope (Higher level topic)

The varying *PED* along a straight-line demand curve should be contrasted with the *slope*, which is always constant along a straight line (see 'Quantitative techniques' chapter on the CD-ROM, page 28). In the special case of demand (and supply) functions, whose corresponding curves plot the dependent variable on the horizontal axis (in contrast to mathematical convention), the slope is defined as $\frac{\Delta Q}{\Delta P}$, or the horizontal change between two points on the curve divided by the vertical change between the same two points. A comparison of the slope with *PED* shows that the two should not be confused:

$$\text{slope of demand curve} = \frac{\Delta Q}{\Delta P}$$

$$PED = \frac{\%\Delta Q}{\%\Delta P} = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} = \text{slope} \times \frac{P}{Q}$$

In these two expressions we can see why the slope is constant, while *PED* varies along a straight-line demand curve. In a straight line, the ratio $\frac{\Delta Q}{\Delta P}$, or the slope, does not change between any pairs of points on the line. However, *PED* is defined as the slope (which is constant) times $\frac{P}{Q}$, which clearly changes as we move along the demand curve, thus accounting for the changing *PED*.

The slope of the demand curve measures the responsiveness of quantity demanded to changes in price in absolute terms, while *PED* measures the same responsiveness in percentage terms. *PED* is far more useful as a measure of responsiveness for the reasons discussed on page 48. (See also the discussion in 'Quantitative techniques' chapter on the CD-ROM, page 28.)

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PED should not be confused with the slope of a demand curve. Whereas the slope is constant for a linear (straight-line) demand curve, *PED* varies throughout its range.

Determinants of price elasticity of demand

- Explain the determinants of PED, including the number and closeness of substitutes, the degree of necessity, time and the proportion of income spent on the good.

We will now consider the factors that determine whether the demand for a good is elastic or inelastic.

Number and closeness of substitutes

The more substitutes a good (or service) has, the more elastic is its demand. If the price of a good with many substitutes increases, consumers can switch to other substitute products, therefore resulting in a relatively large drop (large responsiveness) in quantity demanded. For example, there are many brands of toothpaste, which are close substitutes for each other. An increase in the price of one, with the prices of others constant will lead consumers to switch to the others; hence demand for a specific toothpaste brand is price elastic. If a good or service has few or no substitutes, then an increase in price will bring forth a small drop in quantity demanded. An increase in the price of petrol (gasoline) is likely to lead to a relatively small decrease in quantity demanded, because there are no close substitutes; therefore, demand for petrol is price inelastic.

Also important is the closeness of substitutes. For example, Coca-Cola® and Pepsi® are much closer substitutes than Coca-Cola and orange juice; we say that Coca-Cola and Pepsi have greater *substitutability*. The closer two substitutes are to each other, the greater the responsiveness of quantity demanded to a change in the price of the substitute, hence the greater the *PED*, because it is easier for the consumer to switch from one product to the other.

A factor that affects the number of substitutes a good has is whether the good is defined broadly or narrowly. For example, *fruit* is a broad definition of a good if it is considered in relation to *specific fruits* such as oranges, apples, pears, and so on, which are narrowly defined. Note that a broad or narrow definition involves how goods are defined *in relation to each other*. If we had considered fruit in relation to

food, *food* is the broadly defined good, and *specific foods* such as fruits, vegetables, grains, fish, and so on, are narrowly defined. (Therefore, fruit is broadly defined in relation to specific fruits, and narrowly defined in relation to food.) The point here is that the narrower the definition of a good, the more the close substitutes and the more elastic the demand (compared with the broadly defined good). The demand for apples is more elastic than the demand for fruit, because of the availability of oranges, pears or other fruits that are close substitutes for apples. The demand for fruit is more elastic than the demand for food. Similarly, a Honda has a higher price elasticity of demand than all cars considered together.

Necessities versus luxuries

Necessities are goods or services we consider to be essential or necessary in our lives; we cannot do without them. **Luxuries** are not necessary or essential. The demand for necessities is less elastic than the demand for luxuries. For example, the demand for medications tends to be very inelastic because people's health or life depend on them; therefore, quantity demanded is not very responsive to changes in price. The demand for food is also inelastic, because people cannot live without it. On the other hand, the demand for diamond rings is elastic as most people view them as luxuries. In general, the more necessary is a good, the less elastic the demand.

A special case of necessity is a consumer's addiction to a good. The greater the degree of addiction to a substance (alcohol, cigarettes, and so on), the more inelastic is the demand. A price increase will not bring forth a significant reduction in quantity demanded if one is severely addicted.

Length of time

The longer the time period in which a consumer makes a purchasing decision, the more elastic the demand. As time goes by, consumers have the opportunity to consider whether they really want the good, and to get information on the availability of alternatives to the good in question. For example, if there is an increase in the price of heating oil, consumers can do little to switch to other forms of heating in a short period of time, and therefore demand for heating oil tends to be inelastic over short periods. But as time goes by, they can switch to other heating systems, such as gas, or they can install better insulation, and demand for heating oil becomes more elastic.

Proportion of income spent on a good

The larger the proportion of one's income needed to buy a good, the more elastic the demand. An item such as a pen takes up a very small proportion of one's income, whereas summer holidays take up a much larger proportion. For the same percentage increase in the price of pens and in the price of summer holidays, the response in quantity demanded is likely to be greater in the case of summer holidays than in the case of pens.

Real world focus

What happens when demand is highly price inelastic?

A girl sells lemonade at a stand for 50 cents (= $0.50) a cup. On a very hot day, the lemonade becomes even more popular, and the girl realises she can raise her price a little and still sell all her lemonade. One afternoon, a diabetic boy comes along asking for lemonade with extra sugar because his blood sugar has fallen to dangerously low levels. The girl sees an opportunity and increases her price by 500%. The boy doesn't have enough money, but she tells him she will give him the lemonade right away provided he promises to run home afterward, get the money and return to pay her the full price. Having no choice, the boy agrees.

Source: Adapted from Teymour Semnani, 'Free markets don't always do the right thing regarding health care' in *The Deseret News*, 15 November 2009.

Applying your skills

1 **(a)** What can you conclude about the boy's price elasticity of demand for sweet lemonade at that particular moment? **(b)** What determinant of *PED* accounts for this?

2 What would have happened to the quantity of lemonade demanded if the other children were faced with a 500% increase in its price? Explain in terms of their price elasticity of demand for lemonade.