October 24 2006

1 The effect of a commodity tax

Suppose that a government imposes a tax on a *non-traded* commodity. The assumption that the commodity is non-traded means that domestic supply equals domestic demand for this commodity. In contrast, with trade, domestic supply and demand differ because of imports or exports. As a matter of common sense, it might seem that it matters whether consumers or producers are charged the tax. The prominence of the Polluter Pays Principal also suggests that it is important which agent is charged with paying for environmental damage. However, in a competitive equilibrium, the outcome – the equilibrium price and quantity and thus the consumer and producer surplus – is exactly the same regardless of whether the tax is levied on consumers or producers. In addition, both producers and consumers effectively end up paying part of the tax.

This equivalence between consumer and producer taxes has implications for optimal policy to remedy environmental externalities. This chapter begins by explaining what it means to say that the two taxes are equivalent, and then explains the relevance of this result to environmental policy. The next section explains why the consumer and producer taxes are indeed equivalent, and shows how to measure the effect of a tax.

What does it mean to say that one agent, e.g. producers, "effectively" pays part of the tax that is levied on the other agent, e.g. consumers? Suppose that in the absence of a tax, the equilibrium price is \$12 and the supply and demand is 100 units. Suppose that a tax of \$2 per unit is imposed on consumers. Does the imposition of this tax mean that the price consumers pay rises to \$12+\$2=\$14? In general, the answer is "no". The tax does increase the price that consumers pay, but (in general) this higher price decreases the amount that they demand. In order for producers to want to decrease the amount that they supply, the price that producers receive must fall. The percentage of the tax that consumers pay is called the consumer incidence of the tax, and the percentage that producers pay is the producer incidence.

Consider the following example, in which the \$2 tax causes the tax-inclusive price that consumers face to rise from \$12 to an equilibrium of \$13.50. This higher price reduces their demand. In order for supply to

fall by enough to maintain supply equal to demand, the price that producers receive must have fallen. In this example, it must have fallen to \$11.50, since the tax drives a \$2 wedge between the consumer (tax-inclusive) price and the producer price. The difference in the tax-inclusive price paid by consumers and the price received by producers is \$13.50-\$11.50=\$2, the amount of the unit tax.

Consumers "effectively pay" the share $\frac{13.5-12}{tax} = \frac{1.5}{2} = 0.75$, or 75% of the tax, and producers "effectively pay" the remaining 25% of the tax. The tax causes the consumer price to raise by 75% of the tax, and it causes the producer price to fall by 25% of the tax. In this example, the tax incidence on consumers is 75% and the tax incidence on producers is 25%. In other examples, the incidence could be very different. In general, the tax incidence depends on the elasticities of supply and demand, a relation we derive below.

The important result is that the tax incidence and the equilibrium quantity and price do not depend on whether the tax is directly levied on consumers or producers. This equivalence between the producer and consumer taxes depends on our assumption that the good is non-traded, so that domestic supply equals demand.

In an environmental context, the result is important because it implies that there are circumstances where it does not matter whether an externality is corrected using a tax on production or on consumption. This equivalence appears to undercut the Polluter Pays Principal. That principal suggests that it is important which agent – the polluter or the pollutee – directly pays for the damage caused by pollution. If we think of consumers as being a proxy for the agent that suffers from the pollution, the principal seems to imply that it would matter whether the tax is levied on consumption or production. However, the equivalence between these two taxes implies that it is immaterial whether a consumer or producer tax is used. In this limited sense, the Polluter Pays Principal sets up a meaningless distinction. This point does not imply that the Polluter Pays Principal is vacuous, merely that it has to be interpreted carefully. In other contexts it is important.

In order to make the point that the Polluter Pays Principal happens to be irrelevant in the current context, consider the example in which each unit of production causes \$2 worth of environmental damage, e.g. in the form of pollution emissions. This damage is external to the firm, meaning that the firm does not take the damage into consideration in making its production decisions. Suppose in addition that the environmental damage is an inevitable consequence of production; no abatement technology is available.

The last assumption means that production and pollution are equivalent, in the sense that society cannot have one without the other. This assumption means that targeting production is equivalent to targeting pollution.

The optimal policy causes firms to internalize this environmental cost, just as firms internalize costs of production associated with hiring capital and labor. One means of achieving this internalization is to charge producers a $2 per unit tax on output. However, in view of the equivalence of a producer and consumer tax, we conclude that the same end is achieved by charging consumers a $2 per unit tax on consumption. The incidence of the two taxes is exactly the same; the two policies have exactly the same effects on welfare, i.e. on the level of environmental damage and on consumer and producer surplus. In this case, it does not matter whether the polluter (producers) or the "pollutee" (consumers, as proxies for society) pays the tax.

Not only does it not matter who "officially" pays the tax, but it does not matter which agent is responsible for the environmental damage. In some cases (e.g. driving), a major source of environmental damage arises from consumption of the good (cars) rather than production. Suppose for example that production causes no pollution, but that each unit of consumption causes $2 worth of environmental damage. As in the previous example, suppose that there are no opportunities for abatement, so that pollution is an inevitable consequence of consumption. In this case, targeting pollution and targeting consumption are equivalent. The optimal policy is to charge consumers a $2 per unit consumption tax. However, in view of the equivalence between producer and consumer taxes for non-traded goods, exactly the same outcome is obtained if a $2 producer tax is charged.

In summary, for non-traded goods that are associated with fixed environmental damage (i.e. no abatement opportunities), the optimal policy is to charge a tax equal to the per unit environmental cost. It is irrelevant whether this environmental cost is associated with consumption or production, and it does not matter whether the tax is charged to consumers or producers. The basis for this result is the equivalence between consumer and producer taxes for non-traded goods; the source of that equivalence the requirement that domestic supply equal demand in the absence of trade.

When we consider open economies, domestic supply and demand are no longer equal, and the equivalence between consumer and producer prices disappears. With open economies it does matter (for the determination of optimal policy) whether the environmental damage is associated with consumption or production, and it does matter whether a consumer or producer

tax is used. Also, in both open and closed economies, if there were opportunities for abatement, the optimal policy is to impose a tax on pollution rather than on production or consumption. Even in this case, if we restrict ourselves to commodity taxes (as distinct from pollution taxes), the consumer and producer taxes are equivalent.

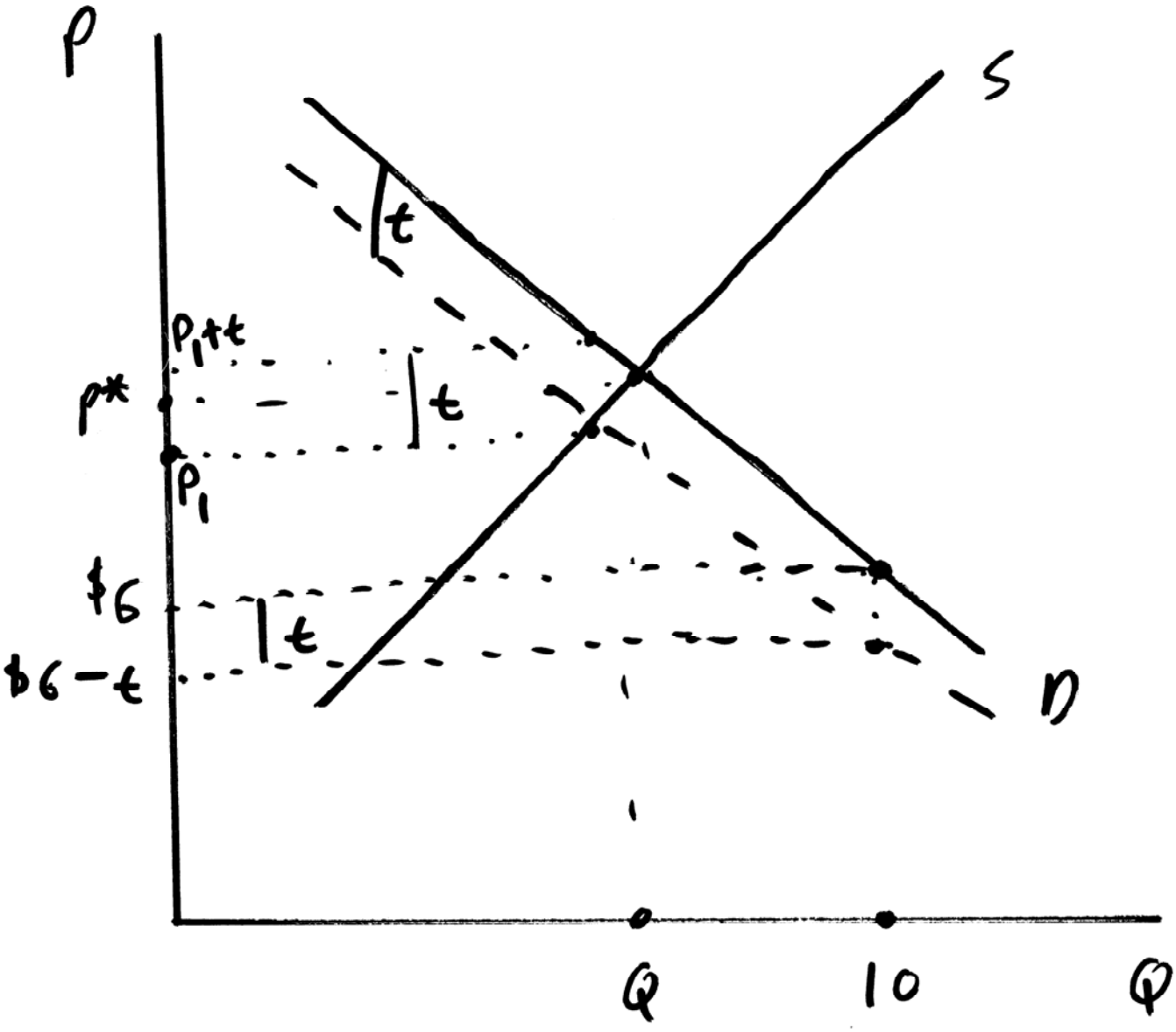
1.1 Demonstration of the equivalence between consumer and producer taxes for non-traded goods

The following discussion explains why consumer and producer taxes are equivalent for non-traded goods. Figure 1 shows a supply and demand curve and the initial equilibrium (denoted by stars), in the absence of a tax. When there is no tax, the price paid by consumers equals the price received by producers. The vertical axis measures this price, p.

Once we introduce a tax, the consumer and producer prices are different, so we can no longer use the same axis to measure both prices. We have to be clear about what the vertical axis now measures. Suppose that we introduce a consumer tax of $\$t$ per unit. We will continue to let the vertical axis be the price that producers receive and we will continue to denote the producer price by p. Therefore, the tax does not alter the location of the supply curve.

The tax causes the consumer price to be $p + t$. The demand function shows the relation between quantity demanded and the *price that consumers pay.* However, we decided to let the vertical axis represent the price that producers receive. Since the price that consumers pay and the price that producers receive are not the same when a tax is imposed, we cannot use the original demand function (the solid line) to read off the quantity demand for an arbitrary price. The difficulty is that supply is a function of p and demand is a function of $p + t$, and we cannot let one axis represent both of these values. Fortunately, this difficulty is easily resolved.

We want to have the supply and demand curves on the same graph, in order to be able to determine the equilibrium by finding the intersection between these two graphs. What does the demand function look like, when we hold the tax t fixed and consider the quantity demanded to be a function of the *producer* price, p? The answer is that the tax shifts down the demand curve by the magnitude t, resulting in the dashed demand function shown in Figure 1. This "new" demand function contains exactly the same informa-



TAX INCIDENCE FOR

CONSUMERS : $\frac{P_1 + t - P^*}{t} \times 100$

PRODUCERS : $\frac{P^* - P_1}{t} \times 100$

FIGURE 1

tion as the original demand function; it merely shows demand as a function of the producer price rather than the consumer price, recognizing that the consumer price is $p + t$.

A specific example may help to visualize this procedure. Pick an *arbitrary* point on the original demand function. Suppose for example that consumers are willing to buy 10 units when they have to pay \$6 per unit; the quantity 10 and the price 6 is a particular (arbitrary) point on the demand function. If consumers have to pay a tax \$$t$, then they would be willing to pay producers \$$(6 - t)$ when they buy 10 units – because their tax-inclusive price is \$6. Remember, we want to graph consumer demand as a function of *producer*,price, holding the tax fixed. Our example shows that the point $Q = 10$, $p = 6 - t$ is a point on this graph. This point is exactly t units below the point $Q = 10$, $p = 6$. This procedure is the same for any point on the original demand curve. Thus, when we impose a tax of t, the graph of consumer demand as a function of the producer price is simply the original graph, shifted down t units, as shown by the dashed graph in Figure 1.

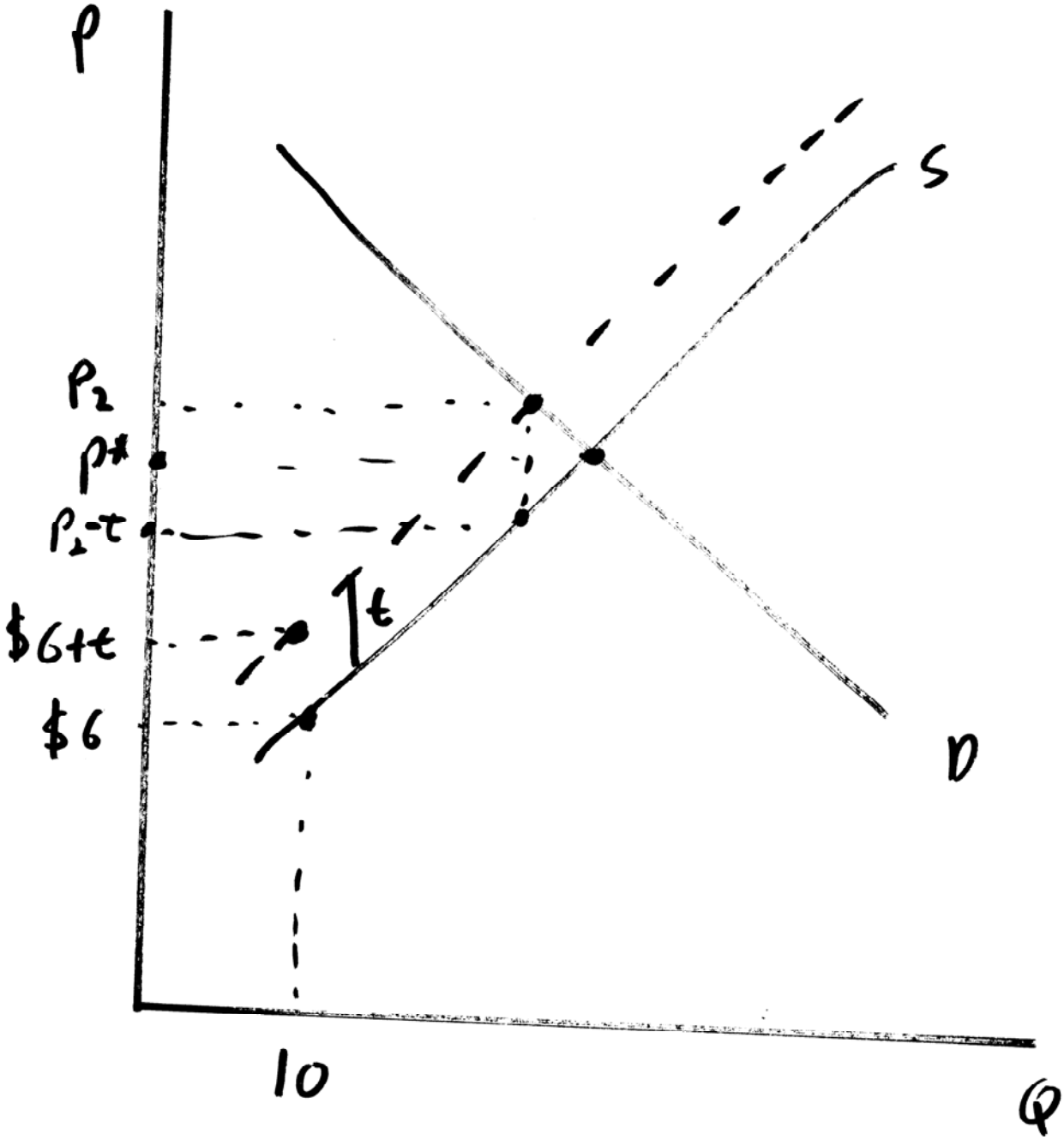
The intersection of the original supply function and the dashed graph occurs at the price P_1; this is the equilibrium producer price in the presence of the tax. The equilibrium quantity is obtained by reading off the quantity associated with this price, Q_1. The equilibrium consumer price is $P_1 + t$. Note that

$$P_1 < P^* < P_1 + t.$$

The tax incidence for producers in this example is $\frac{P^* - P_1}{t} 100$ and the tax incidence for consumers is $\frac{P_1 + t - P^*}{t} 100$.

Figure 2 shows the effect of a tax of \$$t$ per unit when producers pay the tax. In this graph we let the vertical price represent the price that consumer pay. The price that producers receive is the consumer price minus the tax. Using the same reasoning that was used to explain Figure 1, we can see that the producer tax shifts the supply curve (as a function of the consumer rather than the producer price) up by the amount t.

For example, if producers are willing to supply 10 units when they receive a price of \$6, once they have to pay the tax they would need to receive $6+t$ to persuade them to supply 10 units. In the absence of the tax, the equilibrium price is P^* as before. When producers pay the tax, the equilibrium market price increases to P_2, but producers after tax revenue (on each unit sold) is $P_2 - t$. You can show that $P_2 = P_1 + t$. This equation states that the prices that producers receive and that consumers pay do not depend on which agent



TAX INCIDENCE

CONSUMERS : $\frac{P_2 - P^*}{t} \times 100$

PRODUCERS : $\frac{P^* - (P_2 - t)}{t} \times 100$

FIGURE 2

directly pays the tax.

We now confirm that the equilibrium price and quantity are the same under a producer or a consumer tax. Denote the producer price as P^s and the consumer price as P^c and write the market price as P. If consumers pay the tax, the prices are $P^s = P$ and $P^c = P^s + t$ (producers receive the market price and consumers pay this price plus the tax). If producers pay the tax, $P^s = P - t$ and $P^c = P^s$ (consumers pay the market price and producers receive pay this price minus the tax). We want to confirm that prices are the same regardless of who pays the tax.

If consumers pay the tax, the supply equal demand condition is

$$S(P) = D(P + t). \tag{1}$$

Let P^* be the (unique) price that solves this equation; this is the equilibrium producer price when consumers pay the tax. In equilibrium $P^s = P^*$ and $P^c = P^* + t$.

If producers pay the tax, the equilibrium condition is

$$S(P - t) = D(P). \tag{2}$$

Substitute $P = P^* + t$ into this equation to write equation (2) as

$$S(P^*) = D(P^* + t).$$

The last equation reproduces equation (1) evaluated at $P = P^*$, the unique solution to that equation. Thus, the two equations (1) and (2) lead to the same producer and consumer prices – the fact that we set out to confirm.