

Problem Set - Gasoline Demand

Economics of Energy and the Environment

Econ 3391.01

Prof. Richard Sweeney

Boston College

Market based environmental policies, like a carbon tax or cap-and-trade, reduce demand for polluting goods by raising the price consumers pay for them. Thus, in order to set the correct level of the policy, policymakers often want to know how responsive demand is to price. If we raise the gas tax by \$1, how much less will people drive? What about \$2? This would be easy, if we knew the demand curve for gasoline. However, in the real world we have to estimate it. This problem set demonstrates the difficulty involved in estimating demand, due to the fact that quantities and prices are determined by both demand *and* supply.

1 Estimating demand in theory

As in the last problem set, let's start by assuming we know the answer already (ie we know the curves that govern equilibrium in US oil markets). Let the demand for oil in the US be

$$Q^D = A - bp$$

where Q^D is millions of barrels of oil per day, and p is the price of a barrel of oil. A represents the level of demand (say due to weather or the economy) while b reflects the responsiveness of demand to price. As environmental policy makers, we want to know b .

On the other side of the ledger, let the supply for oil in the US be

$$Q^S = Z + wp$$

where Q^S and p are in the same units as before. Z represents the general supply conditions and w reflects the willingness of producers to increase output as prices increase.

1.1 Calculate the equilibrium price and quantity supplied.

Assume $A = 35$, $b = 0.5$, $Z = -10$ and $w = 1$.

Solve for p by finding the point where demand and supply intersect, $Q^D = Q^S$.

Call this quantity and price (Q_0, p_0) .

1.2 Imagine there is a shock to supply, so $Z = -16$.

Recalculate the equilibrium price and quantity. Label these (Q_1, p_1) .

1.3 Now imagine there is a shock to demand, so $A = 41$.

Assume $Z = -10$ again, as in question 1.1. Recalculate the equilibrium price and quantity. Label these (Q_2, p_2) .

1.4 A policy analyst wants know how much demand will respond to a \$1 per barrel tax on oil.

Unfortunately, he does not know what the demand function Q^D looks like. However, he knows that oil prices change over time, and decides to use the corresponding demand changes to estimate the impact of a \$1 price increase. He remembers that to you only need two data points to estimate the slope of a line. If he uses data from periods 0 and 1 (ie he observes (Q_0, p_0) and (Q_1, p_1)) what will his estimate of b be? [Hint: $b = \frac{Q_1 - Q_0}{p_1 - p_0}$].

1.5 Imagine if the analyst had used data from periods 0 and 2 instead.

Ie he observes (Q_0, p_0) and (Q_2, p_2) . If he uses the change in quantity between periods 0 and 2 per dollar change in price, how much will he predict demand changes per dollar of price change?

1.6 Why do these two time periods give such different answers?

Which one is “right” if we want to estimate how demand will respond to a tax?

2 Estimating demand in practice

We will now explore the econometric implications of the previous section. The setup is identical to Part 1, except now consumers will also have to pay a tax on each barrel of oil. So the demand and supply curves are

$$Q^D = A - b(p + tax) \quad (1)$$

$$Q^S = Z + wp \quad (2)$$

2.1 Let's begin by plotting the demand and supply functions and numerically finding equilibrium. Assume the tax is zero.

Open Stata and begin a new .do file. Create two rows and enter the parameters from Part 1 by typing [*italics* signify Stata code]:

```
clear set obs 2
gen A = 35
gen Z = -10
gen w = 1
gen b = .5
```

We can plot the demand and supply functions by picking two arbitrary prices, \$25 and \$35, and calculating Q^D and Q^S .

```
gen p = 25
replace p = 35 if _n == 2
gen qs = Z + w*p
gen qd = A - b*p
tway (line p qs) (line p qd, legend(lab(1 "Supply") lab(2 "Demand")))
```

You can see the curves intersect at equilibrium price and quantity from Q1.1. Confirm this algebraically:

```
gen pe = (A-Z)/(w+b)
sum pe
```

2.2 Now assume that the tax is \$3, and recalculate the equilibrium.

Define the effective price facing consumers as $p^t = p + tax$.

```
gen tax = 3
gen pt = p + tax
gen qdt = qd - b*tax
```

This has the effect of shifting the demand curve facing suppliers inward.

```
twoway (line p qs) (line p qd) (line p qdt, legend(lab(1 "Supply") lab(2 "Demand") lab(3 "Demand w tax")))
```

With the tax, suppliers receive \$29 per barrel of oil, and consumers pay \$32 with the tax.

Again, you can confirm this algebraically:

```
gen pe_tax = (A-b*tax-Z)/(w+b)
sum pe_tax
```

2.3 Simulate equilibrium for 1000 time periods.

The Stata dataset oildata.dta contains supply and demand shocks (Z_t, A_t) and taxes from 1000 time periods. Load the dataset and calculate the average demand and supply shocks. Are these shocks positively or negatively correlated? What is one possible explanation for this correlation?

2.4 Calculate the equilibrium supplier price for each time period.

As before, assume the slope of demand is $b = 0.5$ and the slope of supply is $w = 1$. Solve for the equilibrium p each period by setting quantity supplied equal to quantity demanded:

$$Q^D = A_t - b(p^e + tax) = Z_t + wp^e = Q^S$$

2.5 Calculate the corresponding consumer price and quantity sold for each period.

Label the consumer price $pe_tax = p^e + tax$. You can use either the supply or the demand equation to find quantity. Label it Q .

2.6 Now let's try to estimate b assuming we did not know how this data was generated.

Drop all of the variables in the dataset except pe , pe_tax , tax , and Q .

```
keep pe pe_tax tax Q
```

This is what a typical data set looks like to a policy (or business) analyst: We observe prices and quantities changing over time (or across geographies), and want to use this information to estimate a demand curve.

It is good practice to start with a scatter plot of your data.

```
twoway scatter pe_tax Q
```

Does this look like a demand curve? Explain why we don't see a nice smooth line any more.

2.7 Estimate how oil demand changes when prices change.

As above, assume the demand curve for oil is linear: $Q_t^D = A_t + (-b)(pe_tax)$. Estimate this curve using OLS.

reg Q pe_tax

What is your estimated demand response ($\hat{b}$)? [Hint: your regression results will return a negative estimate of b]

2.8 Why does your estimated demand response $\hat{b}$ differ from the b used to simulate the data?

In parts 2.4 and 2.5 we generated equilibrium prices and quantities assuming a linear relationship and $b = .5$. Now, when we try to recover that linear relationship using a regression, we get a different estimated value of $\hat{b}$ (and of $\hat{A}$, the `_cons`). Explain what is going on.

2.9 As discussed in class, Davis and Killian (2011) suggest we can solve this econometric problem by using taxes as an instrumental variable for prices.

In class we discussed the assumptions necessary for an instrumental variable to be valid. The assumptions we need in this example is that that taxes are correlated with consumer prices (which they are here, mechanically) and that they are uncorrelated with consumer demand shocks.

- Check the latter assumption in the original data before you drop these variables by typing:
`corr At taxes.`
- Then estimated the instrumental variable regression by typing: *ivregress 2sls Q (pe_tax = tax)*

How does the instrumental variable estimate of $\hat{b}_{iv}$ compare to b used to simulate the data?

2.10 Explain the implications of this exercise for policymakers.

The motivation for estimating how demand responds to price was discussed in the introduction to this problem set.