Welfare Implications of Taxes in the Presence of Natural Monopolies: A Theoratical Study

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Abstract: The examples of natural monopolies are widely seen in practice. The existing of natural monopolies leads to government intervention in the economy. Government intervention is witnessed in two ways: regulator and supplier. In addition, governments can alter the quantity supplied and price charged by the natural monopolist through taxes. In the presence of natural monopolies taxes are employed to raise revenue. In general, taxes imposed on natural monopolies can be classified as ad-valorem (VAT) and excise taxes. The taxes in question do not have identical effects on the prices charged and profit, thus lead to different changes in social welfare. Especially, if the product supplied by the natural monopolist is the energy used for domestic purposes, the taxes can be rather harmful to households with low income, since these taxes are a typical example of regressive taxes. This paper aims to trace the effects of the taxes on social welfare. To do this, a micro model is constructed. First, it is supposed that the government is a regulator. Second, it is considered that the government is a supplier. In both cases, the welfare implications of the taxes are examined and compared with each other. The results generated by simulation indicate that the welfare implications of the taxes vary depending on whether the government itself is the supplier or regulator.

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1-Introduction:

Natural monopoly is a result of network.[2] When the technology of production is characterised by economies of scale, natural monopoly exists. There are many examples of natural monopolies such as electricity, telecommunication, railroads, natural gas and water pipelines. In the presence of natural monopolies, government intervention is widely seen to achieve efficiency. The government can be either a regulator or supplier. All network industries[3] have been and are subject to varying degrees of government regulation. As a regulator, the government controls price and entry to the market. As a supplier, as the name itself suggests, it operates in the market.

The aim of this study is to trace out the welfare implications of taxes imposed on the product by natural monopolist. Taxes imposed on different products by natural monopolies will not yield the same results, since some taxes are regresive and others are progressive. For instance, the tax on natural gas used domestically is a typical example of regressive taxes. As income increases, the percentage of income spent on fuel used for domestic purposes decreases (ONS, 1996-97). Although there are many types of products by natural monopolies, natural gas used by households will be employed as an example in this study since the results derived from the model can be applied to other natural monopolies. In the next section, the model is constructed. Section three shows the results generated from simulation. Section four draws a conclusion.

2- The model:

As mentioned in the first section, government intervention changes the outcome desicion of the natural monopolist through price controls. If the government is not a supplier, it determines or controls the level of prices charged by the natural monopolist. In addition to this intervention, the government can alter the level of the quantity supplied and price

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[2] Natural monopoly refers to an industry where industry average cost of production is minimised when there is a single producer.

[3] Electricity, telecommunication, airlines, railroads are an example of network industries.

charged by imposing taxes. Natural gas used for domestic purposes is subject to mainly two kinds of taxes, excise tax and VAT. Some countries such as Turkey impose both taxes, whilst others such as the UK impose only VAT due to political and income distribution concerns (IEA, 1999). Furthermore, since VAT on natural gas used domestically is a regressive tax, the rate of VAT on natural gas in some countries is lower than the standard rate. The UK can be given as an example. The rate of VAT on natural gas is 5 per cent while the standard rate is 17,5 (Smith, 1995).

In our model, we assume that the government imposes either an excise tax or VAT on natural gas. In order to trace out the welfare implications of these taxes on society, we introduce five different scenarios depending on the type of the tax and who is the natural monopolist.

2.1- In the first case, either the government or the firm is the supplier.[4] We suppose inverse demand is linear and given in a specific form.

$$P = a - bQ \qquad (1)$$

The profit function of the monopolist, either the government or a firm, is as below:

$$\Pi = PQ - cQ \qquad (2)$$

where PQ is the total revenue and cQ is the total cost. For simplicity, it is assumed that marginal cost is constant. Taking the derivative of (2) with respect to Q gives the profit maximising quantity and price levels,

$$Q = \frac{a-c}{2b} \text{ and } P = \frac{a+c}{2}$$

Note that in the first scenario, there is no tax imposed yet.

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[4] In this study, the natural monopolist is considered as a supplier, not a producer.

2.2- In the second case, the firm is the monopolist and the government imposes an excise tax. After the introduction of the excise tax, the profit function of the monopolist changes to

$$\Pi = PQ - cQ - tQ \tag{3}$$

where t is the excise tax.

Profit maximising quantity and price levels are found by taking the derivative of (3) with respect to Q.

$$Q = \frac{a - c - t}{2b} \quad \text{and} \quad P = \frac{a + c + t}{2}$$

As can be seen from the optimal quantity and price levels, the excise tax is reflected into the price charged.

2.3- In the third case, the government is the supplier of natural gas. An excise tax is imposed. As a result, the government's profit function shown in (2) changes to

$$\Pi = PQ + tQ - cQ \tag{4}$$

where t is the excise tax imposed on each unit sold. As can be seen from (4), the imposition of the excise tax is added as revenue to the profit function.

Taking the derivative of (4) with respect to Q gives the profit maximising quantity and price levels

$$Q = \frac{a - c + t}{2b} \quad \text{and} \quad P = \frac{a + c - t}{2}$$

2.4- In the fourth case, the firm is supplier and VAT is imposed.

$$\Pi = [a - bQ]Q(1-T) - cQ \tag{5}$$

where T is the rate of VAT.

The profit maximising quantity and price levels are

$$Q = \frac{a(1-T)-c}{2b(1-T)} \quad \text{and} \quad P = \frac{a(1-T)+c}{2(1-T)}$$

2.5- Finally, the government is the supplier and imposes VAT.

$$\Pi = [a - bQ]Q(1+T) - cQ \tag{6}$$

When the government is supplier, as in the case of the excise tax, the imposition of the VAT raises revenue for the government.

Profit maximising quantity and price levels are

$$Q = \frac{a(1+T)-c}{2b(1+T)} \quad \text{and} \quad P = \frac{a(1+T)+c}{2(1+T)}$$

3- Simulation results:

Having found the profit maximising quantity and price levels, we are in a position to show the changes in welfare before and after the introduction of the taxes on natural gas. The following values are used for the parameters, cost and taxes shown in (2), (3), (4), (5) and (6).

a=100

c=2

b=0.8

T=0.17 (VAT)

t=0.20 (excise tax)

Social welfare can be designed as follows:

$$W = \Pi + Cs \tag{7}$$

where Π denotes the profit of the monopolist and Cs is consumer surplus.

Consumer surplus is

$$Cs = \int_0^Q (a - bQ)\,dQ - PQ \tag{8}$$

By using the values given above, the quantity, price, profit and consumer surplus are calculated for each scenario.

Table 1: Simulation results

VAT (f)	VAT(g)	Excise tax (f)	Excise tax (g)	Quantity (Q)	Price (P)	Profit Π	Consumer surplus (Cs)
0	0	0	0	61,25	51	3001,25	1502
0	0	0,20	0	61,125	51,1	2989,013	1494,6
0	0	0	0,20	61,375	49,1	2903,035	1617,25
0,17	0	0	0	54,6	56,3	2442,2	1193,42
0	0,17	0	0	60,9	51,2	3526,35	1488

Excise tax(f): Firm is the monopolist with excise tax

Excise tax (g): Government is the monopolist with excise tax

VAT (f): Firm is the monopolist with VAT

Vat (g): Government is the monopolist with VAT

Table 1 shows quantity, price, profit and consumer surplus before and after the imposition of the taxes. As can be seen from the table, changes occur in the quantity supplied, prices, profits and consumer surplus as a result of the taxes imposed. When the government is the supplier and the excise tax is imposed, consumer surplus is the highest. The reason for this is, the quantity supplied increases and the price decrease. On the other hand, the profit of the government in the presence of the VAT increases considerably.

Having calculated the values of the profit and consumer surplus, the next step is to trace out the changes in welfare. Depending on the scenarios mentioned earlier, five different welfare cases can be formulated as follows:

1) $W_1 = \Pi + Cs$

The firm or the government is the supplier with no tax.

2) $W_2 = \Pi + Cs + Qt$

The firm is the supplier and excise tax is imposed by the government.

3) $W_3 = \Pi + Cs$

The government is the supplier with excise tax.

4) $W_4 = \Pi + Cs + T(PQ)$

The firm is the supplier with VAT.

5) $W_5 = \Pi + Cs$

The government is the supplier with VAT.

The main difference between 2 and 3 is that tax revenue is added to welfare in the case of W_2 and not added in the case of W_3 since it already takes place as revenue in the profit function of the government. The same argument applies to 4 and 5.

Table 2: Welfare changes

W_1	W_2	W_3	W_4	W_5
4503,25	4495,83	4520,28	4158,19	5014,35

As can be seen from Table 2, the welfare implications of the taxes imposed on natural gas vary. The interesting point is that society, including the natural monopolist and households, is better off when the government is supplier and VAT is imposed. However, this increase occurs due to the increase in the profit of the government at the cost of the fall in consumer surplus. The loss in consumer surplus can be offset by re-distribution of the revenue raised by the imposition of the VAT.

4- Conclusion:

Government intervention in the presence of natural monopolies is seen in the type of either being a regulator or supplier. Furthermore, taxes imposed by the government lead to the changes in the quantity supplied and prices charged. The changes is question bring about changes in socail welfare. In this study, the welfare implications of the taxes have been under investigation. The results derived from the model show that ecxise tax and VAT on natural gas do not have the identical impacts on social welfare. When the firm is the supplier of natural gas used domestically, after the introduction of both taxes a fall in social welfare is witnessed. However, the fall varies depending on which tax is imposed. The interesting point is, when the government is supplier, social welfare increases after the introduction of both taxes.

References:

IEA, (1999), *Energy Prices and Taxes.*

ONS, (1996-97), *Family Expenditure.*

Smith, S. (1995), Green Taxes and Charges: Policy and Practice in Britain and Germany, The Institute for Fiscal Studies, London.