

# Estimating price and income elasticity of demand



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# Introduction

- The responsiveness of tobacco consumption to price and income increases is measured by the price and income elasticity of demand respectively.
- Policy makers are interested in learning about the price sensitivity of tobacco consumption with a view to predicting the possible impact of tobacco tax increase that causes tobacco price to increase leading to decrease in tobacco consumption.
- This presentation elaborates the methods of estimating price and income elasticity of demand including selection of demand model, data requirement, specification of functional form and the estimation issues.



# Outline

- Definition, sign and value of price/income elasticity
- Examples of price/income elasticity estimates
- Data types for price/income elasticity estimation
- Selection of the demand model
- Model specification for price/income elasticity estimation
- Endogeneity of price variable
- Tax elasticity of demand
- Net effect of simultaneous price and income change



# Price elasticity defined

- The effect of price change on demand is measured by price elasticity.
- Price elasticity is defined as the percentage change in consumption in response to 1% change in price.
- Suppose,
  - $P_1$  = initial price per pack of cigarettes
  - $Q_1$  = number of packs of cigarettes sold at price  $P_1$
  - $P_2$  = new price per pack of cigarettes
  - $Q_2$  = number of packs of cigarettes sold at price  $P_2$
- Then price elasticity of demand for cigarettes is given by

$$\varepsilon = \frac{\frac{Q_2 - Q_1}{Q_2 + Q_1}}{\frac{P_2 - P_1}{P_2 + P_1}} = \frac{Q_2 - Q_1}{P_2 - P_1} \times \frac{P_2 + P_1}{Q_2 + Q_1}$$



# Sign and value of price elasticity

- Price elasticity is usually negative indicating that when price goes up, consumption goes down and vice versa.
- The greater the absolute value of price elasticity, the higher the price sensitivity of demand.
- For tobacco products, price elasticity is usually less than 1 or tobacco demand is price inelastic. It means when price increases, tobacco consumption decreases by a lesser percentage compared to the price increase.
- A price elasticity of -0.4 indicates that when price increases by 10%, demand reduces by 4% in a reasonable period of time that allows the consumers to adjust that tobacco use behavior. In effect, the cut down in aggregate consumption is expected to appear in the monthly or annual sales data available from government sources.
- Given the price elasticity of demand, it is possible to predict the amount of reduction in consumption in response to a price increase. For example, if price elasticity is -0.4 and price increases by 20%, one can expect that consumption would go down by  $0.4 \times 20\% = 8\%$ . If initial consumption was 100 units, it can be expected that the 20% price increase would lower consumption to 92 units.



# Examples of price elasticity estimates

The studies examining the impact of tobacco product prices on overall tobacco use are numerous. A majority of these studies came from high-income countries including United States, Canada, United Kingdom, Australia, and several others. But there is growing evidence on the negative effect of tax and price increase on tobacco consumption from low and middle-income countries as well. These studies have estimated a wide range of price elasticities with most, but not all, indicating that demand for tobacco products is more responsive to price in low and middle-income countries than it is in high-income countries.

Country	Cigarette price elasticity	Source
Bulgaria	-0.80	Sayginsoy (2002)
Taiwan	-0.66	Lee (2007)
Republic of Korea	-0.66	Chung et al. (2007)
Indonesia	-0.61	Adioetomo et al. (2005)
United Kingdom	-0.56	Jones (1989)
Egypt	-0.47	Hanafy et al. (2011)
USA	-0.37	Franz (2008)



# Data types for price elasticity estimation

- Aggregate time-series data (e.g., per capita sales of cigarettes and annual average price for a country over time)
- Cross-sectional data
  - Aggregate cross-sectional data for countries, states, provinces, etc.
  - Individual cross-sectional data from household surveys
- Time-series of cross-sectional data
  - Panel /longitudinal data (repeated observations of the same unit over time)
  - Pooled data of cross-sectional observations
- Time series data allows one to calculate the percentage change in total tobacco consumption and the percentage change in the average price from one period to the other. The ratio of these two percentages provides the average price elasticity over the time interval.
- Cross-sectional data allows one to estimate price elasticity by utilizing cross-sectional variation in consumption and price to determine the price sensitivity across the population at a point in time.



# Selection of the demand model

- Conventional demand models: static, looks at the effect of explanatory variables on the dependent variable within a single period of time.
- Addictive demand models: dynamic, looks at the effect of demand in the future and/or demand in the past as well as other explanatory variables in the current period on the demand variable
  - Myopic addiction model: demand in the past is used as an explanatory variable
  - Rational addiction model: both demand in the past and demand in the future period are used as explanatory variables





# Model specification for price elasticity estimation

- Demand function: Consumption = f (own price, price of substitutes/compliments, income, policy and environmental factors)
- Linear model: Both dependent and independent variables are used as levels
  - Price elasticity = Coefficient of price x Average price/Average consumption
- Log-linear model:
  - The dependent variable is expressed as logarithm of the original level and the independent variables are used as level
    - Price elasticity = Coefficient of price x Average price
  - The dependent variable is used as level and the independent variables are logarithmic transformation of the original levels
    - Price elasticity = Coefficient of log price/Average consumption
- Double log model: Logarithm is taken of both dependent and independent variables
  - Price elasticity = Coefficient of log price
- Detailed description can be found in World Bank Economics of Tobacco Toolkit: Economic Analysis of Tobacco Demand



# Endogeneity of price variable

- The quantity and price are simultaneously determined in the market by the equilibrium of demand and supply. It means price is endogenous.
- Failure to account for endogeneity of price may result in bias in the price elasticity estimate.
- One possible solution is to use instrumental variable technique:
  - Find variables that are correlated with price but do not directly influence demand.
  - Common instrumental variables are excise tax and lagged price.
  - Regress price on the instrumental variables and other exogenous independent variables in the demand model.
  - Obtain the predicted values of price from the price regression and use the predicted values as exogenous price variable in the regression of the demand function.
- The second possible solution is to use simultaneous equation model where both demand and supply functions are estimated. However, the variables necessary for estimating the supply function need to be collected from the tobacco industry which may not be readily available.



# Tax elasticity of demand

- When quantifying the impact of tax increase on demand, usually the effect of price increase on demand is estimated using the concept of price elasticity, as price is the final value confronting the consumers.
- However, the tax component can be used as a proxy or instrument for retail price. Then the relationship between demand and tax is estimated by tax elasticity.
- Tax elasticity is generally lower than price elasticity as tax is a proportion of retail price unless there is a case of over-shifting (when consumer prices increase more than the tax increase itself).
- Tax elasticity can be converted to price elasticity if we know the relationship between tax and price.



# How is tax elasticity estimated

- The tax rate can be directly used in place of the price variable in the demand equation. In this case, the coefficient of the tax variable provides the tax elasticity of tobacco consumption which can then be converted to price elasticity of demand.
- From the linear demand model,  $\text{Consumption} = \alpha + \beta \text{ Tax} + \mu$ , we can estimate the tax elasticity at the mean values as  $(\rho / q)\beta$ , where  $\beta$  is the the estimated coefficient of tax variable,  $\rho$  is the sample mean of the cigarette price, and  $q$  is the sample mean of per capita cigarette consumption
- Then we can estimate the price elasticity of demand for cigarettes with this by:

$$[(\rho / q)\beta ]/(\partial \rho / \partial t)$$

where:  $\partial p/\partial t$  = the change in cigarette prices resulting from a change in excise taxes. This can be estimated by regressing price as a function of tax:

$$\text{Price} = \alpha + \gamma \text{ Tax} + \mu$$

and the estimated coefficient of tax ( $\gamma$ ) is  $\partial p/\partial t$ .



# Income elasticity defined

- The effect of change in income on demand is measured by income elasticity.
- Income elasticity is defined as the percentage change in consumption in response to 1% change in income.
- Suppose,
  - $I_1$  = initial income level
  - $Q_1$  = number of packs of cigarettes purchased at income level  $I_1$
  - $I_2$  = new income level
  - $Q_2$  = number of packs of cigarettes purchased at income level  $I_2$
- Then income elasticity of demand for cigarettes is given by

$$e = \frac{\frac{Q_2 - Q_1}{Q_2 + Q_1}}{\frac{I_2 - I_1}{I_2 + I_1}} = \frac{Q_2 - Q_1}{I_2 - I_1} \times \frac{I_2 + I_1}{Q_2 + Q_1}$$



# Model specification for income elasticity estimation

- The price and income elasticity can be estimated from the same model specification as:

Demand function: Consumption = f (own price, price of substitutes/compliments, income, policy and environmental factors)

- Linear model: Both dependent and independent variables are used as levels
  - Income elasticity = Coefficient of income x Average income/Average consumption
- Log-linear model:
  - The dependent variable is expressed as logarithm of the original level and the independent variables are used as level
    - Income elasticity = Coefficient of income x Average income
  - The dependent variable is used as level and the independent variables are logarithmic transformation of the original levels
    - Income elasticity = Coefficient of log income/Average consumption
- Double log model: Logarithm is taken of both dependent and independent variables
  - Income elasticity = Coefficient of log income



# Sign and value of income elasticity

- Income elasticity is usually positive indicating that when income goes up, consumption also increases.
- The greater the value of income elasticity, the more sensitive is demand to income change.
- For tobacco products, income elasticity is usually positive, signifying that tobacco is a normal good. Besides, with growing income, consumers tend to switch to higher-priced tobacco products.
- An income elasticity of 0.2 indicates that when income increases by 10%, demand increases by 2% in a reasonable period of time that allows the consumers to adjust that tobacco use behavior. In effect, the growth in aggregate consumption is expected to appear in the monthly or annual sales data available from government sources.
- Given the income elasticity of demand, it is possible to predict the amount of growth in consumption in response to an income increase. For example, if income elasticity is 0.2 and income increases by 5%, one can expect that consumption would go up by  $0.2 \times 5\% = 1\%$ . If initial consumption was 100 units, it can be expected that the 5% income increase would raise consumption to 101 units.



# Examples of income elasticity estimates

The positive income elasticity is more likely to be observed in low and middle income countries that are at an earlier stage of the tobacco epidemic. Since many low and middle income countries are growing rapidly, large increases in tobacco consumption is likely to occur over a short period of time. For example, with an annual GDP growth rate of 5% and an income elasticity of 0.4, tobacco consumption may grow annually by  $5 \times 0.4 = 2\%$ .

Country	Income elasticity	Source
Turkey	0.56	Yurekli et al. (2010)
Egypt	1.60	Hanafy et al. (2011)
Ukraine	0.30	Peng and Ross (2009)
China	0.90	Yuanliang and Zongyi (2005)
Bangladesh	0.23	Nargis et al. (2013)
South Africa	0.59	Reekie (1994)
Poland	0.43	Florowski and McNamara (1992)





# Data types for income elasticity estimation

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  - Individual cross-sectional data from household surveys (per capita household consumption and per capita household income)
- Time-series of cross-sectional data
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- Time series data allows one to calculate the percentage change in total tobacco consumption and the percentage change in the per capita income from one period to the other. The ratio of these two percentages provides the average income elasticity over the time interval.
- Cross-sectional data allows one to estimate income elasticity by utilizing cross-sectional variation in consumption and income to determine the income sensitivity across the population at a point in time.



# Net effect of simultaneous price and income change

- If price elasticity is  $-0.4$  and price increases by  $20\%$ , one can expect that consumption would go down by  $0.4 \times 20\% = 8\%$ . If initial consumption was 100 units, it can be expected that the  $20\%$  price increase would lower consumption by 8 units.
- If income elasticity is  $0.2$  and income increases by  $5\%$ , one can expect that consumption would go up by  $0.2 \times 5\% = 1\%$ . If initial consumption was 100 units, it can be expected that the  $5\%$  income increase would raise consumption by 1 unit.
- The net effect of both price and income increases on aggregate consumption is given by reduction by 7 units ( $8-1$ ).
- Thus income growth can partially offset the discouraging effect on consumption from a price increase.



# Reference

- A comprehensive description of the estimation techniques for price and income elasticity of demand for tobacco products can be found in Wilkins, N., Yurekli, A., and Hu. T. Economic Analysis of Tobacco Demand. Tool 3: Demand Analysis, Economics of Tobacco Toolkit, Yurekli, A. and Beyer J (editors). World Bank.



# Summary

- An increase in tax is expected to lead to increase in price and reduce consumer demand. Price elasticity is used to measure the expected reduction on consumption from a given increase in price.
- At the same time, consumers may experience income growth that causes consumption to rise. This impact is measured by income elasticity of demand.
- The net impact on consumption from price and income increases is given by the sum of the above two changes in consumption in opposite directions.

