THE ENERGY CENTRE
BUSINESS SCHOOL

Transport Economics

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Transport Economics

- Transport demand
- Transport supply
- Econometric modelling
  - Road transport demand
  - Transport mode preference

Transport Demand

- Derived demand
  - An individual's demand for transport is instigated through their demand for something else.
  - Transport is not typically consumed because people like travelling, but because transport supports other activities (i.e. JTW commuting, the movement of freight)
- Time specific
  - When transport services are demand they are demanded NOW.
  - People generally travel to engage in activities at various locations at specific time period – demand for transport has a very short 'expiry date'.
- Follows peaks and troughs
  - The morning & afternoon rush hours – significant impact upon the way in which transport services are provided and indeed the whole 'economics' of transport operations.

Microeconomic Theory

Transport Economics deals with individual units (per trip) or certain sectors of economy (road transport), Qs:

- What determines the demand for a particular journey or the demand for a particular mode of transport?
- How can an airline operator charge passengers different prices for the same flight when schools are ‘in session’ or ‘on holidays’?
- What are the effects of a change in the price of petrol on private car usage?
- What may happen to the level of congestion if a road pricing system is introduced? etc.

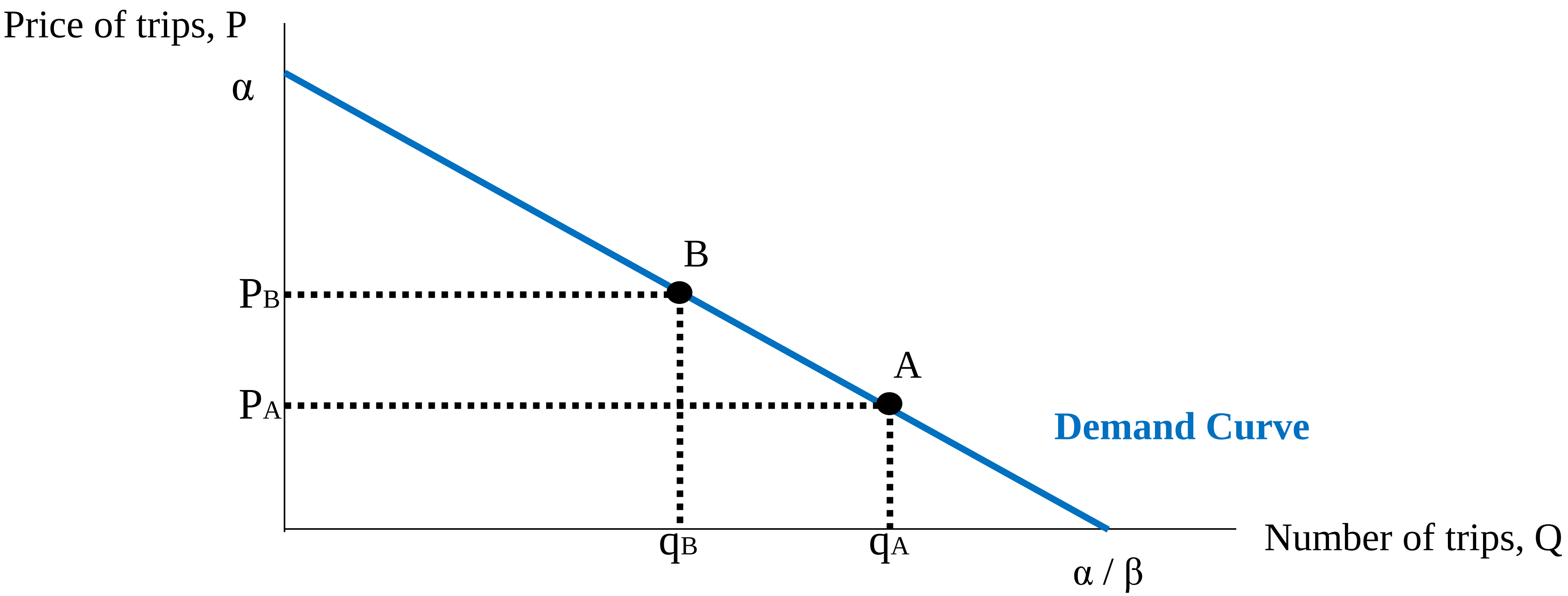
The Demand Function

- A key component of any form of economics
- The willingness of consumers to purchase the product at different prices (of different expenditures of resources)
- Relates to price (cost to the consumer) and quantities demanded
- Can be expressed in terms of a number of “prices”
    - Fare
    - In-vehicle time
    - Overall generalised travel cost
- Assumptions:
    - Consumer utility maximisation
    - Rationality: as the price increases the quantity demanded reduces
    - Ceteris Paribus: a number of the other characteristics of the journey & of the traveller remain constant.

A Typical Linear Demand Curve

Equation: $p = \alpha - \beta q$

Where q is the quantity of trips demanded, p is the price and α and β are constant demand parameters



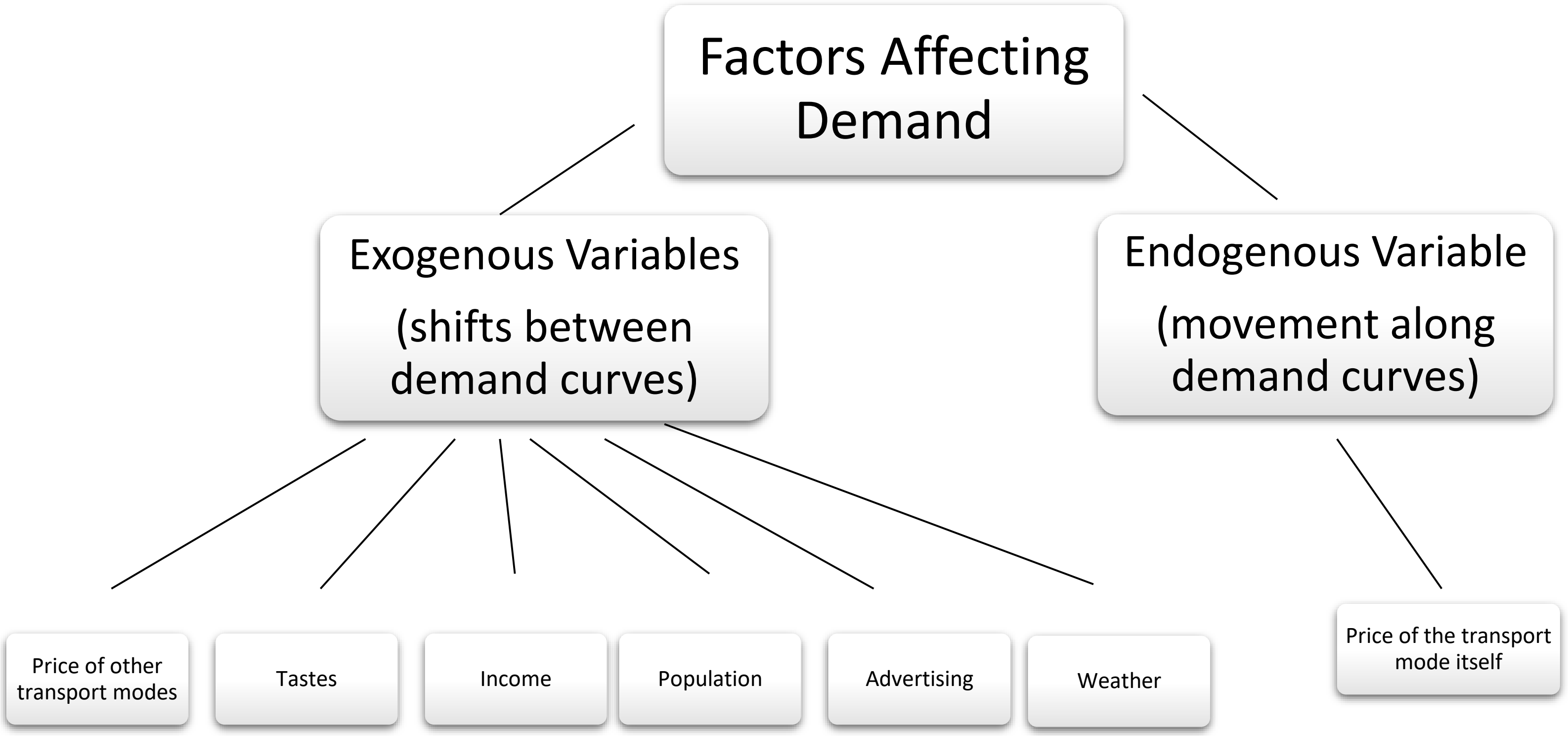
Characteristics of the Demand Curve

- Equation of form $p = \alpha - \beta q$
- When price = 0, quantity demanded q = α/β
- When price = α, quantity = 0
- Negative relationship with price means curve slopes downwards as prices increase

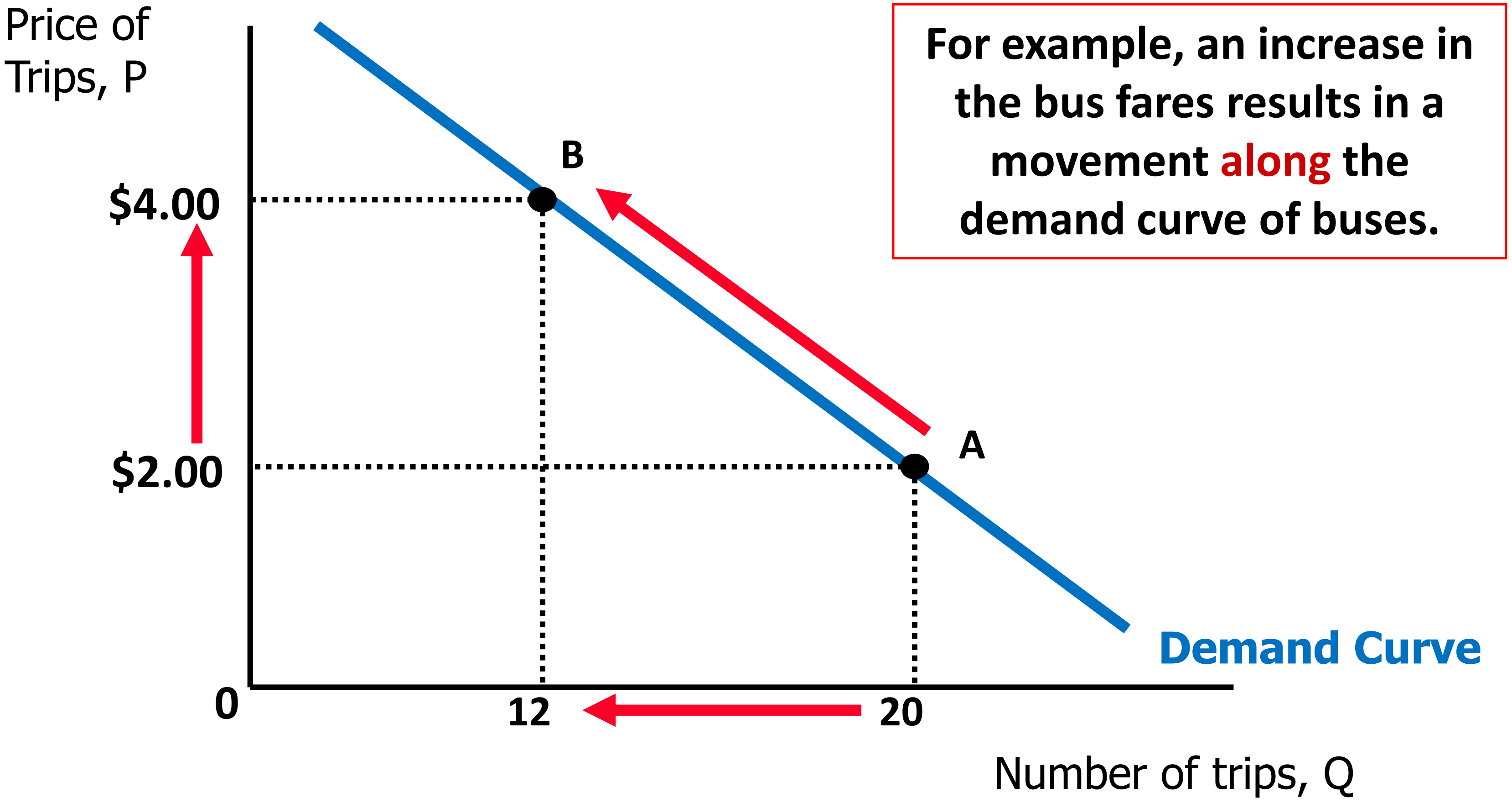
Shifts Along and Between Demand Curves

- **Along** demand curve possibly under control of operator
  - Short term changes
- **Between** demand curves more general changes or changes in other modes
  - Often longer term and may be outside control of transport operators

Factors Affecting Demand

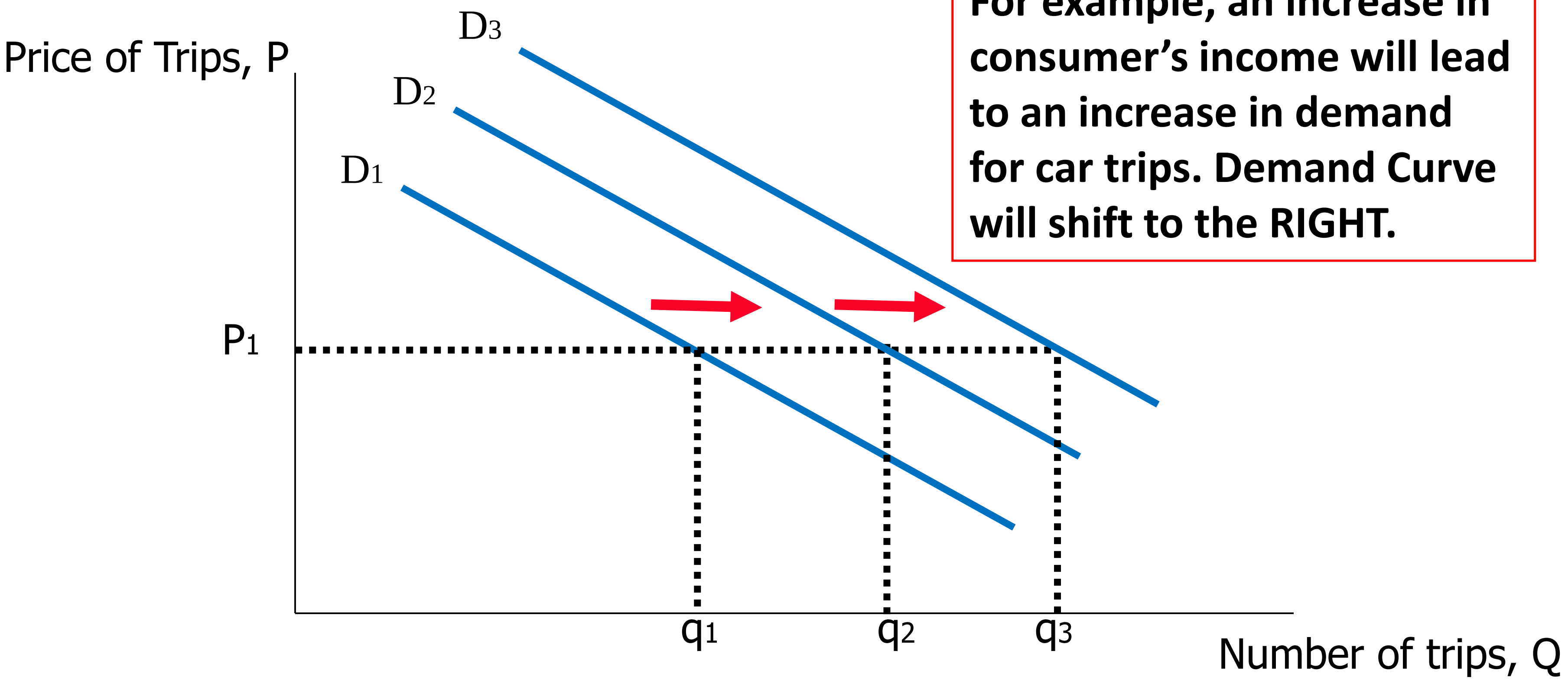


Movement along the Demand Curve



For example, an increase in the bus fares results in a movement along the demand curve of buses.

Shift between Demand Curves



For example, an increase in consumer's income will lead to an increase in demand for car trips. Demand Curve will shift to the RIGHT.

The Elasticity of Demand

- Need to understand how demand changes if we alter the cost to the traveller of a service
- Elasticity of demand
- Measures the change in demand in response to changes in the "price" of the service
- Proportional change in quantity divided by the proportional change in "price"

Elasticity Formula

- Price elasticity of demand; Or
- Elasticity of demand with respect to price

$$e_p = \frac{\delta q / q}{\delta p / p} = \frac{\delta q}{\delta p} \times \frac{p}{q}$$

where δq is the change in the number of trips that accompanies δp, the change in price

Calculating Elasticities

- If fare increases from \$1.0 to \$1.1
- Proportional increase in fare

  = (1.1-1.0)/1.0 = 0.1 or 10%
- Qd changes from 100 to 97
- Proportional decrease in Qd

  = (97 – 100)/100 = -0.03 = -3%
- Elasticity therefore = -0.03/0.1 = <u>**-0.3**</u>

Transport Supply -1

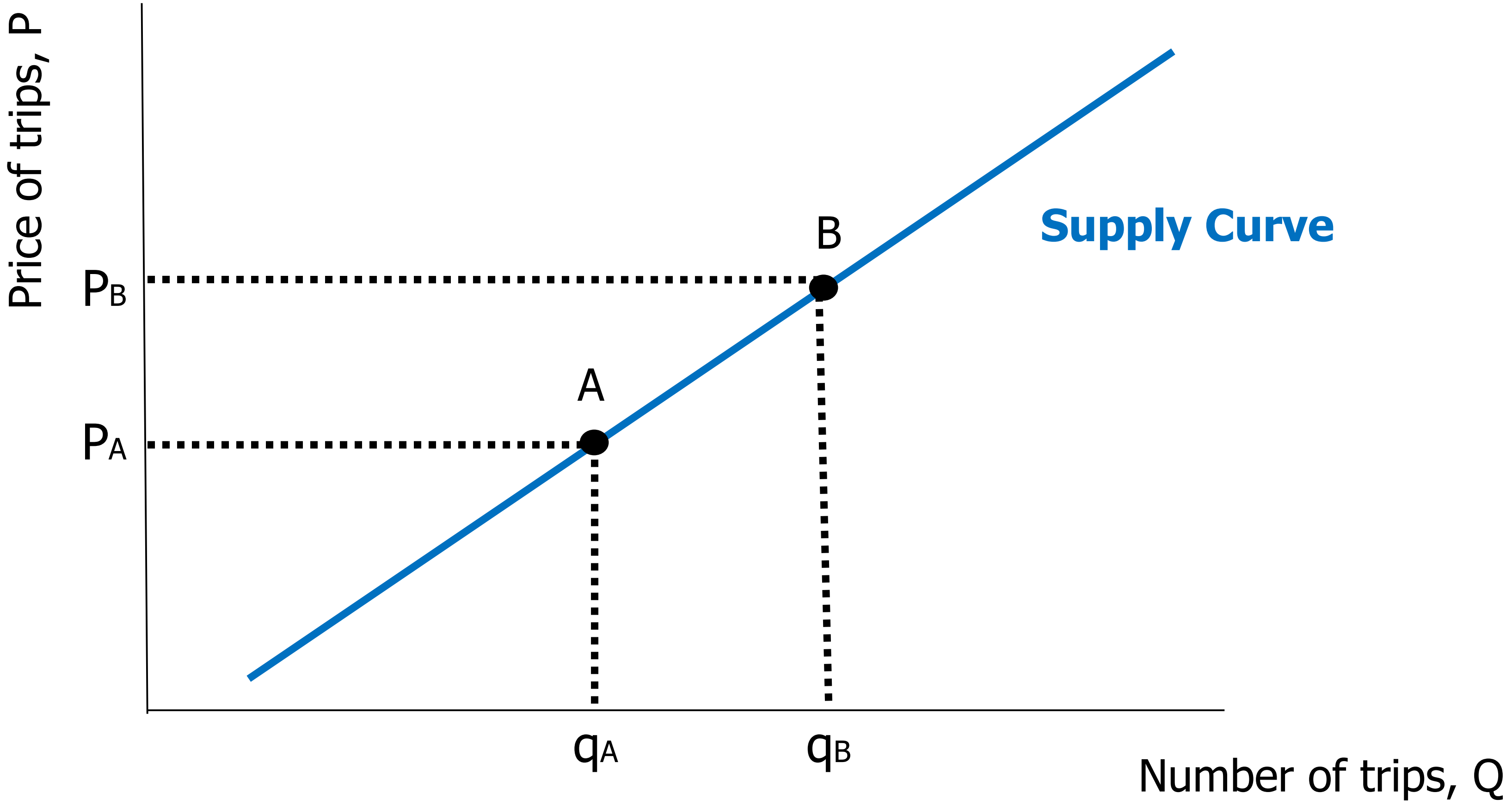
- Who supplies transport
  - Government
  - Private sector
- What is supplied
  - Infrastructure
  - Transport services

Transport Supply -2

- Private sector – financial criteria
  - Flow of funds to generate income
    - But may come from subsidy or similar source
  - Revenues greater than costs
  - Need for precise assessment
- Government – social welfare criteria
  - Need to be sure that benefits > costs
  - Financial criteria is important in funding of schemes

Transport Supply -3

- As in case of transport demand, transport supply also reveals the relationship between market price and Qs
- Quantity is based on what suppliers are prepared to offer



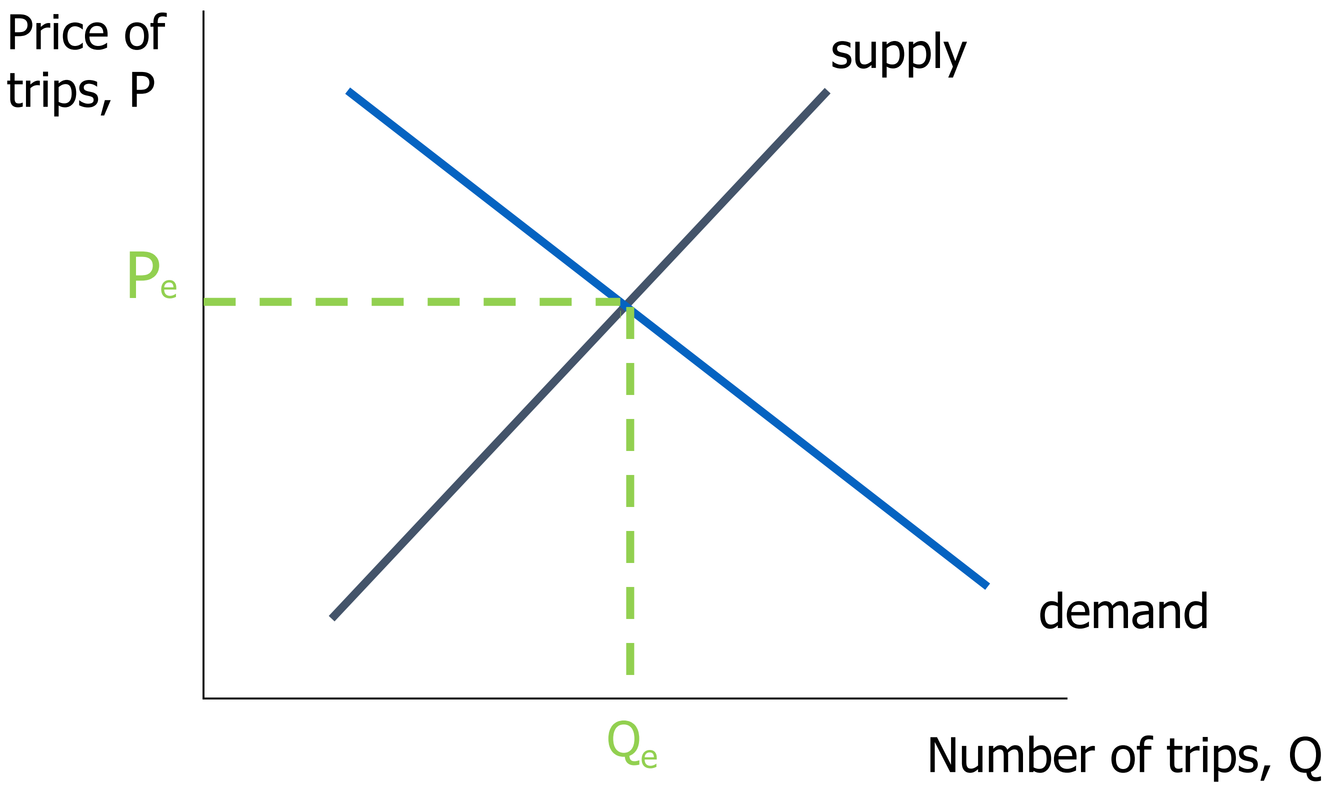
Costs of Production

- Costs of production is a major determinant of the level of supply
- Supplier needs revenues to cover costs (types costs will be examined later).
- Profit = Revenue – Cost
- All transport operators are assumed to be profit maximisers:
  - An ↑ in cost will ↓ the supply: some operators will leave the market due to a loss in profit,
  - A ↓ in costs will ↑ the supply: existing operators will supply more to the market & new entrants will enter the market due to higher profit opportunities.

Market Equilibrium

- We drew the transport market demand curve on a graph with P on the vertical and Q on the horizontal
- We did the same for transport supply...
  - Hence we can actually show transport demand & supply on the **same graph**, with P on the vertical and Q on the horizontal
- What is happening at the point where they cross...?
- At this point we have an ‘equilibrium’

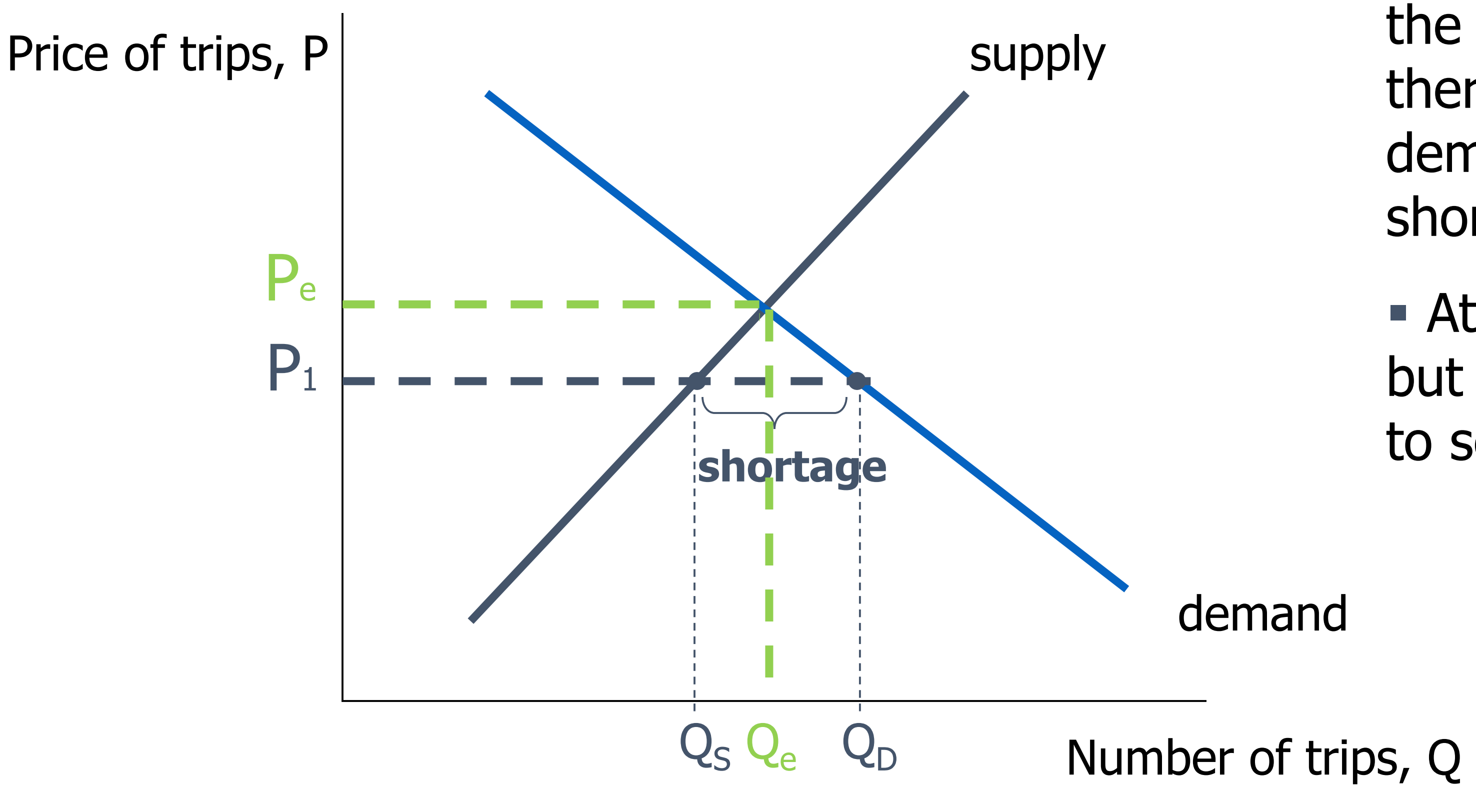
The Market at Equilibrium



What is Equilibrium?

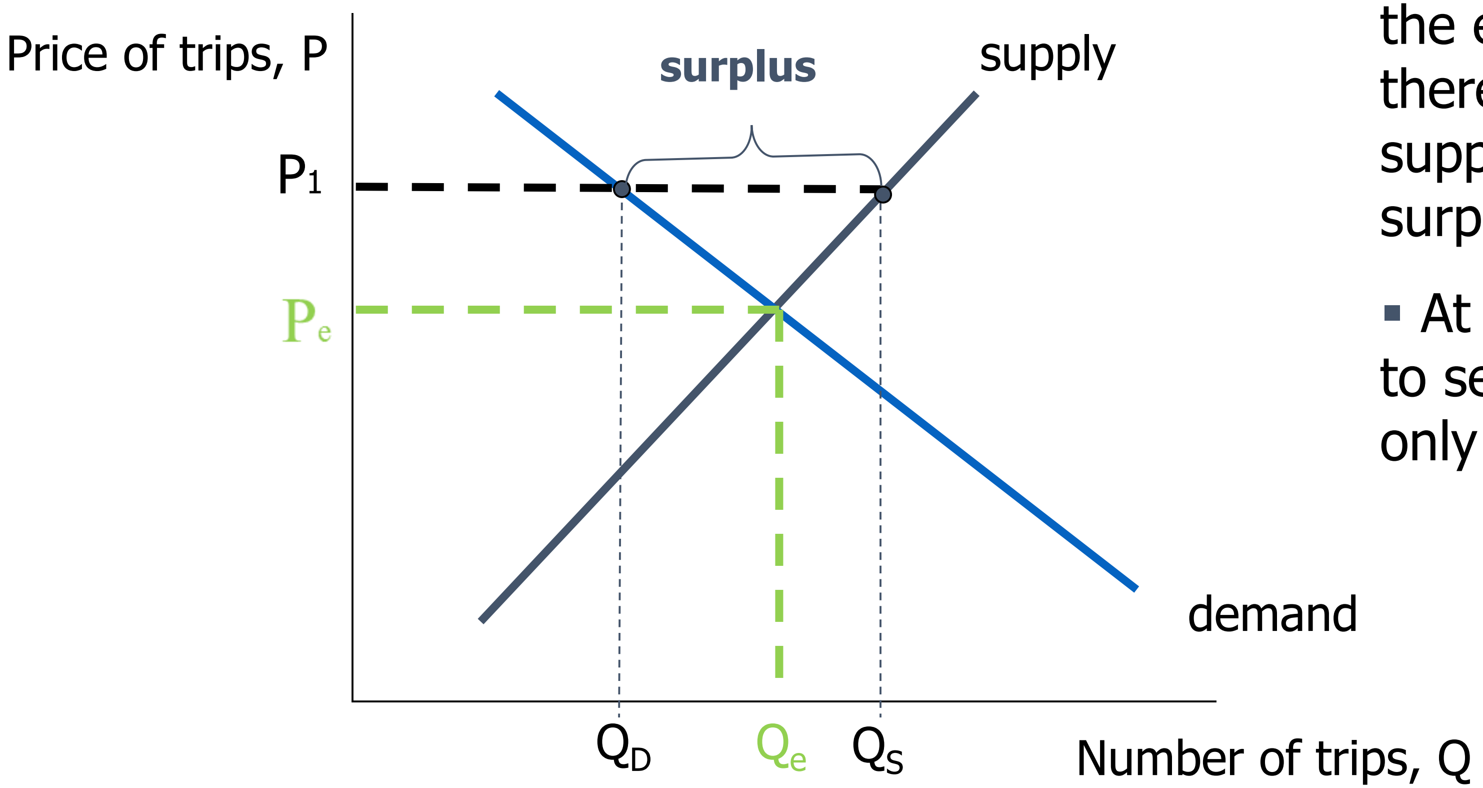
- **Equilibrium** is a stable situation that occurs in the market when Qd in the market = Qs in the market
  - On the graph this appears as the intersection of the market demand curve and the market supply curve
  - This occurs at one unique (single) price and quantity
    - What is this price? What is this quantity?
  - At this point D = S → Qd = Qs (there is no over- or under-supply of the commodity)
  - We say the market 'clears' at equilibrium

Determination of Price in a Competitive Market -1



- If the price is set below the equilibrium price, there will be an excess demand, which leads to a shortage
- At P_1, buyers want Q_D but sellers are only willing to sell Q_S

Determination of Price in a Competitive Market -2



- If the price is set above the equilibrium price, there will be an excess supply, which leads to a surplus
- At P_1, sellers are willing to sell Q_S but buyers are only willing to buy Q_S

Econometric modelling

- The objective of econometric methods is to try and identify the precise importance of each of the factor that broadly determine the demand for transport (e.g. income, price of the service, quality of the service, price and quality of alternatives, journey time and population size, etc.), in order that we can determine the effect on demand of changing these in the future.

Econometric modelling

1. Understanding the problem:

   Identifying all the key factors and making preliminary estimates of the size and direction of the effect.

2. Obtaining the data:

   Data on ALL the factors has to be acquire.

   a) Time series: where the data, going back a significant number of years, relates to a single location
   b) Cross Section: where the data has been obtained from a series of locations (or individuals) at a specific point in time
   c) Panel data: where data has been obtained from the same series of locations over a period of years.

Econometric modelling

3. Specifying the model:
   a) Selecting the functional form (i.e. linear, log-log)
   b) Selecting the variables (& in time series any lagged effects)
   c) Making reasonable assumptions about the error term
4. Estimating the specified model:

   Identifying values for the parameter estimates for each factor to be used in the forecast, that makes the predicted values lie as close as possible to the actual values. This normally involves minimising the SSR.

Econometric modelling

5. Validating the model:

a) The values of the coefficients (the elasticities in log-log) have the right signs (i.e. income +, price – for demand analysis) & are of the expected size.

b) The model fit is statistically significant (i.e. the R^2 value)

c) The individual variables are statistically significant (i.e. the p value)

d) The residuals have no pattern over time or location (i.i.d)

6. Simulation/Forecasting:

Once we have the final model then it is a Q of inserting expected future values of the factors into the equations. Sometimes we use suggested values obtained from expert groups, or use different sets of predictions to form scenarios, or simply use trend extrapolation of the external factors.

Econometric modelling for road transport demand -1

$$Q_{it} = f(\, I_t \,, P_{it}, P_{it}^{S}, SD_t)$$

where

- Q_{it} = quantity demanded of the i^{th} road passenger transport mode in the t^{th} quarter;
- I_t = income of road passenger transport users in the t^{th} quarter;
- P_{it} = price of the i^{th} road passenger transport mode in the t^{th} quarter;
- P_{it}^{S} = price of substitutes of the i^{th} road passenger transport mode in the t^{th} quarter;
- SD_t = socioeconomic and demographic factors in the t^{th} quarter

Econometric modelling for road transport demand -2

Passenger transport choices as a system of equations: Main transport modes (petrol cars, diesel cars & buses) → substitutes to one another → strong possibility that an interrelationship exists between the travel demand functions → the correlation between their disturbances.

A linear Seemingly Unrelated Regression model is a system of *N (N = 3)*linear regression equations:

$$y_{it} = X_{it} + \mu_{it} \ , \qquad i = 1, \cdots, N, \text{and } t = 1, \cdots, T$$

where

- y_{it} is a transport demand;
- $x_{it} = (1, x_{it,1}, x_{it,2}, \ldots, x_{it,Ki-1})'$ is a K_i-vector of explanatory variables for observational unit *i*;
- u_{it} is an unobservable error term, *i.i.d.*
- where the double index *it* denotes the t^{th} observation of the i^{th} equation in the system

Econometric modelling for road transport demand -3

Lagrange Multiplier (LM) statistic proposed by Breusch and Pagan (1980):

where r_{mn} is the estimated correlation between the residuals of the *M* equations & *N* is the number of obs. It is distributed as χ2 with *M(M −1)/2* d.f.

We can reject the H_0 that the covariance between the three different equations are = 0 at 5% significance level.

This implies that the residuals from each SUR regression are significantly correlated with each other, representing identical unsystematic influences.

Table 6
Correlation Matrix of Residuals*

	r_Car_P	r_Car_D	r_Bus_VKT
r_Car_P	1		
r_Car_D	-0.1069	1	
r_Bus_VKT	-0.2893	-0.3111	1

* Breusch-Pagan test of independence: χ2 (3) = 11.129, *Pr* = 0.0110

The Breusch-Pagan test of independence confirms the existence of correlated error terms of the 3 demand equations → SUR model → consistent & efficient results.

Econometric modelling for transport mode preference -1

In the context of transport mode choice, the utility U of individual commuter $i = 1, \ldots N$ for each alternative j is a function of a vector of attributes x describing the alternative:

$$U_{ij} = \beta x_{ij} + \varepsilon_{ij} \qquad (1)$$

where:

- U_{ij} denotes the utility of the i^{th} commuter for alternative j;
- β is the unknown vector of commuters' preference to be estimated;
- x_{ij} is the attribute vector of the i^{th} commuter for alternative j; and
- ε_{ij} is a random error component, representing the unobserved portion of utility.

Econometric modelling for transport mode preference -2

Social Network Effect: people prefer to use public transit together with others b/c

1) A utility gain through complementarity - since people are not alone;
2) Avoiding a utility loss by not following others - if they travel together, they can meet and communicate with each other, and thus feel safer;
3) A rise in utility level which stems from internalising an information externality: when people using public transport, they send a signal to everyone else that this is a feasible, and/or reliable mode.

Eq. (1) is rewritten by adding a spatially autoregressive mode choice term $\boldsymbol{WU}$, so that the above RUM is modified as the following probit mode choice model, estimated by conditional ML estimation method.

$$\boldsymbol{U} = \alpha + \boldsymbol{WU}\rho + x\beta + e \qquad (2)$$

where:

- $\boldsymbol{U}$ = unobserved utility of the chosen mode (taking public transit to work or not);
- $\boldsymbol{W}$ represents the $n \times n$ spatial weight matrix; the spatial lag term, $\boldsymbol{WU}$, indicates the spatially weighted average mode share of mode j of all the commuters in surrounding locations of individual i; and
- ρ is the spatial lag parameter = can be interpreted as the existence of social network effects if > 0.

Econometric modelling for transport mode preference -3

Endogeneity: $\boldsymbol{WU}$ *is determined simultaneously with* $\boldsymbol{U}$

Ideal instrument :

1) highly correlated with the endogenous explanatory variables, &
2) ≠ correlated with unobserved shocks e.

First estimate $\boldsymbol{WU}$ by regressing it on the spatial lags of the independent variables (IVs), and to then use $\boldsymbol{U}^*$instead of $\boldsymbol{WU}$ in equation (2).

The final spatial autoregressive IV probit mode choice model is:

$$\boldsymbol{U} = \alpha + \boldsymbol{U}^*\rho + x\beta + e \qquad (3)$$

Econometric modelling for transport mode preference -4

Average Marginal Effects of the Spatial Autoregressive IV Probit Models

	(1)	(2)	(3)	(4)
Variables	Full	Excl. Long Trips	Excl. Walking Distance Trips	Excl. Both Long & Walking Distance Trips
HHsmall	-0.106***	-0.106***	-0.103***	-0.103***
	(6.559e-04)	(6.604e-04)	(6.657e-04)	(6.704e-04)
HHchildren	-0.0420***	-0.0424***	-0.0267***	-0.0269***
	(6.688e-04)	(6.731e-04)	(6.868e-04)	(6.922e-04)
ln_HHvehicle	-0.111***	-0.112***	-0.0856***	-0.0862***
	(5.629e-04)	(5.656e-04)	(6.150e-04)	(6.182e-04)
Higher-income	-0.0159***	-0.0159***	-0.0101***	-0.0101***
	(5.017e-04)	(5.047e-04)	(5.257e-04)	(5.294e-04)
Female	0.0735***	0.0741***	0.0781***	0.0788***
	(5.190e-04)	(5.217e-04)	(5.582e-04)	(5.610e-04)
Full-time	0.0113***	0.0112***	0.00126	0.00116
	(0.00120)	(0.00121)	(0.00123)	(0.00124)
Young	0.0268***	0.0270***	0.0280***	0.0282***
	(5.444e-04)	(5.478e-04)	(5.687e-04)	(5.723e-04)
Senior	-0.0491***	-0.0494***	-0.0308***	-0.0310***
	(0.00114)	(0.00115)	(0.00115)	(0.00116)
Distance	-0.00602***	-0.00607***	-0.00543***	-0.00549***
	(4.030e-05)	(4.050e-05)	(4.710e-05)	(4.750e-05)
Origin_AKL	-0.0834***	-0.0847***	-0.0664***	-0.0688***
	(8.518e-04)	(8.492e-04)	(8.357e-04)	(8.317e-04)
Destination_AKL	0.123***	0.124***	0.102***	0.103***
	(6.140e-04)	(6.180e-04)	(6.467e-04)	(6.500e-04)
Petrol	2.030e-04***	2.057e-04***	6.161e-04***	6.221e-04***
	(1.650e-05)	(1.660e-05)	(1.710e-05)	(1.720e-05)
2006/07	0.0414***	0.0416***	0.0586***	0.0590***
	(7.187e-04)	(7.236e-04)	(7.499e-04)	(7.551e-04)
2007/08	0.0520***	0.0523***	0.0357***	0.0359***
	(6.802e-04)	(6.852e-04)	(7.238e-04)	(7.306e-04)
2008/09	0.0253***	0.0254***	0.0305***	0.0307***
	(7.382e-04)	(7.430e-04)	(7.604e-04)	(7.659e-04)
ρ	0.265***	0.266***	0.324***	0.323***
	(0.00911)	(0.00904)	(0.00827)	(0.00816)
Sample Size	814	801	733	720

Note: *** Estimated coefficients significant at 1% level; standard errors are in parenthesis

1. The estimated coefficient for *ln_HHvehicle* = -0.111, indicating that if there is an additional household vehicle available to use, people who reside in the household will be about 30.2% less likely to take public transport to work (based on the use of *e* calculation, where we take $e \approx 2.71828 \times -0.111 = -0.302$).
2. The social network effects (ρ) has the 2nd largest impact on commuter's transport mode choice in Auckland, where a 1% increase in the peer's transit use will increase the probability for a commuter to choose public transit to work by 26.5%.
3. Control for car ownership
4. "Soft" behavioural change related transport policies, given the fact that a commuter's travel mode choice is largely affected by his/her neighbours' travel decision.

References

1. M. Sheng (2017). CIVIL770 Coursebook. Transport Systems Economics, Department of Civil and Environmental Engineering, University of Auckland.
2. Sheng, M. & Sharp, B. (2017). Aggregate Road Passenger Travel Demand in New Zealand. *Energy Centre Working Paper*.
3. Sheng, M. & Sharp, B. (2018). Commuter's Transport Mode Preferences and Social Network Effects in New Zealand: An Instrumental Variable Approach. Revised version submitted to *Journal of Transport Economics and Policy*.
4. Cowie, J. (2010). The economics of transport: A theoretical and applied perspective. London; New York: Routledge.