# Water Resource Management Strategy in a water scarce city

Haripriya Gundimeda
Vinish Kathuria
Madras School of Economics

Seminar on Water Management Strategies , March 16, 2005

# Motivation

- Water shortages – A Chronic Problem in Different Parts of the world
- Affect the rich and the poor alike.
- Poorer Societies - Breeds sickness, hampers development, deepens inequalities and undermines the survival of entire society.
- Developed countries - curtails economic growth and result in poor quality of life.

# Main culprits for water stress?

- **Supply side**
- Paucity of funds
- Over exploitation of water resources
- Degradation of water recharge structures
- Competing demand on the available water resources
- Declining water availability due to failure of monsoon
- **Demand side**
- Growing urbanization
- Increase in population
- Changing life styles
- Wrong tariff structures
- Inadequate institutional and legislative framework.

# Situation in India

- Water scarcity is reaching alarming proportions.
- Per capital annual renewable fresh water withdrawals are around 40 percent as against 8 percent of the world average.
- Annual ground water recharge - around 413 cum/capita
- 45% is withdrawn annually, which is also 1.5 times more than the world average.
- The distribution of water is also not uniform.
- The percapita availability of water in India is 2208 cum. The availability in Brahmaputra basin is 16,589 cum and Barak basin is 360 cum.
- Any situation of less than 1000 cum is considered as situation of water stress

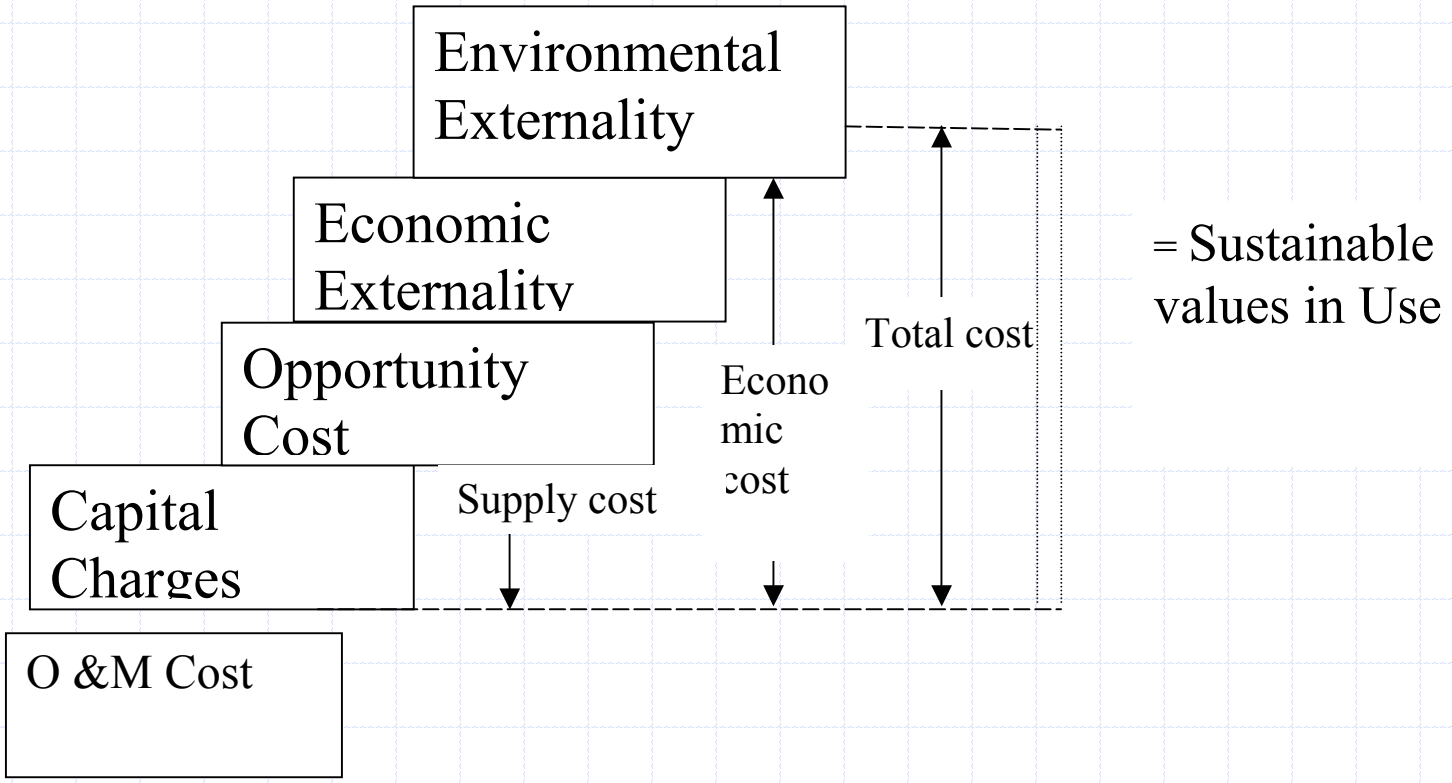
# Situation in India

- Urban people in many metropolitan cities depend on at least three sources of water:
- 1) Water supplied by municipality/corporation from lakes/ rivers
- 2) Ground water
- 3) Private vendors
- Ground water over extracted due to lack of proper mechanism to restrict the usage of ground water
- Depletion of ground water can have dire consequences

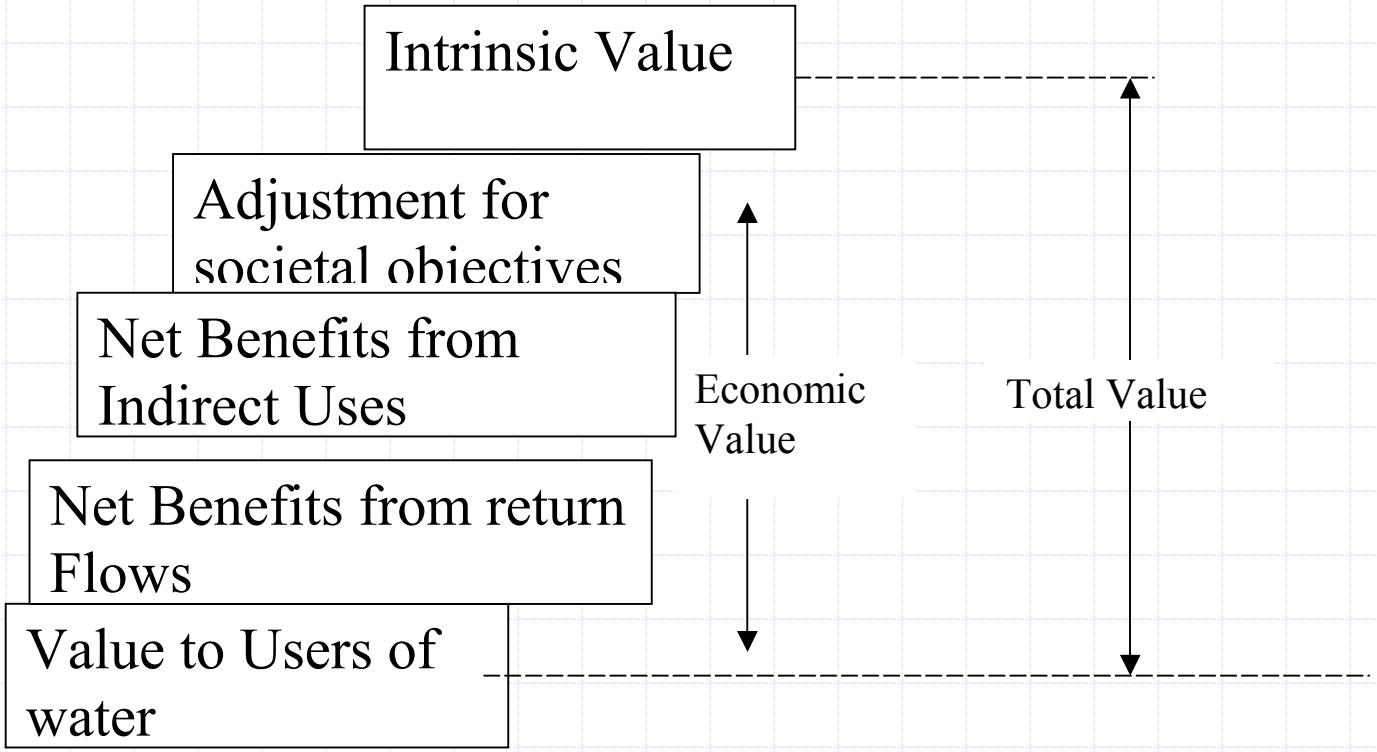
# What measures were taken?

- Several measures were taken to meet both demand and supply.
- These measures did not yield sustainable solution due to under pricing
- This leads to inadequate funds to meet the investment needs.
- It is imperative to know the total economic value of water and the total costs associated with its provision for sustainable management of water resources

# Cost of water



# Value of water



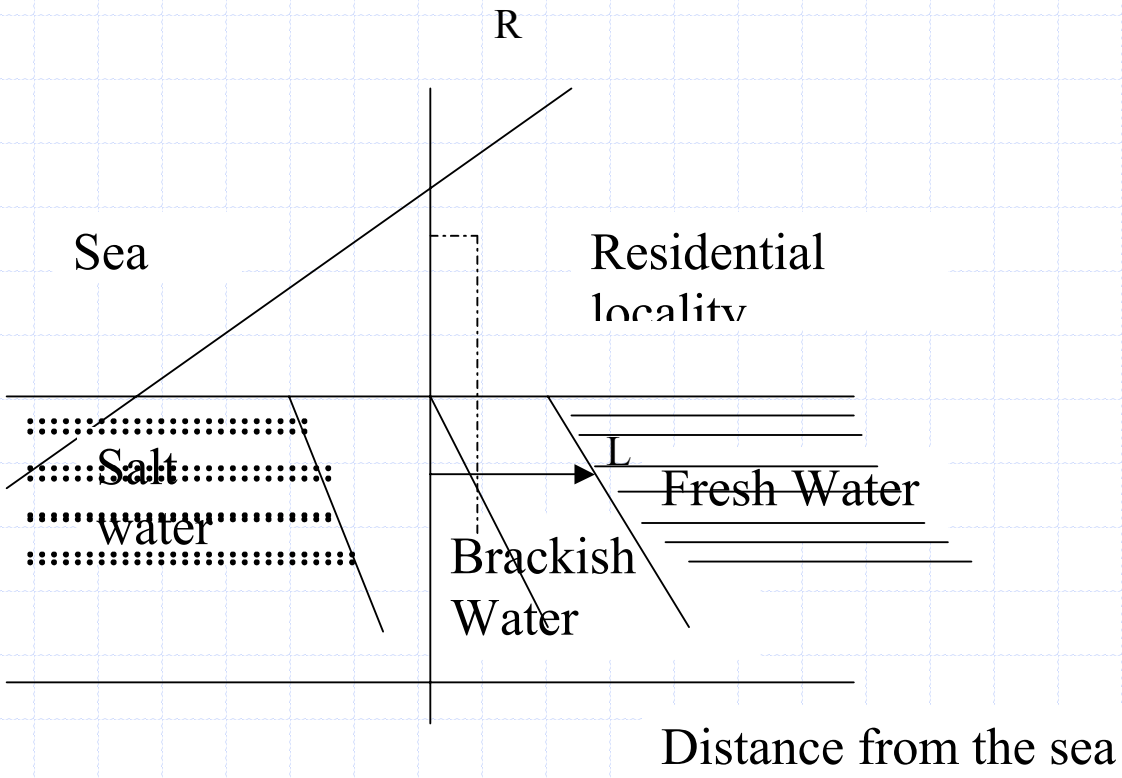
# How to measure the value?

- Total value placed by users - very difficult to measure
- These Values can be estimated using techniques of non-market valuation of environmental resources
- Most commonly used methods include
- 1) Hedonic price method
- 2) Travel cost method
- 3) Contingent valuation method

# Hedonic price method

- Study uses hedonic price method to estimate the economic value of water to different sections of the society.
- Quantity and quality of an attribute in a particular zone may affect the preferences of the households to reside in that area or not.
- HPM is uses since it provides the theoretical basis for observing non-observed economic values of non-market goods from observed house market prices.

# An Illustration



# Objectives of the study

- 1) Analyse the influence that water scarcity and quality has on house prices in Chennai;
- 2) Estimate the willingness to pay among people in Chennai for an improvement in water quality;
- 3) Compare the estimated aggregate benefits obtained through improving the water supply situation with that of costs involved in improvement;

# Theoretical Hedonic Price Model

A housing unit is completely described by
$Z_i = (S_{1i}, S_{2i}, \ldots. S_{ni}, N_{i1}, N_{2i} \ldots.. N_{ni}, E_{1i}, E_{2i} \ldots. E_{ni})$

The hedonic price function

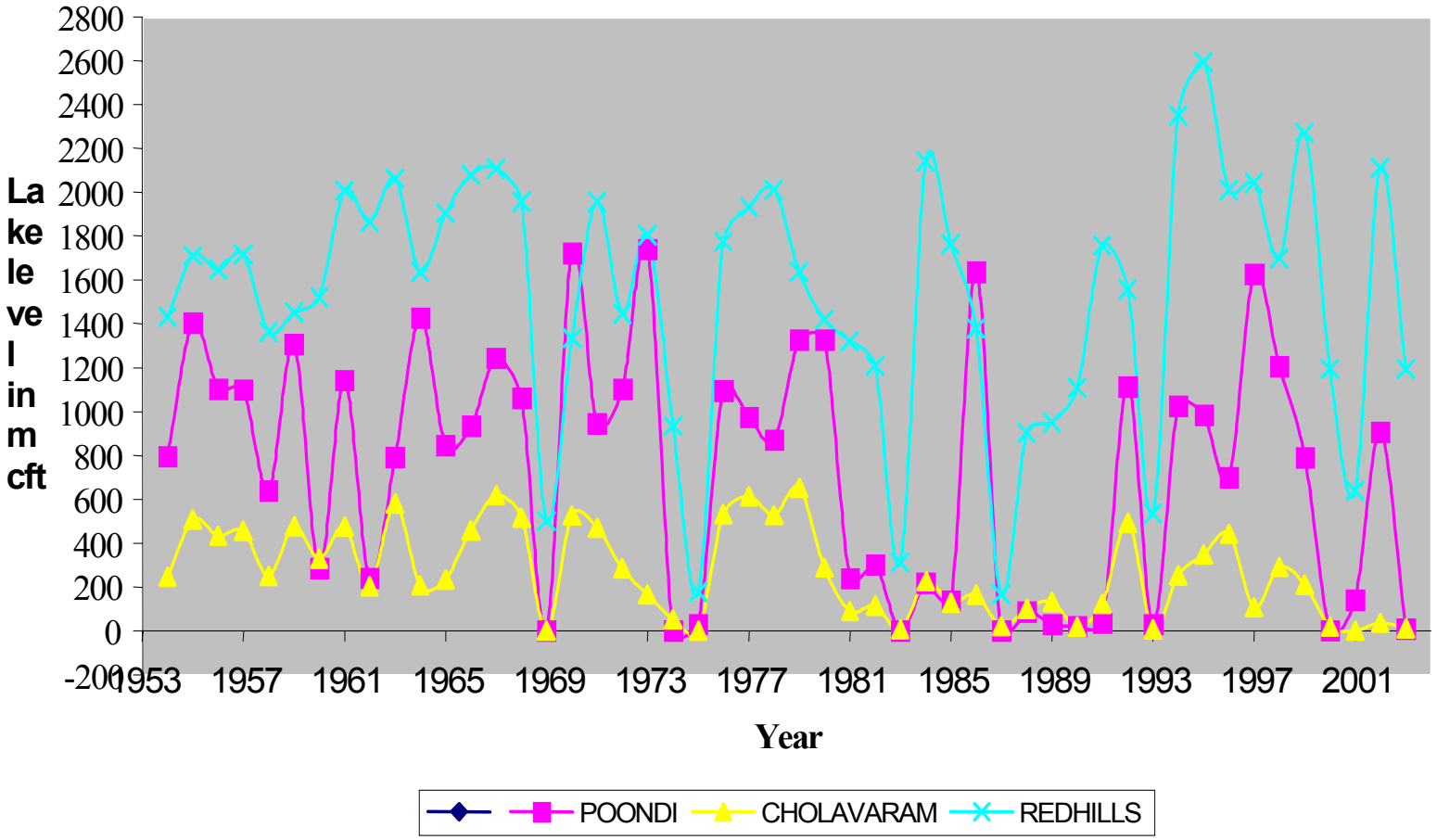
$P_i = h(Z_i) = h(S_{1i}, S_{2i} \ldots S_{ni}, N_{1i}, N_{2i} \ldots N_{ni}, E_{i1}, E_{2i} \ldots..E_{ni}$
$P_{Ei} = \partial P/\partial q_i = \partial h/\partial E_i$ (implicit marginal purchase price)

Consumer's will solve the utility maximisation problem
Max $U_j = U_j (X_j, Z_j)$
s.t. its budget constraints
$Y_j = X_j + P_j * Z_j$
$Y_j$ – disposable income;
$X_j$ – vector of private goods consumed
$MWTP(E_i) = \partial U_j/\partial E_j = \partial P_i/\partial E = IMP(E_i)$ (I
MWTP = Implicit price of the attribute

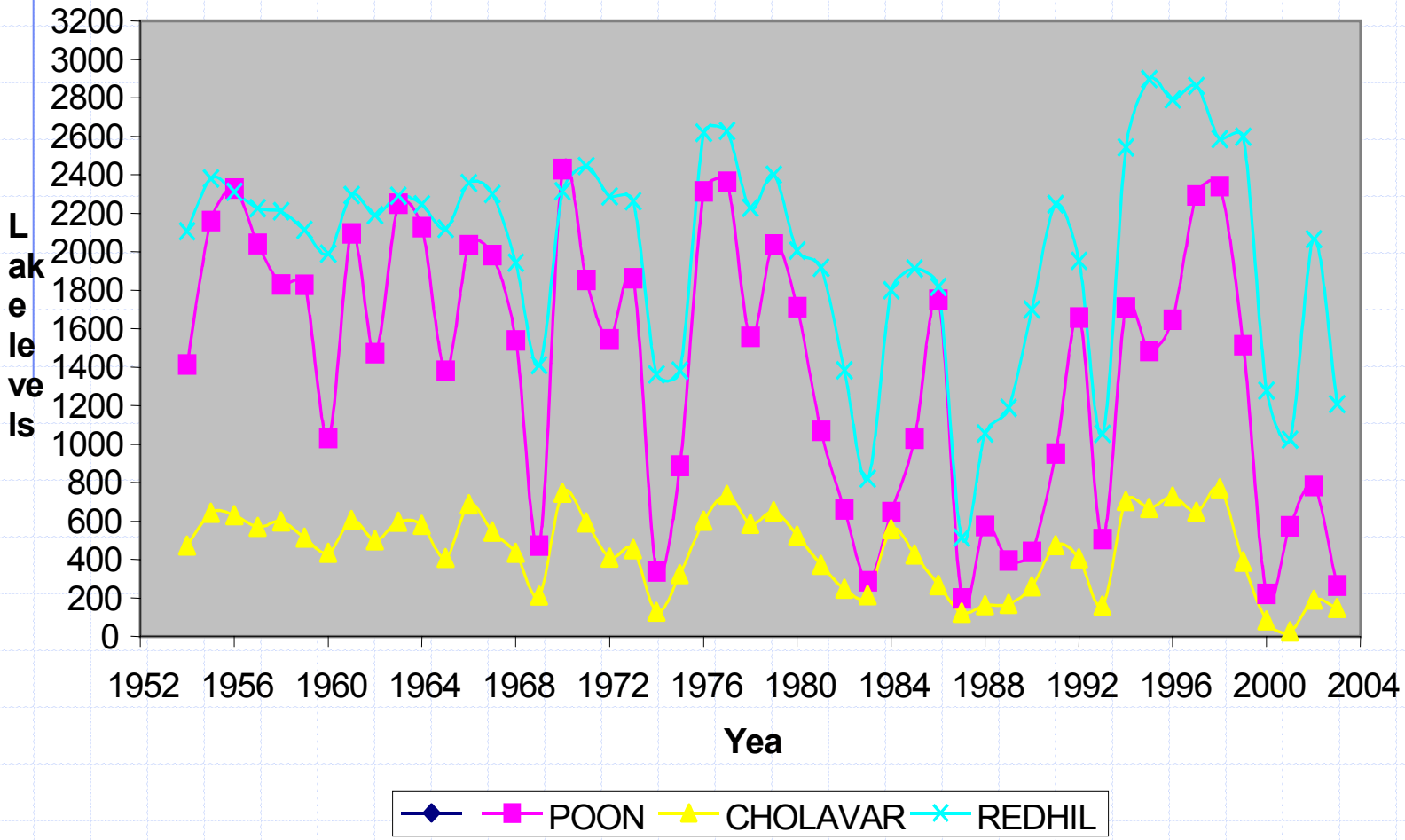
# Description of the study area

- Focuses on Chennai that has been facing water shortage for over three decades now.
- Metropolitan city without perennial source of fresh water
- The availability of water is 72 lpcd in normal season and 32 lpcd during drought years
- Lake levels reached below the 500 mcft or dried up.
- Considerable variation in water supply in different areas and for different sections of the society
- Average gross availability of water is 69 lpcd
- 8 lpcd in slums

# Average lake levels in Summer (April - Aug)



# Average lake levels during and after the monsoons (Nov - March)



# Study area (contd..)

- Four distinct systems of water supply found:
- 1) Supply of water by the Metro Board
- 2) Municipal supply
- 3) Self provision by many households and industries
- 4) Private supply - tanker trucks, jerry cans
- Ground water mainly drawn from the well fields along the coast south of Chennai
- The ground water extraction is reaching its limits

**An illustration of three advertisements depicting different status of water in one single area**

- Thiruvanmiyur, nr Sacred Heart college, 650 sqft, grd flr, 1 B/R, granite flrg, 24 hrs sweet water, small family pref, Rs.4000/-, Anbalagan Mb: 944175519.

- Thiruvanmiyur, Radhakrishna ngr, independent, 1300 sqft, 1 flr, 3 B/R, carpark, 24 hrs water, Rs.7000/- pm, Natrajan Mb: 32150928

- Thiruvanmiyur, behind post office, 400 sqft, 1 flr, B/R, Rs.2000/-, Rajagopalan Ph: 24929581. Ch-41.

Source: Free Ads, Chennai, July 11-14, 2004

# Testing of Hypothesis

- Hypothesis
- Due to variability of water supplies (quantity and quality), in Chennai rental values can differ quite significantly depending on whether water is scanty or abundant and also depending on whether ground water is saline or sweet.
- Estimation done through Box-Cox transformation

# Empirical estimation

The general form of Box-Cox model is:

$$p(z)^{(\theta)} = \eta_0 + \sum_{ii=}^{k} \eta_i z_{i}^{\lambda}{}_{i} + 0.5 \sum_{i} \sum_{j} \gamma_{ij} z_i^{(\lambda)} z_j^{\lambda}$$

$P(z)^{(\theta)} = [(P(z))^{(\theta)} - 1)]/\theta$

$z^{(\lambda)} = ((z^{\lambda}) - 1)/ \lambda.$

The following are the forms that emerge for different values of $\{\theta, \lambda, \gamma\}$.

1. $\theta = 1, \lambda = 1, \gamma_{ij} = 0$ : Linear
2. $\theta = 0, \lambda = 1, \gamma_{ij} = 0$ : Semi-log
3. $\theta = 0, \lambda = 0, \gamma_{ij} = 0$ : log-log
4. $\theta = 1, \lambda = 1$ : quadratic
5. $\gamma_{ij} = 0$ : Box-Cox linear
6. $\{\theta, \lambda, \gamma\}$ unrestricted : Box-Cox quadratic.

# Data

- Primary Survey through Random sampling
- The localities fall within a radial distance of 10 km from either of the two city centres - T nagar or Adyar.
- Survey carried out in two phases: First phase (1st June- 20th September, 2003)
- Second phase (March 2004 to 26th June 2004).
- Phase 2 intended to check if the willingness to pay estimates are affected by seasonality
- Field investigators were employed.
- Survey and coding of the questionnaire were carried out simultaneously.
- In case of inconsistency, the investigator was sent back to collect the missing information.

# Survey instrument

- Primary data - questionnaire method
- Questionnaire contain 3 sections
- 1) Perception of the respondents about the environmental conditions/characteristics (air quality, water quality, extent of green cover etc.)
- 2) Structural and neighborhood characteristics
- 3) Socioeconomic characteristics
- Around 1750 household were surveyed
- 284 questions were discarded

# Variables

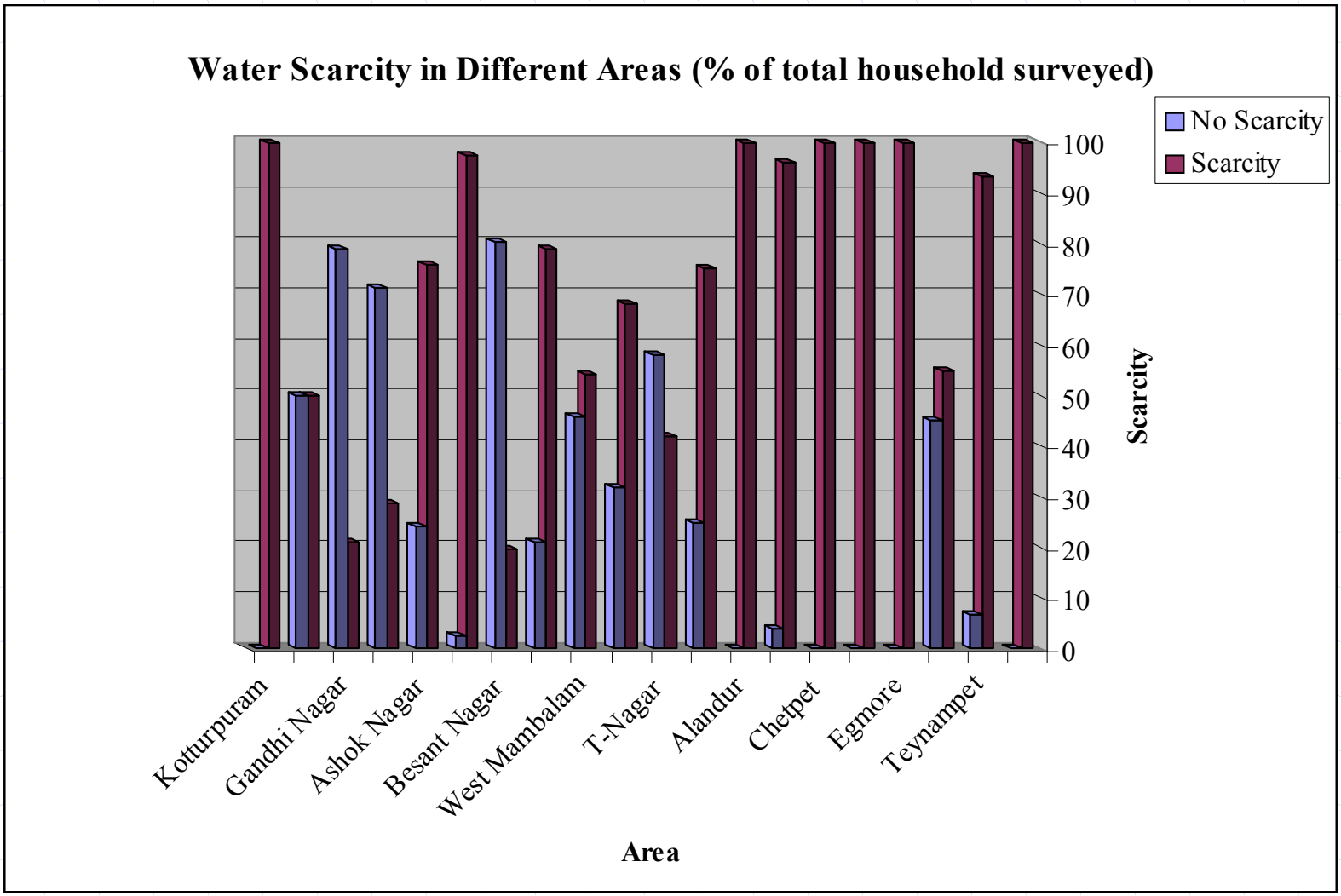
| | Variables | Definitions | Expected sign |
|---|---|---|---|
| 1 | *Dependent variable: Rent* | Rent paid/expected rent of the house in Rs. | |
| *Structural variables* | | | |
| 2 | *Area_sqft* | Area of the house in square feet | + |
| 3 | *Rooms* | No. of Rooms | + |
| 4 | *Bathroom* | Number of bathrooms in the house (0 if the bathroom is shared or common) | + |
| 5 | *Age_hse_yrs* | Age of the house in years | – |
| 6 | *Hstyp* | Type of the house (1 - bungalow, 2 - independent house, 3 - flat, 4 - portion, 5 – chawl and 6 – hut) | – |
| 7 | *Length of stay* | Length of stay in Years | – |
| 8 | *Garage* | Whether house has exclusive car-parking | + |
| 9 | *Floor* | Floor | – |
| 10 | *Ownership* | Own house or on rent | + |

# Variables

| | | | |
|---|---|---|---|
| | *Neighborhood variables* | | |
| 11 | *Distance from city centre* | Distance to city centre in Kms | – |
| 12 | *Qlty_localty* | Quality of the locality ranked from 1 to 4 (1-very clean, 4 – dirty) | – |
| 13 | *Qlty_roads* | Quality of the roads in the locality ranked from 1 to 4 (1 if very wide 4 – very narrow) | – |
| 14 | *Location_noisy* | If the location is noisy ranked from 1 to 4 (1 – very quiet, 4 – very noisy) | – |
| 15 | *Location scenic* | Location scenic | + |
| 16 | *Posh* | If the locality is posh (1 for posh and 0 otherwise) | + |
| 17 | *Bus_freq* | Frequency of buses ranked from 1 to 4 (1 – very often 4 – no buses) | – |

# Variables

| | | | |
|---|---|---|---|
| *Environmental variables* | | | |
| 18 | *Greenery* | Presence of greenery in the locality ranked from 1 to 3 (1 if green, 2 – somewhat green; and 3 – not green) | – |
| 19 | *Env_disameniti es* | Environmental disamenities like water logging, solid waste etc. (1 – yes, 0 – No) | – |
| 20 | *Water_quality* | Perception of respondents about water quality ranked in increasing order (1 good, 5 very bad). | – |
| 21 | *Water_scarcity* | Water fetching (1 if at home; 0 – outside). | – |
| 22 | *Air_qulty_prob lem* | Perception of respondents about air quality ranked in increasing order (1 good, 4 very bad). | – |
| 23 | *Education* | No. of years of education | + |
| 24 | *Profession* | In increasing order (0 – not working/low income, 1 salaried and 2 business / self-employed) | + |
| 25 | *Hhd_members* | Total Members in the house | – |
| 26 | *Hhd_income* | Total Household income in increasing order (1 – less than 10,000, 6 – 45,000 and above) | + |


Water Scarcity in Different Areas (% of total household surveyed)
No Scarcity
Scarcity
100
90
80
70
60
50
40
30
20
10
0
Scarcity
Kotturpuram
Gandhi Nagar
Ashok Nagar
Besant Nagar
West Mambalam
T-Nagar
Alandur
Chetpet
Egmore
Teynampet
Area

## Number of sources used by households in Chennai

| No. Water fetching Sources used | Households (No.) |
|---|---|
| 1 | 991 (65.5%) |
| 2 | 478 (31.6%) |
| 3 | 36 (2.4%) |
| 4 | 9 (0.5%) |
| **Total** | **1514** |

Source: Primary Survey

*Note*: Figure in parenthesis are percentage of the total households.

# Key Findings

- All the explanatory variables are significant at 95% level and follow expected theory
- Rent/ Expected rent increases with the area of the house, number of rooms, presence of Garage, type of house
- Age – no significant impact on rent
- Longer a person stays in the house the lesser the rent (rents become sticky)
- Quality of Roads - +ve impact on rent
- Houses in posh and having green surroundings carry higher rent
- Area with less noise fetch more rent
- More the house is distant from the city centre less is the rent

# Key Findings

- Water scarcity and Water quality are found to be directly influencing the rental price of the house
- A house where water is scarce is fetching less rent
- Contrary to our expectations, a house having salty water gets more rent once all the other attributes of the house are accounted for
- People may be valuing the availability of water more than the quality
- Distributed the sample into two parts:
- - Households having scarcity of water
- - Household having no scarcity

# Key Findings

- Area in which there is no water scarcity – rents have a negative relationship with the water quality
- Rents increase in water scarce areas despite the fact that water quality is poor
- People are willing to pay more for areas that have some water irrespective of the quality
- However, the preference of water quality changes once they are assured of water

# Aggregate WTP

- Marginal WTP for improved availability and quality of water for a household:
- increases with monthly income and educational level
- Decreases with household size.
- Profession does not affect the MWTP
- Results indicate that with the change in existing situation from fetching water to a better situation of piped water supply directly in homes - there is an increase in WTP.

# Key Findings

- For an individual
- Facing acute water shortage - WTP increases by Rs. 65 if water scarcity changes from scarcity to availability stage.
- Receiving contaminated water WTP increases by an amount equal to Rs. 54 to get partially contaminated water.
- For a representative household
- For improved quality from contaminated to unpolluted water is Rs. 1,155.
- The Mean monthly Welfare gain from the current situation of water scarcity to improved water supply through piped water is Rs. 2,918.
- The aggregate consumer surplus for the entire city of Chennai is around Rs. 2480 million and Rs. 981 million respectively.

**Costs of different projects implemented and in implementation to meet the water requirements in the year 2021.**

| | Scheme | Quantity in Mld | Year of completion | Cost (Rs Crores) |
|---|---|---|---|---|
| 1 | Chennai Water Supply Augmentation Project- I | 180 | 2004 | 720 |
| 2 | Veeranam project (Chennai Water Supply Augmentation Project II) | 60 | 2005 | 778 |
| 3 | Third Chennai Project (Proposed) | 70 | 2006 | 750 |
| 4 | Tertiary Treatment/Reverse Osmosis Plant | 50 | 2006 | 200 |
| 5 | Aranier-Kortaliyar River Basin | 200 | 2007 | 124 |
| 6 | Desalination Plant (Sea Water) | 300 | 2007 | 1500 |
| 7 | Total | 860 | | 4072 |

Source: Different websites and www.chennaimetrowater.com and Metrowater (2003)

# Key Findings

- The aggregate Consumer surplus is much higher compared to the investment made in different projects
- Economies of scale in supplying water
- The cost of providing water 1000 liters of water is Rs 25 much lower than the WTP (over a period of 5 years) .
- These are not the total economic cost but just the supply costs
- Need to consider the total economic cost for appropriate pricing

## Table A4: Metered Consumer Tariffs in Chennai (In Rs.)

| | Category | Qty of water | Rate/KL | Minimum Rate Chargeable (including sewerage charges) |
|---|---|---|---|---|
| 1 | Residential<br><br>Domestic Residential premises (Other than Flats or Block or line of Houses) | Upto 10 KL | 2.50 | Rs.50/- per month per dwelling unit (including sewerage charges) |
| | | 11 to 15KL | 10.00 | |
| | | 16 to 25 KL | 15.00 | |
| | | Above 25 KL | 25.00 | |
| 2 | Flats or houses in a Block of flats or line of houses respectively used wholly for residential purposes. | Upto 10 KL | 2.50 | Rs.50/- per month per flat (including sewerage charges) |
| | | 11 to 15KL | 10.00 | |
| | | 16 to 25 KL | 15.00 | |
| | | Above 25 KL | 25.00 | |

Source: www.chennaimetrowater.com accessed on July 27, 2004

# Strategy

- Equate total costs with total value
- Rainwater harvesting
- Suitable water tariffs
- Metering and charging a volumetric price that reflects the full costs of the service
- Though in Chennai it is volumetric, but not adequate to meet the costs.
- Proper charging will also reduce waste by the users