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# Estimating Demand for Cooling Systems in India

## Estimating QUAIDS Demand System for Durable Goods in India using HCES-24

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# A. Introduction

India, being a country that experiences high temperatures for a significant part of the year, faces a substantial and growing demand for cooling solutions. To cope with the persistent heat, households across income groups adopt a range of cooling technologies throughout the year. This report utilizes data from the Household Consumption and Expenditure Survey (HCES) 2023–24 to analyse the purchase patterns of durable goods related to cooling.[1]

We estimate a Quadratic Almost Ideal Demand System (QUAIDS) model for key durable items, including air conditioners, air coolers, and electric fans. Given that the operation of these appliances significantly increases electricity consumption, electricity expenditure is also incorporated into the analysis. The inclusion of electricity expenditure is particularly important for understanding the rising demand for energy-efficient appliances

India has witnessed a rapid rise in the demand for durable goods in recent years. The selected items represent the primary cooling solutions adopted across diverse income groups, reflecting both the accessibility and usage of such products by households throughout the country.

# B. Policy

Policies aimed at improving access to cooling solutions—such as subsidies on energy-efficient appliances, or reductions in import duties on cooling technologies—can have a direct and measurable impact on commodity prices. These interventions typically alter the market prices of targeted goods, thereby making them accessible to a wider segment of the population. Typically, air coolers and electric fans are subject to lower tax rates, whereas air conditioners continue to be classified as luxury items and are therefore taxed at higher rates.[2] Policies promoting energy efficiency, such as labeling schemes or electricity tariff adjustments, can indirectly affect electricity prices, further influencing household decisions and preferences. Consequently, both durable good prices and electricity prices emerge as key channels through which policy affects household consumption behavior.

# C. Engel Curves

The section provides insight into Engel curves for four categories of cooling systems considered in the report. The inverted U-shaped curve for electricity expenditure

[1] Refer to appendix for treatment of missing values

[2] Air conditioners are subject to a 28% GST and air cooler and electric fans are taxed at 18%

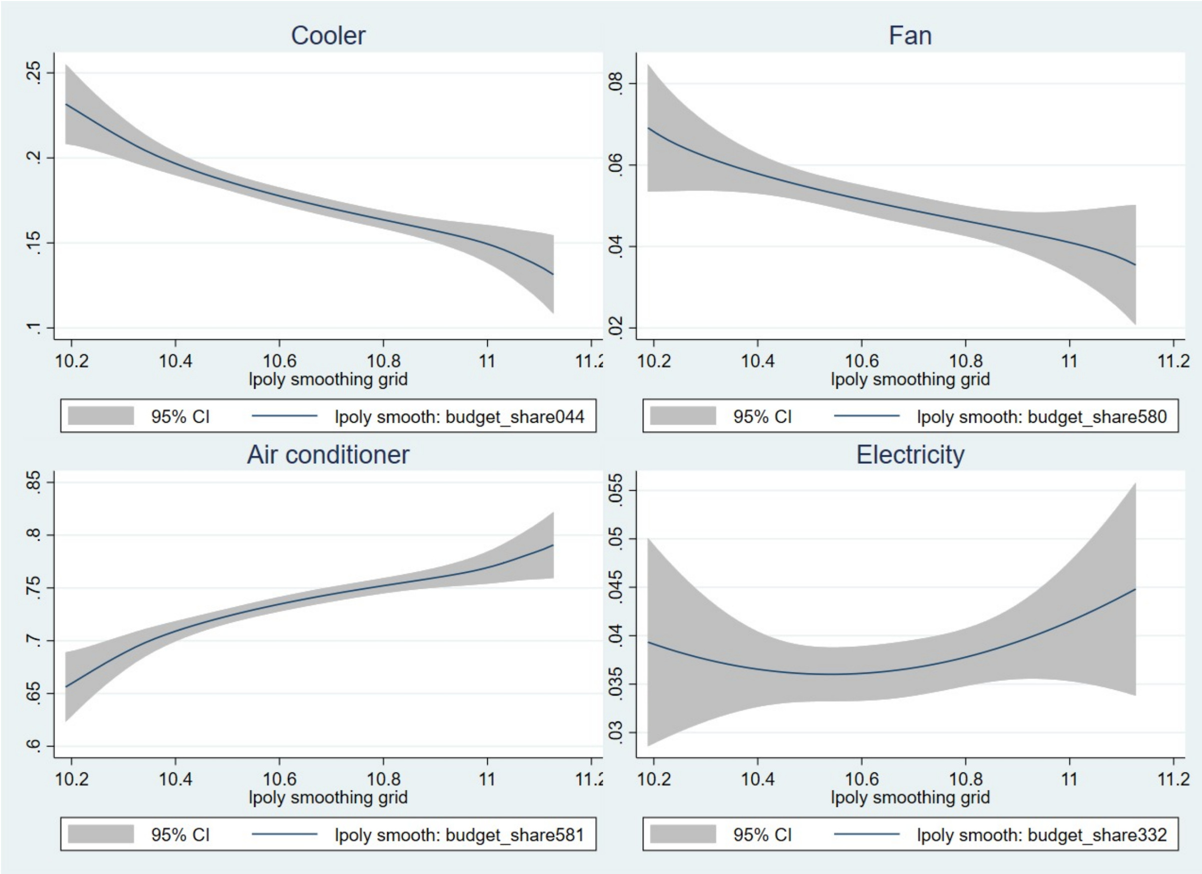


Figure 1: Estimated Engel Curves for Cooling Systems

demonstrates that the share of the budget allocated to electricity increases with income initially, before eventually declining. This pattern emerges to be quadratic. The Budget share is relatively flat for fan at the initial total expenditure level but then rises eventually. Finally, budget share is falling on cooler with rising income level. Notably, there is a wide confidence band at higher and lower levels of total expenditure, indicating imprecision in the estimates at these higher expenditure points due to lower data in that range.

## D. Demand System

The Engel curves exhibit a quadratic pattern, indicating a non-linear relationship for most goods. This suggests the appropriate use of the Quadratic Almost Ideal Demand System (QUAIDS), which allows for a precise representation of a broad range of income levels that consume these goods. Additionally, the trend for substitutes and complements can be effectively predicted for the relevant goods.

The following shows the results for two categories:[3]

[3]HCES data records household-level purchases. Including all four commodities reduced the sample to 5 households. To address this, two separate demand systems were estimated: Group 1 (cooler, fan, electricity with 6000 unique observations) and Group 2 (cooler, AC, electricity with 1200 unique observations).

## E1: Results

Table 1 shows uncompensated elasticities. The diagonal terms are still negative, aligning with the inverse relation of the law of demand. Due to the income effect, signs of various pairs of uncompensated elasticity have flipped. The cooler and fan in the table are compliments, which is counterintuitive. There is a lack of symmetry of sign of elasticity of electricity and fan. All coefficients are significant at a 5% level of significance.

Table 1: Uncompensated Price Elasticities (Standard Errors in Parentheses)

| | **Cooler** | **Fan** | **Electricity** |
|---|---|---|---|
| **Cooler** | −.624 | -.136 | -.023 |
| | (.010) | (.008) | (.004) |
| **Fan** | .-.912 | -.427 | -.051 |
| | (.039) | (.034) | (.016) |
| **Electricity** | -1.28 | -.075 | -.912 |
| | (.052) | (.0.36) | (.03) |

All the diagonal terms in table 2 are negative, which shows that own price elasticity is negative. Cross price elasticity of all pairs of cooler, fan and electricity is positive. It is intuitive for the cross price elasticity of cooler with respect to fan (or vice-versa) to be positive since they are substitutes. We find the cross price elasticity of cooler with respect to electricity being positive as counter-intuitive since they are complements and so is the case with cross price elasticity of fan with respect to electricity. The relative magnitude comparison shows the small effect of percent change in fan price to percent change in cooler's demand compared to percent change in cooler price to percent change in fan's demand, which also makes sense. The standard errors are quite low.

Table 2: Compensated Price Elasticities (Standard Errors in Parentheses)

| | **Cooler** | **Fan** | **Electricity** |
|---|---|---|---|
| **Cooler** | −.051 | .008 | .042 |
| | (.008) | (.008) | (.004) |
| **Fan** | .03 | -.188 | .159 |
| | (.030) | (.034) | (.016) |
| **Electricity** | .381 | .343 | -.724 |
| | (.033) | (.0.35) | (.03) |

Table 3 shows income elasticity of electricity and fan to be greater than 1 that is they are luxury goods. The coefficient of income elasticity of demand for cooler is less than 1 which shows it is necessary good. Both these results are contrary to our expectations. All of the coefficients are significant.

Table 3: Income Elasticity (Standard Errors in Parentheses)

| | **Cooler** | **Fan** | **Electricity** |
|---|---|---|---|
| **Income Elasticity** | .783 | 1.287 | 2.259 |
| | (.007) | (.031) | (.049) |

## E2: Results

Table 4 shows that uncompensated demand for all three items—cooler, AC, and electricity—is negatively related to price, as expected. AC appears to be the most price-sensitive, while coolers and electricity show moderate responsiveness, not as per our expectations. The low standard deviations indicate the estimates are precise.

Table 4: Uncompensated Price Elasticities (Standard Errors in Parentheses)

| | **Cooler** | **AC** | **Electricity** |
|---|---|---|---|
| **Cooler** | -.479 | .271 | -.0530 |
| | (.071) | (.064) | (.037) |
| **AC** | .-108 | -1.058 | -.0162 |
| | (.016) | (.020) | (.009) |
| **Electricity** | -.357 | -.146 | -.425 |
| | (.183) | (.196) | (.148) |

Table 5 highlights the main findings of our report. The compensated price elasticity estimates indicate that the demand for coolers, air conditioners (ACs), and electricity is inelastic. This suggests that consumers exhibit limited responsiveness to price changes for these goods, implying a relatively higher burden from price increases.

As per our expectations, a notable substitutive relationship is observed between coolers and ACs. This suggests that, as AC prices rise, consumers are likely to shift towards coolers.

The relationship between coolers and electricity is slightly complementary as expected. Finally, the ACs and electricity are weakly substitutes. The small standard deviations across the estimates indicate that the results are statistically robust. We do not anticipate that consumers will alter their demand for coolers and ACs in response to higher electricity bills.

In summary, the findings highlight a modest price responsiveness, with a significant substitution effect between coolers and ACs as per our expectation.

Table 5: Compensated Price Elasticities (Standard Errors in Parentheses)

| | **Cooler** | **AC** | **Electricity** |
|---|---|---|---|
| **Cooler** | -.431 | .473 | -.043 |
| | (.069) | (.063) | (.037) |
| **AC** | .-113 | -.143 | -.030 |
| | (.015) | (.019) | (.009) |
| **Electricity** | -.182 | -.571 | -.389 |
| | (.174) | (.175) | (.148) |

Table 6 shows positive income elasticities indicating that coolers, ACs, and electricity are all normal goods, with demand rising as income increases. As per our expectations, ACs show the highest responsiveness, suggesting they are more of a luxury compared to coolers and electricity. Coolers have the lowest income elasticity, indicating relatively stable demand across income levels. Standard deviations are quite low.

Table 6: Income Elasticity (Standard Errors in Parentheses)

| | **Cooler** | **AC** | **Electricity** |
|---|---|---|---|
| **Income Elasticity** | .261 | 1.182 | .928 |
| | (.037) | (.012) | (.123) |

# F. Policy Implications

Several important policy implications can be drawn from the results. Given the inelastic demand for these goods, the tax burden predominantly falls on consumers. Coolers, being relatively less inelastic, are likely to experience a shift in demand towards air conditioners (ACs) if taxed. Since air conditioners are considered luxury goods, their demand is expected to increase as consumers transition from lower to middle-income groups. Consequently, a tax on air conditioners would place a greater financial burden on middle and higher-income groups.

# G. References


- Kulshrestha, A. GST Rate on Air Conditioners and Spare Parts with HSN. Available at: https://blog.saginfotech.com/gst-rate-hsn-code-air-conditioners-spare-parts
- Indian consumer durables presentation: IBEF India Brand Equity Foundation.(Accessed: 05 April 2025)
- How India's Consumer Durables Industry Can Foster Global Leadership by 2030 EY
- Vyas, H.D. (2011) Consumer purchase of consumer durables: A factorial study
- Nasima, V. (2025) Effective strategies for handling missing values in data analysis

# Appendix

## A.1 Data and Methodology

This study utilizes the Household Consumption Expenditure Survey (HCES) 2023-24 to estimate the elasticity of demand for cooling-related durable goods. The primary advantage of using HCES is its comprehensive coverage of household consumption data across a wide range of goods, including food items, durable goods, and energy products. The dataset provides both quantity and expenditure information, making it well-suited for demand estimation. Additionally, HCES contains extensive household characteristics data, including household size, religion, caste group, and usual monthly average consumption, which serve as key control variables in the analysis.

## A.2 Data Processing and Challenges

We specifically extracted level-13 consumption data, which contains information on air coolers, electric fans, and air conditioners. A major challenge encountered was the substantial amount of missing data related to the first-hand purchase of durables, particularly air conditioners and air coolers. This issue arises naturally due to the durable nature of these goods, as households are unlikely to purchase new items within the same survey year. However, to accurately estimate demand elasticity, a sufficiently large sample size is essential to ensure statistical precision and robustness.

Table 7: Total vs Missing values

| | **Total values** | **Missing values** |
|---|---|---|
| **Air cooler** | 40783 | 36404 |
| **Electric fan** | 132555 | 90194 |
| **Air conditioner** | 12883 | 12379 |

Table 7 illustrates the severity of the missing data problem. The total number of available observations for cooling appliances is significantly lower than that for food and energy items. Furthermore, the subset of households that purchased all three cooling goods (air coolers, electric fans, and air conditioners) within the survey period is extremely limited, reducing the final sample size to fewer than 100 observations. To address this issue, we employed a regression-based imputation approach to estimate the missing expenditure values for air conditioners and air coolers.

## A.3 Regression-Based Imputation Approach

Households with positive expenditure on repairs of air conditioners or air coolers were assumed to own these goods. We eliminated observations where repair expenditure was either zero or missing, and the purchase expenditure data was also missing. The goal of this regression exercise was to predict the number of durable goods purchased and their total expenditure, thus improving the sample size for elasticity estimation.

However, this approach comes with notable limitations. First, the reliance on a small fraction of observations to estimate thousands of missing values introduces the risk of overfitting. Second, the validity of this method depends on the assumption that the prices faced by households when they originally purchased the goods have not changed significantly over time. Nevertheless, expanding the sample size for estimation provides enough data points to estimate the QUAIDS demand system with a reasonable level of confidence, ensuring that the results are reflective of national consumption patterns rather than those of a small subset of households.

To integrate household characteristics into our analysis, we merged the household consumption data of the relevant cooling goods with:

- Level-3 household characteristics data (e.g., demographic variables),
- Level-15 expenditure data (usual average monthly consumption per household),
- Level-8 energy consumption data (electricity usage and expenditure)

Household usual average consumption was computed as the mean individual consumption within a household.

Estimation of Total Expenditure on Cooling Appliances A multiple linear regression model was used to predict total expenditure on air conditioners and air coolers, specified as follows:

$$Total\ Expenditure\ AC_i = \beta_0 + \beta_1 Electricity\ units_i + \beta_2 Avg.\ cons._i + \beta_3 Avg.\ Cons._i^2 + \beta_4' X_i + \epsilon_i \quad (1)$$

where $X_i$ represents household characteristics, including household size, urban/rural classification, state fixed effects, caste, religion, and occupation type.

A similar regression model was estimated for air cooler expenditure:

$$Total\ Expenditure\ Cooler_i = \beta_0 + \beta_1 Electricity\ units_i + \beta_2 Avg.\ cons._i + \beta_3 Avg.\ Cons._i^2 + \beta_4' X_i + \epsilon_i \quad (2)$$

To estimate the price per unit, it was necessary to determine the number of items purchased for households with missing quantity data. Since the number of units purchased is an ordinal variable, an ordered probit model was used:

$$Quantity\ Cooler_i^* = \beta_0 + \beta_1 Electricity\ units_i + \beta_2 Avg.\ cons._i + \beta_3 Avg.\ Cons._i^2 + \beta_4' X_i + \epsilon_i \tag{3}$$

where $Quantity\ Cooler_i^*$ is an unobserved continuous variable and odered probit calculates the cutoff such that quantity of air coolers correspond to different mutually exclusive intervals and hence, $P(Quantity\ Cooler_i = 0) = P(Quantity\ Cooler_i^* \leq \tau_0) = \Phi(\tau_0 - Z_i\beta)$ where $\tau_o$ corresponds to the value below which $Quantity\ Cooler_i$ takes value 0 if $Quantity\ Cooler_i^* \leq \tau_0$ and beyond which it takes 1. Here $Z_i$ is the vector of all the variables including constant for the $i^{th}$ observation.

The same framework was applied to estimate the number of air conditioners purchased by households with missing quantity data but positive repair expenditure.

## A.4 Data Cleaning and Price Estimation

After estimating quantities, extreme values of prices were identified and removed. A box plot analysis was conducted for each good, and outliers were defined as prices:

- Below zero (resulting from prediction errors)
- Exceeding the upper whisker of the box plot (potential data entry errors or misreporting)

State-level price indices were then constructed using median prices for air conditioners and electricity, assuming that prices should vary primarily at the state level. This assumption holds because:

- Electricity prices are regulated at the state level
- Air conditioner prices exhibit significant state-level variation, but district-level fluctuations may reflect quality differences rather than true price variation

For air coolers, district-level variation was deemed more appropriate, as prices are unregulated and vary based on market competition.

Finally, the dataset was reshaped to retain only households with complete consumption data for all goods included in the QUAIDS demand system estimation. This ensured that the estimation was conducted on a consistent and representative sample.