Assessing the Returns of Investment in Energy Efficient Household Appliances in Singapore Using a Hedonic Pricing Method

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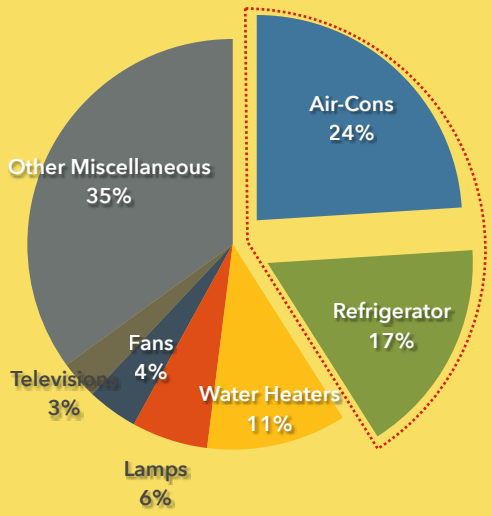
1. INTRODUCTION

A rebound in global demand for natural gas and sanctions placed on Russia over its invasion of Ukraine have driven a surge in global energy prices to all-time highs, leaving households and businesses feeling the crunch with inflated energy bills. This research aims to **assess the returns of upgrading appliances to one of higher energy efficiency** through the estimation of **price differential** and **energy savings** of appliances in Singapore.

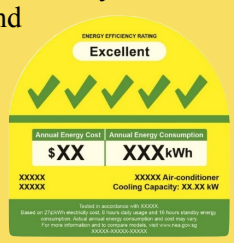
2. BACKGROUND & DEFINITIONS



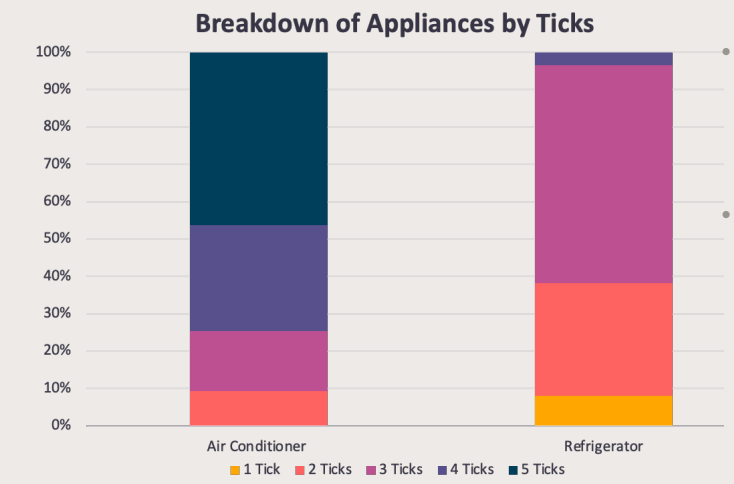
- Air Conditioners and Refrigerators are the two **most energy intensive** appliances in Singapore
- **Ownership** rates of these two appliances are **high**: Air-conditioners (79.7%) , Refrigerators (98.5%)

Our research **focuses on refrigerators and air conditioners** as appliances as they are mainstays of a Singaporean household in a humid and tropical climate and accounts for **close to half** of the typical household energy usage.

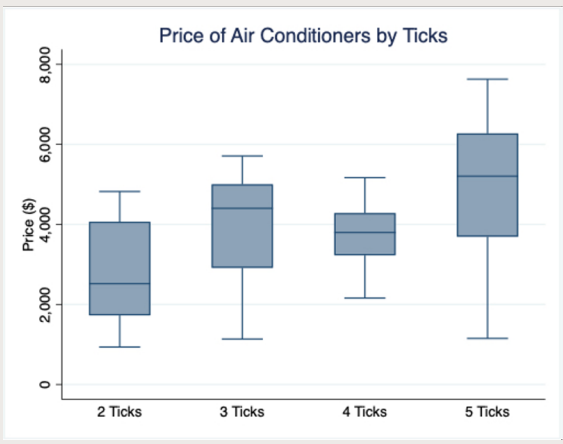
Energy efficiency ratings in Singapore are indicated by **National Environmental Agency's (NEA) Tick Rating**, where a **higher** tick implies that the appliance is more **energy efficient**.

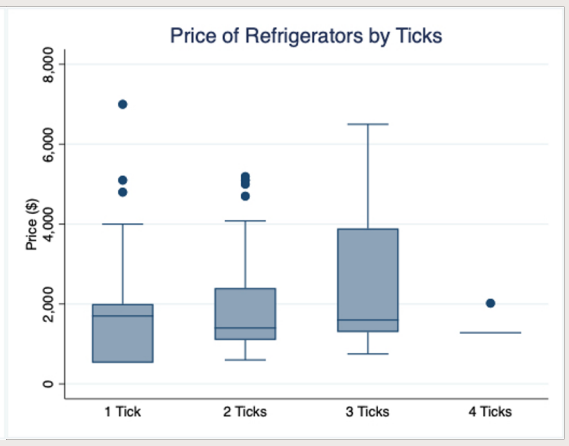


3. SUMMARY STATISTICS

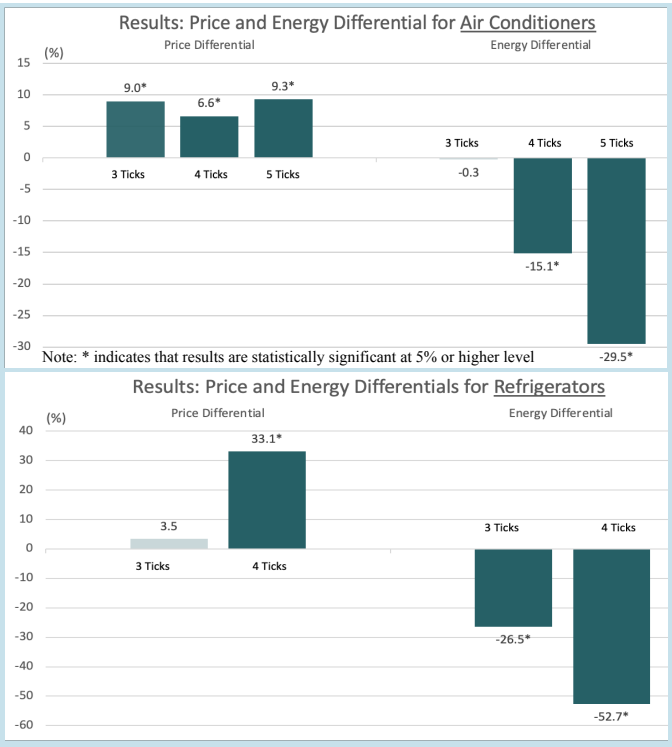


- **88%** of refrigerators in our sample sample are concentrated around the **2 and 3 ticks banding**
- This is **representative** of the overall population covered in the NEA database where 86% of registered refrigerators are in the 2-3 ticks banding





- Based in the box plots that graphs the relationship between price of appliances and the energy ticks, there appears to be a **broadly positive correlation**, with **more energy efficient appliances commanding higher prices**



Results of the Regression Model:
The price and energy differential for air conditioners and refrigerators are as shown on the left.

Air Conditioners:

- Positive correlation between price differential/energy differential and ticks
- However, appliances with 3 ticks may actually cost more than those with 4 ticks

Refrigerators:

- Positive correlation between price differential/energy differential and ticks
- Larger disparity in prices of refrigerators for every addition of tick compared to that of Air Con

4. MODEL SPECIFICATION & RESULTS

A **log-linear regression model** was used as price and energy are continuous, while independent variables are mostly ordinal or dummy variables.

Price	$lnPrice_i = \alpha_0 + \alpha_j Ticks_i^j + \sum \beta_i X_i + \varepsilon_i$
Energy	$lnEnergy_i = \alpha_0 + \alpha_j Ticks_i^j + \sum \beta_i X_i + \varepsilon_i$

Where
$Price_i$ is the price of appliance i
$Energy_i$ is the annual energy consumption of appliance i
$Ticks_i^j$ is the NEA tick rating of appliance i and where j ϵ {3 ticks, 4 ticks, 5 ticks}
X_i is a series of control variables:
For Air conditioner: Brand, cooling capacity, air conditioner system
For Refrigerator: Brand, volume, doors, external LED display, external water dispenser

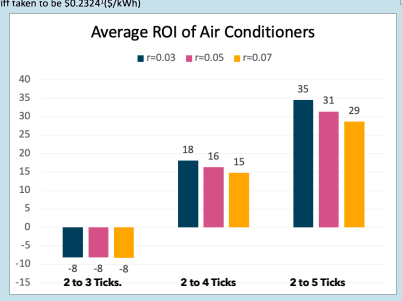
Calculation of Net Present Value(NPV) and Return on Investment (ROI)

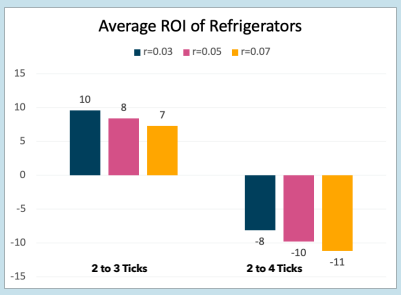
NPV_i
$= Estimated\ additional\ cost\ of\ upgrading\ to\ higher\ ticks\ appliance + Present\ value\ of\ energy\ savings\ of\ appliance\ over\ lifespan$

$$= -(P_2 - P_1) + \sum_{n=1}^{x} \frac{(E_1 - E_2)(T)}{(1+r)^x}$$

$$ROI = \frac{Net\ Return\ on\ Investment}{Cost\ of\ Investment} \times 100\% = \frac{NPV_i}{P_2} \times 100\%$$

Where
P_2 is the price of appliance i with a higher tick rating
P_1 is the price of appliance i at current 2 ticks rating
x is the average lifespan of appliance i, taken to be 7 years for air conditioners and 10 years for refrigerators
E_2 is the annual consumption of appliance i with a higher tick rating (kWh)
E_1 is the annual consumption of appliance i at current 2 ticks rating (kWh)
T is the electricity tariff taken to be $0.2324[1]($/kWh)
r is the discount rate, for sensitivity analysis we varied r ϵ {0.03, 0.05, 0.07}
For instance, to calculate the NPV of an appliance for a change from 2 to 3 ticks,
P_2 is calculated as follows:
$P_2 = P_1 * e^{(\alpha_{3tick})}$, where α_{3tick} is the dummy coefficient for 3 ticks in the regression model for $lnPrice$
Similarly, E_2 is calculated as follows:
$E_2 = E_1 * e^{(\alpha_{3tick})}$, where α_{3tick} is the dummy coefficient for 3 ticks in the regression model for $lnEnergy$





- **Substantial savings** from upgrading to more energy efficient appliances, shown by the relatively **large and positive ROI** figures
- However, an upgrade from a less energy efficient appliance may lead to **negative NPV** and hence ROI where the **price differential** of the more energy efficient appliance **outweighs** the **savings** from the **decreased lifecycle energy** consumption e.g. upgrade of 2 to 3 ticks for air conditioners
- The ROI remained **largely similar** when **different** discount rates of 3%, 5% and 7% were applied

5. LIMITATIONS

- In the Hedonic Price Model, we may run into **omitted variable bias** as it is impossible to account for all attributes/features that have an impact on the price of the appliance
- In the study, we used the **original retail prices** of appliances to analyse the impact of tick ratings. However this could be complicated by:
  - Strategic **promotions** by dealers that saw discounts off retail prices for a sustained period of time
  - Presence of **"hidden fees"** e.g., installation fee, delivery fee, disposal of existing appliance fee
  - Other features such as **warranty period** for the appliance
- In the NPV and ROI calculations, the study assumed that consumption patterns remained the same after the switch/upgrade. However, there have been studies which showed a **rebound effect** when investments are made in more energy efficient appliances

6. POLICY IMPLICATIONS

- A broad view of our results reveal that there is **economic and monetary sense** for appliance buyers to **switch/upgrade to higher tick ratings** for air conditioners and refrigerators
- **Imposition of mandatory energy labelling schemes** such as the NEA ticks or UK's A-G energy label scale are in the **right policy direction** to **nudge** consumers towards purchasing more energy-efficient appliances
- However, there are **several challenges** that could stymie the benefits from switching:
  - Average lifespan of durable goods are relatively **long** and purchases tend to be **infrequent**, so **significant time lag** might persist before upgrades are made and savings materialised
  - Other factors like **brand loyalty** and **marketed features** may take precedence over energy efficiency in influencing consumer's purchase decision