An investigation into energy efficiency : household and food retail sectors in Singapore

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**NANYANG
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**AN INVESTIGATION INTO ENERGY EFFICIENCY:
HOUSEHOLD AND FOOD RETAIL SECTORS
IN SINGAPORE**

TAN TSIAT SIONG

INTERDISCIPLINARY GRADUATE PROGRAMME

2021

AN INVESTIGATION INTO ENERGY EFFICIENCY: HOUSEHOLD AND FOOD RETAIL SECTORS IN SINGAPORE

TAN TSIAT SIONG

INTERDISCIPLINARY GRADUATE PROGRAMME

Supervisor: Prof Euston Quah

A thesis submitted to the Nanyang Technological University in partial fulfilment of the
requirements for the degree of Doctor of Philosophy

2021

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Executive summary

The topic of energy efficiency is an emerging one with the continued emphasis to address global emissions and climate change. Energy efficiency offers the opportunity of reducing emissions at zero cost. This thesis is concerned with developing an understanding in energy efficiency and energy use through empirical studies in both the household and the food retail sectors.

The thesis consists of two self-contained essays.

Chapter 1 investigates the role of energy label for home appliances in Singapore. Provision of energy usage information can drive investments in energy efficiency. Using a discrete choice experiment, a hypothetical marketplace allows the willingness-to-pay for efficiency to be estimated. The conditional and mixed logit models uncovered a higher-than-expected willingness-to-pay, and that the energy labels seemingly do bridge the information gap and drive the demand for efficiency.

Chapter 2 studies the food-retail industry in their energy-efficiency investment and energy-use behaviours. Through a stated preference approach, the study aims to identify the barriers and the drivers of energy efficiency and conservation. Ordered probabilistic models are applied to show that the energy-use reductions are motivated by both private and social gains, and that imperfect information explains the lack of efficient investments.

Introduction

Singapore has made strong commitments to reduce its carbon emissions. To meet the environmental targets, consumers are, amongst other policies, encouraged to adopt energy-efficient equipment and engage in energy-saving practices.

The uptake of energy-efficient equipment is often found to be below economically justifiable or rational levels. Although investing in energy efficient equipment brings about long term monetary savings in operating costs as well as environmental benefits, empirical evidence has shown that consumers are consistently underinvesting in energy efficiency. This is also known as the energy efficiency gap/energy efficiency paradox.

This thesis is an attempt at studying the investment behaviours in energy efficiency in the Singapore context, and particularly, in the household sector and the food retail industry. These two sectors represent largely homogeneous economic agents, in which broad based policies could potentially be applied to encourage green behaviours.

The objective is to examine if the energy efficiency gap is present in these two sectors, explain the determinants of energy-efficiency adoption and energy saving behaviours, and provide empirical insights to consumer preferences. For the household sector, this is studied through a Discrete Choice Experiment, where the Willingness-To-Pay for future cost savings is quantified and heterogeneous effects, such as environmental attitudes, uncovered. In the food retail sector, the analysis is extended beyond energy efficient investments. Respondents are also examined, through a stated preference survey, on their energy-saving practices. As such, we achieve a better understanding of energy consumption behaviours and preferences that could potentially shape policies and reduce Singapore's carbon emissions in the long run.

Chapter 1:

Energy Labels and Willingness-To-Pay;

A Choice Experiment on Households

1.1 INTRODUCTION

The attention on climate change has grown significantly over recent years. The goals of the 2015 Paris Agreement target global warming at well below two degrees Celsius relative to pre-industrial levels. To achieve this, developed countries have to lower carbon emissions by up to 95 percent below 1990 levels by the year 2050 (UNFCC, 2020). In line with the COP21 agreement, Singapore has committed to reduce its emissions intensity by 36 percent below 2005 levels by the year 2030 – to 0.113kgCO₂e/S\$GDP from 0.176 kgCO₂e/S\$GDP – followed by a gradual reduction in emissions thereafter (NCCS, 2020). The government has laid out four broad strategies to fulfil this pledge: to improve energy and carbon efficiency, reduce emissions in power generation, develop low-carbon technologies, and encourage collective climate action (NCCS, 2016). These strategies branch out into a long list of policies, including the provision of energy usage information via energy labels for household appliances.

The National Environmental Agency introduced the Mandatory Energy Labelling Scheme (MELS) for air-conditioners and refrigerators in 2008. Since its implementation, the Energy Label (EL) has been extended to other major appliances including clothes dryers and televisions, and the design of the EL has also been revised in 2014. In addition to the MELS, home appliances that are to be sold in Singapore are subjected to the Minimum Energy Performance Standards (MEPS), which withdraws appliances that have failed to reach a predetermined energy efficiency threshold from the market (NEA, 2020).

Energy labelling schemes for electronics is now a commonplace worldwide, with more than 2000 measures of comparative and endorsement labels (EES Australia and Maia

Consulting, 2014). The MELS adopts a comparative EL, providing information that allows consumers to compare appliance attributes during purchase. As shown in Figure 1.1, provided information in the Singapore EL includes (1) Energy efficiency rating, (2) Tick rating, (3) Annual energy cost, (4) Annual energy consumption, (5) Brand name of appliance, (6) Model of appliance, (7) Product type, (8) Product size, (9) Test standards, (10) Disclaimer and (11) Registration number as issued by NEA.

Figure 1.1: EL for Air-conditioner, Refrigerator, Clothes Dryer and Television
(Source: NEA, 2020)

The adoption of energy-efficient equipment yields economic welfare gain in the form of both private benefits – from monetary savings in operating costs and equipment’s overall lifecycle costs, and social benefits – from reduced carbon emissions and its associated negative environmental externalities. Despite the win-win opportunity, empirical observations suggest that investments in energy-efficient technologies are often below economically justifiable levels. This behaviour is referred to as the energy efficiency gap or the energy efficiency paradox. The asserted existence of the energy efficiency has been attributed to both market failures and non-market failure (see Hirst and Brown 1990; Jaffe and Stavins, 1994).

An illustration of market failures includes imperfect information regarding energy-efficient technologies. For example, there could be lack of information on potential cost-savings and the availability of product options. Information failure could also be due to

improper presentation of energy usage information within the Energy Label. As such, a rational decision maker refrain from committing to energy-efficient appliances, in which the benefits are uncertain and only arrives in the long run. Another market failure explanation of the energy efficiency gap is liquidity constraints, where the consumer is unable to finance the high upfront cost of efficient technologies during the point of purchase.

Non-market failure explanations of the energy efficiency gap could be explained by behavioural biases. For example, consumers might be inattentive to information about energy usage and potential gains. Other explanations of the energy efficiency gap are discussed in Chapter 2.

Information programmes such as ELs have been argued to narrow the gap between actual and optimal energy use, accelerating the slow diffusion of energy-efficient technologies by bridging information asymmetry between manufacturers and household appliance users. Yet, since the implementation of MELS in Singapore, along with the assortment of other energy reduction policies, the compounded annual growth rate of greenhouse gas emissions in Singapore is 2.1% from the period 2000 to 2012¹. Similarly, per capita residential electricity consumption continues to move in an upward trend, from 1256.2kWh in 2008 to 1349.8kWh in 2016 (Statista, 2018), seemingly not moving towards the energy-efficiency and emission goals. End-use electricity consumption by households in Singapore constitutes 15 percent of the nation's total electricity consumption (EMA, 2019), a significant player in the overall demand for energy. Within residential electricity consumption, 36% is attributed to air-conditioners, 21% to water heaters, 18% to refrigerators, and the remaining to other appliances including televisions, computers, clothes dryers, and other appliances.

¹ Compared to the compounded annual growth rate of GDP at 5.7%, rise in GHG emissions can be argued to be moderate. Note that this increase is sustained since the implementation of MELS in 2008, although it could also be due to time-delays in retrofitting home appliances.

The objective of this study is to examine the influence of energy labels for refrigerators on the propensity to purchase for Singapore consumers through a choice experiment. Specifically, the study estimates the willingness-to-pay (WTP) for refrigerators that are energy-efficient, controlling for the other effects of product attributes, individuals' environmental attitudes, demographic and socioeconomic factors. The estimated WTP and its implicit discount rate is then used to evaluate the effectiveness of energy labels and the presence of the energy efficiency gap in Singapore. The rest of this chapter is organised as follows. Section 1.2 reviews the literature. The data collection, design of the choice experiment, and the econometric models are presented in Section 1.3. The results and analysis follow in Section 1.4, and in Section 1.5, further discussions and conclusions are made.

1.2 LITERATURE

1.2.1 Effectiveness of energy labels

The effectiveness of energy labels for home appliances has been widely studied. The larger part of the literature is centred around the effectiveness of the energy labels based on its visual design and the information displayed. Waechte, Sutterlin and Siegrist (2015), using an eye-tracking approach, found the presentation format of the European Union (EU) energy label to be insufficient and draws attention to energy-efficiency ratings but not energy consumption levels. Andor, Gerster and Sommer (2020), through a randomised controlled trial, demonstrated that the inclusion of annual operating cost² in the EU energy label increases the incidence of energy-efficient investments. Verplanken and Weenig (1993) found that a symbolic energy label is the optimal design in simple decision environments using process tracing. Stadelmann and Schubert (2018), using an online field experiment, found that larger-sized vacuum cleaners

² As shown in Figure 1, the Singapore EL includes this information.

and freezers are bought when monetary lifetime cost labels are provided, producing an adverse effect on energy reduction in Switzerland.

The literature has been largely consistent³ in showing that ELs do encourage investments in energy efficiency (Newell, Jaffe and Stavins, 1999) and that the magnitude of this effect-size lies the labels design (Wiel and McMahon, 2003). This provides a presumed agreement that the EL in Singapore should be to some degree effective; it includes information of annual operating cost but not monetary lifetime cost, it uses ticks as a symbolic representation, and the presentation format is clear and visible.

1.2.2 Willingness-to-Pay

Quantifying the effects of ELs commonly requires estimating consumers' WTP, through the use of revealed preference approach or stated preference approach. Revealed preference approach relies on observing actual market transactions and making inferences on consumers' preferences for energy efficiency in the presence of ELs. An example of the revealed preference approach is Anderson and Hansen (2004), which studied the effects of eco-labelled⁴ forest products in the United States using a field experiment and purchase data from Home Depot stores. Bjørner, Hansen and Russell (2004) used quantified the effects of the Nordic Swan environmental label⁵ on consumers' WTP for toilet products. Such revealed preference studies are few in the literature for good reasons despite its advantage of validity; it requires the cooperation of retailers⁶ and high financial and time costs of implementation.

³ Although some studies suggest limited impacts. E.g., see Dyer and Maronick, 1988.

⁴ While this is distinct from Energy Labels, the function of information provision/accreditation is similar to that of ELs.

⁵ Similarly, distinct from Energy Labels, but serves a similar function.

⁶ For this study, selected retailers in Singapore have been approached but no agreement was reached. Thereby, a revealed market approach was not adopted.

Stated preference approach are more prevalent in WTP estimation studies. Stated preference approach relies on survey questionnaires to measure consumers preferences, such as the Contingent Valuation Method and Discrete Choice Experiments, of which the latter is frequently used in studies on WTP for ELs. Ward et al. (2011), using an online choice experiment, found that the WTP premium for an Energy Star labelled refrigerator in the United States is US\$250 to US\$349. A study in China (Zhou and Bukenya, 2016) adopted a choice experiment and concluded that the WTP for energy efficient technologies rises when information made available and comparable through the China Energy Label, thereby resulting in significant national energy savings. Another study conducted in China (Shen and Saijo, 2009), with a similar methodology, found a WTP of \$35 to \$89 for air-conditioners and refrigerators that are more energy efficient as defined by the China Energy Label. In Switzerland, a choice experiment applied to washing machines revealed that the WTP premium even exceeds the potential relative cost savings of energy-efficient options (Sammer and Wüstenhagen, 2006), suggesting not only the absence of the Energy Efficiency Gap but an over-investment in energy efficiency.

1.2.3 Choice experiments

The use of choice experiments offers the advantage of allowing the marketplace for appliances, albeit hypothetical, to be controlled and abstracted from most confounding effects otherwise found in the real-world. In addition, existing studies which applies both the revealed and stated preference approaches on the same goods show that WTP estimates for desirable properties are similarly positive across the two different methodologies, and not merely an outcome of hypothetical settings in stated preference surveys (Arnot, Boxall and Cash, 2006; Adamowicz, Louviere and Williams, 1994). Nevertheless, Banerjee and Solomon (2003) found, through a meta-analysis of five energy labelling schemes in the United States, that actual

purchase decisions are often not guided by ELs although survey results might misleadingly suggest so. This is due to the warm glow effect in which respondents answer WTP questions in a manner which makes them feel good but is not truly representative of their underlying preferences. While the warm glow effect generally applies to stated preference approaches, the problem is alleviated with choice experiments. Respondents are not directly asked to express their WTPs in monetary terms, but WTPs are instead estimated indirectly using trade-offs between the different choices that respondents make.

This study therefore adopts a Discrete Choice Experiment, a form of stated preference approach, to explore consumers' WTP for energy-efficient refrigerators in Singapore. Research that studies the EL in Singapore has never been conducted to the author's knowledge, and that similar studies in the region is scarce. In addition, most existing WTP studies examine the impact of the presence of endorsement labels (such as the US ENERGY Star), while studies conducted on comparative labels (such as Singapore's Energy Label) focuses on the behavioural responses to information presentation. This study explores and provides a methodological framework not limited to endorsement labels. Additional covariates are also considered, innovatively exploring possible underlying relationships between WTP and the influence of a salesperson, experience of appliance purchase, saliency of electricity spending, preference to available options in the market, and ability to understand the provided information on Energy Labels. Therefore, this study contributes to the literature by offering new empirical insights into the effects of Energy Labels in Singapore, a key policy to reduce residential electricity consumption and consequently, carbon emissions for the country.

1.3 METHODOLOGY

1.3.1 Choice Model

The basis of choice models is the random utility theory. The random utility theory posits that individuals are rational economic agents whose objective is to maximize his/her utility given mutually exclusive choice alternatives. Each alternative is assigned a perceived utility level depending on the choice's combination of characteristics. The probability that the individual then makes a certain choice depends on the assigned utility, conditional on the other alternatives available within the choice set.

This can be expressed as follows:

$$U_{iq} = \beta'X_{iq} + \varepsilon_{iq} \quad (1.1)$$

Where

U_{iq} is the utility for individual q faced with alternative i

X_{iq} is the vector of the choice's characteristics (In this study, X represents the attributes of the refrigerator)

β is the parameter vector

ε_{iq} is the independently and identically distributed (iid) error term that follows a Type-I extreme value distribution across alternatives and cases

Therefore, the probability that individual q chooses alternative i from a choice set J (with j alternatives) can be expressed as follows:

$$P_{iq} = P(U_{iq} > U_{jq}; \forall j(\neq i) \in J) \quad (1.2)$$

Following the conditional logit model (McFadden, 1974), the choice probability can be expressed as follows:

$$P_{iq} = \frac{\exp(\beta'X_{iq})}{\sum_{j=1}^J \exp(\beta'X_{jq})} \quad (1.3)$$

The WTP for attribute k can be expressed as follows:

$$WTP_K = -\frac{\hat{\beta}_k}{\hat{\beta}_p} \quad (1.4)$$

Where $\hat{\beta}_k$ is the estimated coefficient for attribute k

$\hat{\beta}_p$ is the estimated coefficient for price

McFadden (1974)'s conditional logit model assumes homogeneous preferences with a constant β parameter (Steckel and Vanhonacker, 1988), and has since been extended by Train (2003) in the mixed logit model to allow for heterogeneous preferences with random parameter. Equation (1.1) can therefore be expressed as follows:

$$U_{iq} = \beta_p P_i + (\beta + \eta_{xq})'X_{iq} + \varepsilon_{iq} \quad (1.5)$$

Where

β is the vector of population mean parameters

η_{xq} is the vector of individual stochastic deviation from the population mean

Following the mixed logit model (Train, 2003), the WTP for attribute k can be expressed simply:

$$WTP_K = -\frac{\widehat{\beta}_k}{\hat{\beta}_p} \quad (1.6)$$

Where

$\widehat{\beta}_k$ is the estimated mean of the coefficient for attribute k

$\hat{\beta}_p$ is the estimated coefficient for price, which remains a fixed parameter since individuals are expected to be homogeneous with respect to price.

Hanley et al. (2001) offers an equivalent and clearer model specification by explicitly expressing the deterministic component of utility as a function of demographic, socioeconomic and environmental attitudinal controls. The regression coefficient can therefore be expressed as follows:

$$\beta_k^* = \beta_{k0} + \beta_{k1}Z_1 + \beta_{k2}Z_2 + \dots + \beta_{kn}Z_n \quad (1.7)$$

Replacing $\hat{\beta}_k$ with equation (1.7), one returns to equation (1.4) to derive the WTP for attribute k , which is now interacted with the controls Z .

The above illustrates the case for McFadden's conditional logit and can be similarly applied to the mixed logit model by substituting the following equation (1.8) into equation (1.6).

$$\hat{\beta}_k^* = \hat{\beta}_{k0} + \hat{\beta}_{k1}Z_1 + \hat{\beta}_{k2}Z_2 + \dots + \hat{\beta}_{kn}Z_n \quad (1.8)$$

Six models are employed in this study; three fixed parameters (conditional logit) models and three random parameters (mixed logit) models. For both fixed and random parameter models, each comprises one specification with only product attributes, and two other specifications with the addition of interaction terms with demographic, socioeconomic and environmental attitudinal controls.

1.3.2 Choice experiment design

Refrigerator is chosen as the household durable to be studied for a few reasons. Refrigerator is one of the first two appliances subjected to ELs since MELS was implemented in 2008. It consumes a sizable proportion of electricity in households. In addition, refrigerators are not subjected to confounds such as the rebound effect. For appliances such as air-conditioning with variable usage, consumers might increase usage having purchased an energy efficiency option. The choice of studying refrigerators is consistent to existing studies on WTP for energy labels.

In the choice experiment, four product attributes/characteristics were identified based on a pilot survey to generate the hypothetical choice tasks, namely: price, energy efficiency, brand and functionality. Using the database of registered goods (NEA, 2019) and a survey of local retail stores, price is assigned to four levels at S\$899, S\$999, S\$1099 and S\$1199⁷. Energy efficiency is assigned to three levels: energy rating of 1-tick, 2-ticks and 3 ticks⁸, and the corresponding annual electricity consumption and costs are calculated using current price of electricity. Brand is assigned to two levels: LG, a well-known and reputable brand, and Beko, a less-known and less popular brand based on the pilot survey. Functionality is assigned to two levels: with or without an ice dispenser, corresponding to current market data on available options.

Applying a full factorial 4-3-2-2 design would yield 48 choice cards with more than 17,000 combinations for choice tasks with three options, rendering the survey impossibly intensive to conduct. A fractional factorial design based on Street and Burgess (2008) is therefore adopted in this study. The Street and Burgess designs are one of few Discrete Choice Experiment designs with optimal efficiency properties; the design is balanced⁹ and orthogonal¹⁰. The adopted design is D-optimal with uncorrelated main effects and interaction effects, allowing the maximum information to be extracted from the choice tasks (Carlsson and Martinsson, 2003; Burgess and Street, 2005). 24 choice tasks were generated, which is further divided into three questionnaire versions through blocking (Lancsar and Louviere, 2008) to reduce survey fatigue. Version A contains choice tasks 1 to 16, Version B contains choice tasks 17 to 24 and 1 to 8, and Version C contains choice tasks 9 to 24. Respondents are randomly

⁷ The choice of pricing at S\$xx99 is reflective of how majority of the appliances are actually priced in main local stores, including Gain City, Harvey Norman and Best Denki.

⁸ While energy rating spans from 1 to 5 ticks, the number of 4-5 ticks (highly energy efficient) refrigerators is very limited.

⁹ Levels within each attribute appears with equal frequency.

¹⁰ There is strictly independent variation of levels across attributes. Levels within each attribute appears with equal frequency in combination with other attributes.

assigned to the three versions of questionnaires. For each choice task, respondents were asked to select the preferred alternative out of three options, or none-of-the-above. The examples of two choice tasks are provided in Figure 1.2. The original ELs and brand logos were used to simulate a realistic information exposure during an actual purchase transaction.

1.3.3 Survey procedure

The face-to-face surveys were conducted by the researcher with a team of trained research assistants in two waves between September 2017 and June 2018 with the purpose of eliciting WTP for energy efficiency for refrigerators in Singapore. A total of 132 respondents were surveyed across Singapore through stratified sampling, yielding 6336 observations. Pearmain et al (1991) suggests that for Discrete Choice Experiments, a sample size of over 100 would be able to provide a basis for modelling preference data. In addition, Louviere (2008) also stated that “our empirical experience is that one rarely requires more than 20 respondents per questionnaire version to estimate reliable models...”. For this study, a sample size of over 100, with more than 40 respondents for each questionnaire set, fulfils these recommendations.

The average time for each survey was 45 minutes. No multiple respondents were selected from the same household to avoid repeated and confounding observations. However, the respondent within each household is not selected based on who is the decision-maker in purchasing appliances, but by voluntary participation and stratified sampling. The objective is to achieve representativeness of the population by age group and gender, whereas it would be ideal but elusive to achieve representativeness of the actual decision-makers, for there is largely no information on this. Subsequently, the experience of purchasing a refrigerator is controlled for in the model specification, partially mitigating this possible concern.

The survey questionnaire comprises of three parts (see Appendix 1.6). In the first section of the questionnaire, respondents were to complete the choice task as described in Figure 1.2. Respondents were informed that the refrigerators options do not differ in aspects

not explicitly described in the choice tasks, including the appliance size, design, colour, and promotion and warranty clauses that could distract the decision-making process. The choice tasks were given at the start of the survey such that respondents are not subjected to possible priming effects the questions on environmental attitudes that could aggravate any warm-glow effects.

In the second section of the questionnaire, 5-point Likert scale questions are used to reveal the respondents' attitude towards the environment. The 15 questions are drawn from the New Ecological Paradigm by Dunlap et al. (2000)¹¹, with questions on the level of agreement to statements such as “The balance of nature is very delicate and easily upset” and “Nature is able to cope with the effects of modern infrastructure”. The list of questions is provided for in Appendix 1.6.2.

Question 7

A	B	C	D
<p>Function: None Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>Function: Ice Dispenser Price: \$1199</p>	<p>None: I will not choose any of these options</p>

Question 24

A	B	C	D
<p>Function: Ice Dispenser Price: \$1199</p>	<p>Function: None Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>None: I will not choose any of these option</p>

Figure 1.2: Example of Choice Tasks in Choice Experiment Questionnaire

¹¹ The questions are reworded to a small extent to increased understandability, following the pilot survey.

The third section of the survey is on respondents' demographic and socioeconomic characteristics – gender, age, level of education, household size, annual household income, etc. Further questions such as on prior experience to the purchase of refrigerators, and the level of trust in labels, were also asked. The list of modelled variables and hypothesized signs are presented in Table 1.1, and the summary statistics of the variables are shown in Table 1.2. Overall, the collected sample is representative of the general population of Singapore.

The expected sign of *Efficiency* is positive, as consumers would have a positive WTP for long-run cost-savings. A better-known *Brand* signals higher quality of the product, longer appliance lifespan, and possibly confers a general feeling of confidence and status (Marta, 2016); thus, a positive sign. Similarly, if there is greater *Functionality*, consumers are expected to want to pay more for the product.

The expected heterogeneity from sociodemographic controls, which are to be interacted with *Efficiency*, are less obvious. Selected studies have shown that WTP for environment-related attributes is lower with *Age* (Diamantopoulos et al., 2003; Poortinga et al., 2003) and for males (Aguilar and Vlosky, 2007). Conversely, higher *Income* and *Education* leads to higher WTP on average (Jensen et al., 2004; Zarnikau, 2003). For a pro-environmental attitude (*NEP*), it is expected that concern for the environment translates to higher WTP for *Efficiency*, and vice versa for the opposite (*DSP*). Additional variables of interest include *Lessinfo*, in an attempt to test if individuals who have difficulty understanding the energy label have a lower WTP for efficiency simply because they do not understand their purchase. *Lessvariety* identifies individuals who prefers that less-efficient appliances be removed from the market entirely, essentially favouring a stricter MELS instead of a broader range of choices with information provision. If respondents are able to recall, show greater concern and saliency of their electricity *Bill*, the incentive to pay for energy efficiency might be larger.

Table 1.1: Overview of variables

Name	Explanation	Expected sign
Dependent variables		
<i>Purchase</i>	1 if the option is chosen, 0 if otherwise	
Independent variables		
<i>Price</i>	{\$899, \$999, \$1099, \$1199}	+
<i>Efficiency</i>	1 if 1 Tick, 2 if 2 Ticks, 3 if 3 Ticks	+
<i>Brand</i>	1 if LG, 0 if Beko	+
<i>Functionality</i>	1 if equipped with ice dispenser, 0 if otherwise	+
<i>Asc</i>	Alternative-specific constant (Vermeulen et al., 2008). 1 if "None of the options" alternative is chosen, 0 if otherwise	
Independent variables crossed with <i>Efficiency</i>		
<i>Age</i>	Age in years, using categorical mid-points	-
<i>Gender</i>	1 if male, 0 if female	-
<i>Education</i>	Years of education	+
<i>Income</i>	Monthly income in S\$ using categorical mid-points	+
<i>Residential</i>	From 1 to 4; 1 if 1-2 Room HDB, 2 if 3-5 Room HDB, 3 if Executive Apartment, Maisonette, Jumbo Apartments, 4 if Condominium/Landed Housing	+
<i>DSP¹²</i>	Factor analysis score for Dominant Social Paradigm (DSP)	-
<i>NEP</i>	Factor analysis score for New Ecological Paradigm (NEP)	+
<i>Lessinfo</i>	1 if respondent prefers less information on energy labels, 0 if no such preference	-
<i>Lessvariety</i>	1 if respondent prefers that inefficient appliances are removed from the market, similar to a stricter MELS; 0 if no such preference	-
<i>Bill</i>	1 if respondent is able to remember his/her electricity bill; 0 if otherwise	+
<i>Sales</i>	1 to 5; 5 if purchase decisions are always driven by salespeople, 1 if never	+/-
<i>Experience</i>	1 if there is at least a past experience of refrigerator purchase, 0 if otherwise	+/-

¹² See (Dunlop et al., 2000) for a discussion of DSP and NEP.

Table 1.2: Descriptive statistics (N = 132, yielding 6336 observations)

Variable	Mean	Std. dev.	Min.	Max.
<i>Purchase</i>	0.291	0.454	0	1
<i>Price</i>	1048.167	111.598	899	1199
<i>Efficiency</i>	2.000	0.817	1	3
<i>Brand</i>	0.500	0.500	0	1
<i>Functionality</i>	0.500	0.500	0	1
<i>Asc</i>	0.125	0.330	0	1
<i>Age</i>	38.428	12.094	23	68
<i>Gender</i>	0.466	0.498	0	1
<i>Education</i>	13.428	3.524	6	22
<i>Income</i>	4176.122	2755.339	0	11000
<i>Residential</i>	2.361	0.705	2	4
<i>DSP</i>	0.000	0.871	-2.512	1.647
<i>NEP</i>	0.000	0.866	-1.886	2.394
<i>Lessinfo</i>	0.076	0.265	0	1
<i>Lessvariety</i>	0.457	0.498	0	1
<i>Bill</i>	0.457	0.498	0	1
<i>Sales</i>	2.857	0.960	1	5

1.4 RESULTS

1.4.1 Base models

Results for first two models, a fixed parameter logit model (Model 1) and random parameter logit model (Model 2), with four product attributes and no other controls, are shown in Table 1.3. For both models, all four variables are significant ($p < 0.01$) and consistent with expected signs. *Price* is negative, *Efficiency*, *Brand* and *Functionality* are positive. Overall, respondents are price-sensitive.

1.4.2 Factor analysis

To control for the effects of environmental attitudes, responses from the second section of the questionnaire are utilised. The overall KMO measure of sampling adequacy is 0.624, larger than the recommended 0.5, suggesting that the data in this survey section is suitable for factor analysis. An exploratory factor analysis was conducted on the 15 questions, and with varimax rotation, two usable constructs with initial eigenvalues greater than 1 were uncovered. The Bartlett test of sphericity confirms that the variables are related and suitable for structure detection. The rotated factor loadings and uniqueness values are presented in Table 1.5, with the questions corresponding to Appendix A.

The first factor corresponds to most of the odd-numbered questions, while the second factor corresponds to all the even numbered question. An agreement on odd numbered questions indicates a pro-environment view (Lawton, 2016); e.g., Q7 Plants and animals have as much right as humans to exist. Q15 And If things continue as it is, we will soon experience a major environmental disaster. These questions to measure a “pro-ecological” world view has been used in the environmental literature (Dunlop, 2000) and referred to as the New Ecological Paradigm (*NEP*).

Table 1.3: Results of logit models: Without controls

Explanatory variables	(1) Conditional Logit	(2) Mixed Logit
<i>Price</i>	-0.005*** (0.0004)	-0.008*** (.0005)
<i>Efficiency</i>	1.463*** (0.056)	2.541*** (0.217)
<i>Brand</i>	0.345*** (0.076)	0.542*** (0.125)
<i>Functionality</i>	0.579*** (0.077)	0.847*** (0.172)
<i>Log likelihood</i>	-939.911	-758.202

Note: Standard errors in parenthesis. Significance codes: 0.01***, 0.05**, 0.10*

Table 1.4: WTP: Without controls

Explanatory variables	(1) Conditional Logit	(2) Mixed Logit
<i>Efficiency</i>	281.986	327.471
<i>Brand</i>	67.113	69.909
<i>Functionality</i>	112.842	109.170

Table 1.5 Factor loadings and uniqueness

Question	Factor 1 (NEP)	Factor 2 (DSP)	Uniqueness
1	0.566		0.669
2		0.374	0.853
3	0.652		0.572
4		0.391	0.843
5	0.723		0.468
6		0.390	0.816
7			0.944
8		0.390	0.496
9			0.919
10		0.390	0.614
11	0.374		0.844
12		0.671	0.546
13	0.415		0.797
14		0.348	0.849
15	0.381		0.829

The second factor corresponds to questions such as Q8 Nature is able to cope with the effects of modern industrialization and Q12 Humans were meant to rule over the rest of nature. Higher scores in this factor supports the world view of humans ruling over the natural environment (Kilbourne, Beckmann and Thelen, 2002). This is referred to in the literature as support for the Dominant Social Paradigm (*DSP*) (Dunlap and Liere, 1984).

As such, we derive at the two variables *NEP* and *DSP* to be included in subsequent models as a measure of environmental attitudes. These two factors are found to cumulatively explain 80.6% of the total response variance.

1.4.3 Conditional and mixed logit models

Through running a series of models, the models with the best performance (Model 3 to Model 6) are selected and presented here in Table 1.5. The corresponding WTPs are shown in Table 1.6. For the mixed logit models, all variables were randomised except price, and the models were estimated using Halton draws with 500 repetitions.

Table 1.5: Results of logit models

Explanatory variables	(3) Conditional Logit	(4) Conditional Logit	(5) Mixed Logit	(6) Mixed Logit
<i>Price</i>	-0.006*** (0.0004)	-0.005*** (0.0004)	-0.008*** (0.0006)	-0.008*** (0.0006)
<i>Efficiency</i>	2.350*** (0.429)	2.489*** (0.280)	3.861*** (1.210)	3.024*** (0.704)
<i>Brand</i>	0.387*** (0.080)	0.385*** (0.079)	0.545*** (0.125)	0.545*** (0.128)
<i>Functionality</i>	0.633*** (0.081)	0.628*** (0.081)	0.836*** (0.175)	0.848*** (0.180)
<i>Asc</i>	-			
<i>Gender*Efficiency</i>	-0.231*** (0.115)	-0.202*** (0.109)	-0.131 (0.328)	-0.118 (0.280)
<i>Age*Efficiency</i>	0.004 (0.006)		0.012 (0.019)	
<i>Education*Efficiency</i>	-0.079*** (0.018)	-0.071*** (0.016)	-0.132** (0.054)	-0.075* (0.043)
<i>Income*Efficiency</i>	-0.000 (0.00002)		-0.00005 (0.00008)	
<i>Residential*Efficiency</i>	-0.0450 (0.081)		-0.137 (0.225)	
<i>Experience*Efficiency</i>	-0.046 (0.138)		0.039 (0.376)	
<i>Bill*Efficiency</i>	0.189 (0.150)		0.217 (0.445)	
<i>NEP*Efficiency</i>	0.102 (0.065)		0.0257 (0.194)	
<i>DSP*Efficiency</i>	-0.366*** (0.068)	-0.315*** (0.060)	-0.364 (0.191)	-0.176 (0.206)
<i>Lessinfo*Efficiency</i>	-1.045*** (0.165)	-1.027*** (0.151)	-1.387*** (0.496)	-1.646*** (0.436)
<i>Lessvariety*Efficiency</i>	1.032*** (0.121)	0.989*** (0.117)	1.433*** (0.317)	1.697*** (0.337)
<i>Sales*Efficiency</i>	0.078 (0.060)		0.063 (0.156)	
<i>Log likelihood</i>	-853.874	-857.386	-737.999	-726.343

Note: Standard errors in parenthesis. Significance codes: 0.01***, 0.05**, 0.10*

Table 1.6: WTP

Explanatory variables	(3) Conditional Logit	(4) Conditional Logit	(5) Mixed Logit	(6) Mixed Logit
<i>Efficiency</i>	425.247	454.264	495.323	399.324
<i>Brand</i>	70.164	70.359	69.994	72.048
<i>Functionality</i>	114.560	114.665	107.324	112.100
<i>Gender*Efficiency</i>	-41.975	-36.874	-16.826	-15.658
<i>Age*Efficiency</i>	0.773		1.517	
<i>Education*Efficiency</i>	-14.280	-13.032	-17.050	-9.949
<i>Income*Efficiency</i>	-0.00449		-0.00641	
<i>Residential*Efficiency</i>	-8.157		-17.624	
<i>Experience*Efficiency</i>	-8.384		5.039	
<i>Bill*Efficiency</i>	34.265		27.860	
<i>NEP*Efficiency</i>	18.484		3.303	
<i>DSP*Efficiency</i>	-66.271	-57.637	-46.772	-23.369
<i>Lessinfo*Efficiency</i>	-189.223	-187.408	-177.967	-217.487
<i>Lessvariety*Efficiency</i>	186.909	180.473	183.899	224.125
<i>Sales*Efficiency</i>	14.122		-737.999	

Overall, all the models show high consistency. For all model specifications, *Price* is negative and significant at 1%, suggesting price responsiveness. *Efficiency*, *Brand* and *Functionality* are all in the hypothesized direction, and significant at 1%. Respondents have a strong preference for refrigerators that are efficient. Respondents also prefer an LG refrigerator, and a refrigerator with a built-in ice dispenser. *Lessinfo*Efficiency* gave negative coefficients, significant across all four models. And that for *Lessvariety*Efficiency* was positive and significant across the board.

From Table 1.6, The WTP for *Efficiency* was consistently high in the range of S\$425.25 to S\$495.32. This is higher than but similar to comparable studies conducted internationally. For example, Ward et al. (2011) found that consumers in the United States are, on average, willing to pay USD250 to USD349 (S\$338 to S\$473) for an Energy Star labelled refrigerator. Respondents, through the choice experiment, makes expensive trade-offs to pursue efficiency. Using current energy prices and assuming that refrigerators have an average lifespan of 10 years, the lifecycle energy-savings of a refrigerator that is one energy rating better than its counterpart is estimated to save no more than S\$250. The high elicited WTP can be represented as a very low to negative discount rates, calculated to be in the range of 6.32% to -3.46%. This could be explained by willingness-to-pay beyond private gains and for the social good, which seems a less plausible conclusion here, where pro-environmental attitudes (*NEP*) did not play a significant role in affecting WTP. The likely explanation that remains is that respondents highly overestimated the future cost-savings.

Males have a smaller WTP than females in Models (3) and (4). This is consistent with the literature (e.g. Huang et al., 2021; Kesternich, 2010; Asinyaka, 2019) in which males consistently are willing to pay less for energy efficient refrigerating appliances.

It is interesting to find that consumers who prefers less information on Energy Labels (*Lessinfo*) have a significantly negative impact on WTP of S\$177.97 to S\$217.49. Respondents that struggle to understand the energy labels, and prefer that less information be provided on these labels, seemingly could not care for or reap efficiency cost-savings, resulting in a lower WTP. For this group of respondents, the information asymmetry was not resolved through Energy Labels and as such, the energy efficiency gap persists due to information failure.

On the other hand, respondents that prefer to have lesser variety (*Lessvariety*) of more efficient refrigerators are oriented towards efficiency, with a WTP that is S\$180.47 to S\$224.13 higher than otherwise. This group of respondents, who are unlikely to purchase inefficient

refrigerators (since they prefer that no such option exist), recognises the cost savings of energy efficiency and are willing to invest in lowering their future electricity expenditure.

Lastly, education seems to negatively affect WTP, although the magnitude of this effect is too small and can be considered as non-existent. Models (3) and (4) also found some negative effects of low environmental attitudes, but this effect disappears in the mixed logit models. The effects on WTP for efficiency caused by the influence of salespeople (*Sales*), *Age*, *Income*, *Residential* type, *Experience* in purchasing refrigerators, saliency of electricity *Bills* and pro-environmental attitudes (*NEP*) are not evident in this model.

1.5 DISCUSSIONS AND CONCLUSIONS

The choice experiment found a high WTP of S\$425.25 to S\$495.32, while the estimated “rational” WTP should be no more than S\$250. The high saliency of energy efficiency in the context of a stated preference survey, the effects of warm glow, or the overestimation of cost savings due to innumeracy could explain this overestimation. Therefore, caution must be taken before interpreting the large WTP for *Efficiency*. Empirical observations of high WTPs are not unseen, and this study could provide insights to the literature of overestimation in stated preference surveys.

As one recalls, even though the electricity usage of refrigerators is lower than that of air conditioners and water heaters, refrigerators still constitute a significant proportion of electricity usage within the household. It would also be expected that if consumers were to regard the electricity usage of refrigerators as less important, a small WTP would result. The findings refute this likelihood.

While the choice experiment might have overestimated the true WTP, it also appears that there could not be a serious problem of the energy efficiency gap in Singapore households. A conservative inference would be that energy labels are able to effectively inform consumers on efficient choices, and drive WTP.

The results also present two interesting observations; (1) Respondents that presumable struggle to interpret energy labels, and prefer to have less energy information, do not pay for energy efficiency. Nevertheless, this proportion of respondents is only 7%. (2) Some consumers prefer to have only efficient appliances in the market, and these are the consumers that have a higher WTP for *Efficiency*. As such, retailers and manufacturers can consider

targeting the market with efficient appliances, or that the thresholds in the MELS as set by the government could be raise. This proportion of respondents is 46%.

All in all, the preference for energy efficiency for refrigerators in Singapore is strong, with a high WTP for *Efficiency*. For manufacturers and retailers, there is room for the provision of efficient equipment even if the price is higher compared to its inefficient counterparts. The models are highly consistent in the direction and magnitude of estimates.

The robustness of the estimates is further supported by reasonable WTP estimates for the other attributes of *Brand* and *Functionality*; compared to available market products, these WTPs are not unexpected. Further controlling for other variables such as saliency of electricity *Bills* and purchase *Experience*, we can conclude that they have no evident effect on WTP. The information on energy labels is sufficient to guide even first-time consumers in their purchase decision, and even in the situations where respondents are not well-aware of how much they pay in energy operating costs. Lastly, while it has been anecdotally observed that purchase decisions are highly influenced by salespeople (*Sales*) at appliance retailers, consumers in this category do not exhibit a significantly different WTP for *Efficiency*. The study also tested models which includes a dummy variable for trust for labels (91%), number of children, nationality, race, self-declared importance of energy and water savings, and others, but these variables are omitted from the analysis as they are deemed not to be important.

1.6 APPENDIX: SURVEY OVERVIEW

Part 1

Q	Choose the refrigerator you prefer, given the following information:								
1	<p>Question 1</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: Ice Dispenser Price: \$899</p> </td> <td> <p>Function: None Price: \$999</p> </td> <td> <p>Function: None Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
2	<p>Question 2</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: None Price: \$899</p> </td> <td> <p>Function: Ice Dispenser Price: \$999</p> </td> <td> <p>Function: Ice Dispenser Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
3	<p>Question 3</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: Ice Dispenser Price: \$899</p> </td> <td> <p>Function: None Price: \$999</p> </td> <td> <p>Function: None Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
4	<p>Question 4</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: None Price: \$899</p> </td> <td> <p>Function: Ice Dispenser Price: \$999</p> </td> <td> <p>Function: Ice Dispenser Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
5	<p>Question 5</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: Ice Dispenser Price: \$899</p> </td> <td> <p>Function: None Price: \$999</p> </td> <td> <p>Function: None Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: Ice Dispenser Price: \$899</p>	<p>Function: None Price: \$999</p>	<p>Function: None Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
6	<p>Question 6</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: None Price: \$899</p> </td> <td> <p>Function: Ice Dispenser Price: \$999</p> </td> <td> <p>Function: Ice Dispenser Price: \$1099</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: None Price: \$899</p>	<p>Function: Ice Dispenser Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>None: I will not choose any of these options</p>						
7	<p>Question 7</p> <table border="1"> <thead> <tr> <th>A</th> <th>B</th> <th>C</th> <th>D</th> </tr> </thead> <tbody> <tr> <td> <p>Function: None Price: \$999</p> </td> <td> <p>Function: Ice Dispenser Price: \$1099</p> </td> <td> <p>Function: Ice Dispenser Price: \$1199</p> </td> <td> <p>None: I will not choose any of these options</p> </td> </tr> </tbody> </table>	A	B	C	D	<p>Function: None Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>Function: Ice Dispenser Price: \$1199</p>	<p>None: I will not choose any of these options</p>
A	B	C	D						
<p>Function: None Price: \$999</p>	<p>Function: Ice Dispenser Price: \$1099</p>	<p>Function: Ice Dispenser Price: \$1199</p>	<p>None: I will not choose any of these options</p>						

8	<p>Question 8</p> <div> <div>A</div> <div>B</div> <div>C</div> <div>D</div> </div> <div> <div> <p>None: I will not choose any of these options</p> </div> </div>
9	<p>Question 9</p> <div> <div>A</div> <div>B</div> <div>C</div> <div>D</div> </div> <div> <div> <p>None: I will not choose any of these options</p> </div> </div>
10	<p>Question 10</p> <div> <div>A</div> <div>B</div> <div>C</div> <div>D</div> </div> <div> <div> <p>None: I will not choose any of these options</p> </div> </div>
11	<p>Question 11</p> <div> <div>A</div> <div>B</div> <div>C</div> <div>D</div> </div> <div> <div> <p>None: I will not choose any of these options</p> </div> </div>
12	<p>Question 12</p> <div> <div>A</div> <div>B</div> <div>C</div> <div>D</div> </div> <div> <div> <p>None: I will not choose any of these options</p> </div> </div>
...	
24	

Part 2

Q	How strongly do you agree with the following statements?					
		1: Strongly disagree	2	3	4	5: Strongly agree
1	We are reaching the maximum number of people that the Earth can support.					
2	Humans have the right to change the natural environment for their needs.					
3	When humans interfere with nature it often produces disastrous consequences.					
4	Humans are smart enough to ensure that we do not make the Earth unliveable.					
5	Humans are seriously abusing the environment.					
6	The Earth has plenty of natural resources if we just learn how to develop them.					
7	Plants and animals have as much right as humans to exist.					
8	Nature is able to cope with the effects of modern industrialization.					
9	Despite our abilities, humans are still subject to the laws of nature.					
10	The so-called "environmental crisis" that humankind is facing has been greatly exaggerated.					
11	The Earth has very limited space and resources.					

12	Humans were meant to rule over the rest of nature.					
13	The balance of nature is very delicate and easily upset.					
14	Humans will eventually learn enough about how nature works to be able to control it.					
15	If things continue as it is, we will soon experience a major environmental disaster.					

Part 3

Q													
1	Age	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50	51- 55	56- 60	61- 65	66- 70	71+	
2	Gender	Male		Female									
3	Nationality	Singaporean				Others: ____							
4	Race	Chinese		Malay		Indian		Others: ____					
5	Monthly income (to the nearest thousand)	\$ ____											
6	Highest education level attained	No formal education		Primary school		Secondary school		Vocational training/ITE		Junior college/Diploma		Degree/Post-graduate	
7	Type of residence	1-2 room HDB		3-5 room HDB		Executive apartments, Maisonettes, Jumbo apartments		Condominium, Landed property					
8	Marital status	Single		Married		Divorced		Widowed					
9	No. of children	____											
10	Have you purchased a refrigerator before as a decision maker?	Yes							No				
11	During your previous purchase, did you pay attention to the energy labels?	Yes				No				N.A.			
12	From this survey, do you think there should be more or less information provided in the energy labels?	More							Less				
13	Do you have difficulties understanding the information provided in energy labels	1: Yes, I could not understand most of the information		2		3			4		5: No, I perfectly understand the provided information		
14	Do you prefer that energy labels have more or less information, compared to the existing label?	Less							More				

15	Suppose only highly energy efficient appliances are sold in the market. These appliances are also expected to be more expensive than inefficient appliances. Do you support this change?	1: No, I prefer a larger variety	2	3	4	5: Yes, I prefer that only efficient appliances are a choice.
16	Do you think the information provided by energy labels can be trusted?	1: Not at yes	2	3	4	5: Yes, I fully trust the labels
17	Are you often influenced by salespeople when purchasing electrical appliances	1: Never	2	3	4	5: Always
18	How important is saving energy to you?	1: Not important at all	2	3	4	5: Extremely important
19	How important is saving water to you?	1: Not important at all	2	3	4	5: Extremely important
20	Can you remember how much you paid for water and electricity bills in the last month?	S\$____	I cannot remember			

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Chapter 2:

Assessing Energy Efficiency in the Food Retail Sector: A Stated Preference Approach

2.1 INTRODUCTION

Policy measures aimed at encouraging industries to achieve greater energy efficiency comes in multifaceted forms. In Singapore, such schemes range from developing firms' capabilities through encouraging the adoption of energy management systems e.g., ISO 50001, subsidized trainings for energy managers, to incentive schemes such as public co-funding of energy audits and of retrofitting energy efficient equipment (NCCS, 2016). In promoting energy efficiency and conservation in the commercial sector, broad-based policies sometimes neglect specific groups of firms. In particular, this study identifies the hawker sector in Singapore as one with a general absence of such public intervention. Hawkers date back to the 1950s in the period of Singapore's rapid urbanisation, back then peddling street food with a reputation for poor hygiene. Today, hawkers refer to the food vendors who sell affordable and hygienic food in hawker centres, which are the 15,000+ cooked food establishments located near public housing estates island-wide.

Taking a comparison between the hawker food retail sector and the household sector, which will later be argued to be similar in the context of this study, incentives for the latter to reduce energy demand and carbon emissions include the use of social comparisons in utility bills and the provision of energy labels for home appliances. Hawker stalls, as revealed in the interviews over the course of this study, are not subjected to similar information provision or resources. There is a Hawkers' Productivity Grant which encourages the use of automation

equipment, but incentives for hawkers to adopt energy-efficient technologies are not easily accessible. For example, grants that encourage Singapore firms to adopt of energy-efficient technologies are only made available to manufacturing companies. A look at the other policies also suggests that they are targeted at larger firms and at other industries, involving relatively high capital costs, complicated eligibility criteria and rigorous application processes (NEA, 2019). There is also no standardised energy label for commercial kitchen appliances.

The hawker industry offers sizable potential energy savings and emission reductions that could advance Singapore towards its emission-reduction pledge. The commercial and service sector consumes about double the amount of electricity and natural gas compared to total residential consumption. Within the commercial and service sector, the Food & Beverages (F&B) sector is the largest consumer of natural gas, and constitutes around 10% of the sector's electricity consumption. In addition to the role of reducing carbon emissions and energy demand, the focus on the hawker industry stems from a few additional reasons.

The hawker culture is an integral part of the Singaporean lifestyle. Hawker centres are not only dining spots, but also serves as a multicultural community space. In recognition of this, the hawker culture recently became Singapore's first item on the UNESCO intangible cultural heritage list (Straits Times, 2020). The hawker experience also extends to improving the experience of tourists in Singapore (Henderson et al., 2012). The profit margin per serving of hawker fare stands at a meagre S\$0.20 to S\$0.30 (CNA, 2018). Reducing their energy demand, which constitutes close to 9% of total costs (MTI, 2015), can make a considerable impact on the financial feasibility of this low-margin business. Lower-income households are also heavily dependent on this affordable food option. The lowest income quintile spends 80% of their food expenditure at hawker centres, and an estimated 58% of total national food expenditure is spent on hawker food (Tan, 2015). It is to be noted that despite its public good

properties, hawkers are one of the fastest fading trade (CNA, 2021) due to the aging labour force and psychological barriers in entering the industry.

Using a stated preference approach, the objective of this study is to examine the adoption of energy-efficient technologies and behaviours in energy-saving within this key industry, through the framework of the energy efficiency gap. Specifically, the study examines the possible barriers and drivers to energy efficiency and conservation. The chapter is organised as follows: Section 2.2 discusses the literature on energy efficiency gap; Section 2.3 presents the methodology. The results are shown in Section 2.4, followed by discussions and conclusions in Section 2.5.

2.2 LITERATURE

2.2.1 The energy efficiency gap

Improving energy efficiency is often considered a cost-effective means to conserve energy and to reduce emissions. However, the literature suggests observations of the energy efficiency gap (see Hirst and Brown, 1990; Jaffe and Stavins, 1994; Howarth and Stanstad, 1995 for a detailed discussion); investments in energy efficiency seems to be not only lower than the social optimal levels, but also lower than private sub-optimality (Jaffe et al., 2004). Where the gap exists, users could increase the level of energy efficiency and enjoy cost-savings – a win-win opportunity.

A simplified representation of the cost-minimizing decision to adopt efficient technologies is as follows (Gerarden, Newell and Stavins, 2015):

$$\min(\text{total costs}) = \min K(E) + O(E, P_E) \times D(r, T) + C \quad (2.1)$$

Where $K(E)$ is the equipment purchase cost, a function of E , the annual energy use
 $O(E, P_E)$ is the annual operating cost, a function of E and P_E , the price of energy
 $D(r, T)$ is the discount factor, a function of r , the discount rate, and T , the time horizon
As such, $O(E, P_E) \times D(r, T)$ is the discounted operating cost
 C is the other associated costs to adopting the technology

2.2.2 Barriers and drivers to energy-efficiency

An understanding of the factors that drives and hinders the adoption of energy efficiency, and that affects energy conservation behaviours, can provide guidance for policy measures. Most empirical literature that employs stated preference methods analyses the household sector (e.g. Astmasson et al., 2013; Mills and Schleich, 2012; Nair, Gustavsson and Mahapatra, 2010; Sardianou, 2007), the industry sector (e.g. Abdelaziz, Saidura and Mekhilef, 2011; Stenqvist et al., 2011; Stenqvist and Nilsson, 2012; Thollander and Ottosson, 2010) and the tertiary sector (e.g. Cagno et al., 2010; Gruber and Brand, 1991; Fleiter, Schleich and Ravivanpong, 2012; Jochem and Gruber, 1990; Schleich and Gruber, 2008; Schlomann and Schleich, 2014; Schleich, 2009; Thollander, Danegstig and Rohdin, 2007; Thollander and Ottosson, 2010; Thollander and Dotzauer, 2010; Trianni and Cargo, 2012). Of which, studies in the region are few, and to the authors best knowledge, no studies have been conducted on the food retail sector before. The study aims to fill this research gap.

The food retail sector for Singapore hawkers closely resembles characteristics of the household sector for a few reasons: (1) The business model is straightforward. The objective

of profit maximization is to some extent analogous to that of cost-minimization in households, assuming that efficient technologies serve the same function as their counterparts and have no significant impact on revenue. (2) The energy demand of hawkers is uncomplex and transparent; energy is consumed for food preparation and for the operation of stall (3) Energy efficiency investments only concerns the fitting of kitchen appliances and lighting. (4) The industry is composed of many small, competitive and relatively homogenous units. Against this backdrop, in identifying the drivers and barriers of energy-efficiency, reference is taken to theoretical and empirical factors of the energy efficiency gap for households and industries without distinction. Explanations for the energy efficiency gap can be categorized into three broad categories: (1) market-failures, (2) behavioural biases, and (3) model and measurement errors.

2.2.3 Market failures

Market failure occurs due to imperfect information regarding energy-efficient technologies, for example, information on the potential cost-savings and the availability of product options. Imperfect information comes in the form of lack of easily accessible information, asymmetric information between the manufacturers and the consumers, that collecting this information is deemed too costly relative to the potential cost-savings, or that information on energy efficiency is not presented in a suitable format (Hamann et al., 2013). Individuals might not even possess the knowledge of how to be more energy efficient or sustainable to begin with (Attari et al., 2010; Gardner and Stern, 2008; Larrick and Soll, 2008).

Imperfect information for future time periods comes in the form of uncertainty (Metcalf and Hassett, 1999; Hassett and Metcalf 1993) of lifecycle costs, composing of energy use E , price of energy P_E (Alberini et al., 2013), the appliance lifespan T , the depreciation of the level of energy efficiency, the behaviour of others, the behaviour of oneself in the future, and the new technological innovations that could emerge in the future. As such, decision makers refrain from committing to an energy-efficient equipment which only yields benefits in the longer run.

What might seem cost-minimizing in the current period might not be so when these parameters change.

Another market failure explanation concerns liquidity constraints (Golove and Eto, 1996). Where consumers might be willing to invest in energy-efficient products, these options tend to involve state-of-the-art technologies and thus have a higher purchase cost $K(E)$. Despite the higher purchase cost being more than offset by the discounted operating cost $O(E, P_E) \times D(r, T)$, the consumer is unable to finance the high upfront cost from the start. Furthermore, the inability, or the lack of willingness to take on debt leads to the unviability of efficient options. Principal-agent problem could also lead to underinvestment in efficiency, where buyers and users have misaligned incentives.

2.2.4 Behavioural biases

Behavioural explanations, for the seemingly irrational wedge between the cost-minimizing energy-efficiency level and the actual-realised level, are varied. Consumers might be inattentive to information about energy usage and potential gains (Anderson and Claxton, 1982; Blumstein et al., 1980; Jaffe and Stavins, 1994; Sanstad and Howarth, 1994), although it has been argued that one could be also rationally inattentive (Gabaix, 2014; Sallee, 2014). Gabaix and Laibson (2006) found that consumers do not pay attention to “add-on” costs, and Chetty, Looney, and Kroft (2009) and Hossein and Morgan (2006) similarly found empirical evidence of inattentiveness to ancillary product costs. This is especially so when the ancillary product costs are low relative to purchase cost, similar to when energy costs are small relative to the high purchase price for large durables such as refrigerators and freezers. Allcott and Taubinsky (2014), through a field experiment, also found that increasing attention on energy savings encouraged purchase of efficient compact fluorescent light bulbs. Inattention is closely

linked to the issue of saliency; higher saliency of purchase cost vis-à-vis operating costs leads to greater emphasis of the former component.

There are multiple other behavioural explanations that could further explain the energy efficiency gap. For example, innumeracy and myopia – decision makers are not able to accurately calculate the present value of their investments or are unable to account for the long-run costs due to cognitive limitations; mental accounting (Thaler, 1985) – allocating a fixed budget for equipment purchase and not treating money as fungible; loss aversion (Kahneman et al, 1991– where higher purchase cost is framed as a loss; uncertainty-loss aversion (Greene, 2011) – avoiding potential losses due to imperfect information; inertia and status quo bias (Anderson, 2003; Epstein, 1999; Loewenstein et al., 2001; Weber, 2006) – in retrofitting inefficient technologies; social norms; availability bias and representative heuristics; and the list goes on.

2.2.5 Model and measurement errors

Lastly, model and measurement errors in assessing the energy efficiency gap suggests that the observed gap might not be paradoxical to begin with. Identification of the gap is misattributed to unaccounted costs C and its associated uncertainty, for example, inconvenience, preference for certain product attributes, government policies in place, or use of inappropriate discount rates (Gerarden, Newell and Stavins, 2015).

2.3 METHODOLOGY

2.3.1 Survey procedure

The study was conducted using face-to-face surveys from January to October 2019 in two phases. In designing the survey questionnaire, hawkers were interviewed in the pilot phase to ensure the understandability and appropriateness of the questions. The final survey questionnaire was distributed in two languages: English and Chinese. Interviewers were trained to only approach the respondents during the off-peak periods between 3p.m. to 5p.m. when there are no patrons, and to guide the respondents through the questions. Each survey takes around 30 minutes to complete, excluding any interruptions due to customers.

The survey respondents were 177 hawkers comprising 100 stall-owners and 77 staff in Singapore. Five hawker centres were randomly selected each from the central, east, north, north-east and west regions. The hawker centres selected were determined to be similar to and representative of most hawker centres in Singapore, based on the authors' experience living in the country. For example, hawker centres in industrial areas were not picked, as they typically pay a lower rental and sell at a lower price. The respondents were then chosen randomly (excluding hawker stalls that sell drinks), subjected to voluntary participation and availability. Regrettably, it was impossible to survey hawkers who are perpetually facing long queues and could not take time to answer the survey, nor hawkers who only operate during peak hours. The selected respondents ages ranged from the 21-30 age-group to 61 and above age-group. Of the participants, 55% were male.

The survey questionnaire comprises of four parts. The first part consists of general questions on the characteristics of the hawker stall and the respondent (e.g., sociodemographic variables, experience in the F&B industry, number of staff, franchise or independent model). The second part involves questions about energy-efficiency investments and energy-saving practices. The third part includes additional questions pertaining to the measurement of

payback period, pair-wise comparisons and response to the implementation of the carbon tax. The final part of the survey measures the environmental attitude of the respondents.

2.3.2 Dependent and independent variables

In the second part of the survey questionnaire, respondents were asked questions on their preference towards energy-efficient equipment and whether they adopt energy-saving practices, following Schlomann and Schleich (2015). These two measures serve as the dependent variables of the multivariate model. Descriptions of the dependent variables, and the independent variables which are elaborated next, can be found in Table 2.1 and Table 2.2.

The dependent and control variables are driven by the literature. Allcott and Greenstone (2012) suggests that insufficient information is the most important barrier to energy efficiency adoption. *Know* measures the level of knowledge on energy-efficiency and energy conservation. Therefore, the coefficient of *Know* is expected to be positive for both dependent variables. Similarly, *Experience* is a proxy for accumulated knowledge in the industry, and being part of a *Franchise* could also lead to knowledge and resource spillover from the parent company. The expected number of years the respondent will remain in the existing business (*Stayinbusiness*) controls for whether it would be economically rational to invest in efficiency, or to acquire information on energy-saving. If respondents are planning to operate a short-lived business, investing in future cost-savings would not make much sense. Similarly, *Profitability*, *Electricitybill*, and *Gasbill* serves a similar function of identifying if *Purchase* and *Switchoff* has a higher score if potential gains are larger and vice versa.

Liquidity constraint is also identified to be a plausible barrier to energy efficiency, having established that hawkers are small businesses with limited access to funds. *Afford* measures the perceived affordability of efficient equipment, and therefore a high score denotes lesser liquidity constraints, and should drive the adoption of energy efficiency. In addition,

controls for environmental attitudes, sociodemographic factors, and stall characteristics (*Size, Hygiene*) were included.

Table 2.1: Overview of variables

Name	Explanation	Expected sign
Dependent variables		
<i>Purchase</i>	From 1 to 5; 5 if energy efficiency is very important for new purchases; 1 if energy efficiency is not important at all	
<i>Switchoff</i>	From 1 to 5; 5 if energy-using equipment are switched off whenever not in use; 1 if energy-using equipment are never switched off even if not in use	
Independent variables		
<i>Know</i>	From 1 to 5; 5 if knowledgeable about energy-efficiency and energy conservation practices; 1 if no knowledge	+
<i>Experience</i>	Number of years working in the food retail industry	+
<i>Franchise</i>	1 if stall is part of a franchise; 0 otherwise	+
<i>Afford</i>	From 1 to 5; 5 if energy-efficient equipment is perceived to be affordable; 1 if unaffordable	+
<i>Stayinbusiness</i>	From 1 to 6; 6 if expected to stay in existing business for > 10 years; 1 if 0-2 years; in intervals of 2 years	+
<i>Profitability</i>	From 1 to 5; 5 if energy costs are considered to impact profits a lot; 1 if energy costs are considered to not affect profits	+
<i>Electricitybill</i>	Monthly electricity bill in S\$	+
<i>Gasbill</i>	Monthly gas bill in S\$	+
<i>Environment</i>	From 1 to 5; 5 if strong preference for protecting the environment, 1 if no preference for protecting the environment	+
<i>Age</i>	Age group; 1 if 21 to 30; 2 if 31 to 40; 3 if 41 to 50; 4 if 51 to 60; 5 if 61 and above	
<i>Gender</i>	1 if male, 0 if female	
<i>Nationality</i>	1 if Singaporean, 0 if otherwise	
<i>Race</i>	1 if Chinese, 0 if otherwise	
<i>Income</i>	Monthly income in S\$	
<i>Education</i>	From 1 to 7; 7 if highest education level attained is post-graduate; 1 if no formal education	
<i>Married</i>	1 if married, 0 otherwise	
<i>Children</i>	Number of children	
<i>Hygiene</i>	1 if hygiene rating is A; 0 if otherwise	
<i>Size</i>	Number of people working in the stall	

Table 2.2: Descriptive statistics (N = 177)

Variable	Mean	Std. dev.	Min.	Max.
<i>Purchase</i>	3.597	1.284	1	5
<i>Switchoff</i>	3.845	1.204	1	5
<i>Know</i>	2.341	0.804	1	5
<i>Experience</i>	11.584	10.497	0	45
<i>Franchise</i>	0.0487	0.216	0	1
<i>Afford</i>	2.707	0.895	1	5
<i>Stayinbusiness</i>	2.682	1.910	1	6
<i>Profitability</i>	3.170	1.141	1	5
<i>Electricitybill</i>	328.353	222.276	0	1500
<i>Gasbill</i>	457.122	382.946	0	2500
<i>Environment</i>	4.085	0.688	2	5
<i>Age</i>	2.829	1.293	1	5
<i>Gender</i>	0.548	0.500	0	1
<i>Nationality</i>	0.243	0.432	0	1
<i>Race</i>	0.170	0.378	0	1
<i>Income</i>	2182.927	1137.227	300	6000
<i>Education</i>	2.890	1.648	1	6
<i>Married</i>	0.317	0.468	0	1
<i>Children</i>	1.439	1.423	0	6
<i>Hygiene</i>	0.5	0.503	0	1
<i>Size</i>	2.268	1.042	1	7

2.3.3 Econometrics model

Fixed-effects model

Two ordinal dependent variables were used in this study: *Purchase* and *Switchoff*. Unlike interval scale measures, ordinal scale measures are characterised by (1) a clear ranking of levels, and (2) unknown absolute distances between the different levels. In this study, *Purchase* and *Switchoff* are stated responses measured on a 5-point Likert scale as shown in Table 2.1. Instead of applying standard probit/logit models, the treatment of the variables as ordinal provides greater statistical power, higher flexibility, straightforward interpretations, and results in parsimonious estimates (Agresti, 2010).

A representation of the ordinal model is as follows:

$$Y = j \quad \text{if} \quad \alpha_{j-1} < Y^* \leq \alpha_j \quad (2.2)$$

Where Y^* is the continuous latent variable underlying the observed Y ,
defined as $Y^* = \beta'X + \varepsilon$, where X is the vector of explanatory variables
 β is the vector of coefficients
 ε is the error term
 j is the ordinal response
 α is the set of cut-points defining Y^* into ordinal levels

The cumulative probabilities are subjected to the logit transformation as follows:

$$\text{logit}[P(Y \leq j)] = \log\left[\frac{P(Y \leq j)}{1 - P(Y \leq j)}\right] \quad (2.3)$$

The model can be represented as follows:

$$\text{logit}[P(Y \leq j|X)] = \alpha_j + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n = \alpha_j + \beta'X \quad (2.4)$$

Where $j = 1, \dots, J - 1$; J being the total number of levels
 x denotes the explanatory variables
 β denotes the corresponding coefficients

This study employs the proportional-odds model (Green and Hensher, 2009), represented by equation (2.4). The log-odds ratio is constantly proportional to the distance between two points of X , and this holds true for different levels of Y . The odds of giving a response ($Y \leq j|X_a$) is proportionate to that at ($Y \leq j|X_b$) by a factor of $\exp \beta'(X_a - X_b)$. This is shown as follows:

$$\text{logit}[(P(Y \leq j|X_a))] - \text{logit}[(P(Y \leq j|X_b))] = \beta'(X_a - X_b) \quad (2.5)$$

Where X_a and X_b are two vectors of explanatory variables

Random-effects model

The proportional-odds model is a fixed-effects model, of which equation (2.4) can be extended to include a random variable to derive at equation (2.6), representing the random-effects model.

$$\text{logit}[(P(Y_{it} \leq j|X_{it}))] = \alpha_j + (u_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \dots + \beta_n x_{nit}) = \alpha_j + (u_i + \beta' X_{it}) \quad (2.6)$$

Where Y_{it} is the observation t for individual i
 X_{it} is the vector of explanatory variables for observation t individual i
 u_i is the random effect for individual i , which is unobservable, and assumed to be normally distributed $N(0, \sigma_u^2)$

This study also adopts the random-effects model; the data can be interpreted as panel data since multiple survey observations on *Purchase* and *Switchoff* were collected. The random-effects model has two advantages over the fixed-effects model; (1) it allows for observations from the same individual to be correlated, and (2) it accounts for subjectivity in the ordinal responses due to different unobserved cut-points α_j .

2.4 RESULTS

2.4.1 Ordered logit model

A series of fixed-effects and random-effects models were estimated and compared; fixed-effects models were preferred according to the Hausman test – unique errors are correlated with the regressors. The models with the best performance – fixed-effects ordered logit – are selected and presented in Table 2.3.

The results find that parameter estimates across models are fairly similar within each dependent variable. Across dependent variables, the decision to *Purchase* and to *Switchoff* could be related but does not necessarily have to be dependent nor correlated. *Experience*, *Profitability*, *Experience*Profitability* and *Environment* are significant across all four models.

Years of *Experience* in the industry is found to be statistically significant for both *Purchase* and *Switchoff*, and the effect is positive as expected. A more experienced hawker, equipped with accumulated experiential knowledge, is more able to engage in energy-saving behaviours. If energy costs have a larger impact on *Profitability*, hawkers are also more inclined to *Purchase* energy efficient equipment and *Switchoff* to save energy, as such cost-related decisions naturally becomes a larger component of the profit-maximisation objective. It is further found that the effects of *Experience* and *Profitability* are positively associated as shown by the significant interaction term. A pro-environmental attitude (*Environment*) drives both *Purchase* and *Switchoff* as hypothesized. Care for the environment and for climate change induces hawkers to be motivated not only by the private gains of cost-savings, but the social gains of emission reductions.

Table 2.3: Results of ordered logit model

Explanatory variables	<i>Purchase</i>	<i>Purchase</i>	<i>Switchoff</i>	<i>Switchoff</i>
<i>Know</i>	0.698** (0.352)	0.635* (0.331)	-0.110 (0.546)	
<i>Experience</i>	0.257*** (0.077)	0.231*** (0.069)	0.183** (0.077)	0.0846* (0.501)
<i>Franchise</i>	0.868 (1.158)		1.602 (1.283)	
<i>Afford</i>	-0.210 (0.299)		0.128 (0.340)	
<i>Stayinbusiness</i>	0.0296 (0.124)		0.295** (0.149)	0.151 (0.124)
<i>Profitability</i>	0.585* (0.350)	0.558* (0.292)	0.179** (0.260)	0.361* (0.212)
<i>Experience*Profitability</i>	0.0565*** (0.021)	0.0513*** (0.020)	0.067** (0.034)	0.027 (0.019)
<i>Electricitybill</i>	0.0002 (0.001)		-0.0009 (0.001)	
<i>Gasbill</i>	-0.001 (0.0008)		0.001 (0.0009)	
<i>Environment</i>	1.196*** (0.378)	1.072*** (0.322)	1.181*** (0.444)	1.112*** (0.381)
<i>Age</i>	-0.015 (0.277)		0.224 (0.317)	
<i>Gender</i>	-0.544 (0.536)		0.238 (0.589)	
<i>Nationality</i>	1.100* (0.660)	0.974* (0.555)	-0.217 (0.688)	
<i>Race</i>	0.283 (0.678)		1.272** (0.758)	1.327*** (0.620)
<i>Income</i>	-0.002** (0.0008)	-0.002** (.0008)	-0.001 (0.0009)	
<i>Income²</i>	0.000** (0.000)	3.15e-07*** (1.20e-07)	0.000 (0.000)	
<i>Education</i>	-0.008 (0.184)		-0.008 (0.211)	
<i>Married</i>	-0.847 (0.650)		1.730** (0.736)	0.501 (0.511)
<i>Children</i>	-0.250 (0.222)		0.164 (0.245)	
<i>Hygiene</i>	-0.237 (0.525)		-0.66 (0.594)	
<i>Size</i>	0.571** (0.282)	0.532** (0.249)	0.066 (0.271)	

Note: Standard errors in parenthesis. Significance codes: 0.01***, 0.05**, 0.10*

Being knowledgeable (*Know*) about energy-efficiency and energy conservation practices turns out to only increase the probability of *Purchase* but not *Switchoff*. This could be explained by differentiating declarative knowledge from procedural knowledge (Baudelaire,

2014; Sardanou, 2008). In simple terms, the former refers to the “know-what”, while the latter can be understood as the “know-how”. From the survey questions, it would be reasonable to infer that *Know* is a closer proxy to declarative knowledge, and that *Experience* builds procedural knowledge. Both declarative and procedural knowledge are needed before one can make an informed *Purchase* of energy-efficient equipment, but the “know-what” for *Switchoff* is not as crucial a determinant as knowing the methods of minimizing energy-use in day-to-day operations of the hawker stall through *Switchoff*.

The estimated coefficient for *Stayinbusiness* only exhibits a positive significant effect on *Switchoff*, although it is expected that if hawkers intend to continue operating in the long-run, there should be an incentive to invest in energy-efficiency and yield future cost-savings. Heterogeneous effects are also found for *Nationality*, *Income* and $Income^2$ for *Purchase*, and *Race* and *Married* for *Switchoff*. One should note that the effect size of income is very small, and that the average marginal effect is calculated to be negligible. For *Nationality*, *Race* and *Married*, there are no clear explanations, although one could make inferences based on ground-experience and interactions with hawkers through the conduct of the survey. For example, the type of cuisine sold could be an omitted variable, but attempts to control for it did not improve the model.

Being part of a *Franchise* did not yield possible advantages through resource and knowledge spillovers. Perceptions of *Affordability* of energy efficient equipment did not significantly hinder *Purchase* decisions as well, suggesting that liquidity constraint is not a main concern for hawkers. Costs of electricity and gas use (*Electricitybill* and *Gasbill*) were expected to give a positive coefficient; if energy bills are high, potential cost savings through *Purchase* and *Switchoff* should be. Nonetheless. Lastly, larger stalls (*Size*) have a greater incentive to invest in efficiency.

2.5 DISCUSSIONS AND CONCLUSIONS

Overall, the empirical results suggest that energy-use reductions are motivated by both private cost-savings and positive environmental externalities. The cost-saving objective can be observed from the following: If hawkers intend to stay in the business for longer, they have a greater tendency to reduce energy wastage. If energy-costs are an important determinant of profits, there is greater incentive to both invest in efficiency and engage in energy-saving behaviours. On the aspect of social gains, respondents that reportedly have pro-environmental attitudes also behaves in more environmentally friendly ways.

From the multitude of explanations for the energy efficiency gap in the literature, it has been identified that insufficient information and liquidity constraints are prime candidate reasons in the food retail industry. Determining the validity of these explanations is paramount to designing public policy responses. Results from this study hint that to behave in an energy-saving manner takes experience and industry-specific knowledge. Anecdotal accounts through survey interviews could explain this; Switching off appliances or lighting could lead to delays in food preparation when a patron unexpectedly turns up, or could mislead approaching customers into thinking that the hawker stall is not operating. In comparison, promoting the adoption of energy-efficient technologies, often involving retrofitting old equipment, requires both experience and declarative knowledge. A handful of interviewees have casually dismissed this decision as one that is too difficult to gather information on, and usually base their investment decisions on word-of-mouth recommendations. It also appears that liquidity constraint is not a prominent issue; the relationship between energy-efficient investments and the perceived affordability of the purchase is an empirically unclear one.

The main policy implication is therefore to bridge the information gap, through industry focused-group sharing, or through directly providing and increasing the accessibility of technical information. The survey also found that hawkers have a low level of trust (average

of moderately reliable, score of 3.23/5) in energy-usage information provided by equipment suppliers. Perceptions amongst hawkers towards equipment salespeople are by-and-large negative. Direct government intervention in information provision would likely be helpful, and emphasis on both private and public benefits be ideal.

This chapter does not provide empirical support for specific policies, but investigation into the hawker sector gives an overall and cautious policy guidance. Meanwhile, it is necessary to point out some caveats to this study. The process of surveying hawkers is hectic and often riddled with interruptions from customers. This could have led to inconsistencies in data collection and measurement errors. To some extent, selection bias is present. The findings have to be verified using a larger sample size. The set of modelled independent variables is far from exhaustive and could result in omitted variable bias, although the study took some precautions in reducing confounding effects. For example, respondents were asked to estimate the cost-savings of energy efficiency. This is to identify the general extent of innumeracy. Others explanations for energy investment and usage decisions, and for other sectors, lies beyond the scope of this work and is left for future studies. Nonetheless, using this uniquely-collected dataset, the study provides further exploratory findings, which are intentionally excluded from the main text and left in the Appendix. Topics that are covered include: 2.6.2 Pairwise comparison on the response to carbon tax; 2.6.3 Principal-agent problem; and 2.6.4 Payback period using doubled-bounded Contingent Valuation Method. These analyses were conducted in consideration of identifying possible confounds to the main study and findings.

2.6 APPENDIX

2.6.1 Survey overview

Part 1

Q							
1	Age	21-30	31 - 40	41 - 50	51 - 60	61 - 70	71+
2	Gender	Male	Female				
3	Nationality	Singaporean		Others: ____			
4	Race	Chinese	Malay	Indian	Others: ____		
5	Monthly income (to the nearest thousand)	\$ ____					
6	Highest education level attained	No formal education	Primary school	Secondary school	Vocational training/ITE	Junior college/Diploma	Degree/Post-graduate
7	Marital status	Single	Married	Divorced	Widowed		
8	No. of children	____					
9	Stall's hygiene rating	A	B	C			
10	No. of staff members working at stall at any one point in time	____					
11	Is your stall part of a franchise?	Yes	No				
12	Type of cuisine sold	____					
13	No. of years working in the food retail industry	____					
14	How did you obtain the current energy equipment at stall	Passed down	Purchase	Rental			

Part 2

Q	In the context of your business operations:					
15	Do you actively seek information about the alternative options for energy-efficient equipment during purchase?	1: Never	2	3	4	5: Always
16	To what extent do you think you are aware of available purchase options?	1: Totally unaware	2	3	4	5: Extremely aware
17	Are you familiar with the monetary cost-savings pertaining energy-efficiency within the stall?	1: Not familiar at all	2	3	4	5: Extremely familiar
18	For an energy efficient commercial refrigerator that offers energy savings of 40% compared to an average model, how much money do you think you can save per month?	\$ ____				
19	Do you actively seek information about other ways to reduce energy consumption?	1: Never	2	3	4	5: Always
20	To what extent do you think you are aware of methods to reduce wastage of energy?	1: Totally unaware	2	3	4	5: Extremely aware
21	Are you familiar with the monetary cost-savings pertaining reducing wastage within the stall?	1: Not familiar at all	2	3	4	5: Extremely familiar
22	If you were to always switch off all energy equipment when not in use, how much money do you think you can save per month?	\$ ____				
23	What is the average monthly gas bill for your stall?	\$ ____				
24	What is the average monthly electricity bill for your stall?	\$ ____				
25	To what extent does the electricity & gas bill affect the profitability of your stall	1: Not at all significant	2	3	4	5: Extremely significant
26	How frequently do you monitor changes to your monthly gas and electricity bill for your stall?	1: Never	2: Once every year	3: Once every 6 months	4: Once every quarter	5: Once every Month

27	Do you find energy-efficient equipment to be affordable during purchase?	1: Not affordable	2	3	4	5: Extremely affordable	
28	For long do you think your stall will certainly remain in operation?	0-2 years	3-4	5-6	7-8	9-10	>10 years
29	Rate the level of importance for energy-efficiency for a stove/burner	1: Not important at all	2	3	4	5: Extremely important	
30	Rate the level of importance for energy-efficiency for a deep fryer/an oven	1: Not important at all	2	3	4	5: Extremely important	
31	Rate the level of importance for energy-efficiency for a refrigerator/freezer	1: Not important at all	2	3	4	5: Extremely important	
32	Rate the level of importance for energy-efficiency for a boiler/hot water generator	1: Not important at all	2	3	4	5: Extremely important	
33	Rate the level of importance for energy-efficiency for a rice/noodle cooker	1: Not important at all	2	3	4	5: Extremely important	
34	Rate the level of importance for energy-efficiency for lighting	1: Not important at all	2	3	4	5: Extremely important	
35	Overall, rate the level of importance for energy-efficiency for equipment/appliances	1: Not important at all	2	3	4	5: Extremely important	
37	How often do you remember to switch off your stove/burner when not in use?	1: Never	2	3	4	5: Always	
38	How often do you remember to switch off your deep fryer/oven when not in use?	1: Never	2	3	4	5: Always	
39	How often do you remember to switch off your refrigerator/freezer when not in use?	1: Never	2	3	4	5: Always	
40	How often do you remember to switch off your boiler/hot water generator when not in use?	1: Never	2	3	4	5: Always	
41	How often do you remember to switch off your rice/noodle cooker when not in use?	1: Never	2	3	4	5: Always	
42	How often do you remember to switch off your lights when not in use?	1: Never	2	3	4	5: Always	
43	Overall, how often do you remember to switch off your equipment/appliances	1: Never	2	3	4	5: Always	

Part 3

44	How much do you trust the information provided by suppliers relating to cost-savings from commercial energy-efficient equipment for your stall?	1: Complete distrust	2	3	4	5: Complete trust
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45	<p>We are interested in examining the investment decisions of hawkers, specifically on their maximum acceptable Payback Period in purchasing commercial energy efficient equipment.</p> <p>Fridge A: You purchase a commercial energy-efficient refrigerator that costs \$3000. If you take 3 years to earn back \$3000 from savings in your electrical bill, the Payback Period is 3 years.</p> <p>Fridge B: You purchase a commercial energy-efficient refrigerator that costs \$6000. If you take 5 years to earn back \$6000 from savings in your electrical bill, the Payback Period is 5 years.</p> <table border="1"> <thead> <tr> <th></th> <th>Fridge A</th> <th>Fridge B</th> </tr> </thead> <tbody> <tr> <td>Cost</td> <td>\$3000</td> <td>\$6000</td> </tr> <tr> <td>Cost-Savings</td> <td>\$1000 per year</td> <td>\$1200 per year</td> </tr> <tr> <td>Payback Period</td> <td>3 Years</td> <td>5 Years</td> </tr> </tbody> </table> <p>Therefore, a shorter Payback Period is better, as your investment takes less time to break-even.</p>							Fridge A	Fridge B	Cost	\$3000	\$6000	Cost-Savings	\$1000 per year	\$1200 per year	Payback Period	3 Years	5 Years
	Fridge A	Fridge B																
Cost	\$3000	\$6000																
Cost-Savings	\$1000 per year	\$1200 per year																
Payback Period	3 Years	5 Years																

a	Suppose you are presented with an opportunity to invest in a commercial energy-efficient equipment for your stall, will you invest if the equipment has a Payback Period of 1 year?	Yes	No
b	Will you invest if the equipment has a Payback Period of 2 years?	Yes	No
c	Will you invest if the equipment has a Payback Period of 3 years?	Yes	No
d	What is the maximum length of Payback Period you are willing to accept for the purchase of commercial energy-efficient equipment?	___ months	

46	At your stall, rank the importance of the following factors when purchasing new commercial electrical equipment. (1 = Most important, 5 = Least important)	Price: ____ Design and aesthetics: ____ Functionality and ease of operation: ____ Durability: ____ Energy efficiency: ____				
47	At your home, rank the importance of the following factors when purchasing new household electrical appliance. (1 = Most important, 5 = Least important)	Price: ____ Design and aesthetics: ____ Functionality and ease of operation: ____ Durability: ____ Energy efficiency: ____				
48	At your stall, how often are the following behaviours practiced?					
a	Switch off electrical appliances when not in use	1: Never	2	3	4	5: Always
b	Turn off the tap when not in use	1: Never	2	3	4	5: Always
c	Purchase energy efficient equipment	1: Never	2	3	4	5: Always
d	Purchase Environmentally-friendly products	1: Never	2	3	4	5: Always
e	Reduce plastic usage (e.g. packaging)	1: Never	2	3	4	5: Always
49	At your home, how often are the following behaviours practiced?					
a	Switch off electrical appliances when not in use	1: Never	2	3	4	5: Always
b	Turn off the tap when not in use	1: Never	2	3	4	5: Always
c	Purchase energy efficient equipment	1: Never	2	3	4	5: Always
d	Purchase Environmentally-friendly products	1: Never	2	3	4	5: Always
e	Reduce plastic usage (e.g. packaging)	1: Never	2	3	4	5: Always

50	A carbon tax was introduced in Singapore starting 2019, at a rate of S\$5 per tonne of greenhouse gas emissions (tCO₂e)	
	In view of the energy price increase, which option would your stall be more likely to adopt? Choose 1 of 2.	
a	Invest in commercial energy-efficient equipment to save energy cost	Increase the price of my products / Reduce the serving size
b	Invest in commercial energy-efficient equipment to save energy cost	Adjust labour cost (e.g., owners commit to longer working hours, reduction in number of workers, reduction in workers' hours/salary)
c	Invest in commercial energy-efficient equipment to save energy cost	Status quo and absorb the extra cost, incurring a loss in profits
d	Increase the price of my products / Reduce the serving size	Adjust labour cost (e.g., owners commit to longer working hours, reduction in number of workers, reduction in workers' hours/salary)
e	Increase the price of my products / Reduce the serving size	Status quo and absorb the extra cost, incurring a loss in profits
f	Adjust labour cost (e.g., owners commit to longer working hours, reduction in number of workers, reduction in workers' hours/salary)	Status quo and absorb the extra cost, incurring a loss in profits

Part 4

51	Do you agree with the following statements?					
a	The effects of climate change are a significant concern.	1: Strongly disagree	2	3	4	5: Strongly agree
b	I am environmentally friendly even if others are not environmentally friendly.	1: Strongly disagree	2	3	4	5: Strongly agree
c	I am environmentally friendly not only because it saves money.	1: Strongly disagree	2	3	4	5: Strongly agree
d	Singapore should combat climate change even when other countries are not doing so.	1: Strongly disagree	2	3	4	5: Strongly agree
e	Being environment friendly is important to me.	1: Strongly disagree	2	3	4	5: Strongly agree

2.6.2 Pairwise comparison and response to carbon tax

In Q50 of the survey, binary choices were presented regarding the business responses to the implementation of carbon tax. This is an application of the pairwise comparison method, where a cardinal ranking is derived from a series of alternative pairs. The pairwise comparison method has advantages over direct ranking of items; binary choices are easy to make for the respondents where choices are finite and distinct.

Four main responses/outcomes to the carbon tax were identified: Lowering labour cost; taking no action against the increase in energy price and earning less; increasing price of food product or reducing serving size; investing in energy-efficiency. Six combinations of these four choices were provided to the respondents in Q50.

This part of the study was only administered during the first wave of survey. Using the variance stable rank method, the ordinal and cardinal rankings are as follows:

- (1) Investing in energy efficiency; with a cardinal score of 62.5
- (2) Inaction and absorbing the higher cost; with a cardinal score of 54.2
- (3) Lowering labour cost; with a cardinal score of 43.3
- (4) Raising prices or reducing serving size; with a cardinal score of 40.0.

The unexpectedly large preference towards energy efficiency could possibly be explained by the warm glow effect (and learning effect towards the end of the survey). Another point to note is that the impact of the carbon tax on small retailers is only calculated to be a 1% increase in energy cost. It seems that respondents have overestimated its impacts. Kendall's coefficient of concordance = 0.059*** show that consensus between respondents was low.

2.6.3 Principal-agent problem; work-home heterogeneity

Stall owners and staff were separated and tested for between-group differences in *Switchoff*, but a t-test did not find any evidence of the principal-agent problem. This could be due to the close-proximity work relationship or low cost of monitoring.

Testing the difference in Q48 and Q49 also found that respondents conserve more energy at home than in the workplace, although this could not be easily explained.

2.6.4 Payback period using doubled-bounded question

In Q45, a double-bounded question was conducted for the payback period of efficient equipment. Double-bounded questions are usually used for Contingent Valuation Methods in estimating WTP, but a variation here was applied in experimentation to elicit the maximum payback period. Results found that the mean payback period was less than two years, much shorter than what the market offers, suggesting an unrealistically high level of impatience.

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Conclusion

The two chapters provides a better understanding of consumers' preferences in energy-efficiency investments and consumers' behaviours in energy consumption. Overall, there is no strong evidence of an energy efficiency gap in Singapore's household sector and food retail industry. Examining the determinants driving energy investments and usage has provided useful insights. For example, environmental attitudes are a key driver of energy savings. Information failures exist to a greater extent for commercial energy equipment, whereas Energy Labels for household appliances are generally able to increase consumers' Willingness-To-Pay. Liquidity constraints are also unique to the food-retail sector where profit margins are small. As such, policy suggestions have been made with respect to the findings of this research.

It is important to recognise that both chapters employ stated preference approaches; Chapter 1 utilises a Discrete Choice Experiment whereas Chapter 2 utilises a stated survey. While the findings are found to be robust and comparable to the literature, a potential disparity between stated and revealed preference approaches could still exist. This remains the main caveat of this study. For future research, moving beyond a hypothetical marketplace and studying the actual behaviours of consumers, through expressed preference surveys, would build on the existing findings.

Another limitation across both studies is that the context is constrained to Singapore, which presents an isolated case study. For example, Energy Labels differ across jurisdictions, and the findings of Chapter 1 cannot conclude that Energy Labels broadly work in narrowing the information gap in other nations. The hawker industry is also dissimilar to the food retail industry worldwide. Therefore, the external validity of the study might be limited, subjected to the effects of differing cultures, lifestyles, and political systems. This is a topic to be explored in future research.

Lastly, in light of the recent 2021 energy crunch and energy price surge, the investment and usage behaviours could be greatly affected. In the second study, respondents were asked to react to an increase in electricity tariffs brought about by a carbon tax, which is a small increase in price and in the name of environmental conservation. The larger magnitude of a price spike globally could have interesting impacts that is certainly worth examining.