A BEHAVIORAL PERSPECTIVE ON TRANSITION PATHWAYS TO CLEAN COOKING FUELS: THE CASE OF LIQUEFIED PETROLEUM GAS (LPG) USAGE IN INDIA

by

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Abstract

About 2.9 billion people, primarily in rural areas of low-income countries, do not have access to clean cooking fuels (e.g. gas and electricity). Instead, they burn solid fuels (e.g. firewood and coal) in polluting primitive cookstoves. These traditional cooking methods and associated solid fuel gathering practices, contribute to gender inequalities, forest degradation, climate change and millions of premature deaths annually due to air pollution. Even when households adopt (acquire) clean cooking solutions, often both solid and clean fuels are used. Past research has rarely focused on post-adoption fuel choices. Moreover, while socio-economic demographics like income and education are identified as key transition factors, these are not amenable to near-term change. I drew upon three influential behavior change and technology adoption theories to develop a conceptual framework of self-regulatory behavior change to understand post-adoption usage and expedite the transition process. I developed hypotheses involving psychological variables to explain the how and why of transition across the pre and post-adoption periods, which I tested in the context of liquefied petroleum gas (LPG) use in rural India. I accessed gas purchase records for all LPG users (N= 25,000) across 126 villages in Karnataka and administered two cross-sectional household sample surveys (n1=402, n2= 205). Three novel insights emerge from this research. First, the majority of consumers do not use LPG as their primary cooking fuel and, contrary to studies based on self-reports, LPG use does not increase with experience or familiarity. This highlights the need for post-adoption interventions. Second, in line with theory, the transition is a five-stage process, wherein people in different stages have significantly different perceptions of the advantages, disadvantages, and self-confidence related to regular LPG use. Further, perceived disadvantages emerge as more influential during the transition compared to household wealth, highlighting the need for behavior change strategies. Third, the comparison of self-reports of use with purchase data shows 2/3rd of respondents over-reporting LPG use, highlighting the need to account for survey biases. Overall, the dissertation shows that the application of behavior change theories and the use of fuel sales data provided valuable insights about post-adoption fuel choice decisions.
Lay Summary

About 2.9 billion people burn solid fuels like firewood to cook food. This has adverse health, environmental and societal consequences. Even when rural poor adopt clean cooking solutions like Liquefied Petroleum Gas (LPG), they continue to use both clean and solid fuels. The determinants of transition from solid to clean fuels in the post-adoption phase are under-studied.

I created a conceptual framework to understand transition using behavior change theories. I administered two household surveys and analyzed multi-year LPG purchase records to understand the why and how of the transition to LPG in rural India. I found that the transition is a five-stage process wherein psychological variables emerge as more important than socio-economic demographics. Surprisingly, experience with LPG did not help increase LPG use over time and most people over-report usage when asked. Additional research on the transition process after technology adoption through the lens of behavior change is recommended.
Preface

Four original stand-alone research chapters (Chapter 2-5) are included in this dissertation and are published/intended for publication in peer-reviewed journals. I am the primary responsible person for this work. In all of the research chapters, my contributions include: 1) identification of research objectives and specific research questions, 2) developing the study design including methodology, 3) undertaking research activities, 4) conducting primary and secondary data collection and analysis, and 5) preparing the manuscripts.

My Ph.D. supervisory committee comprises Professor Hisham Zerriffi, Professor Michael Brauer and Dr. Sumi Mehta. They have helped in shaping my doctoral research objectives and research proposal. They provided invaluable feedback to my multiple research proposal drafts and guided me on what questions to focus on for analysis keeping the policy relevance of the study in mind. My Ph.D. supervisor, Prof. Hisham Zerriffi, contributed to the data analysis in terms of providing new ways to examine the data, offered a competing interpretation of results, and drew attention to the limitations/conceptual shortfalls of the work. My supervisory committee members also provided comments for the revision of several drafts for each of the chapters included in my dissertation.

Chapter 2: A conceptual framework of cooking energy transition using behavior change theories

In this chapter, I conducted the literature review, developed the conceptual framework, and wrote the manuscript. Hisham Zerriffi helped with refining the conceptual development and provided valuable comments for the revision of several drafts. Three anonymous reviewers for the Energy Research and Social Science offered constructive comments on the manuscript, scope, and structure of the paper. A paper closely based on this dissertation chapter has been published in the Energy Research and Social Science journal in August 2018. https://doi.org/10.1016/j.erss.2018.02.015
Chapter 3: Cooking Energy Transition and ‘Ujjwala’ in rural communities

In this chapter, I designed the study, collected the secondary data, conducted the literature review, performed data collection and analysis, and wrote the manuscript. Dr. Shonali Pachauri and Dr. Hisham Zerriffi offered valuable comments on the approach to data analysis, helped with the interpretation of findings and provided comments for the revision of several drafts. Three anonymous reviewers for the Nature Energy offered constructive comments on the manuscript content and outline, suggested additional analyses, and provided inputs on the scope and structure of the paper. Dr. Shonali Pachauri, Dr. Rob Bailis and Dr. Hisham Zerriffi reviewed the manuscript, suggested a new data analysis approach, and proposed changes to manuscript to address reviewer comments. A paper closely based on this dissertation chapter will be published in the Nature Energy journal in July/August 2018 titled: “Using sales data to assess cooking gas adoption and the impact of India’s Ujjwala program in rural Karnataka”. The codes for the plots and analysis are available at https://figshare.com/s/985a99cca3fcd6787260 (National data analysis) & https://figshare.com/s/8f2f6d2b5cd06ac665d0 (Field Site- Koppal data analysis)

Chapter 4: Transition stages, and the transtheoretical model of change

In this chapter, I designed the study, conducted the literature review, performed data collection and analysis, and wrote the manuscript. Dr. Hisham Zerriffi contributed to the conceptual development, provided valuable insights into the analysis and interpretation of findings, and provided valuable comments for the revision of several drafts. Dr. Jiaying Zhao and Dr. Elisa Puzzolo helped with the identification of research questions, finalizing the data analysis methods, proposed several methods to analyze data and suggested an interpretation of findings. A paper based on this dissertation chapter will be
submitted to an interdisciplinary journal in the field of development studies or social psychology. The codes for the plots and analysis are available at

https://figshare.com/s/2a984012207b8102f67e

Chapter 5: Cooking fuel choices, the theory of planned behavior and survey biases

In this chapter, I designed the study, conducted the literature review, performed data collection and analysis, and wrote the manuscript. Dr. Hisham Zerriffi and Dr. Michael Brauer contributed to the conceptual development, provided valuable insights into the analysis and interpretation of findings, and provided valuable comments for the revision of several drafts. Dr. Jiaying Zhao and Dr. Rob Bailis helped with the identification of research questions, finalizing the data analysis methods, proposed several methods to analyze data and suggested an interpretation of findings. A paper based on this dissertation chapter will be submitted to an interdisciplinary journal in the field of development studies or social psychology. The codes for the plots and analysis are available at

https://figshare.com/s/d4b8ca165f13d68d4a48

This research was approved by the Behavioral Research Ethics Board at the University of British Columbia (UBC BREB Number: H16-00017, Project Title: SAMUHA SEWA-GLPGP Monitoring and Evaluation).
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List of Abbreviations

BPCL: Bharat Petroleum Corporation Limited
CCS: Clean Cooking Solutions
HAP: Household Air Pollution
HPCL: Hindustan Petroleum Corporation Limited
IOCL: Indian Oil Corporation Limited
LPG: Liquefied Petroleum Gas
OMC: Oil Marketing Company
PC: Precontemplation stage
PCA: Principal Component Analysis
PMUY: Pradhan Mantri Ujjwala Yojana (in Hindi, means Prime Minister LPG Program)
SE: Self-Efficacy
TCS: Traditional Cooking Solutions
TPB: Theory of Planned Behavior
TTM: Transtheoretical Model
WHO: World Health Organization
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It has been a long professional journey which began with my school teachers at St. Pauls in Khidderpore, Kolkata. I was never in the top 50% of the class, in any subject ever, till grade IX. I still remember the shock filled joy to once get the highest marks in English literature in IX standard. Mr. S. D’Costa’s style of teaching Shakespeare which even I could understand and his personal attention made me realize the important lesson: If I try hard enough, with adequate guidance, I can master any topic. It really helped me to upgrade my skills in R programming language with almost nil experience in programming fairly quickly. Moreover, his openness to me asking questions repeatedly, till I was satisfied, was fundamentally consequential in terms of building up my self-confidence. Thank you D’Costa Sir for preparing me to stand my ground, in a polite but firm way, during my interactions with a host of people in positions of authority over the years- from a professor to a cabinet minister.

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My research career formally began at the Indian Institute of Forest Management, Bhopal. Dr. D. Debnath was my first research guide. He mentored my first field research in a village in Madhya Pradesh. Guided me through every step. I made numerous mistakes in terms of framing questions and the flow of

\(^1\) Disclaimer: The EPA has not formally reviewed it. The views expressed in this document are solely mine and do not necessarily reflect those of the Agency. EPA does not endorse any products or commercial services mentioned in this publication.
the case study which I prepared from this fieldwork. He never once showed his frustration and patiently taught me the ABCs of research. Getting paid a princely sum of 350 dollars by publishing the case study in the Stockholm Research Institute newsletter gave me far more extrinsic motivation to do good research than the prestigious 2-year 50,000 dollars CREATE AAP scholarship. I am also grateful to Dr. C.S. Rathore, the manifestation of a perfect teacher. I still remember after class discussion with my room mate Rishi that we have never seen a better teacher- in terms of the complete package of content and delivery. He was by far the best teacher then, and even after four years at UBC, he will rank number 1 in terms of his sheer capability to create content for a diverse audience and deliver with a soft-spoken yet charming élan.

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Dedication

To

Ma, Trina & Hiya

&

Millions of mothers and sisters who aspire to cook in a smokeless kitchen...one day
1. Introduction

About 2.9 billion people, sans access to clean fuels, rely on solid fuels like biomass (wood, cattle dung, agricultural residue) and coal in ancient three stone fire or mud stoves to cook food every day (IEA, IRENA, UNSD, WB, WHO, 2019). Clean fuels for the purpose of the thesis are fuels with zero or negligible emissions, such as biogas, liquefied petroleum gas (LPG), electricity and natural gas (known as BLEN fuels)\(^2\). In addition, there are millions of people who own (uptake or adopt\(^3\)) clean cooking solutions who continue to stack fuels, i.e. use both solid and clean fuels (Gordon & Hyman, 2012; Gould et al., 2018; Ruiz-Mercado & Masera, 2015). The incomplete combustion of solid fuels in such traditional cooking solutions (TCS) results in the emission of health-damaging and climate-altering gases and particles (Grieshop, Marshall, and Kandlikar, 2011). A recent study has indicated that about 3.6 billion people are exposed to household air pollution from the burning of solid fuels for cooking purposes (Health Effects Institute, 2019). Household air pollution has severe public health (HEI Household Air Pollution Working Group, 2018; Smith et al., 2014; World Health Organization, 2014), environmental (Robert Bailis, Drigo, Ghilardi, & Masera, 2015; Masera, Bailis, Drigo, Ghilardi, & Ruiz-Mercado, 2015), and developmental (Dutta, Kooijman, & Cecelski, 2017; Parikh, 2011) consequences which has an economic cost in billions of dollars annually (Putti, Tsan, Mehta, & Kammila, 2015).

Increasing evidence of the climate and public health impacts of traditional cooking coupled with innovations in technology and financing (e.g. carbon credits) have renewed policy and media attention to the issue of clean cooking energy access in recent years (Khandelwal et al., 2017; Lewis and Pattanayak, 2012). Transition from solid fuels to clean cooking fuels at a mass scale has been historically associated with these factors- individually or in combination: urbanization (e.g. Brazil), increased household income, 

\(^2\) Solar and Ethanol stoves are not included as they are not yet at market commercialization stage for household purpose at a global scale

\(^3\) As the word ‘adopt’ has different connotations in the literature, hence forth we use the word *uptake* to signify purchase or acquisition of a new clean cooking technology- such as LPG stove
high government fuel subsidy (e.g. Ecuador)/ gross domestic product (GDP) growth, and regulations (e.g. household coal burning ban in China) (Barrington-Leigh et al., 2019; Gould et al., 2018; McLean et al., 2019; Quinn et al., 2018; Zhao et al., 2018). This thesis focuses on rural, low-income communities in developing countries across Asia and Africa (with limited ability to subsidize clean fuels) where strict regulation enforcement at the household level is unlikely in the near future. My thesis is primarily situated in the Indian context where a massive new program- *Ujjwala* to promote LPG to the rural poor is in effect since 2016.

Past research on clean cooking transitions and fuel choices (Lewis & Pattanayak, 2012; McLean et al., 2019; Puzzolo, Pope, Stanistreet, Rehfuess, & Bruce, 2016) have often focused on socioeconomic demographics of the population (e.g. education, income etc.) and fuel cost, “reflecting a pro-innovation bias” (Jagadish & Dwivedi, 2018). These studies do not help guide the transition as many of those adverse demographic/ market conditions are not amenable in the near term (e.g. education) or under the control of clean technology promoters (e.g. NGOs/ LMIC national governments cannot influence international gas prices). Hence, there is a need to better understand the understudied aspects of willingness and choice in the household decision making within these adverse conditions (Jagadish & Dwivedi, 2018). Surprisingly, the application of behavior change theories, especially in the post-uptake phase of clean cooking solutions is mostly missing in the current literature (Thompson, Diaz-Artiga, Weinstein, & Handley, 2018). In this dissertation, I frame the problem of clean cooking energy transition in the target communities as a behavior change problem (Chapter 2), assess the level of transition (Chapter 3), and then use behavior change theories (Chapters 4 and 5) from other domains to provide novel insights to the transition process. While there are other effective pathways to change such as urbanization, fuel subsidy and regulations, I argue that for the vast majority of households without clean cooking energy access behaviour change may be a useful tool.

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4 Low and middle income countries (LMICs)
1.1 Why ‘clean cooking’ matters?

A recent study estimates that 3.6 billion people are exposed to household air pollution (HAP), often at levels that far exceed the standard guidelines for clean air (Health Effects Institute, 2019). World Health Organization guidelines for annual average PM2.5 concentration (benchmark) and interim target are 10 μg/m3 and 35 μg/m3 respectively. In contrast, the average exposure to HAP for men, women, and children were 120, 160, and 140 μg/m3 respectively in rural households where traditional solid fuels were used for cooking (Shupler et al., 2018).

Exposure to high levels of HAP from solid fuel usage causes millions of deaths. However, the mortality estimates vary due to methodological differences. The World Health Organization (WHO) estimates that deaths attributed to HAP are 3.8 million in 2016, while the Health Effects Institute puts a lower estimate of 1.6 million deaths in 2017 (Health Effects Institute, 2019). Past studies have reported that population with household air pollution exposure were 41% more likely to have chronic obstructive pulmonary disease (COPD) outcomes (Siddharthan et al., 2018), 16% more likely to suffer from hypertension (Arku et al., 2018), 78% more likely to encounter life-threatening respiratory illness [in children] (Upadhyay, Singh, Kumar, & Singh, 2015), 95% higher risk of lung cancer [in women] (Bruce et al., 2015), and 20% greater risk of cardiovascular mortality due to ischemic heart disease and stroke (Yu et al., 2018). Furthermore, household air pollution is responsible for a multitude of adverse pregnancy outcomes, including stillbirth and low birth weight (Adeladza K. Amegah, Quansah, & Jaakkola, 2014). Exhaustive literature reviews (HEI Household Air Pollution Working Group, 2018; Smith et al., 2014; World Health Organization, 2014) on this topic suggest that household air pollution is a serious threat to public health across Asia and Sub Saharan Africa. HAP is also responsible for more than 25% of ambient air pollution in South Asia and southern sub-Saharan Africa (Chafe et al., 2014).

Further, TCS contributes significantly (18%-30%) to anthropogenic black carbon (BC-commonly is known as soot) emissions (Masera, Bailis, Drigo, Ghilardi, and Ruiz-Mercado, 2015). One study has claimed that Black Carbon is the second most important anthropogenic emission in terms of its climate
forcing in the present-day atmosphere; the best estimate of industrial-era climate forcing of black carbon, carbon dioxide, and methane are +1.1 W/m², +1.56 W/m², and +0.86 W/m² respectively (Bond et al., 2013). Despite wood being a renewable energy source, TCS also contributes to a net increase in greenhouse gas emissions as 27%-34% of the wood fuel harvest is unsustainable (Masera et al., 2015; Sanford and Burney, 2015).

Moreover, as women and young children are generally responsible for the collection, processing, and transportation of solid fuels, reliance on TCS not only undermines their safety but also restricts educational and economic opportunities (Parikh, 2011). Using data from India, Bangladesh, and Nepal, one study has claimed that women spend approximately 374 hours every year collecting firewood and spend 4 hours cooking every day when using traditional stoves (Bloomfield & Malla, 2014). However, there is only mixed evidence of the effectiveness of improved cooking solutions to prevent gender violence, particularly in refugee camp settings, though it is often highlighted by donor agencies (Abdelnour & Saeed, 2014). Overall, the “mid-range economic value of the health, environmental and economic effects” of TCS usage is estimated to be $123 billion ($22-224 billion) per year (Putti, Tsan, Mehta, and Kammila, 2015).

1.2 What is clean cooking?

Enhancing access to cleaner cooking technologies has emerged as a top-priority agenda for a number of governments and international bodies, resulting in major global and national initiatives (Malla and Timilsina, 2014). International bodies like the ‘Clean Cooking Alliance’ (CCA) have promoted enhanced access to “clean cooking solutions” or CCS- an umbrella term that encompasses a multitude of technologies with varying performance and price (Jetter et al., 2012; Urmee and Gyamfi, 2014).
Broadly two types of approaches and interventions⁵ are currently being undertaken to promote clean cooking—making the ‘clean’ available and making the available ‘clean’ (Smith, 2014). First, accelerate access to modern commercial cooking fuels—electricity and liquefied petroleum gas (LPG), or its variants (along with accompanying devices) that can result in dramatic reductions in emissions (World Health Organization, 2014). For example, the government of India has introduced a major scheme named Ujjwala Yojana that subsidizes capital cost related to new LPG connection along with mass-media campaigns promoting LPG. It has enabled 70 million poor households in rural India to get an LPG stove in the last three years (PIB, 2019). However, due to affordability and supply chain challenges related to commercial cooking fuels, it is unlikely that they would fully replace solid fuels in the foreseeable future (WEO, 2017). Hence, as the second near-term approach, dissemination of and market creation for 1) household level devices that burn solid fuel more efficiently (often called "improved" [biomass] cookstoves- ICS) and/or 2) processed solid fuels (e.g. pellets- densified biomass) or charcoal that burns more efficiently has been undertaken (Urmee and Gyamfi, 2014). For example, the private sector and government subsidy have helped the promotion of ICS in 33% of rural households in Ethiopia (Putti et al., 2015). It has been argued that ICS would not truly reduce HAP health risks; “to actually reduce health impacts significantly…only achievable by gas or electricity at scale” (Smith and Sagar, 2014) with only marginal climate gains (Jetter et al., 2012; Simon, Bailis, Baumgartner, Hyman, & Laurent, 2014).

Against this context, a somewhat arbitrary classification of ‘cleaner’ (than TCS- the baseline situation) and ‘clean’ (safe levels of emissions) cooking solutions have emerged. Among popular technologies, electric stoves, LPG stoves, and Tier IV ICS with pellets (high density processed biomass fuel) are generally considered to be ‘clean’ cooking fuels which can have wide-ranging positive health, environmental, and societal consequences, if and when they replace solid fuels.

⁵ The general term “intervention” is used throughout to describe “any legislation, regulation, policy, program, project activity, or event” (Wilson and Dowlatabadi, 2007) that aims to promote clean cooking.
Instead of wading into the technological and emission/efficiency performance differences in various cooking solutions, I use a technology agnostic definition for my purpose to define ‘clean cooking’. Hereafter, I use the term ‘clean cooking solutions’ to imply commercially available stoves that burn commercial fuels—be it electricity, gas or pellets\(^6\), which cannot be typically\(^7\) gathered free of cost, are considered to be reasonably clean, and which require a market system based supply chain. Biogas, part of the BLEN technologies that are considered to be the cleanest and safest by both leading technology metrics developed by International Organization for Standardization (ISO) and World Bank’s Global Tracking Framework (GTF) (Fuso Nerini, Ray, & Boulkaïd, 2017), does not typically require a commercial fuel supply chain.

### 1.3 Who is the target for clean cooking interventions?

My target communities are primarily situated in ‘developing economies’—as defined by the United Nations (UN, 2019)—in Africa, Asia and Latin America (Bonjour et al., 2013). Governments in some of these countries are too “cash-strapped” to even extend the electricity grid in rural areas (Economist, 2016). The ‘cooking’ energy-poor are overwhelmingly low-income households who often survive on subsistence-level income from informal jobs, with low levels of “disposable” cash to buy non-essential items like commercial fuels where free alternatives are generally available (Khandelwal et al., 2017; P. Kumar, Kaushalendra Rao, & Reddy, 2016; Malakar, 2018). The target communities are live in ‘rural’ areas which are characterized by greater access to non-monetized solid fuels compared to their urban counterparts wherein, agriculture and allied activities as the primary occupation of the rural population. Moreover, rural areas on average have lower education levels and lower economic opportunities for both genders, greater dependence on agriculture, and higher gender disparity in

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\(^6\) Household often burn solid fuel in pellet stoves that result in inferior stove performance

\(^7\) Ignoring the prevalence of illegal hooking of electricity, for example, for now
household level decision-making. (Khandelwal et al., 2017; Quinn et al., 2018). So, rural low-income households in developing countries are the primary targets of clean cooking interventions.

1.4 What is the clean cooking energy transition?

Ideally, a clean cooking transition in the target communities starts with the purchase of a clean fuel stove kit (stove, initial bottle/bag of commercial fuel and accessories), which typically leads to initial fuel stacking (simultaneous use of both clean and solid fuels). In a successful transition, clean fuels replace solid fuels as the primary cooking fuel. It is followed by sustained and growing CCS use which ultimately should lead to solid fuel displacement, i.e. clean fuels are used exclusively, or near exclusively (Ruiz-Mercado, Masera, Zamora, and Smith, 2011). This transition pathway may look different if there were a ban on the use of solid fuel, like the ban on household coal burning in Beijing and surrounding areas in China (Barrington-Leigh et al., 2019). However, I have made the assumption that such regulations would not be politically tenable or enforced or effective in the target communities across many countries in Asia and Africa.

While the word “adoption” (Lewis & Pattanayak, 2012; Palit & Bhattacharyya, 2014; Slaski & Thurber, 2009) has been commonly used in transition literature, I generally refrained from using it considering the very different ideas associated with the word (Shankar et al., 2014). Some studies (Ruiz-Mercado, Masera, Zamora, & Smith, 2011; Stanistreet, Puzzolo, Bruce, Pope, & Rehfuss, 2014) have offered time frame linked definitions of adoption (as "acquisition and initial use of less than one year") and sustained use (as usage for "more than one year after acquisition"). Adoption has also been characterized in terms of intensity of usage, such as correct, consistent use over time, as the main or only stove (Jürisoo & Lambe, 2016). Some others view adoption as a process that includes “some” (Lewis & Pattanayak, 2012) or “substantive” (Shankar et al., 2014) level of continued usage. A broader definition of adoption (Troncoso, 2014) (that is focused on ICS) suggests that adoption is achieved only when “the
user likes having the stove, knows how to use it, uses it on a regular basis, and maintains the stove in good working condition”.

After a preliminary literature review, I modified this three-stage purchase, initial stacked use, and exclusive clean fuel use pathway, and used two additional stages of transition (which is validated later in Chapter 4) (Figure 1-1: Cooking energy transition). First, the target households who use TCS exclusively and do not have plans in the near future to contemplate transition are considered as the baseline. Also, I also consider someone who plans (not, wishes or desires or aspires!) to move towards clean cooking as a step towards transition.

Figure 1-1: Cooking energy transition The green boundary on the left of the image suggest in-depth research on the topics around determinants of access and purchase. The right side of the transition journey suggests with a red border is where the knowledge gaps are situated.
1.5 Why is the transition in target communities challenging?

Some developing nations like Brazil, Ecuador or Indonesia with high urbanization with concomitant economic development and high CCS subsidy achieved success in displacing TCS as the primary cooking fuel (Suani Teixeira Coelho, Sanches-Pereira, Tudeschini, & Goldemberg, 2018; Gould et al., 2018; Thoday, Benjamin, Gan, & Puzzolo, 2018). Urbanization leads to modernity as well as lower access to solid fuels, while economic development allows governments to provide higher levels of CCS subsidies, raising incomes to afford commercial fuels as well as increasing the opportunity cost of solid fuel gathering (Andadari, Mulder, & Rietveld, 2014; Puzzolo et al., 2016; Troncoso & Soares da Silva, 2017; WEO, 2017). Urban households are more likely to move away from solid fuels as they have higher monetary costs of solid fuels or higher opportunity costs of time & effort and even stronger perception of fuel scarcity, and also would have access to electricity which “spurs people to a greater acceptance of modernity” (van der Kroon, Brouwer, & van Beukering, 2013). So, while solid fuel use as secondary fuel is still persistent to some extent (Suani Teixeira Coelho et al., 2018; Gould et al., 2018; Thoday et al., 2018), urbanized and relatively more developed economies have largely transitioned to clean fuels as the primary cooking fuel (McLean et al., 2019; Quinn et al., 2018).

However, in countries like India and Kenya with a large number of poor rural communities, CCS (as well as ICS) have not been used consistently, sufficiently or correctly enough to even displace TCS as the primary cooking solution (Duflo, Greenstone, & Hanna, 2012; Puzzolo et al., 2016; Rehfuess, Puzzolo, Stanistreet, Pope, & Bruce, 2014; Ruiz-Mercado, Masera, Zamora, & Smith, 2011). Empirical evidence suggests that rural households with better access to solid fuel (compared to urban areas) spend their meager and irregular cash income (often derived from seasonal agricultural work) on other priorities where free alternatives are not available (Khandelwal et al., 2017). This may be especially true when the opportunity cost of time-savings from fuel switch in the form of cash income is low (Heltberg, 2004). For example, even the richest 10% of India’s rural households (most with access to LPG) continue to depend on solid fuels to meet more than 50% of their cooking energy demand (P. Kumar et al., 2016). Failure to
achieve a successful, stable & long-term transition from TCS to CCS as the primary or exclusive cooking fuel in rural, poor communities with striking public health, societal and environmental consequences poses a major development and multi-disciplinary research challenge in modern times (Rosenthal et al., 2017).

Currently, about 55% of the world primarily or exclusively depend on electric and gas-based cooking systems (IEA, IRENA, UNSD, WB, WHO, 2019). If billions of people could meet most (excluding occasional barbeque!) of their cooking needs with either gas or electric stoves (microwave, induction, stovetop, ovens, etc.), why is this transition so challenging in the target communities.

While there is much to learn from the historical transitions, we do not have many examples of successful transitions to exclusive clean fuel use in the “perfect storm” situation of (1) low-income, (2) rural communities in (3) developing economies. In the age of economic growth and urbanization, the population under these three conditions is probably decreasing (not implied to be static). However, the population who face these three conditions at any point in time, have not been able to transition to clean fuels as long as these conditions hold true. I view this ‘triple whammy’ of rural, low-income households in developing economies as the environment within which the problem-at-hand (insufficient clean cooking transition, albeit, at different stages in different countries) is situated. Modest percentage changes in these factors in different countries over the last two decades have not been able to reduce the absolute number of population that is dependent on solid fuels (Putti et al., 2015; Quinn et al., 2018).

Notably, even in countries that are more urbanized and economically well off compared to the target communities in South East Asia and Sub-Saharan Africa (Puzzolo et al., 2016; Quinn et al., 2018), exclusive clean fuel use is uncommon. For example, in Brazil, after 40 years of massive investment in LPG subsidies and supply infrastructure, fuelwood supplied 45% of the total cooking energy and 99% of urban households have TCS as a backup (Coelho and Goldenberg, 2013; Smith and Jain, 2019) though LPG is considered to be a popular clean fuel with the “greatest current and historical scale-up activities

8 “Three simultaneous deleterious blows with compounded effect” (Thomas M., 2000)
around the world” (Quinn et al., 2018). Notably, 80% of Brazil’s population resides in urban areas sans access to abundant non-monetized solid fuels. In Indonesia, another poster-child of LPG expansion within developing economies, 24% of households use firewood as primary cooking fuel while another study reported that 73% of sample households stack LPG with solid fuels (Thoday, Benjamin, Gan, and Puzzolo, 2018). Even in relatively prosperous Ecuador⁹, where LPG is perhaps most subsidized (consumers pay 2.5 to 5 USD/ 15 kg cylinder) across the developing economies and an impressive 90% of households use it as primary cooking fuel, 10% of households use firewood as exclusive/primary fuel while 65% use LPG as secondary fuel (Gould et al., 2018). In Peru, a relatively late-starter in LPG promotion, a voucher that reduces the cost of a 10 kg cylinder cost (10 USD) by 50% for poor families is popular, but 95% of people still continue to use stack firewood in their cooking energy mix (Pollard et al., 2018). Scalability has remained a challenge for clean fuels like electric induction stoves. Further, Ecuador has moved the goalpost forward by promoting the zero-emission electric induction stoves in lieu of LPG since 2014. Recent reports based on fieldwork in 2017/18 suggest that the use of induction stove as primary cooking technology is negligible (Gould et al., 2018). New initiatives to promote biogas in some parts of Africa are welcome measures, but it has not yet demonstrated the scale of penetration (Quinn et al., 2018), which would remain a challenge considering the lack of viable business models to provide biogas as a service when household level biogas systems have not been sustainable (Smith and Jain, 2019).

Acknowledging this triple-whammy as a boundary condition, the key question is what should be done to further the transition process. If the transition is viewed as a two-step process, with the vision of clean fuels as primary (stage 1) and exclusive (stage 2) cooking fuel, the immediate pertinent question is what should be done by the target communities to emulate the countries which have at least reached stage 1.

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⁹ In 2017 per capita international dollars, to put into perspective, China/Brazil: ~16,000, Ecuador: ~11,000; India/Vietnam-7000, Nigeria/Congo :~6,000, Kenya/Bangladesh: ~3500
Here, I have assumed that the success in universal/near-universal LPG penetration (physical access) is multiple developing economies have provided a reasonable template, roadmap and knowledge pool for other developing economies to emulate to at least ensure physical access. The examples of LPG penetration in Brazil (Coelho and Goldemberg, 2013), Indonesia (Thoday et al., 2018), and Ecuador (Gould et al., 2018) strongly suggest that if there is political will, massive scale-up of production/distribution system for clean stoves/fuel and a mix of financial incentives along with awareness campaigns can improve the acceptance of clean fuels. So, I will not dwell on this challenge of fuel supply chain infrastructure/uptake any further, though I acknowledge that this is a tough task, at least we know how to do it from multiple experiences from varied settings across Brazil, Ecuador, and India. It is akin to traveling very far in a tiresome journey, but at least Google Maps is there if we get lost at every step. This research is also relevant to those countries in Asia and Africa sans near universal physical access to clean fuels in rural areas. As soon as billions of rural low-income communities gain physical access to clean fuels, the challenges of moving to stage 1 (primary use of clean fuels) would become policy relevant\textsuperscript{10}.

In contrast, the post-uptake fuel stacking with solid fuels as the primary fuel is a much harder problem within the boundary condition of rural, low-income households in developing economies. Even when the target households have been provided CCS at subsidized or/and under micro-financing options in India, they have purchased it but refrained from repeat purchase of commercial fuels- the indicator of regular use (Dabadge, Sreenivas, & Josey, 2018; Giri & Aadil, 2018; Kishore, 2017). The level of subsidy in countries like Ecuador (2.5-5.0 USD end user price for 15 kg cylinder) (Gould et al., 2018)- may be difficult for countries like India (9.5 USD for 14.2 kg cylinder) (Smith & Jain, 2019) and Cameroon (11.5 USD for 12 kg cylinder) to emulate. Commercial fuels like LPG, unless 100% subsidized, cannot compete with non-monetized solid fuels on the issue of household affordability (Thoday et al., 2018). Governments in developing economies have not shown any inclination (and unable) to date to fully

\textsuperscript{10} While here I view LPG use as exclusive fuel as the ultimate goal, in the long term, renewables based electricity should be the ideal cooking energy source for a host of reasons
subsidize commercial cooking fuels like LPG. So, under the business-as-usual (BAU) scenario, unless at least one of the three long-term trends of urbanization, and economic development (both at household and national level) match that of their peers who are in stage 1 (clean fuel as primary cooking fuel), “persistent” fuelwood stacking with solid fuels as the primary cooking fuel would continue in target communities. In countries where the population has reached stage 1, the ideal cooking energy transition involving the disadoption of clean fuels (stage 2) keeps eluding us (Gould et al., 2018; Quinn et al., 2018; Smith and Jain, 2019). For this thesis, I specifically focus on the challenges of reaching stage 1.

To summarize, the focus of this thesis is limited to stage 1 (clean fuel as primary cooking fuel) transition in the “triple whammy” of (1) rural, (2) low-income communities in (3) developing countries, with two additional conditionalities of (4) reasonable physical access to clean fuels and (5) no role of regulations in the post-uptake period due to political or enforcement issues.

1.6 Knowledge gaps in the transition literature

The transition process from TCS to clean fuels has been primarily framed in the cookstove literature as a technology-centric issue about the identification of a multitude of factors that encourage or discourage technology acquisition/uptake (purchase or acceptance) and usage of ICS or CCS (Khandelwal et al., 2017; Palit & Bhattacharyya, 2014). Alternatively, it is also framed from a product-centric outlook as a consumer demand (ex. affordability) and supply (ex. lack of after-sales support) issue that requires “cross-cutting enablers” (ex. quality standards and testing infrastructure) (Putti et al., 2015). Notably, most past research is on ICS; studies on clean, modern fuels like LPG are much more limited (Puzzolo et al., 2016).

Further, recent systematic reviews (Lewis and Pattanayak, 2012; Puzzolo et al., 2016; Rehfuess et al., 2014; Stanistreet, Puzzolo, Bruce, Pope, and Rehfuess, 2014) have identified anywhere from eighteen to thirty-one such socio-economic, demographic and fuel-specific factors that influence the transition process. These factors “operate on a spectrum: if factors are present or satisfactory they act as enablers;
conversely, if absent or unsatisfactory, they act as barriers” (Puzzolo et al., 2016). These include price of competing fuels (Troncoso and Soares da Silva, 2017) or ease of access to non-monetized fuel (Heltberg, 2004), high initial cost of CCS (Elgarah, 2011), volatility of LPG price linked to global oil markets (Puzzolo et al., 2016), low irregular family income to pay for regular fuel expenses (Troncoso and Soares da Silva, 2017), infrastructure for reliability and accessibility of fuel supply (Lucon, Coelho, and Goldemberg, 2004), individual perceptions about safety (USAID, 2005), limited usefulness/ specificity of applications, i.e. not able to perform space-heating and all local cooking tasks that TCS can perform (Khandelwal et al., 2017), lack of awareness about TCS ills and CCS benefits (Lewis and Pattanayak, 2012) and gender driven intra-household decision-making conflicts (Khandelwal et al., 2017).

Sporadic attempts have also been made to integrate theoretical insights from diverse fields to study cooking energy transition. Some studies (Frederiks, Stenner, & Hobman, 2015; Kowsari & Zerriffi, 2011; van der Kroon, Brouwer, & van Beukering, 2014; Wilson & Dowlatabadi, 2007) have proposed conceptual frameworks related to household energy transitions drawn from theoretical constructs primarily from economic theories, behavioural economics, and innovation-diffusion literature. Review of these empirical studies, systematic reviews and inter-disciplinary frameworks related to cooking energy transitions, suggest two broad knowledge gaps from the perspective of implementers/ practitioners aiming to change the situation at the ground.

First, the mechanisms to prioritize the multitude of socio-economic determinants, product-specific factors and decision environment attributes that matter for cooking energy transition are not clear (Lewis & Pattanayak, 2012; Puzzolo et al., 2016; van der Kroon et al., 2014; Wilson & Dowlatabadi, 2007). This exhaustive list of identified factors (sometimes up to thirty-one factors) cut across policy, markets and technology (Puzzolo et al., 2016) and are often not ranked by degree of importance or precedence (Ruiz-Mercado and Masera, 2015), making them of limited utility for real-world intervention planning. In practice, implementation practitioners with limited resources (both in terms of personnel and dollars) cannot simultaneously address all these factors to achieve the intended changes within a project period, typically spanning a few months or years.
Even when some studies using ‘revealed preference’ methods or related economic models have attempted to quantify the relative importance of the factors, this prioritization is framed around two narrow questions that don’t solve the implementation challenges. One, ‘who’ are more likely to adopt CCS? This question examines the socio-economic characteristics of households such as income, education, and size (Lewis & Pattanayak, 2012; van der Kroon et al., 2014). For example, high income, educated female-headed urban households from communities that are not socially marginalized are more likely to adopt CCS (Lewis & Pattanayak, 2012). Understanding the question of who is more likely to adopt does not help guide efforts that target low income, uneducated male-headed rural households in socially marginalized communities. This demography far more likely to find in typical energy-poor communities compared to high income, educated, female-led households. Two, ‘under what circumstances’ are people more likely to adopt CCS? This question examines the decision environment, such as whether there is a local market for alternative fuels, availability of electricity, awareness about health and environmental problems of using TCS, and if fuel is purchased, at what price (Lewis & Pattanayak, 2012; van der Kroon et al., 2014). Generally, CCS program implementers have more control over some of these aspects such as awareness creation (Lewis et al., 2015) while other factors can be either out-of-control (e.g. electricity access) or are not amenable in the short term (e.g. market price of alternative fuels).

Second, though past studies have warned against the “one-size-fits-all” approach- “a common feature of many failed interventions in the past” (Barnes et al., 2015), there are no clear guidelines on target audience segmentation for ICE and other intervention strategies. It is a particularly important issue due to three levels of targeting- region, community, and household. While the regional difference in culture, habits, and taste (Carbone, Carlson, Baroni, and Gomez, 2016) are generally considered for ICS selection, CCS interventions are generally planned at the national level (due to nature of government subsidies associated with them) (Puzzolo et al., 2016). Further, there is no guidance on how to design interventions when household level attributes (e.g. family size, income) within a target community have significant inter-household variation (Thacker, Barger, and Mattson, 2014). Moreover, there are markedly
different priorities, needs and requirements within a household based on socially sanctioned gender
dynamics related to norms, values, roles, and behavior (WHO, 2016). The basis for segmentation and how
to approach the segmented audience are important questions that are key knowledge gaps from a
practitioner perspective.

Finally, it is useful to have theories in this inter-disciplinary domain that can act as frameworks to
generate testable hypotheses and then evaluate and aggregate individual empirical results (Pritchett, 2017)
from geographical/ socio-cultural/ economically diverse areas across Africa, South America, and Asia. A
recent study comments that evidence around the transition process is “idiosyncratic and patchy”
(Pattanayak et al., 2019). For example, there is contradictory reporting on the role of some factors, such as
whether messaging around health and environmental concerns influence positively (van der Kroon et al.,
2014) or do not matter (Khandelwal et al., 2017) for desired outcomes, and whether household size acts as
an enabler or barrier to clean fuel choice (Lewis & Pattanayak, 2012). Yet, this “complex multi-sectoral”
process of clean cooking transitions with its wide-ranging implications for development, gender equity,
the environment, and public health is studied in a somewhat arbitrary manner (Goodwin et al., 2015;
Rosenthal et al., 2017). Hence, “empirical understanding of the drivers of this transition [is] very limited”
(Pachauri and Rao, 2013) in the literature, primarily driven by a gap related to stove use over the long
term (Thompson et al., 2018). It makes this decades-old domain (of CCS intervention) a relatively new
(not mature) field of study from the knowledge perspective when the focus is on stacking of fuels.

1.7 Problem statement and research objectives

Understanding how individual users carry out cooking behavior and why they make underlying
decisions can inform CCS interventions to “persuade or otherwise influence individuals to make
decisions commensurate with public policy objectives” (Wilson & Dowlatabadi, 2007). This philosophy
of pragmatism in terms of helping solve the problem of insufficient post-purchase use (stacking) by
providing novel insights and testable hypotheses of the theory of change is at the core of my thesis.
All research objectives, research questions, methods, and analyses are developed and carried out with the sole focus on a better understanding of what is happening in the post-purchase/post-uptake period. Our understanding of the long term fuel choices, after uptake of clean cooking solutions, and its determinants are limited (Duflo et al., 2012; Thompson, Diaz-Artiga, Weinstein, & Handley, 2018). Further, as this long term decision-making process contains elements of choice and behavioral factors, going beyond objective socio-economic demographics, it is useful to study the transition process through the lens of behavior change (Barnes et al., 2015; Jagadish & Dwivedi, 2018; Thompson et al., 2018). In order to guide clean cooking energy transition, there is a need to better understand the consumption trend of clean fuels (signalling levels of use) in the post-uptake period, and to map the transition pathway by providing insight on why some are able to transition (and others cannot) in the target communities from a behavioral perspective. From a practical implementation perspective, it is also useful to develop a framework to identify the most influential behavioral determinants of transition, so that scarce resources could be prioritized to influence these determinants.

Consequently, in order to address the overall objectives and to help fill this gap in the literature on the clean fuel use trends and analyze the determinants of fuel choices in the post-uptake period from a behavioral perspective, the main objective for each of the four core chapters to follow are:

Chapter 2 – Develop a conceptual framework to examine the how and why of the transition process;

Chapter 3 – Describe the transition process with a focus on new LPG consumers and LPG consumption

Chapter 4 – Examine whether the transition process is associated with changes in behavioral variables; and

Chapter 5 – Identify the barriers and drivers of transition from a behavioral perspective.

In order to fulfill the objectives of this dissertation, I have used multiple sources of quantitative data, and it included both primary and secondary data collection. The detailed methods and analyses are
explained in each chapter, respectively. Table 1.1 shows the basic research objectives, data used, and methods for the four core chapters of the dissertation to follow.

*Table 1-1 Thesis overview of objectives, research questions, data sources and methods*

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<td>Chapter 2: Develop a conceptual framework to determine the how and why of the transition process</td>
<td>1) Why cooking energy transition is a behavior change challenge? 2) How do households progress through the transition process? 3) What behavioral factors drive or hinder the transition process?</td>
<td>I conducted an extensive review of published literature in the fields of social psychology, health psychology, behavioral economics, (dealing with general behavior change) and information system and technology diffusion literature (dealing with technology adoption) to: 1) Make a case why the transition process could be viewed as a behavior change problem 2) I adapted and combined three theories from other domains to develop a conceptual framework for the cooking energy transition. Based on these theoretical constructs, I hypothesize (then test in subsequent chapters) <em>How:</em> The cooking energy transition is a five-stage process as per the transtheoretical model (TTM) with distinct changes in perceptions and self-confidence when people move through stages <em>What:</em> The fuel choices are driven by variation in three psychological variables, namely, attitude, perceived norms and perceived control of the cook as per the theory of planned behavior (TPB). [I also propose that TPB’s expectancy-value model could help identify the most influential variables.]</td>
</tr>
<tr>
<td>Chapter 3: Examine fuel choices</td>
<td>1) What is the pattern of clean fuel</td>
<td>I used a case study approach of using secondary LPG sales data from 100+ villages in the Koppal district of Karnataka state in India (study area for the thesis) for</td>
</tr>
</tbody>
</table>
over the years in the post-uptake period

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
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<tbody>
<tr>
<td>2) Does clean fuel use increase over time?</td>
<td>I also conducted a literature review and analyses to develop benchmarks for exclusive and primary clean fuel (LPG) use for a typical rural household. I used descriptive analyses and visualization of the sales data (as a proxy for consumption or fuel choice) in the R platform to assess the pattern of clean fuel consumption in the post-uptake period.</td>
</tr>
<tr>
<td>3) What role does price and seasonality play in clean fuel consumption choices?</td>
<td>I used heat maps and statistical estimates to estimate the role of experience, if any, in terms of changes in fuel consumption over the years. I also conducted logistic regression to find the comparative influence of price and seasonality on clean fuel choices.</td>
</tr>
</tbody>
</table>

Chapter 4: Examine whether the transition process is associated with changes in behavioral variables

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Is cooking energy transition associated with five distinct stages of varying perception about the advantages, disadvantages, and confidence to cook with clean fuels?</td>
<td>In the same study area, I conducted a survey of 400 households (S1) (both with and without LPG) who are in different stages of the transition process as per pre-defined criteria that are in line with the transtheoretical model (TTM) of change. I used this primary data to test the key hypotheses on whether the perception of people in different stages of change varies significantly using standard statistical tests to assess the effect size and whether it is statistically significant (at 95% confidence level). I used ordinal logistic regression using data from the same survey (S1) to compare the standardized coefficients of the psychological variables as defined in TTM and the objective household wealth index.</td>
</tr>
<tr>
<td>2) In comparison to psychological</td>
<td></td>
</tr>
</tbody>
</table>

11 The entire population of LPG users in the study area, i.e. all LPG users in the study area (as on 31 December 2018) were included in the data analysis.
Chapter 5: Identify the barriers and drivers of transition from a behavioral perspective

| 1) | How behavioral beliefs related to attitude, norms and perceived control vary regarding regular use of clean fuels? |
| 2) | How does attitude, norms, control, intention, and actual behavior relate to one another? |
| 3) | To what extent do survey response biases impact results? |

I used the dataset from 400 sample households in the study area (S1) and apply the expectancy-value model as described in the Theory of Planned Behavior (TPB) to rank the behavioral attributes related to attitude, perceived norms and perceived control - the three psychological variables listed in TPB.

I used a second dataset from 200 sample households in the same study area (S2) where no houses overlap between S1 and S2. I used this primary dataset partial correlation methodology to test the relationship between the three aforementioned TPB psychological variables, intention and actual behavior.

I then compared:

a) direct attitude, norms and control scores with the indirect scores based on the summation of their individual attribute scores to estimate survey bias, if any.

b) the secondary dataset D1 (discussed in Chapter 3) to compare the self-reported behavior (based on primary data in S2) with the observed behavior (based on D1) to estimate survey bias, if any.

In Chapter 2, I conducted a literature review to present a case on why viewing the transition through the lens of behavior change is useful. I then developed a theoretical framework of the ‘how’ and ‘why’ of the theory of change (cooking energy transition) by integrating concepts/theoretical constructs from different domains and generate testable hypotheses around the transition process. In Chapter 3, I
used a secondary dataset of clean fuel sales to quantify clean fuel purchases over multiple years as a proxy for consumption/ fuel choices. I also test the effect of experience in the cooking transition process.

In Chapter 4, I used a cross-sectional research design to test the hypothesis around the ‘how’ of transition process by testing if the transition process can be visualized as a five-stage process with markedly different perceptions and confidence levels. I also compared the relative influence of household affluence (objective) and psychological variables (subjective) in the journey toward clean fuels. In Chapter 5, I used two different cross-sectional survey datasets to estimate a) relative ranking of the behavioral factors in the decision-making process and b) the relationships between psychological variables and observed behavior. I also explored the issue of survey biases by comparing a) self-reported and observed data and b) response to direct and indirect questions. In Chapter 6, I synthesized the main empirical findings of the dissertation and integrated the results by key themes/ findings. I also discussed the contributions to literature, and limitations to the study. Finally, I detailed future research directions, applications, and policy relevance.

1.8 Case study and field site

1.8.1 Case study

After considering the various cooking fuel options that are available to study the transition process, I selected Liquefied Petroleum Gas (LPG). It is widely considered as the most scalable clean fuel for developing nations while it is also relatively one of the cleanest fuels available (Putti et al., 2015; Smith & Jain, 2019). I choose India’s Pradhan Mantri Ujjwala Yojana (PMUY) scheme as my case study to study the transition from solid fuels to LPG for two reasons. First, PMUY is the world’s largest cooking energy access program (Jindal, 2019; Smith, 2018) which is currently live/ active. It started when I was about to begin data collection for my Ph.D.), and it is still ongoing. It addresses the challenge of the high capital cost associated with the purchase (LPG “connection” cost in Indian parlance). Further, its target population of low-income rural households in India (a developing economy) fits well with my triple whammy conditions, and the results from my thesis will have direct policy relevance in terms of mid-
course correction of PMUY, if needed. Moreover, in this setting, I can benefit from my prior experience working in the Indian cooking energy sector.

1.8.2 Study location

The main study area is the villages around Kanakagiri Town Panchayat\(^\text{12}\) in Gangawati taluk (sub-district) of Koppal where two surveys have been administered. However, we have also captured additional data on LPG purchase for all LPG consumers across 126 villages spread around two additional town panchayat areas: Tawargera TP in Kushtagi taluk, and Yelbarga TP in Yelbarga taluk of Koppal district. Tawargera and Kanakagiri TP were formed after the 2011 census and hence no urban-rural distinction from census data is possible. Gangawati TP (categorized as urban) has less than 3,000 households while the rural areas of these three taluks cover more than 150,000 households. Also, the segregation of consumers by urban and rural based on observations of amenities/infrastructure is not easy. The LPG marketing companies do not keep any distinction in their records to distinguish rural vs. urban consumers. Hence, for convenience, the entire study area (villages from three taluks) is considered as part of rural Koppal (which consists of four taluks).

Koppal is primarily dry land, with rain-fed agriculture. We compare some relevant key demographics of this district with rural India to examine how closely the study area’s relevant socio-economic indicators match that of rural India. We look at six indicators that are considered to be influential in clean cooking decision-making, namely, education, women’s empowerment and income (Lewis & Pattanayak, 2012). Regarding the average Monthly Per Capita Expenditure (MPCE), as Koppal district-specific data is not available, ‘Karnataka state- rural’ data is used as a proxy in this case. The rest of the data is procured from

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\(^{12}\) Town panchayats are classified as one step up from village panchayats in terms of amenities. So, while the 2011 Census considers TPs as urban, per official directives of the state of Tamil Nadu, which introduced the concept of TP, these are considered “as a transitional area i.e. an area in transition from rural to urban… and should therefore be logically bracketed with rural institutions” (DTP, 2018).
the census of India. Koppal has slightly higher female workforce participation and MPCE compared to rural India.

Table 1-2 Comparison of rural Koppal with rural India on key metrics. MPCE from National Sample Survey (NSS) report administered in 2011-12 (NSSO, 2014; Planning Commission, 2013) and rest from the Census of India 2011 data table (GoI, 2018).

<table>
<thead>
<tr>
<th>Indicators</th>
<th>India Rural</th>
<th>Koppal Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male-literacy</td>
<td>77%</td>
<td>77%</td>
</tr>
<tr>
<td>Female-literacy</td>
<td>55%</td>
<td>58%</td>
</tr>
<tr>
<td>Household size</td>
<td>4.94</td>
<td>5.31</td>
</tr>
<tr>
<td>The proportion of males who work for more than six months</td>
<td>42%</td>
<td>47%</td>
</tr>
<tr>
<td>The proportion of females who work for more than six months</td>
<td>17%</td>
<td>28%</td>
</tr>
<tr>
<td>The proportion of main worker (male) in agriculture and allied activities as cultivator or laborer</td>
<td>71%</td>
<td>73%</td>
</tr>
<tr>
<td>The proportion of main worker (female) in agriculture and allied activities as cultivator or laborer</td>
<td>79%</td>
<td>85%</td>
</tr>
<tr>
<td>Monthly Per Capita Expenditure (MPCE)- Rs.</td>
<td>1,287</td>
<td>1,395</td>
</tr>
</tbody>
</table>
2. A conceptual framework of cooking energy transition using behavior change theories

2.1 Cooking energy transition as a behavior change challenge

Why should a clean cooking energy transition process be viewed through the lens of behavior change? Irrespective of the technology options, implementation strategy choices or geographical contexts, a successful household-level transition essentially involves undertaking new behavioral actions and ceasing old behavioral actions by three key individual(s) or group(s) within a household (Clark, Heiderscheidt, & Peel, 2015; Goodwin et al., 2015). One, the cook(s) (almost exclusively women in target households) may have to change the type of food being cooked as some CCS models can be ill-suited to prepare all types of traditional food (ex. when the size of the traditional bread is bigger than the burner size) (Barnes, Krutilla, & Hyde, 2005; Rosenbaum, Derby, & Dutta, 2015). Further, firepower and pot size differences between TCS and fixed-dimension CCS may alter cooking styles (e.g. requiring more attention to food as it cooks) or how what quantity of food can be prepared at one time (Khandelwal et al., 2017; Stanistreet et al., 2015). Moreover, the cook’s behavior can also directly influence the health outcome metrics such as personal exposure level depending on where they cook and how they enhance ventilation (Dasgupta, Martin, & Samad, 2013).

Two, other household members (including children) may find real or perceived changes in the size, texture, taste, and flavor of food cooked in CCS that influence the familiarity or desirability of the food (Khandelwal et al., 2017). The spatial behavior of other family members in the household (near or away from the kitchen) during the cooking period also moderates the health impact of CCS interventions (Goodwin et al., 2015).

Three, the financial decision-maker(s) (often senior male members in target households) have to reallocate current consumption expenses and savings decisions, especially in cash-lean seasons, to cover significant expenses on regular fuel purchase and occasional CCS purchase/repair cost (Khandelwal et
al., 2017; Martin et al., 2013). However, in some cases, time/effort savings from CCS usage may lead to additional income generation to offset the expenses (Parikh, 2011). Notably, if 10 LPG cylinders (exclusive LPG use) are purchased at a subsidized cost of Rs. 550/ (14.2 kg) cylinder annually, it would cost about Rs. 15 per household per day, or, about Rs. 450 per month (detailed estimates in Chapter 3).

For primary use of LPG as cooking fuel, the minimum expense would be about Rs. 8 per day (or, Rs. 240/month). This is comparable to what low-income rural households typically spend on average on other discretionary expenses like cigarette and tobacco products. A recent study suggested that an average cigarette smoker and a bidi smoker from a low-income family in India spend Rs. 18/day and Rs. 5/day respectively (Pawar et al., 2015). Another study found that about 5% (Rs. 140) of the monthly budget in a rural family goes towards local alcohol and about 7% (Rs. 196) is spent on tobacco (Tandon, 2016).

Moreover, while the cook would have a key role in the decision-making process (she has to use it after all!), the male members may have veto power generally over the fuel choice, irrespective of the affordability aspect (Miller & Mobarak, 2013). Further, male household members may also become responsible to arrange for transport of CCS (in case of LPG) from far-off supply point if door-step delivery is not available (Puzzolo et al., 2016).

Thus, the “bundle” of behavioral actions by key individuals—cooks, financial decision-makers, and other family members can be viewed as the ‘clean cooking energy transition’. It not only includes actions that lead to regular, consistent and sufficient usage of CCS (Shankar et al., 2014) but also actions that can maximize the impact of such usage, especially from a health perspective (Goodwin et al., 2015). Here, the ‘desired behavior change’ at the household level necessarily involves a multitude of relatively new, complex and effortful behavioral actions to be undertaken by the cook(s), financial decision-maker(s) and other household members at an individual level. Technology options, intervention strategy choices and geographical contexts would obviously promote or hinder these actions, but irrespective of these choices/contexts, behavior changes are integral and in a way, demonstrative of the transition process.
While there has been limited research on the role of behavior change strategies in the post-uptake period (Thompson et al., 2018), successful applications of behavior change strategies are recorded for CCS uptake decisions. After reviewing 55 interventions carried out in 20 countries to promote uptake of CCS, a study concludes the behavior change approaches have been effective in the implementation process (Goodwin et al., 2015). Surprisingly, there are only sporadic mentions of behavioral aspects such as the role of habits (Kowsari & Zerriffi, 2011), individual perceptions & knowledge (Puzzolo et al., 2016; Rehfuess et al., 2014), and motivation (Martin et al., 2013) to achieve the post-uptake transition process. In most of the fifty plus CCS interventions that claimed to use ‘behavior change techniques’ (BCT), “their implementation as part an established behavior change model or framework appeared to be rare” (Goodwin et al., 2015) with notable exceptions (Martin et al., 2013). BCT strategies were primarily aimed at social marketing for uptake (purchase/acceptance) of CCS by undertaking interventions for information sharing, subsidies, and marketing by local community organizations with a focus on "willingness to pay" (Goodwin et al., 2015; Lewis et al., 2015). There are not many studies or even theoretical frameworks that explore ‘willingness to use’ CCS in lieu of TCS over the long term from a behavior change perspective. Hence, the “evidence gap” related to the behavioral aspects of transition merits urgent research attention (WHO, 2016).

Hereafter, I use the term ‘key individuals’ to refer to primary cook(s), financial decision-maker(s) and other household members who possibly have direct or indirect veto power over CCS usage in the household kitchen. Also, the clean cooking energy transition would be referred to as transition for conciseness unless specified otherwise. Further, the term ‘desired behavior change’ would imply, unless specified otherwise, switching from exclusive TCS (old behavior) use to use of CCS (new behavior) as exclusive cooking fuel and maximization of its impact through other behavioral actions.

13 Defined as an “active component within a clean cooking intervention that helps produce behavior change to improve human and/or environmental impact” (Goodwin et al., 2015)
14 Primary cooking fuel in the immediate near term
2.2 An interdisciplinary approach to study behavioral determinants of transition

Insights from prominent and influential “behavior change” and “technology adoption” literature in different domains can be a useful starting point, as cooking energy transition involves behavior change in the process of embracing technology. “Theory borrowing” from other domains in interdisciplinary domains which do not themselves have a long history of theory construction and testing has a long tradition in fields such as consumer marketing (Murray, Evers, & Janda, 1995). Application of the COM-B model from health psychology to study the cooking usage and perceptions of cooking with LPG in Guatemala (Thompson et al., 2018) is a model example in the field of cooking energy transition. The COM-B Model is a popular “behavior system” that provides the structure for assessing Capabilities, Opportunities and Motivations towards the Behavior of interest (Thompson et al., 2018; Tombor & Michie, 2017).

The core aim of this chapter is to borrow distinct concepts from different disciplines that can seamlessly be integrated into a conceptual framework to provide insight into the problem at hand. Social psychology, sociology, judgment and decision-making, and behavioral economics have a long history of examining behavior change across various domains. Health behavior psychology has examined behavior in the context of initiating health behavior or ceasing unhealthy behavior while consumer research studies have explored purchase and repeat purchase (indicating long-term behavior change) behaviors. Past studies (see (Kowsari & Zerriffi, 2011; Wilson & Dowlatabadi, 2007) on household energy decision making have drawn from many of these domains to explain individual and household behavior.

I have additionally drawn upon two other research domains hitherto untapped for understanding and guiding household level cooking energy decisions. Information systems research and education research domains have long explored behavior change in the context of technology acceptance and continued usage. Some of the theories which I use to explain and guide cooking energy transition have been successful in actually predicting behavior change (e.g. online shopping) (Venkatesh, 2014) and
affecting behavior change (e.g. smoking cessation) (Bandura, 1998). Such multi-disciplinary approach towards “integration of multiple streams of work to shed light on phenomena of interest is important” both from a scientific standpoint and to bring a fresh perspective to the issue (Venkatesh, Thong, & Xu, 2012). Moreover, past application of “opportunity, ability, and motivation behavior change framework”, borrowed from sanitation space, to highlight key issues related to cookstove dissemination (Martin et al., 2013) demonstrate the utility of testing ‘cross-border’ theories.

Such a multi-disciplinary approach towards “integration of multiple streams of work to shed light on phenomena of interest” is important both from a scientific standpoint and to bring a fresh perspective to the issue (Venkatesh et al., 2012). Moreover, past application of “opportunity, ability, and motivation behavior change framework”, borrowed from the sanitation literature, to highlight key issues related to cookstove dissemination (Martin et al., 2013) demonstrates the utility of testing ‘cross-border’ theories.

Another notable example is using a framework developed for the study of agricultural preferences from development economics to explaining household energy choices (van der Kroon, Brouwer, & van Beukering, 2013).

2.3 Principles and approaches towards a conceptual framework

2.3.1 Guiding principles

The proposed framework to study transition aims to address the aforementioned critiques/ gaps in the existing literature to improve our “empirical understanding” of the process. A new theoretical should provide new insights in the form of testable hypotheses while being consistent with known empirical results (Prochaska, Wright, & Velicer, 2008). I focus on the black-box problem, namely that even though the multitude of household cooking energy choice determinants (inputs) and the consequences in terms of energy transition success or failures (outputs) are identified, how they interact or dominate over each other during the transition is mostly unknown. As suggested by Heclo, “understanding is best advanced, not [just] by giving priority to one or another type of variable, but by concentration on the
interrelationships of ideas, interests, and institutions. The 'action,' so to speak, is at the intersection” (Heclo, 1994). So, two new aspects of the transition process are explored in this framework: ‘how’ do households move through the transition process and ‘why’ are some individuals able to make the transition while others are not?

A useful framework would consist of key theoretical constructs borrowed from different domains to generate testable hypotheses around transition related to the key questions of “how” and “why”. Priority is given to well-tested theories that have addressed similar questions about behavior change. Research domains that have studied either household technology specific behavior choices related to acceptance and usage (e.g. how usage decisions are shaped by technology attributes) or individual self-regulatory behavior change (e.g. how habits are formed and changed) were included. The underlying assumption is that in the absence of any comprehensive theoretically rooted theories on the cooking energy transition process, it is worthwhile to test important adoption/behavior theories that have been used across different domains. Broadly, for consistency and validity purposes, the framework should conform to (i.e. not be inconsistent with) our understanding of input factors of ‘who’ is more likely to succeed and ‘under what conditions’ based on empirical evidence.

2.3.2 Objective conditions vs. behavioral constructs

The existing literature mostly uses objective indicators spanning technology characteristics, regulatory regimes, market conditions and demographic factors to the ‘why’ of the cooking energy choices (Lewis & Pattanayak, 2012; Takama, Tsephel, & Johnson, 2012; van der Kroon et al., 2014); ‘knowledge and perceptions’ are sometimes added to this list (Puzzolo et al., 2016). However, behavioral sciences literature also suggests that human decision choices are influenced by impressions of reality driven by effortless and associative perceptions and intuitions (Kahneman, 2003; Evans, 2008). The worldview that people hold and the action that they take is often distorted by heuristics, biases, anomalies, mood and past habits (Evans, 2008; Kahneman, Knetsch, & Thaler, 1991; Tversky & Kahneman, 1974).
For example, awareness generation (information, communication, education- ICE) campaigns are considered as an important factor in the decision environment (Lewis et al., 2015). However, miscommunication on either side can create negative perceptions (Vanschoenwinkel, Lizin, Swinnen, Azadi, & Van Passel, 2014) while the absence of trust by the community in the messengers can reduce the impact of messaging (Lewis et al., 2015). In this framing, ICE communication messages, channels and actors (objective measures) should logically increase favourability and the probability of a transition, but it is the (subjective) perceptions formed as a result of these ICE activities that determine whether they have the intended effect.

Critiques may argue that it is a semantics issue as there would be obvious overlaps, such as low-income households (economic condition) would likely not find ‘value for money’ (perception) in switching to a commercial fuel. Or, an older cook (age) would be more used (habit strength) to use TCS (Khandelwal et al., 2017). Critics may also argue that as the studies have accounted for actual cooking behavior/ verbal survey responses, I have already accounted for the perceptions. My view is that behavioral constructs (perceptions/ habits) derived from objective conditions are more immediate to explain and predict the transition process. For example, the cookstove literature finds that education has a positive effect on the probability of a household moving away from TCS (Lewis & Pattanayak, 2012; Puzzolo et al., 2016; Rehfuess et al., 2014). The linkage has been described as follows: “increasing opportunity costs of fuel collection time at higher levels of education and the increased level of awareness of the negative effects of wood and charcoal use on health” (van der Kroon et al., 2013). It suggests that perceptions around opportunity cost and awareness levels are influenced by education. As education (measured by a degree or level of literacy) cannot guarantee higher opportunity cost or enhanced awareness level, it is more useful to assess the proximate (immediate) factors that lead to the decision-making process such as perceptions of health risks of using TCS. Under this framing, an individual's perceptions about (availability of and accessibility to) subsidy (behavioral construct) are more relevant to his/ her decision-making compared to the written policies on subsidy (objective conditions).
In the case of divergence between subjective perceptions and objective measures, perceptions matter more during the actual behavioral action (Clarkson, Hirt, Jia, & Alexander, 2010; Duncan et al., 2011). Moreover, numerous behavior change studies have demonstrated that reflex action/muscle memory related to habits can counter the impact of objective factors such as knowledge and awareness in actual performance of behavioral action (Gardner, 2015; Verplanken & Wood, 2006) that has led to knowledge-action gap across different domains (Gollwitzer & Sheeran, 2006; Schwarzer, 2008).

Reverting back to the analogy of a black box, the objective conditions can be labeled as input factors and the behavioral constructs of perceptions and habits are process factors to explain transition that exist within that black box. In this thesis, behavioral constructs such as attitudes (driven by individual perceptions about objective conditions related to technology, demography, market, laws, and geography) and habits (driven by repeated behavior in similar settings) would be used to explain the transition process. So, in contrast to traditional scholarship that focuses on factors such as income and age of cook to explain the transition, the transition factors would be behavioral constructs such as subjective perceptions of whether there is ‘value for money’ and the strength of the habit of using TCS. Hence, rather than assuming an overlap of input and process factors, it is more prudent to capture the perceptions (process factor). For example, ‘am I too old to learn a new technology’ may be more relevant and an immediate predictor of actual transition levels (output) than the more distant age parameter (input factor). In other words, I hypothesize that the effect of objective measures (income, education, etc.) on behavior is mediated via the subjective perceptions (also known as the self-sufficiency assumption in Theory of Planned Behavior) (Sniehotta, Presseau, & Araújo-Soares, 2014).

Further, rather than focus on the prioritization of objective factors (Lewis & Pattanayak, 2012; Takama et al., 2012; van der Kroon et al., 2014), the framework would focus on the prioritization of the behavioral constructs. As a simplistic example to explain the role of prioritization of process factors, the aim is to create a model, which can quantitatively compare whether the perceived capacity deficiency or perceived safety concerns is a bigger concern. It can help decide whether an information campaign should
focus on generating awareness about the ease of cooking or on alleviating safety concerns when resource constraints won't allow multiple campaigns.

2.3.3 Literature review beyond traditional knowledge domains

While theories and models from energy economics and related domains in economics have been primarily used to study the uptake of CCS (Takama et al., 2012; van der Kroon et al., 2014), the search was widened to include insights from two different but overlapping research areas. First, technology adoption research deals with behavioral interactions directly related to acceptance and usage of a new technology, which is influenced to a large extent by the characteristics of the technology (Takama et al., 2012). For example, the extent to which a cook has to modify the current cooking practices would depend on the new stove’s firepower (Rhodes et al., 2014). This technology-human interaction has been covered by both technology adoption literature (micro-perspective on change when studied at individual/household scale) or innovation diffusion literature (macro-perspective on the spread of innovation over time at the population scale) (Straub, 2009). Of the two, I argue that is the micro-level perspective that is most suited to understanding CCS as an innovation adopted by households. The macro perspective is more suitable to study technology innovation, supply chain or distribution and often at a decadal scale. I broadly view uptake and usage of CCS as an innovation, even when it is a known & aspirational technology like LPG (Smith & Dutta, 2011), because it would be a “novel idea” (Straub, 2009) for the target household to actually use CCS for cooking in lieu of traditional solid fuels. Our literature review suggested that information systems (e.g. online banking) (Venkatesh, 2014), and education technology (e.g. new pedagogy) (Straub, 2009) research have both studied technology adoption extensively. Journals in the field of management research (Srinivasan, Lilien, & Rangaswamy, 2002) and decision sciences (Venkatesh, 2006) have also published work related to technology adoption.

Second is research relevant to changes in age-old cooking habits, adjustment to a perceived change in taste of food or reprioritization of financial behavior (household budget) to pay for CCS
(Goodwin et al., 2015; Khandelwal et al., 2017). Such self-regulatory individual behavior changes are indirect but essential for the technology adoption to be successful and have been extensively studied in the fields of behavioral economics (Kahneman, 2003), psychotherapy (Hayes, 2016), social psychology (Fishbein & Ajzen, 2011) and health (behavior) psychology (Armitage & Conner, 2000), and applications in the fields of financial behavior (Perry & Morris, 2005) and tourism (Chen & Chen, 2010).

A review of these fields reaffirmed Prochaska’s views that many disciplines suffer from “too many theories and too few data to evaluate them” (Prochaska, Wright, et al., 2008). A recent study identified 89 theories just around behavior and behavior change (Michie, West, Campbell, Brown, & Gainforth, 2014). Hence, while short-listing theories, importance (citation, contribution to other theories) and generalization (application to diverse domains) were important criteria. Most importantly, any theory that directly addressed the questions that are being asked about ‘how’ and ‘why’ of a behavior change process were further studied.
2.4 CI-CHANGE behavior change framework

![CI-CHANGE framework of cooking transition](image)

Figure 2-1 A conceptual framework of cooking transition from a behavioral perspective. The CI-CHANGE model of behavior change as a vehicle for cooking energy transition (theoretical constructs presented are explained in the text); where conscious (behavior) Change, driven by Intention, which in turn is influenced by (perceived) Control, (past) Habits, Attitude and (perceived) Norms, as a General [cooking] Energy transition framework.

2.4.1 CI-CHANGE: Theories and behavioral constructs

A new inter-disciplinary conceptual framework (Figure 2-1) named CI-CHANGE is proposed to compensate for the lack of cookstove specific behavior change frameworks as well as to address the aforementioned critiques and gaps in the existing literature. It proposes that conscious (behavior) change necessary for clean cooking energy transition is driven by intention (Fishbein & Ajzen, 2011). The intention is influenced by (perceived) control, (past) habits, attitude and (perceived) norms (Venkatesh et al., 2012). Based on the literature review, expert interactions and our judgment based on combined field
experience of over two decades, I decided to use the transtheoretical model-TTM (stages of change model) (Prochaska & Velicer, 1997) from health behavior change psychology to hypothesize ‘how’ clean cooking energy transition process happens. Then, the theory of planned behavior- TPB (reasoned action approach) (Fishbein & Ajzen, 2011) from social psychology was added to develop a mechanism to identify and prioritize the key ‘process factors’ that provide insights on the ‘why’ aspect. Finally, the Unified Theory of Acceptance and Use of Technology (UTAUT-2) for consumer technologies from the information systems domain is used to expand upon TPB’s ‘why’ conceptualization to make the framework more appropriate for technology adoption (acceptance and usage) related behavior change (Venkatesh et al., 2012). Finally, the linkage between UTAUT-2 constructs (detailed ‘why’ related to technology adoption) with the empirical evidence around ‘who’ and ‘under what conditions’ related to cooking energy transition is established. A brief discussion on how these theories complement each other to answer the ‘how’ and ‘why’ questions are further discussed later.

While this cooking behavior change model would be expected to apply across a range of interventions spanning different clean cooking fuels (electricity, LPG, etc.), socio-economic contexts (e.g. South Asia, Latin America, Sub-Saharan Africa) and implementation modes (e.g. donor-driven, corporate, government programs), I have used the Indian government’s LPG programme as an example to make the discussion less abstract and more readable. India’s Ujjwala initiative is a landmark energy access initiative that has enabled 32 million poor women to access subsidized LPG within 20 months since its launch. Only women are eligible to be enrolled under the scheme, though the decision of enrolment is perhaps a household decision. Under Ujjwala, half of the upfront total capital cost (stove, first cylinder/bottle of 14.2 kg LPG, accessories, and administrative costs total ~50 USD) required for a new connection is waived off while the balance amount can be availed as an interest-free loan (Jindal, 2019; Smith, 2018). So, the desired transition is framed as moving away from the current practice of using solid fuels as primary to making LPG as the primary cooking fuel (Figure 1 blue arrow in the box on the right).
2.4.2 Delineation of the stages of change

Prochaska's Transtheoretical Model (TTM) is the most cited theoretical framework in health behavior psychology to explain, predict, motivate, and intervene on behavior changes across diverse domains such as smoking cessation (Prochaska, Velicier, Rossi, Goldstein, & et al, 1994) and sustainable transportation (Redding et al., 2015). TTM introduces the idea that a transition from an existing behavior (i.e. solid fuels as primary cooking fuel) to the desired behavior (i.e. LPG as the primary option) is not a single event but rather a five-stage temporal process that is gradual and iterative in nature, i.e. individuals can go both forward (along the blue arrow) and backward (orange arrows) during the transition process (Prochaska & Velicer, 1997). Considering the transition from solid fuels to LPG (as primary cooking fuel) as an example of behavior change, the five stages would be: (1) Precontemplation: Key individuals hold a neutral or negative opinion about using LPG as primary cooking fuel in the near future and are unlikely to have an LPG connection; (2) Contemplation: Key individuals have positive opinions about LPG but don’t have an LPG connection yet as they grapple with the pros and cons of such a change; (3) Preparation: Households have an LPG connection (either old connection with minimal usage or new connection) and key individuals express intention/plan to use it as their primary fuel in the immediate future but it is currently not used as primary cooking fuel; (4) Action: Key individuals make efforts to use LPG regularly as the primary fuel and usage is significant enough to have an effect on health outcomes; however, any change in environment (e.g. price increase) would likely bring them back to the preparation stage; (5) Maintenance: LPG is regularly used as the primary fuel out of habit and key individuals are now so used to LPG that they would advocate its continued use as primary fuel even in face of obstacles (e.g. supply disruption) (Prochaska, Redding, & Evers, 2008; Prochaska, Velicier, Rossi, Goldstein, & et al, 1994). In many TTM studies, especially for smoking cessation, this is considered to occur roughly six months after the Action Stage (Prochaska et al., 1994). These stages based on process factors can be used for target audience segmentation for cookstove interventions.

Here it should be noted that the TTM framework, often applied to pro-health behaviors, views that “not all modification of behavior count as an action. An individual must attain a criterion that
scientists and professionals agree are sufficient to reduce the risk of the disease” (Prochaska, 2008). So, in order to count as “action”, the user needs to undertake the “desired” behavior changes that entail sufficient LPG usage in order to significantly reduce the health risks significantly. Due to the supra-linear relationship between reduction in health risk and replacement of TCS (Smith et al., 2014), such health gains would be possible only when LPG is used as a primary cooking fuel (M. A. Johnson & Chiang, 2015). So, stacked users who use CCS intermittently would not qualify to be categorized as part of the “action stage” and would remain in the “preparation” stage. However, I have recognized that the accrual of other social and environmental benefits from LPG is more proportional in nature and can be realized even at lower levels of usage.

2.4.3 Identification of the key process variables for change

TTM helps categorize the behavior change journey and postulates strategies to progress through the stages based on focusing differentially on stage-dependent pros vs. cons of change and increasing self-efficacy as drivers of change (West, 2005). However, it has been criticized for “failing to specify the precise variables involved in shifting from one stage to another” (Armitage & Arden, 2002), i.e. factors influencing key individuals’ behavior change that leads to progression through stages. Fishbein and Ajzen’s social psychology Theory of Planned Behavior (also known as the Reasoned Action Approach) (Fishbein & Ajzen, 2011) provides an elegant framework to identify these variables. It helps explain the effort by an individual towards behavior change. It states that “behavior is performed not automatically or mindlessly but follows reasonably and consistently” from three behavioral constructs (Ajzen, 2012). These constructs contribute to strengthening, or weakening an individual’s intention to perform the target/desired behavior; the effect of all other factors is hypothesized to mediate via TPB (Sniehotta et al., 2014). First, attitude is the product of the strength of the attitudinal belief that performing a behavior will lead to a particular outcome (ex. likely/unlikely increase in social status from using LPG) and the level of desirability (ex. increase in social status is good/bad) of the particular outcome (Ajzen, 2012). Second,
perceived norms are determined by the strength of the normative beliefs weighted by the motivation to comply (Ajzen, 2012). It includes both injunctive (perception of what others would say about using LPG) and descriptive (perceptions of others cooking habits) norms. Third, perceived behavioral control (PBC) is determined by a person's subjective probability that a control factor is present (ex. fuel supply reliability would be high/low), weighted by the power of each control factor (availability of reliable fuel supply is very important/does not matter) (Fishbein & Ajzen, 2011). Some researchers consider that TTM's self-efficacy is about personal control (confidence in own ability to maintain the desired behavior in a difficult situation) while TPB’s PBC is viewed as external control, where the situation is difficult because of a “lack of opportunities or resources in the environment” (Armitage & Arden, 2002). However, in this thesis, control beliefs are considered similar to self-efficacy and include beliefs about personal, technological and environmental factors that can help or impede their attempts to carry out the desired behavior in relevant situations (Bandura, 2012; Fishbein & Ajzen, 2011).

2.4.4 Addition of household technology specificity to the process factors

TPB states that users generally consider five to eight salient beliefs (Fishbein & Ajzen, 2011). However, TPB does not help identify the particular beliefs (process factors) relevant for technology adoption necessary to incorporate the specific input factors that systemic reviews of the cookstove literature have identified as influencing behavior (e.g. age, gender, local environment, household economics, and culture) (Lewis & Pattanayak, 2012; Puzzolo et al., 2016; Rehfueß et al., 2014; Stanistreet et al., 2014). The Unified Theory of Acceptance and Use of Technology (UTAUT-2) is an established theory in information systems (IS) research to explain individual (consumer level) ‘adoption’ of IS products/services like computers and the internet (Venkatesh et al., 2012). UTAUT-2 specifically focuses on seven predictors of behavioral intention (process factors) to accept and use a technology that likely matters the most from the user’s perspective (Venkatesh, 2014).
Considering CCS such as LPG as the consumer technology in question, the seven predictors would be: (1) **Performance expectancy** is the belief that using LPG would result in process gains (e.g. less time to cook) and/or output gains (e.g. cook more food with similar efforts); (2) **Effort expectancy** is the ease or difficulty of using a new technology such as LPG, often in comparison to the old/baseline technology like TCS; (3) **Social influence** is based on whether other influential actors believe a user should adopt LPG; however I adopt TPB’s more expansive definition that also includes descriptive norms; (4) Facilitating conditions are favorable environmental factors such as reliability of LPG refill supply that could support/not impede their use of the technology; (5) **Hedonic motivation** describes the pleasure user (cook) derives from using LPG, which can simply be lack of eye irritation that happens when LPG is used instead of TCS; (6) **Price value** is trade-off of benefits/advantages to cost/disadvantages of transition to LPG; and (7) **Habit** is the automatic repeated behavior (of using TCS) impedes adoption of a new technology like LPG (Venkatesh, 2014; Venkatesh et al., 2012). This last factor is important as critiques of TPB have identified ‘past behavior’ as important drivers of both intentions and observed behavior (Armitage, 2015; Sniehotta et al., 2014).

Most of the objective input factors identified empirically in the cookstove literature (Lewis & Pattanayak, 2012; Puzzolo et al., 2016; Rehfuess et al., 2014; Stanistreet et al., 2014) can be incorporated into the conceptual framework (Figure 2). All the process factors (blue squares) from UTAUT-2 are derived from perceptions of the reality/conditions based input factors (ochre yellow, pink and green rectangles). So, a behavioral construct like ‘effort expectancy’ captures perceptions about the technology's capacity to deliver similar quantity, taste, and texture of food; mishandling of the technology can also create a divergence between perception and reality.

I extended TPB’s sufficiency assumption that the effect of all other biological (age), social (education), environmental (abundance of solid fuel), economic (family income), and cultural (head of household/key financial decision-maker) influences are hypothesized to be mediated by the TPB constructs (Sniehotta et al., 2014) to also include UTAUT's construct of habit. For example, the cognitive trade-off between the (non-monetary) perceived benefits of technology use and the monetary cost for
using them in form of ‘price value’ (Venkatesh et al., 2012) would be different between key individuals from high and low-income households. Again, greater the age, more experience a cook would have with TCS (considering a typical target household where TCS is exclusively used) (Khandelwal et al., 2017). As habit is developed by the experience of repeatedly performing a behavioral action (Gardner, 2015; Verplanken & Wood, 2006), age (input factor) influences behavior in our proposed conceptual framework via habit (process factor).

Figure 2-2 Attributes of behavioral determinants. Integration of cooking energy transition input factors based on published literature to process factors (CHAN) identified in the CI-CHANGE framework. While there would be obvious overlaps, process factors are more immediate and relevant to the formation of behavioral intent.
2.4.5 Inter-linkage of theoretical constructs

TTM helps explain the ‘how’ of the behavior change journey and postulates audience segmentation strategies based on focusing differentially on stage-dependent pros vs. cons of change and increasing self-efficacy (Armitage, 2015). While TTM can help identify a list of pros and cons (factors) for a given behavior through focus groups, experts and a review of literature, TPB provides value addition to the list of factors in two ways. One, TPB introduces three categories for items under that list- attitude, norms, and behavioral control. This categorization and ability to distinguish between attitudes, norms and behavioral control are critical for then designing interventions that address specific types of pro and con factors. Two, the mathematical model of TPN captures two aspects for each category compared to TTM’s unidimensional uniform approach. For example, PBC captures the “relevance” of a controlling factor and “belief intensity” related to the presence of the control factor, while attitude captures both the strength of the attitudinal belief that performing a behavior will lead to a particular outcome and the level of desirability of the particular outcome. In contrast, TTM only assesses the “importance” of a given attitude or control related to pro or con while making decisions.

In the proposed model, TPB could explain the ‘why’- the effort (or, lack of it) and the underlying intention by an individual to change their cooking energy behavior (Fishbein & Ajzen, 2011). Through the expectancy-value model and similar concepts, it is possible to quantify and prioritize specific aspects (e.g. social norms related to opinion leaders, attitude towards safety) users consider as most important as well as how favorably or unfavorably CCS usage is perceived with respect to a given aspect. I view the predictor strength/weakness numbers (in TPB) to be conceptually similar to the pros and cons of decisional balance (in TTM) but more detailed, useful, and practical to apply. The behavioral intention to perform the desired behavior improves as people move from precontemplation to maintenance stage. Someone at the preparation stage would have more positive predictor values (as per the expectancy-value model) as compared to someone in the precontemplation stage. For this person to move to the action stage, interventions have to target the weak predictors.
While TPB states that users generally consider belief strength/ feasibility and corresponding attribute evaluation/ desirability for 5-8 salient beliefs (Fishbein & Ajzen, 2011) for any generic behavior, those beliefs related to technology adoption would be more relevant for the problem at hand. UTAUT-2 helps identify and narrow down those salient and accessible beliefs that determine attitude (TPB construct) and its utility has been demonstrated in other technology domains. Moreover, as UTAUT-2 introduces the new construct of habit, it addresses a major critique that TPB fails to account for past repeat behavior (Sniehotta et al., 2014). Also, UTAUT-2 itself already borrows from more generalizable theories such as TPB and social cognitive theory (Venkatesh et al., 2012) and its constructs can easily be matched to those of TPB.

The three models, therefore, form a nested framework. The existing set of input factors identified in the cookstove literature can be linked to process factors in the UTAUT-2 model. Those technology-specific process factors can be tested empirically with TPB to explain the behavioral intentions of an individual. The intention levels calculated from the mathematical models of TPB can be differentiated according to the TTM stage of the individual.

2.5 The utility of CI-CHANGE framework

Application of the CI-CHANGE model advances theoretical knowledge by attempting to link three domain-specific theories in two novel ways. First, I proposed the integration of TPB and TTM in a novel manner as “behavioral intentions would be relatively negative in pre-contemplators, and progressively more positive in contemplators, preparators, actors, and maintainers, respectively” (Armitage & Arden, 2002). I hypothesized that changes in the TPB variables- attitude, perceived norms and perceived behavioral control- scores can be considered as inputs to the two-step behavior change process (formation of intent followed by behavioral action). This would then lead to changes in the TTM variables of self-efficacy, and perceived pros & cons of changing behavior and, therefore, progression through the stages. Second, UTAUT-2 helps identify four salient/ accessible constructs in the domain of
consumer technology that influences the TPB constructs of attitude. These are performance expectancy, effort expectancy, hedonic motivation and price value. UTAUT-2 also aligns with the other two TPB constructs of norms (social influence) and behavioral control (facilitating conditions) while adding value to TPB by the addition of the role of habits.

The framework helps generate testable hypotheses adapted from the TTM and TPB theories. I hypothesize that the medium ‘between groups’ effect size at 95% confidence level in terms of Hedge’s g would be ≥ +0.50 for Pro score and ≤ - 0.50 for Con scores) (Prochaska & Velicer, 1997). Second, I hypothesized that attitude, norms and control scores would correlate closely with the intention to perform the behavior as it was the key postulate in TPB. I hypothesized that the medium ‘measures of association’ effect size at 95% confidence level in terms of Pearson’s r correlation would be ≥ 0.50) (Fishbein & Ajzen, 2011).

The framework also provides three key benefits related to better understanding of transition process: 1) Existing knowledge about clean cooking adoption can be integrated and contextualized using this conceptual framework in order to propose an integrated picture of the transition process including identification & prioritization of key process determinants; 2) It provides a consistent method to generate testable hypothesis about acquisition and usage of new cooking technologies and fuels; 3) It can provide guidance regarding stage-specific actions that can be undertaken to increase uptake and usage of LPG. Below I present three implications of the conceptual framework and associated research efforts required to test the validity of the framework.

2.5.1 Design interventions through audience segmentation by stage of change

Based on studies across a wide range of human behaviors, TTM proponents advocate for a “stage paradigm”, where interventions should be “matched to each individual’s stage of change” to be more effective (Prochaska & Velicer, 1997). For example, awareness campaigns on benefits of the target behavior are generally effective in increasing the pros (positively influence decisional balance) during the
early stage of transition, they are not as effective for the later stages of transition where factors that reduce the cons (e.g. stimulus control) play a more decisive role (Prochaska, Redding, et al., 2008).

This staged behavior change process fits well with another conceptualization in behavior science that advocates that three types of behavioral actions- of different durations and different levels of familiarity have different salient determinants and underlying mechanisms (Fogg & Hreha, 2010). Applying it to the problem at hand, the transition process involves the one-time, unfamiliar dot (new LPG purchase to enter the preparation stage), short-term unfamiliar span (new behavior during user trials in initial period that spans the action stage) and long-term familiar path behavior (effortful span behavior turning into the spontaneous habit over time in the maintenance stage).

On similar lines, some CCS researchers have identified these three steps as “acceptance, initial use, and sustained use”, primarily driven by empirical observations but bereft of any theoretical grounding (Ruiz-Mercado & Masera, 2015). However, I have not been able to find any published cookstove literature that clearly identified salient determinants of the desired dot, span, and path behavior separately. They have clubbed dot with span (“acquisition and initial use” as adoption) (Stanistreet et al., 2014) or clubbed span with path (mixing short-term usage with long-term usage as “usage”) (Shankar et al., 2014) or clubbed together dot, span and path (“uptake”) (Rehfuess et al., 2014). For example, while capital cost of CCS is widely considered as an important factor (Puzzolo et al., 2016), its importance at the action stage (once the stove is purchased) would be much less than when progressing to the preparation stage. So, from the perspective of an intervention planner, it is far more useful to have the already identified exhaustive list of factors categorized by stage-wise saliency. Such research would then inform intervention planning for differentiated strategies to promote uptake, initial usage, and sustained usage, or in TTM parlance, progress from precontemplation to preparation, preparation to action, and action to the maintenance stage.
2.5.2 Need for post-sales interventions to break past habits

The TTM literature repeatedly stresses the iterative and gradual characteristics of behavior change during a transition and highlights the fragility of the process, wherein stages are “both stable and open to change” (Prochaska & Velicer, 1997). One of the key unanticipated difficulties in the uptake of LPG is that of breaking old habits (TCS usage) to perform new behaviors (CCS usage) in the context of voluntary behavior, i.e. there are no laws to enforce the desired behavior in the action stage (Verplanken & Wood, 2006). For any experienced TCS user, past repetition of old behavior in a stable kitchen environment has resulted in a well-formed habit of TCS usage. Generally, habit is measured as the extent to which an individual believes the behavior to be automatic (Venkatesh et al., 2012) or the activity ‘kicks in’ automatically when exposed to familiar ‘stimulus’ cues (Verplanken & Wood, 2006). In such cases, primary TCS usage would be prompted automatically by situational cues, as a result of cue-behavior associations learned from past performance (Gardner, 2015). Hence, new CCS customers would struggle in the transition process as every instance of new behavior would necessitate mental struggle to fight old habit that entails primary TCS usage (Kowsari & Zerriffi, 2011). Habit automaticity would be evident in the lack of conscious intention (e.g. use TCS without thinking), minimal awareness (quickly, easily, with little effort, and in parallel with other behaviors) and lack of control (difficult to avoid cooking with TCS) (Verplanken & Wood, 2006). It would have to be countermanded by conscious, deliberative efforts, which can be taxing on the brain at times (Kahneman, 2003). So, uptake of CCS does not automatically guarantee CCS usage, i.e. progress from preparation to action stage is a complex and effortful process. Hence, users should get the “support they need to learn how to use the stove” to progress to the action stage (regular LPG usage as primary cooking fuel) as the learning curve for desired behavior change in early days of usage is intense and can be challenging for average users (Jürisoo & Lambe, 2016).

Yet, most intervention studies are focused on initial sales with scant attention to post-sales challenges (Goodwin et al., 2015; Palit & Bhattacharyya, 2014). Even research around clean cooking transitions tend to be cross-sectional and only examine initial acquisition (sales or uptake) or at best, short-term use; hence, long-term/ sustained usage challenges are not well understood (Puzzolo et al.,
2016). However, in recent years there is widespread acceptance about the importance of long-term consistent and sustained usage of CCS (Shankar et al., 2014).

2.5.3 Long-term monitoring for reliable impact assessment

TPB literature suggests that one should expect a feedback loop in behavior change process such that "when a behavior is carried out, it can result in unanticipated positive or negative consequences, it can elicit favorable or unfavorable reactions from others, and it can reveal unanticipated difficulties or facilitating factors" (Fishbein & Ajzen, 2011). New behaviors are much less stable (varying over the course of the year) and unlikely to be permanent (over device lifetime and then repeat purchase) in the case of the clean cooking energy transition for two reasons. First, there are seasonal variations in energy demands (mud stove provides add-on space-heating in winter) (Khandelwal et al., 2017), fuel access (surplus crop residue during crop harvest season) (Ruiz-Mercado & Masera, 2015), food preferences (seasonal grains and vegetables), change in cooking location (cooking indoors during rainy season) (Nasir, Colbeck, Ali, & Ahmad, 2013), and cash-flows (Palit & Bhattacharyya, 2014). This variation can create temporary negative “individual perceptions and knowledge” (Puzzolo et al., 2016; Rehfuess et al., 2014) or, in TTM parlance, increase the cons of using CCS round the year. New cooking fuel purchase behavior during a cash-rich season may seem less attractive during the cash-lean season and may lead to a reversion to old behaviors (Khandelwal et al., 2017). Feedback from earlier experiences (paying for LPG refill in cash-lean season and cutting back on other expenses) is likely to change the person’s “behavioral, normative, and control beliefs and thus affect future intentions and actions” (Fishbein & Ajzen, 2011).

Second, switching back to the old option (TCS) is easy as it “can be constructed for little or no cost and with minimal technical skill” quickly (Khandelwal et al., 2017). Hence, the temptation to “go back” to the old behavior would always remain high in the face of any disruptive/ unexpected change in the external environment (ex. fuel supply delays), technology features (ex. stove breakdown) or household characteristics (ex. increase in family size) (Kowsari & Zerriffi, 2011; Prochaska & Velicer, 1997;
Verplanken & Wood, 2006). Hence, unless interventions can monitor to confirm household behavior at the maintenance stage, any projections of health and climate benefits based on initial or short-term usage tracking would not be grounded in reality.

2.6 Challenges and way forward

While this multidisciplinary conceptual framework to study cooking energy transition should provide useful insights to tackle the urgent problem of HAP, I foresee at least four major limitations or risks that future work needs to address.

First, as CI-CHANGE does not explicitly deal with which intervention strategies could fast-track the transition process, two key insights from literature review related to intervention planning are excluded. One, it excludes the COM-B (Capability, Opportunity, Motivation, Behavior) model (Tombor & Michie, 2017) or its close variants such as the theoretical domains framework (Cane, O’Connor, & Michie, 2012) and the ‘opportunity, ability, and motivation framework’ (Martin et al., 2013). Two, the ten processes of change in TTM, which have received “the most empirical support” compared to the segmentation based on the five stages of change (Prochaska & Velicer, 1997) are not included. In both cases, the experiential and behavioral processes of change are more relevant for determining the specifics of an intervention rather than a prioritization of process factors (drivers/ barriers) at a given stage. If the input based approach is about the "who" and our approach is about the "how" and "why", these approaches are more about the "which" interventions are more suitable. It represents the next stage of work by practitioners once they understand the behavioral priorities of their potential target audience.

Second, none of the three theories have been tested in the cooking energy domain. This is true of all major health behavior change theories. Though tested more than a hundred times for other health-relevant behaviors (Davis, Campbell, Hildon, Hobbs, & Michie, 2015; Michie et al., 2014), they have never been tested to address cooking behavior despite massive health implications. Application into this new domain poses two risks related to the scope of these theories. One, TTM and TPB have been applied
most often to explain and guide behavior changes related to addictive behavior such as smoking and alcohol abuse. Obviously, the psychological challenges of combating addiction are expected to be different from any cooking energy transition. For example, affordability plays a major role in cooking energy choices in ways that are not the case for addiction. However, there is a precedence for applying TTM and TPB to non-addictive behavior such as pain management, bullying, domestic violence, and readiness for adoption of health behaviors like regular mammography (Fishbein & Ajzen, 2011; Hall & Rossi, 2008; Rakowski et al., 1996). There does not appear to be anything inherent in this domain that would indicate TTM and TPB could not be applied equally well. Two, application of these theories to the main socio-demographic target of CCS interventions - rural low-income populations in developing countries - is limited at best. These theories have been tested with a primarily urban, well-off educated population (Venkatesh, 2014). However, again there is no inherent reason to believe it would not apply to the low-income rural population in the developing countries. TTM has been successfully tested with low-income individuals in industrialized economies, such as low-income Hispanic women in community health clinics in the USA (Babamoto et al., 2009; Mauriello, Van Marter, Umanzor, Castle, & de Aguiar, 2016). Field-tests of these theories has now been reported in Chapters 4 and 5 of this thesis. This framework should provide guidance on how well the theories perform and modifications that would need to be made when applied more widely.

Three, these three theories primarily deal with individual & self-regulatory behavior while in our framework the main indicator of behavior change is the household-level usage of CCS. It is possible that key individuals who influence cooking decisions in a household are heterogeneous with different motives and priorities. For example, the priority for the wife (cook), husband and children could be fast cooking, low cost and tasty food respectively (Khandelwal et al., 2017). If such key individuals within a household are in different stages of change, their alignment with the household behavior indicator and the practicality (from a resource perspective) to introducing the stage-specific behavior change interventions requires more research. This is very different from more homogenous group settings used in the psychology domain to effect behavior change where targets are employees (Venkatesh, 2014) or smokers
who wish to quit (Prochaska & Velicer, 1997). However, there are already notable exceptions, such as a TTM study that targeted parents and children (entities with different motivation triggers) within the same household (Mason, Crabtree, Caudill, & Topp, 2008). I only examine the primary cook’s perception while capturing the perceptions of other key individuals in the injunctive norms of salient referents (Fishbein & Ajzen, 2011). However, it should be a priority for future research in this area to study best practices to manage conflicting priorities of household members in interventions with limited resources.

Four, these theories have been widely critiqued even where widely applied such as in smartphone-based healthcare for UTAUT-2 (Slade, Williams, & Dwivedi, 2013), or addiction research for TTM (Armitage, 2009) & TPB (Sniehotta et al., 2014). Entire special issues of journals have been dedicated to promote and refute proposals on whether to “retire” the theory of planned behavior-TPB (Sniehotta et al., 2014) and should the transtheoretical model (TTM) be put to "rest" (West, 2005). While there are critiques, the approach here is to use dominant theories in a field despite being aware of their limitations (known devil), instead of selecting novel untested theories (unknown angel) with no sense of the extent of their validity, reliability and consistency issues. Even the critiques admit that there are at present no well-tested alternatives with more consistent findings (Sniehotta et al., 2014). It may well be the case that any parsimonious behavior change theory that is tested rigorously in diverse settings would come up with mixed evidence and inability to fully account for the full spectrum of variance observable in human intention and behavior (Ajzen, 2015). The fact that these theories are considered as “standard” (Sniehotta et al., 2014) and continuously tested implies a certain level of general acceptance to scholars across domains. So, testing them to study the cooking energy transition will also help in furthering the ongoing methodological debates regarding these theories. Successful application of the theories in new contexts and for a different set of behavior changes that are centered on technological change may counter some of those critiques. Conversely, issues in applying the theories will further highlight needed modifications and limitations of the theories.

Moreover, an important aspect related to studying the transition process- which specific intervention strategies can fast-track the transition process- is not covered under this framework and is left
to future research. Further, other behavioral determinants like environmental consciousness (Schlegelmilch, Bohlen, & Diamantopoulos, 1996), widely applied in WEIRD (western, educated, industrialized, rich, democratic) contexts (Henrich, Heine, & Norenzayan, 2010) have not been incorporated in this framework. Also, key factors such as perceptions around non-monetized solid fuel supply, and regulation/ law to ban the burning of solid fuels could also be important determinants in the behavior change process.

To summarize, the focus on the conceptual model is directed at understanding the decision making process in both the pre and post uptake period with the boundary conditions of (1) rural, (2) low-income communities in (3) developing countries, with two additional conditionalities of (4) reasonable physical access to clean fuels and (5) focusing on self-regulatory behavior with no role of regulations in the post-uptake period due to political or enforcement issues.

These challenges demonstrate the complexity of the problem at hand, which has even been described as more difficult than ‘rocket science’ (Cheney, 2017). I have argued that this model, for all its potential risks and shortcomings, provides a useful and novel direction to study this age-old problem. Behavior change is key to the transition process and the proposed integration of key behavior change theories leads to three new untested hypotheses and under-explored research/ implementation agendas. First, the salient factors identified in the literature will differ in their impact based on the specific stage of an individual or household’s behavior change process. Second, post-sales interventions would be most effective in moving individuals or households to the action or maintenance stage when they incorporate those stage-specific factors. Third, shifts in behavior can only be identified and explained when both stove usage patterns and associated perceptions are tracked over long timeframes.

To conclude, this multi-disciplinary framework helps provide a testable hypothesis on the behavioral determinants of the post-uptake transition to clean fuels. It also provides a framework to rank the many factors that are identified in the cooking energy literature which is useful from the implementation/ practitioner perspective.
3. Cooking Energy Transition and ‘Ujjwala’ in rural communities

In this chapter, I use a descriptive analysis of quantitative data to describe how transition happens in rural communities by analyzing the data of all LPG consumers (across 100 villages) in a field site in Koppal district of Karnataka in India. I also utilize the data to show the effect of India’s flagship LPG stove promotion initiative which has garnered global attention due to its scale and speed in adoption (purchase). In the initial sections of this chapter, I provide a primer on the Pradhan Mantri Ujjwala Yojana (hereafter, PMUY) to set the context.

3.1 PMUY and India’s LPG market

India recently launched the Pradhan Mantri Ujjwala Yojana (hereafter, PMUY or Ujjwala) to promote liquefied petroleum gas (LPG) (Barua & Agarwalla, 2018; Smith, 2018). PMUY was implemented state-by-state, starting with Uttar Pradesh in May 2016, followed by other economically-backward states with low LPG coverage (Jindal, 2019). PMUY’s deployment in low-income, rural settings is unmatched in terms of scale and pace in the history of modern cooking energy access. Seventy million poor households (PIB, 2019a) took advantage of PMUY to purchase an LPG stove kit within 35 months since its launch. It has garnered international attention (Gould & Urpelainen, 2018; IEA, 2018) and inquiries from other countries hoping to replicate elements of the program (Jindal, 2019). PMUY has fast-tracked access to LPG in India- about 90% of Indian households to own an LPG stove as in January 2019 (PPAC, 2019), a sharp rise since 2015 (56%) (GoI, 2018a).

In addition to the strong political will at the highest levels of government, PMUY’s fast-paced deployment (~80,000 new consumers/day) may be partially attributed to India’s centralized command system for LPG distribution and marketing. Price/subsidy policies are centrally decided by the Ministry of Petroleum and Natural Gas (MoPNG). The operational aspects of LPG bottling, distribution,
marketing, and subsidy administration are handled by three public-sector ‘oil marketing companies’ (OMCs). Consumer sales and service support are provided by over 20,000 private LPG distributors, who act as physical “storefronts” for the OMCs (PPAC, 2018). The relationship between multiple stakeholders in the PMUY is also striking (see, Figure 3-1). For more information, please refer to the published literature (Jindal, 2019; Smith, 2018; Smith & Jain, 2019).

![Figure 3-1: Framework of PMUY and brief role of key players](image)

All households in India have to sign up for an LPG “connection” for household cooking use with these public sector OMCs. One needs to validate a family member’s identity and link her/his bank account to the subsidy system for reduced refill prices (Smith & Jain, 2019). Notably, LPG is a commercial fuel and sold in cylinders (14.2 kg or 5 kg of LPG). All beneficiaries buy the first ‘installation’ cylinder with the stove kit and have to purchase ‘refill’ cylinders for continued usage (Kar, Singh, Pachauri, Bailis, & Zerriffi, 2019). Henceforth, the cylinder implies 14.2 kg unless mentioned otherwise. Typically, 10-12 numbers of cylinders are required to use LPG as an exclusive cooking fuel for an average-sized family (Kar et al., 2019). The government subsidizes 12 cylinders per household per year, though consumers can voluntarily give up the subsidy. Consumers are ineligible for the subsidy if
their income/ wealth is above a threshold (Mittal, Mukherjee, & Gelb, 2017; Smith, 2018). PMUY beneficiaries do not get incentives for refill purchase, beyond the refill subsidy that is available to all LPG consumers.

3.1.1 LPG price

Since January 2015, OMCs linked the subsidy payment to a bank account and India’s universal identification scheme Aadhar under the ‘Direct Benefit Transfer of LPG subsidy- DBTL’ or PAHAL (in the Hindi language) (Gould & Urpelainen, 2018). Now, consumers have to pay the market cost (non-subsidized) of LPG to the distributor (termed ‘distributor price’ hereafter) (blue line) and then receive the eligible subsidy in their linked bank account (see, Figure 3-2). The net cost to the consumer (green line) is the distributor price minus the subsidy (termed ‘net price’ hereafter). Earlier consumers directly paid the subsidized price to the distributor (Mittal et al., 2017). The distributor price and subsidy amount is adjusted on a monthly basis based on the international market price of LPG volatility with the goal to shield the consumers from domestic price fluctuations (green line). Notably, the fluctuation in the international spot price closely reflects the market (distributor) price in India with a one-month lag. Over the last one year, the net price of one domestic LPG cylinder has been hovering around Rs. 500 while the distributor price has fluctuated from Rs. 550 to Rs. 1,000. To put these numbers in a context, monthly per capita expenditure for a typical rural family in India is Rs. 1054.
LPG in India is a mixture of 60% butane and 40% propane (GasIndia, 2018), so the spot price (3MGas, 2018) of propane and butane in Saudi Aramco in the same proportion is used as a benchmark for the international price of LPG. The Rs. valuation of LPG spot price is done as per the monthly average of the USD-INR rates for a given month (Investing.com, n.d.). The spot price does not include the cost of shipment, processing, taxation, and distribution. Also, the price at which OMCs purchase would depend on the terms and conditions of the contract and may vary from the publicly available spot price data.

3.1.2 LPG connection cost

The PMUY program provides poor women with a one-time subsidy and an optional loan to cover the initial upfront cost including the cost of stove, cylinder, and accessories (MoPNG, 2017; Smith, 2018). Past studies suggested that although the poor always aspired to have liquefied petroleum gas (LPG) connections (Smith & Dutta, 2011), the biggest barrier to LPG adoption (here, and hereafter, it implies uptake/purchase unless mentioned otherwise) was the high upfront cost (about Rs 5,000; 1 USD = Rs.)
71.82 as on 14 December 2018)\textsuperscript{15} associated with a new LPG connection (CRISIL, 2016; Puzzolo et al., 2016). To put this in perspective, the average monthly per capita expenditure in rural India is Rs. 1287.17 (Planning Commission, 2013). PMUY was specifically designed to make the cost associated with a new LPG connection (see, Table 3-1) affordable even for the poorest of the poor.

There are two types of domestic consumers by category: SBC (Single bottle cylinder) and double bottle cylinder (DBC) consumers. In the case of SBC consumers, when the bottle empties, the consumer would come to the outlet with the empty bottle and buy a filled bottle. Or, if there is home delivery available, the distributor typically sends a ‘delivery boy’ who delivers the cylinder in lieu of cash. As DBC consumers can have two bottles, so when one bottle is empty, they immediately replace it with the full bottle and then bring the empty bottle to the outlet for replacement (or, get it delivered). So, DBC consumers, who paid Rs. 1600 as additional security deposit compared to SBC consumers, have more flexibility in buying refills without interrupting the cooking process. It should be noted that all Ujjwala consumers are SBC consumers whose security deposit is paid by MoPNG. The first cylinder purchased along with the stove/burner during enrolment (signing up to become LPG consumer) is known as the ‘installation’ cylinder while the subsequent purchases are known as ‘refill’ cylinders. Here it should be noted that PMUY consumers are only eligible for SBC registration though they are eligible for an upgrade to DBC if they pay additional Rs. 1600 for the security deposit for the second cylinder. In the case of PMUY beneficiaries, they are exempt from paying a security deposit of Rs. 1600. Instead, the government pays this amount to the oil marketing companies (OMCs). So, strictly speaking, PMUY subsidizes the upfront investment but it does not subsidize any cost (a security deposit which is an investment which is refundable). For PMUY, OMCs negotiated a special price for the LPG stove with the suppliers such that a PMUY special double burner stove is available for Rs. 999 while typically double burner stoves cost Rs. 1999. PMUY stoves have to meet the exact same quality and safety standards applicable for its more expensive counterpart, and there have not been widespread complaints about its

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\textsuperscript{15} We use Rs. as the currency unit in the rest of chapter
quality or performance. Further, other costs such as accessories and administrative processing costs are absorbed by the OMCs and reimbursed by them to the distributors. In effect, a PMUY consumer’s upfront cost is Rs. 999 for the stove and the net cost of the first cylinder (installation cylinder), which since its launch in May 2016 hovered around Rs. 500.

Table 3-1: Detailed breakup of purchasing an LPG starter kit. It shows the amount of money charged to get a new connection (inclusive of taxes) for both general consumers and PMUY beneficiaries. 1 USD= Rs. 71.82 as on 14 December 2018

<table>
<thead>
<tr>
<th>Charge Description</th>
<th>Amount- PMUY</th>
<th>Amount- General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refundable Deposit (for SBC)</td>
<td>Rs. 1450 (Paid by govt. to OMC)</td>
<td>Rs. 1450 (Rs. 1150 for 7 NE states)</td>
</tr>
<tr>
<td>[For Double Bottle Cylinder, multiply the value by 2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refundable Deposit for One Regulator</td>
<td>Rs. 150 (Paid by govt. to OMC)</td>
<td>Rs. 150</td>
</tr>
<tr>
<td>Installation /demonstration charges</td>
<td>Rs. 88.50 (Paid by OMC to distributor)</td>
<td>Rs. 118</td>
</tr>
<tr>
<td>Administrative Charges for documentation required</td>
<td>Rs. 88.50 (Paid by OMC to the distributor)</td>
<td>Rs. 88.50</td>
</tr>
<tr>
<td>for serving LPG consumers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of issue of DGCC booklet</td>
<td>Rs. 29.5 (Paid by OMC to the distributor)</td>
<td>Rs. 59</td>
</tr>
</tbody>
</table>
For this balance amount, in case a prospective beneficiary expressed her inability to pay upfront then the OMCs offered a loan facility at zero percent interest. PMUY beneficiaries would forgo their cylinder refill subsidy until the loan amount is recovered (Kar & Zerriffi, 2017). About 74% of PMUY consumers had availed the option of purchasing the stove, first/ installation cylinder and stove accessories on loan (PIB, 2019a). The subsidy on the refills which is available to general consumers is withheld by OMCs till it covers the loan amount. In April 2018, the government announced a new scheme to incentivize LPG use wherein all consumers who took a loan under PMUY can continue to get subsidized refills (like general) consumers for one year and only up to first six cylinders (PIB, 2019a). It was intended to cushion poor PMUY beneficiaries from paying the full non-subsidized price of refill (distributor price) based on the international market volatility. At launch, only women who were listed on the socio-economic caste census (SECC) 2011 list as deprived (if they fulfill one or more of the seven deprivation criteria) were eligible (Lok Sabha, 2018). There were widespread complaints and discontent

<table>
<thead>
<tr>
<th>Cost of Suraksha Hose (pipe connecting the burner to cylinder)</th>
<th>Rs. 170 (Paid by OMC to the distributor)</th>
<th>Rs. 170 (1.2 mt) [For 1.5 mt, Rs. 190]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Hot Plate/ Burner</td>
<td>Rs. 990 (Paid by consumer/ OMC provides Loan)</td>
<td>Rs. 1990 (minimum)</td>
</tr>
<tr>
<td>Cost of Installation (first) cylinder (the exact amount depends on provincial taxes; As on Nov 2018- Changes every month, the subsidy provided for first 12 cylinders/ year after purchase; After subsidy: ~Rs. 550)</td>
<td>~Rs. 1,000 (Paid by consumer/ OMC provides Loan)</td>
<td>~Rs. 1000</td>
</tr>
<tr>
<td>Total Amount for Single Cylinder starter kit</td>
<td>Rs. 1990</td>
<td>Rs. 5206</td>
</tr>
</tbody>
</table>
that many poor households were not included in the list (Jain et al., 2018; Jindal, 2019). In March 2018, the eligibility was expanded (known as Ujjwala Plus) to include women who were not in the list but were from seven socio-economically marginalized sections of society (PIB, 2018a). In December 2018, the eligibility was further expanded to include all poor families towards the goal of universal clean cooking access (PIB, 2018a). Here it should be noted that MoPNG/OMCs efforts were also directed towards strengthening the supply chain to cater to this spike in consumer cases in two ways. First, as on 01.04.2016, 10,424 Distributors of OMCs were catering to rural consumers; during FY (April to March) 2016-17 & 2017-18, OMCs increased rural LPG distributorships by 22% (2,286) (M. Grover, personal communication, May 11, 2018). Second, as on 01.04.2016, the rated Bottling capacity of OMC’s LPG Bottling Plants was 15,172 TMTPA (thousand metric ton per annum). During 2016-17 & 2017-18, OMCs increased capacity rated bottling capacity by 15% (2,223 TMTPA) (M. Grover, personal communication, May 11, 2018). As a result of these supply and demand initiatives, domestic LPG sales and import increased. OMCs had imported 8.8 million tonnes of LPG and sold 17.2 million tonnes of LPG to domestic consumers in 2015-16 (prior to PMUY launch). In 2017-18, the total LPG import and Domestic sale by OMCs was 10.7 (22% increase) TMT & 20.3 TMT (18% increase) respectively (M. Grover, personal communication, May 11, 2018).

3.2 Categorization of LPG use by purchase unit

I also categorized the data into four categories of users to indicate the position/role of LPG in the cooking fuel mix of each consumer: an occasional (rare) use of LPG, secondary use of LPG, the primary use of LPG, and exclusive use of LPG as cooking fuel. This is estimated on the basis of how much useful cooking energy is needed for a typical family of five members, and therefore how much LPG is needed to cater to the needs of individual consumers translated into monthly cylinder purchases, on average.
In order to study cooking energy transition, I aimed to define how much consumption implies a successful transition, and intermediate steps. As the discussion is in terms of a number of (14.2) cylinders purchased (and assumed to be fully consumed), I use secondary literature and primary data from a project in the study area (Koppal) to estimate the level of use. I broadly classify four usage types: an occasional (rare) use of LPG, secondary use of LPG, the primary use of LPG, and exclusive use of LPG as cooking fuel. The primary use of LPG is defined as the amount of LPG requires to meet more than 50% of the end-use cooking energy needs, while exclusive/near-exclusive use is when LPG meets almost entire cooking energy needs.

I first estimate how much useful cooking energy is needed for a typical family of five members, then how much LPG is needed to cater to those needs at an individual consumers’ level and finally, what do these numbers translate to in terms of monthly purchases of LPG refills, on average.

Useful energy refers to the energy delivered to the cooking vessel, which accounts for the energy content of the fuel and the net combustion efficiency of the stove/fuel combination. Globally, variations in income levels, cooking and diet preferences fuel a wide range for useful cooking energy requirements that can vary by up to an order of magnitude (0.77-7.22 MJ/capita/day) (Daioglou, van Ruijven, & van Vuuren, 2012). Our analysis of India’s energy consumption survey data suggested that high-income households in urban areas using LPG have higher cooking energy consumption levels compared to low-income rural households who are dependent on firewood. As PMUY specifically targets poor households, it may be more prudent to use the consumption data of low-income families in India, who typically use firewood. Table 3-2 presents a range of estimates specific to the Indian energy context. It includes data from published reports and articles as well as calculations based on solid fuel consumption data from the 68th round of India’s national sample survey, and field survey data from households in rural Karnataka, India (D. Singh, Pachauri, & Zerriffi, 2017). In the face of such diversity, selecting a range of useful cooking energy for rural consumers for this analysis is a challenging (and controversial) task in the absence of representative field data. Even with sample field data, questions related to its representativeness considering the diversity in cooking methods persist. I used three scenarios to capture
the range of useful cooking energy requirements, annually for the study area households: 2500 MJ/ hh, 3500 MJ/hh, and 4500 MJ/hh. Further, published estimates of useful cooking energy needs in rural households of other developing countries are also within this range (Daioglou et al., 2012).

Table 3-2 Range of estimates of useful cooking energy in India

<table>
<thead>
<tr>
<th>Original Data</th>
<th>An estimate of Useful Energy (MJ/hh/Year) for India</th>
<th>Assumptions For conversion to useful energy</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 MJ/hh/day</td>
<td>2450</td>
<td>350 days per year of cooking to account for festivals, travel, etc. where cooking not conducted at home</td>
<td>For all households (Niti Ayog, 2015)</td>
</tr>
<tr>
<td>1299.61 kg/hh/year</td>
<td>2807</td>
<td>14.4 MJ/kg of fuelwood (at 20% moisture content); 15% net thermal efficiency (product of combustion and heat transfer efficiencies) for a traditional biomass stove</td>
<td>For rural households in India exclusively using fuelwood: Extracted from NSSO Round 68 (2011-12) dataset used for fuelwood displacement assessment due to access to LPG (D. Singh et al., 2017)</td>
</tr>
<tr>
<td>4.37 kg/hh/day</td>
<td>3304</td>
<td>-Do-</td>
<td>Fuelwood only users in rural Karnataka: Actual measured wood consumption as per</td>
</tr>
</tbody>
</table>
Commercial LPG stoves in India receive one to five stars based on efficiency tiers that vary from 68% to above 81%. I assume that PMUY beneficiaries would use cheaper stoves, within the lowest LPG stove tier (with a mean efficiency of 70%). However, often rated efficiencies are not representative of field conditions or they decline over time, so I assumed a 10% reduction over rated efficiency levels, with an effective stove efficiency of ~60% (Daioglou et al., 2012). As LPG’s calorific value is 45.84 MJ/kg, the useful energy delivered per cylinder is estimated to be 385 MJ. If a rural household with cooking energy needs defined by the three scenarios mentioned above were to switch all of its cooking over to LPG, the number of cylinders required would range between 6.5 and 11.7 per year. The mid-range estimate is 9.1 cylinders per year (or 3500 MJ of energy requirement/ 385 MJ of energy delivered per cylinder). For households consuming 5 cylinders, this would cater to 43% - 77% of their total cooking energy requirements (55% at midpoint estimate). Hence, households using lower (2500 MJ-3500 MJ) or higher (3501 MJ- 4500 MJ) useful energy, can be considered as using LPG as a primary (>50%) cooking fuel if they use four to five LPG cylinders per year.

It should be noted that I use the word usage, purchase and consumption interchangeably. I have data on LPG purchase and assume that whatever was purchased within a time period was also consumed (or, used) within the same period. As this is maybe considered a questionable assumption, but I
conservatively consider five cylinders purchase (including installation cylinder) as the minimum cutoff for primary usage. So, households that purchased five cylinders in the first year have already consumed four cylinders worth of LPG (lower range of energy requirement) and very likely consumed their fifth cylinder, partially. In that case, the consumption of LPG in the first year for such consumers is very likely the mid-point of estimated cooking energy requirements in rural households with a typical family size of five people. Similarly, I have considered the 10-cylinder purchase as the indicator of exclusive/near-exclusive usage by a typical household. The purchase of the 10th LPG cylinder within one year indicates that nine cylinders and part of the 10th cylinder were consumed within one year. As I assumed that rural households would not pay for non-subsidized LPG, the purchase bracket of 9 to 12 cylinders was considered as exclusive LPG usage. However, field observations indicated that a few households with higher LPG purchase level, do use it for commercial purposes, such as in tea stalls, etc.

I assumed that urban areas are exclusively/near-exclusively dependent on LPG, and then used the average urban LPG consumption as a check on the above estimate of exclusive use. I found that in 2005, urban consumption was 11.9-kg/HH/month, which is equivalent to 142.8 kg per year, which is equivalent to 10 cylinders of 14.2 kg each. Here, it is also assumed that the economic status of an average urban household would be similar to a rural household that can afford 10 cylinders in a year.

As a comparison, the typical LPG standard in “mature” LPG markets in developing economies for near-exclusive use is considered to be 20 kg/person/year (Bruce et al., 2018), which amounts to 100 kg/household/year, which amounts to 7.1 [14.2 kg] cylinders per year for a typical family size of five, i.e. purchase of 8 cylinders/years.

To summarize, I consider the purchase of five to nine cylinders per year as primary cooking with LPG, more than nine as exclusive and less than five as secondary. If a consumer has purchased just one cylinder (installation cylinder) and made no effort to go back for even one refill in the next 364 days, I considered them as “lost” consumers, with rare/occasional usage. In other words, at an individual consumer level, rare usage is 1 cylinder purchased/year, secondary usage is ≥2 cylinders purchased/year.
& <5 cylinders purchased/ year, primary usage is ≥5 cylinders purchased/ year & <10 cylinders purchased/ year, and exclusive usage is ≥10 cylinders purchased/ year & <13 cylinders purchased/ year.

When I considered the monthly refill patterns, I also controlled for the increasing number of registered customers by using a normalized monthly refill. It is estimated as the total number of refills for every 1,000 registered consumers (with a lag of two months as discussed earlier). So, if all consumers were exclusive users (>9 cylinders per month), they would have purchased >9,000 refills over the year. Discounting for seasonal preferences, on average, if all consumers and their purchases were equally spread over the year, it would imply >750 (>9,000/12) monthly refills, on average. By the same method, monthly sales in case of occasional usage would be <167 refills/ month, secondary usage >167 refills/ month & <333 refills/ month, and primary usage >333 refills/ month & <750 refills/ month, according to our estimations.

3.3 State level variance in PMUY

PMUY has brought cooking energy transitions to the fore in the Indian polity and popular media. It is now an electoral issue in the world’s largest democracy (Varma & Bhaskar, 2018). However, the public discourse has largely focused on anecdotal examples of ‘success’ and ‘failure’, particularly around the question of whether beneficiaries are using LPG (DD News, 2018; Jha, 2017). However, there has been no objective evaluation of the extent to which PMUY has actually induced a transition away from solid fuels (Dabadge et al., 2018). Assessment of LPG use is critical, as the health, social, economic and environmental benefits of a transition (Anenberg et al., 2013) are conditional on the extent of replacement of solid fuels by LPG (M. A. Johnson & Chiang, 2015). Typically, a clean cooking transition starts with the purchase of an LPG starter kit (stove, first/ installation cylinder & accessories), which generally leads to partial fuel stacking- use of LPG and solid fuels as secondary and primary fuel respectively- in early days. For a successful transition, this is followed by sustained and growing LPG use (Shankar et al.,
2014), which eventually leads to complete solid fuel displacement by LPG (Kar & Zerriffi, 2018; Ruiz-Mercado et al., 2011).

### 3.3.1 Description of state level variance

I use this national database of LPG purchases by PMUY beneficiaries aggregated at the state level. This data was made available by a senior MoPNG official. It contains data on 30 million PMUY beneficiaries, aggregated by state, who have completed at least one year as LPG consumers (based on their date of enrollment). This MoPNG dataset (as in November 2018) indicates that 30,552,045 (~50% of total beneficiaries) consumers completed at least one year since enrollment (A. Jindal, personal communication, December 4, 2018). 7.2 million consumers (24% of completed year consumers) did not come back for a refill even once, while 8.5 million (28% of completed year consumers) consumers have purchased 5 or more refills within the first year; average purchase per consumer in the first year is 4.9 (including the installation) cylinders (A. Jindal, personal communication, September 26, 2018). The national average numbers mask substantial inter-state variations in LPG use by PMUY beneficiaries (see, Figure 3-3, Figure 3-4, and Figure 3-5).
Figure 3-3 Inter-State variation in the percentage of primary PMUY beneficiaries who purchase 5 or more cylinders of 14.2 kg each (including an installation cylinder) in the first year. Only beneficiaries who have completed at least one year since enrollment is considered. Data as on 30 November 2018 based on the purchase history of LPG in the first year. Only states where there are 10,000 PMUY consumers with one year of experience and where the number of consumers who completed one year is at least 5% of PMUY connections released are considered for the sake of representativeness. Else, ‘Insufficient Data’ is used as a legend for a province (state/union territory).
Figure 3-4 Inter-State variation in the percentage of dormant PMUY beneficiaries who did not return for any refill purchase. Only beneficiaries who have completed at least one year since enrollment is considered. Data as on 30 November 2018 based on the purchase history of LPG in the first year. Only states where there are 10,000 PMUY consumers with one year of experience and where the number of consumers who completed one year is at least 5% of PMUY connections released are considered for the sake of representativeness. Else, ‘Insufficient Data’ is used as a legend for a province (state/union territory).
Figure 3-5 First Year LPG cylinder purchases by PMUY beneficiaries who have completed at least one year. The total purchase includes an installation cylinder. States with fewer than 500,000 experienced beneficiaries are considered to have insufficient data. The number in brackets in the legend is the number of states in each category.

3.3.2 Regression analysis of state-level variance

I explored the predictors of the state-wide variance in average LPG cylinder sales in the first year by PMUY beneficiaries who are active, i.e. returned in the first year to purchase a refill cylinder (no state was excluded from this analysis). I selected three key variables suggested in literature (Lewis & Pattanayak, 2012; Puzzolo et al., 2016): education (state-wise literacy rate for rural male and female) (NSSO, 2016), affordability (household income, consumption expenses and surplus income) (NABARD, 2018), and the extent of availability of solid fuel (proxy indicator of proportion of geographical area that
has forest or scrub) (FSI, 2017). In addition, I had included the average distributor coverage area both in terms of average ‘number of consumers to distributor’ and ‘geographical area to distributors’ for a state as additional factors (see, details in Supplementary Code 1).

<table>
<thead>
<tr>
<th>Regression: State Level Average Annual Purchase: Estimate (Standardized Beta)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable:</strong> First Year Average Purchase (Including installation Cylinder)</td>
</tr>
<tr>
<td>(1)</td>
</tr>
<tr>
<td>Avg. Household consumption expenses</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Female Literacy</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Male Literacy</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Consumer/Distributor</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>% of area with solid fuel resource</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Avg. Household consumption income</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Constant</td>
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<td></td>
</tr>
<tr>
<td>AIC</td>
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<td>BIC</td>
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<tr>
<td>Observations</td>
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<tr>
<td>R²</td>
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<tr>
<td>Adjusted R²</td>
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<tr>
<td>Residual Std. Error</td>
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<tr>
<td>F Statistic</td>
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</tbody>
</table>

Figure 3-6: Regression models for explaining state level LPG use by LPG beneficiaries. The state-wise variance in mean LPG cylinder purchase only for the first year. It shows the estimate (with p-value in the form of stars) with the standardized coefficient- beta in parenthesis.

Regression analyses of these potential explanatory variables indicate that at the state level, rural household expenditure and distributor density (consumers/ distributor) are significant, and together explain 37% of the variation in state-level average cylinder purchase by PMUY beneficiaries. Other state-level factors, such as income, male/ female literacy levels, and forest/scrub area (a proxy for access to solid fuels) are not significant in explaining these differences. I also found that a standard deviation
increase in household consumption and distributor density increase purchase by 0.40 and decrease purchase by 0.41 standard deviations respectively.

3.4 Methodology of Koppal sales data

I now turn attention back to Koppal- the study area and examine whether PMUY has been able to transition at the population level (all LPG consumers in the study area). Literature hitherto published on PMUY (Ahmad, Sharma, & Singh, 2018; Dabadge et al., 2018; Giri & Aadil, 2018; Jain et al., 2018; Kar et al., 2019; Smith & Jain, 2019) has primarily focused on national level LPG connections, average consumption, or in-depth surveys of PMUY beneficiaries from rural areas based on self-reported consumption data. These prior works are either too general (national level and average consumption figures) or need to be complemented with other data sources on consumption. Here I use sales data from a single district to address four critical questions to help assess the efficacy of PMUY in promoting a cooking energy transition, while also providing inputs for potential mid-course corrections and lessons for similar future initiatives. The data used to answer these questions cover sales of LPG by three distributors in Koppal District of Karnataka (see Methods for more detail). It demonstrates a method for moving beyond anecdotal examples and to provide evidence regarding consumption patterns to inform policy-makers. I use an original dataset of >200,000 LPG sales transaction records for all >25,000 rural (PMUY & general) consumers from Koppal district in Karnataka state to address the knowledge gaps (see next section). While the results presented here are specific to the conditions within this region, they address a number of key questions around LPG use and point to implementation issues that may have implications for other parts of India or other countries attempting large-scale LPG rollouts. They also demonstrate the value of large consumer purchase data analysis to support transparent program evaluation. The use of sales data for evaluation is novel, as prior research on stove interventions has primarily used self-reported consumption (Giri & Aadil, 2018; Jain et al., 2018), with a few studies deploying thermal sensors, but typically in small sub-samples of the study population (Graham et al., 2014; Pillarisetti et al., 2014).
3.4.1 Exploratory research questions

To what extent has PMUY enabled a cooking energy transition in rural, low-income settings?

The core premise of PMUY (Smith, 2018) is that ‘deprived’ women aspire to use LPG (Smith & Dutta, 2011) but cannot afford the upfront capital cost (CRISIL, 2016). In other words, the growth of PMUY consumers should ideally be additive, i.e. in addition to any business-as-usual growth, which would have happened in the absence of PMUY. However, it is reported that “many well-to-do [sic] households—who could otherwise afford LPG” benefitted from PMUY (Jain et al., 2018). If PMUY targets consumers who could and would have purchased LPG without financial incentives, ‘subsidy targeting’ emerges as an important line of inquiry. Hence, from a policy evaluation perspective, to understand the impact of PMUY, assessing the growth of customers after accounting for the business-as-usual (BAU) trend is required to assess the actual ‘purchase’ transition.

There is also an assumption in the PMUY promotions (AssamTribune, 2018; MyGov India, 2018) that once the poor are unburdened with the capital outlay for stoves, they will be able to buy enough LPG to “lead a smoke-free, less polluted, convenient and healthy life”(GOI, 2016). Past studies (Kar & Zerriffi, 2018; Ruiz-Mercado et al., 2011; Shankar et al., 2014) indicated, however, that purchases by low-income rural households do not necessarily result in sustained use (Giri & Aadil, 2018; Jain et al., 2018; Ruiz-Mercado & Masera, 2015). The gap between refill purchases and consumption growth rates are important indicators of the impact of PMUY’s one-time capital cost incentive on promoting regular usage (repeat purchase).

How is LPG use different between PMUY beneficiaries and general consumers in rural areas?

India, like many developing countries, has a large urban-rural disparity in LPG use. Urban populations have greater access to LPG distributors, lower access to solid fuels, higher incomes, and higher opportunity costs of labor (Giri & Aadil, 2018; Kar & Zerriffi, 2018; Lewis & Pattanayak, 2012; Smith, 2018). Urban women also have higher income and education levels. These indicators are traditionally associated with greater decision-making autonomy and lower gender disparity (Miller &
Mobarak, 2013). Hence, comparing rural PMUY beneficiary consumption levels against urban or national averages may be misleading, especially in the short term. For these reasons, I considered LPG consumption by general consumers in rural areas to provide a better benchmark for comparison in our analysis.

**Does LPG use to increase over time?**

The literature on technology adoption, in general, suggested that increasing familiarity with technology can help reduce people’s attachment to earlier technologies due to greater comfort, expertise, and confidence that comes with experience (Rogers, 2003; Venkatesh et al., 2012). A recent study suggested that LPG consumption in general households is strongly correlated with experience, with a median difference of 2 cylinders between consumers after their first year and consumers after their tenth year (Jain et al., 2018). This remains to be assessed for PMUY beneficiaries.

**What factors determine LPG consumption?**

Past literature suggested that household demographics, fuel prices, socio-economics, and climatic conditions influence the consumption of clean cooking fuels (Khandelwal et al., 2017; Rajakutty & Kojima, 2002; S. K. Singh, 2014). Considering our data source, which does not include any household level socio-economic or demographic data, I could only focus on natural and market determinants (van der Kroon et al., 2013) here. A better understanding of the quantitative impact of LPG price and seasonality on LPG purchases is, however, largely absent in the literature, as most studies are cross-sectional in nature (Stanistreet et al., 2015). In order to design better promotional campaigns and optimize pricing policies, understanding the relative effect of price and seasonality can be informative.
3.4.2 Novel dataset of electronic LPG sales records

For this chapter, I capitalize on the OMCs’ robust information technology platform, which electronically stores enrollment and sales records for all registered LPG consumers. The dataset comprises sub-district level data gathered from three Indian Oil Corporation Ltd. (IOCL) LPG distributors in the Koppal district of Karnataka state. These were conveniently located near another ongoing project site. The three distributors D1, D2, and D3 serve 25,000 domestic consumers from around 120 villages across four taluks. While the data gathered include both commercial and domestic consumers, I only analyzed data for domestic consumers in this research. This dataset comprises micro-records for individual customers (for full analysis, see Supplementary Code 2) based on our merging of two separate databases from within the IOCL data management system platforms (Spandan / Indsoft). These were accessed from the distributor’s terminals with special permission. Spandan includes a log of every LPG cylinder delivery and critical information such as date of purchase, type of purchase (installation or refill cylinder), equipment category (single cylinder/ double cylinder), distributor price, consumer name and consumer ID- a unique 16-digit identity number. Indosoft contains the consumer’s home address, enrolment date, consumer category (PMUY, general), etc. that can be linked to the first database by the unique consumer ID.

3.4.3 Description of sub-district database

Out of 30,303 (domestic, commercial and institutional) consumers in the dataset, I identified 28,075 domestic consumers (of which 15071 are PMUY beneficiaries) and a corresponding 2,08,694 LPG cylinder sales records across three distributors as of 31 December 2018. For D1 and D3, I have data since they started operations in December 2013 and November 2015, respectively. For D2, who started operations in 2012, data is only available since January 2016. I have used the cumulative number of total consumers as of 1 January 2016 and the number of new enrollments as a consumer on that day to estimate the total number of consumers as of 31 December 2015 for D2 (the baseline). Hence, the full records of
LPG consumers in the study area are available from January 2016 to December 2018. As some of the customers with D3 were transferred from other locations when they started, I had some consumers whose ‘full view’ purchase history (all transactions from the date of enrollment as LPG consumer up to 31 December 2018) is unknown. So, there are full records for all PMUY consumers and 9,695 general (Non-PMUY) consumers. These 36 months of data are equally split into pre-PMUY (January 2016-June 2017) and post-PMUY (July 2017-September 2018) periods. This is because PMUY was launched in Karnataka state on 17 June 2017 (D2 and D3 started enrollment in July 2017), while PMUY’s national launch was on 1 May 2016 in Uttar Pradesh state.

The individual cylinder sales transactions are formally known as ‘delivery’ logs in the IOCL system as LPG cylinders are supposed to be home-delivered. However, as is the case with many rural distributors, only D3 undertakes home delivery (in a partial manner) despite it being “highly recommended” by OMCs. Hereafter, referred to these ‘delivery’ transactions as purchase or sales transactions as I discussed the results from the consumers’ or distributors’ perspective respectively. Information on domestic cylinder subsidies, which vary on a monthly basis and by the distributor, were verified manually using the OMC guidelines issued every month. D1 and D3 also charge an Rs. 10-15 premium (as their outlets are farther from the OMC bottling plant, so additional transportation cost is incurred), and their consumers get an additional subsidy premium of an equivalent amount, which keeps the net price uniform for all consumers irrespective of the distributor that they are associated with. I combine this information with the datasets to get a complete picture of individual purchase transactions, including information on who purchased, when, at what net (& distributor) price and the number of days between transactions.

Based on the date of the transaction, I also broadly designate an individual transaction using two different seasonal classifications - climatic and agricultural. The standard seasonal classification used by India’s meteorological department is pre-Monsoon (March-May), monsoon (Southwest Monsoon) (June-September), autumn (Post Monsoon) (October-December), and winter (January, February), (IMD, 2018). For Koppal, I have slightly modified this as summer (March-May), monsoon (June-August), autumn
(September- November) and winter (December-February) based on local temperature and rainfall trends. I also considered three local agricultural seasons - Cropping (June to September), Harvest (October to January) and no agricultural activity (February to May) based on interviews with local stakeholders. A vast majority of the rural population is directly or indirectly dependent on agriculture or allied activity for their livelihoods.

3.4.4 Data cleaning & grouping

For this chapter, all data processing, analysis, and plots have been carried out in the R platform (R Core Team, 2018). Details of the code and the packages used are provided in the Supplementary Information Codes 1-2. The raw data collected in MS Excel format from the distributor terminals were first processed by the field staff of a partner organization - SAMUHA- in accordance with the Institutional Review Board (IRB) guidelines of UBC. In addition to deleting names, and other personal identifiers (different from the unique 16 digit number provided by OMCs), the first ten characters of the address were scrubbed. The anonymized dataset was then transmitted online to the research team. I used a series of codes in R to join datasets, and format them for further analysis.

I primarily use two types of datasets created for this study from the available data. First, delivery transactions of the domestic consumers in form of a data frame, which were then summarized into daily and monthly sales records both by distributor and in total (see Supplementary R Code file 2 for details). Second, I generate a customer database by summarizing all the purchase transactions related to an individual consumer to get each consumer’s individual records. This includes their enrolment date, and annual purchase records of LPG cylinders, where the annual cycle begins from the date of the first delivery of the installation cylinder for each individual consumer. Once the customer database was created, I then grouped these consumer records by category (PMUY and general), equipment (single or double), by years of experience as a consumer (2 indicating the consumer is in the 2nd year of LPG usage) and by year of enrolment. For all these groups, I also sub-grouped the data by the distributor. In
addition, I manually collected data on the subsidy amount that is credited to a consumer’s bank account by each distributor for every month. I also applied that data to the transaction database to calculate the upfront (distributor price) and the net (upfront price minus subsidy) price.

As the Spandan platform contains data for both domestic and commercial consumers, for the chapter, I used three filters to select individual transactions for domestic consumers after consultation with OMC officials and accounting for typos (detailed explanation is available within the R codes in the Supplementary Code 2), an issue also raised by India’s federal auditor (CAG, 2016). The data was thus also cleaned to adjust for these errors in the following manner. First, I checked if there was a replication of sales transaction records with identical consumer, delivery date and type of refill (installation/refill sales). Thus, 110 transactions out of a total of 214,037 transactions were rejected. Second, to select domestic consumers out of the total list, which included commercial and institutional subsidized consumers (schools), I followed a two-step verification process by focusing on two critical columns - equipment and scheme associated with a transaction. I applied a filter for the type of ‘equipment’ - 14.2 kg cylinder, which is used only by domestic consumers. Next, I applied a filter for four unique scheme codes ("DNSC", "DSC", "DSCBANK", "DSCDBTL") that are currently or were earlier associated with domestic consumers. Even if the codes changed for a domestic consumer’s records due to policy shifts (DSC to DNSC when Direct Benefit Transfer scheme was launched), or errors, if they were domestic, I included them. Generally, the base equipment code (14.2 indicating 14.2 kg LPG) and domestic codes (starting with D) cannot be mistaken as they are linked to payment. Entries linked to payment are done more carefully by the operators. I shortlisted 28,414 unique domestic consumers in this process from the selected transactions. Third, I identified that the “category” column was critical for analysis purposes. When the “category” for consumers was missing, I could not distinguish PMUY or general consumer groups for further analysis. Hence, I dropped a further 339 consumers with “null” category. Fourth, I removed all consumer transactions if the consumer status was either ‘canceled’ or ‘suspended’, generally for failure to provide documentation or because it was found fraudulent during an inspection on a later date.
Once clean ‘domestic’ transactions were identified, I grouped the consumption by a consumer, and further filtered the data to eliminate consumers who had purchased more than 12 cylinders in a year. Field interviews strongly suggested that no domestic consumer in the study area would pay for a non-subsidized LPG cylinder. So, higher usage by domestic consumers could indicate diversion for commercial purposes. I also excluded ‘discontinued’ consumers from the analysis, i.e. those who ceased to be LPG consumers.

For analysis, which requires data since the first purchase to track the effect of experience, I only selected consumers whose enrollment date was either available or could be reasonably estimated, and all records since their enrollment are within our data window. For example, I do not have transaction data for distributor D2 before January 2016, though it was operating before this. In this case, I only selected those consumers of D2 who enrolled on or after 1 January 2016, when I knew their exact enrollment dates.

3.4.5 Data analysis method for specific research questions

*To what extent has PMUY enabled a cooking energy transition in rural, low-income settings?*

I calculated the compounded monthly growth rate and month-on-month growth rates in consumer numbers for both general and PMUY consumers. If there were differences in growth rates of general consumers in the pre and post-PMUY period, the pre-PMUY growth was considered as the business-as-usual (BAU) rate to estimate when the LPG customer base would have expanded to current levels without program implementation. The difference between this and the actual numbers of enrolled customers was then taken to be a measure of the impact of the program. I also considered multiple pre-PMUY periods: prior to the national launch, and prior to Koppal launch of PMUY. I also plotted the daily total refill sales and daily cumulative consumer number for July 2017 to December 2018 to visually assess the gap between enrollment and consumption.
How different is LPG use between PMUY beneficiaries and general consumers in rural areas?

I compared the LPG demand of PMUY consumers with general consumers in two ways. First, I normalized the monthly refill sales by dividing the refills sold in a month by the total number of registered general or PMUY consumers. This shows both seasonal variances in demand for LPG, as well as how new enrolments and monthly (distributor and net) price changes impact the average refill trends. For registered consumers, I used the concept of “effective” registered consumers for a given month which involved using a one-month ‘lag’ adjustment. As rural consumers who enroll in a given month buy an installation (first) cylinder with the stove kit, they would not be able to fully consume their installation cylinder, return the cylinder and then purchase a refill within the same enrollment month, irrespective of the season or price. As these new enrollees wouldn’t possibly buy refills in the same month that they enroll, even as exclusive LPG users, including them in the denominator (number of consumers) does not provide an accurate picture of the actual demand for LPG refills. Hence, I considered the previous month’s consumer number as the denominator. This is particularly important as there are some months of very high consumer enrollments.

Second, I also compared the population distribution of annual LPG cylinder purchases of PMUY and general consumers. When examining the distribution of individual consumer’s purchases, I used all available (including pre-2016) data to capture the first year of purchase data of pre-PMUY consumers. As no PMUY customers have completed a second full year since enrollment, I compared first year mean and median purchases to first year purchases of general consumers to avoid capturing the effect of experience. I also compared the distributions for these two categories of consumers across key percentiles (5, 25, 50, 75, 95) to better describe how much one distribution would need to shift to match the other one (Rousselet, Pernet, & Wilcox, 2017).
**Does LPG use to increase over time?**

I tested for an experience effect by comparing the annual LPG purchase for all consumers who are in their nth year of use over the years 1, 2, ..., n (n>2). As there are no PMUY consumers who have completed two or more complete years, this analysis is limited to only general consumers. I also examined both changes for a cohort over time as well as the initial range of LPG purchases in the first year of each cohort. In addition, I also examined if there are any differences in use over time by comparing the median number of days between two consecutive LPG cylinder purchases over time. This latter indicator has a finer resolution (365 days vs. 12 cylinders), which enabled us to detect the marginal effects of experience if any. Box plots were used to display the comparison of the distribution of consumption by experience.

**What factors determine LPG consumption?**

I applied standard linear regression modeling to explore the effect of an increase in a number of consumers, prices (distributor price, bank subsidy and net price) and season on LPG cylinder refill purchases, in addition to the distributor and the number of consumers. As price changes on a monthly basis, I used aggregated normalized monthly refill sales as the response variable for regression analysis. I converted the two seasonal categorical variables and the distributor details as factors using the base ‘is.factor’ function in R (R Core Team, 2018). I then ran stepwise regression using packages ‘olsrr’(Hebbali, 2018) (based on p-value) and ‘MASS’(Ripley et al., 2019) (based on AIC- Akaike information criterion) for auto-selection of models. Forward selection is a strategy which starts with no predictors in the model, iteratively adds the most contributive predictors, and stops adding predictor variables when no further improvements are statistically significant.

The forward selection method suggested both the total number of registered consumers and a number of general consumers be included as predictor variables along with season- agricultural and net price of a cylinder. Now, when I created a model based on this recommendation and tested its validity, I found that key assumptions underlying a regression model are violated. I applied the R function ‘vif from package
'car' (Fox & Weisberg, 2011) to test for multicollinearity (a key assumption of linear regression models) on the recommended regression model shows that the GVIF exceeds the recommended value of 4 for three of the four proposed predictor variable (except season_agricultural). Also, using the ‘gvlma’ function from package ‘gvlma’ I found that the proposed model violates the assumption of heteroscedasticity (Pena & Slate, 2014).

The examination of the proposed model using the stepwise forward regression method clearly pointed to the issue of lack of independence among the predictor variables. The number of total registered consumers is clearly dependent on the number of PMUY consumers, yet both are included. Hence, instead of having LPG monthly sales as the response variable, I normalized it, by making it LPG monthly sales divided by the number of total registered consumers. As a result, now the predictor variable candidate list excludes the variable: ‘total registered consumers.

Next, I repeat the process of forward regression wherein the predictor variables PMUY and general consumer enrollment numbers are assumed to be independent. This time the stepwise forward regression analysis suggested that just three non-household level predictor variables, namely, number of PMUY consumers, net price and ‘season-agricultural’ in a linear regression model explains about 94% of the variability of the response data (normalized monthly refill) around its mean. The number of PMUY consumers and net price have a negative coefficient in the linear regression model. During a preliminary analysis, I found that the lowest refills happened during the ‘No-agriculture’ season. So, I used this as the reference and found that during ‘cropping’ and ‘harvest’ seasons there is a relative increase in LPG refill sales (Kassambara, 2018). I also do backward selection as well as simultaneous forward-backward selection (Hebbali, 2018; Ripley et al., 2019).

The output models were also subjected to rigorous testing to see if the five key underlying assumptions of a linear regression model are held true. I checked for a linear relationship, multivariate normality, homoscedasticity, statistically insignificant auto-correlation, and low multicollinearity (see, Supplementary Code 2). I also reported scaled coefficients (‘beta’) in order to avoid dismissing an effect
as “small” when it is just the units of measure that are small, especially when there are very different units such as a number of consumers and price included in the model.

3.5 Results and discussion

The dataset used to explore the questions identified in the previous section contains details for all LPG sales transactions in Koppal district between January 2016 and December 2018 for all three distributors of a public sector LPG marketing company (Indian Oil) and data earlier than 2016 for distributors 1 & 2.

3.5.1 PMUY in Koppal: impact and implications

To what extent has PMUY enabled a cooking energy transition in rural, low-income settings?

PMUY was launched in Koppal in June 2017. Within sixteen months, PMUY beneficiaries in this region exceeded the number of general rural consumers. By the end of the available data window (December 2018), there were approximately 15,000 PMUY customers and 12,500 general customers in the database. The median monthly growth rate in PMUY customers was approximately six times that of the general customers over the same time period (Figure 3-7) and twice that of the general customers in the pre-PMUY period.
Figure 3-7 Monthly PMUY and general consumer enrollment growth rates (2016-2018). A logarithmic y-axis is used to capture month-to-month growth rates in consumer enrollment. The first three boxplots (from left to right) refer to monthly growth rates for general (non-PMUY) consumers before PMUY was launched nationally before PMUY was launched in Koppal and after PMUY was launched in Koppal, respectively. The last boxplot presents the growth rate for PMUY consumers after the Koppal launch in June 2017. Median values for the distribution of month-to-month consumer growth rate are depicted on the left of each boxplot.

However, that rapid increase in PMUY customers is also associated with a drop in the growth of general customers. The median value for the distribution of month-to-month general consumer growth rate decreased from 2.4% to 0.9% after PMUY was rolled out (Figure 3-7). Overall, the compounded monthly enrollment growth rate among general consumers dropped by half from 3.2% to 1.5% during this time period. Under a Business-As-Usual trend, with 3.2% monthly growth, the number of (general) consumers ought to have increased from 9,629 consumers (July 2017) to 16,423 (December 2018). Instead, the general consumer numbers only reached 12,364. The current number of actual consumers
(27,431) would likely not have been reached until April 2020. So, after adjusting for the BAU trend, I estimated that PMUY has been able to fast-track LPG consumer enrollments by 16 months but at the same time there was a drop in general customers from the expected number.

There are two possible explanations for the decline in the growth of general consumers. First, some PMUY-eligible consumers would have become consumers regardless but are now enrolled as PMUY consumers and are, essentially, “free-riders” on the program. If the lower rate of growth of general consumers is due to a diversion of potential general consumers to PMUY beneficiaries, then PMUY’s absolute addition of 15,067 consumers’ needs to be adjusted for the loss in general consumers to examine PMUY’s effective contribution to uptake of LPG in rural households. This adjustment suggested the effective impact of PMUY in expanding the consumer base is only 73% of the absolute number of enrolled PMUY consumers. A second explanation emerges from interviews with distributors and field-level OMC officials. These informants suggested that people ineligible for PMUY may have adopted a “wait-and-watch” approach, hoping that rules would change, making them eligible in the future. [Indeed, as discussed above, the eligibility has already been expanded two times in the last eighteen months]. A combination of both factors may be at play. Hence, PMUY enrollment numbers are not strictly additive in nature.

I also found the rapid expansion in LPG users attributable to enrollment in PMUY has not resulted in a comparable increase in LPG sales (Figure 3-8), unlike that of general consumers (Figure 3-9). As a result, the overall refill consumption is outmatched by the enrollment growth for the Koppal rural LPG market (Figure 3-10). There were only ~50 daily refill sales recorded for the 15,000 PMUY customers in December 2018. By contrast, the 12,000 general consumers purchase ~150 refills daily (see, Figure 3-9). This is not surprising, as the poorest households were specifically targeted by the program and their rapid inclusion into the consumer pool has reduced average consumption levels. Thus, while PMUY has been successful in promoting LPG enrollment among the rural poor (Smith & Dutta, 2011), their enrollment has led to an overall decline in consumption among households with a connection.
Figure 3-8 Daily PMUY consumer enrollment and daily refill sales (total across all three distributors) between July 2017 and December 2018. PMUY consumer enrollment began in June 2017, but refill purchase began in August 2017. The orange trend line for daily refill sales data (smoothing function using gam in the R platform) has a 99% confidence interval. The first sharp increase in consumer numbers is when PMUY initially launched and the second post-June 2018 is due to Ujjwala Plus (eligibility expansion).
Figure 3-9 Daily total of general consumer enrollment and daily refill sales (total across all three distributors) during July 2017 and December 2018. The orange trend line for daily refill sales data (smoothing function using gam in the R platform) has a 99% confidence interval.
Figure 3.10 Daily total of all consumer enrollment and daily refill sales (total across all three distributors) during July 2017 and December 2018 in the study area (rural Koppal, Karnataka). The orange trend line for daily refill sales data (smoothing function using gam in the R platform) has a 99% confidence interval. The first sharp increase in consumer numbers is when PMUY initially launched and the second post-June 2018 is due to Ujjwala Plus (eligibility expansion).

3.5.2 PMUY and general consumer use gap

How different is LPG use between PMUY beneficiaries and general consumers in rural areas?

I compare normalized and adjusted monthly refill sales for PMUY and general consumers to assess the difference (see Methods for details). Figure 3-11 shows monthly sales from January 2016 to December 2018 (equally split between the pre-PMUY and post-PMUY period) normalized by the number of registered consumers. In recent months, PMUY refill sales have fluctuated around 100 cylinders per 1000 consumers (suggesting rare use), while the monthly refill for general consumers is around 400 cylinders per 1000 consumers. This suggested that average general consumers use LPG as secondary or primary cooking fuel. Considering that the national (urban + rural) monthly average is about 600
cylinders per 1000 consumers, there is considerable scope to encourage more regular use among general consumers in rural areas.

Figure 3-11 Normalized monthly refill sales for PMUY and general consumers. To estimate monthly sales per 1000 consumers, refill numbers per household are multiplied with 1000 [consumers] and then divided by 12 [months]. As installation cylinders purchased during enrollment typically take one month to consume even if LPG is used exclusively for cooking, the effective number of registered consumers is considered using a lag of one month. Exclusive, Primary, Secondary and Rare use are defined as [10-12], [5-9], [2-4], and [0-1] cylinders purchased in one year by an average household, respectively (Kar et al., 2019) (see Supplementary Note 5 for the derivation of the categories). All-India pre-PMUY average purchase was 7.3 cylinders in 2015-16 (Dabadge et al., 2018).

In order to avoid capturing any effect of experience, I also compare LPG consumption trends of both general and PMUY customers for just their first year as customers (). The mean consumption rate for PMUY and general customers is 2.3 and 4.7 respectively (this includes refill purchases as in Figure 3 above plus the initial cylinder). The gap between PMUY and general consumers widens moving across
the purchase spectrum (at 5th and 95th percentiles the gap increases from 1 to 5 cylinders). Notably, 35% of PMUY consumers purchased no refills in their first year. Only 7% of PMUY consumers have purchased 4 or more cylinders, which is the median purchase level for general consumers.

Figure 3-12 Histogram plot of general and PMUY LPG consumption. Distribution histogram by first-year LPG purchase. Purchase numbers include the installation cylinder. Only consumers with at least one year of experience as on 31 Dec 2018 and whose full purchase history since first (installation) cylinder purchase is known are considered. The arrows indicate how much the PMUY distribution must shift to match the general purchase distribution. The red, orange, green and blue areas represent rare, secondary, primary and exclusive LPG usage. The red square and circle represent the median and mean values of the distribution respectively. The black square, circle, triangle, and diamond shapes indicate the 5th, 25th, 75th, and 95th quartile of the distributions respectively.
3.5.3 Effect of experience on the use

**Does LPG use to increase over time?**

An increase in LPG consumption with experience would conform to patterns of technology adoption in other sectors, but there are few studies that directly measure this for cooking fuels. One recent Indian study (Jain et al., 2018) based on self-reported data, did find an increase in LPG consumption with experience. As PMUY consumers in this region have not yet completed two years since enrolment I cannot assess their use over time beyond the first year. However, based on five years of data for general customers and for these users, I did not find a discernible increase in LPG cylinder purchases over this interval (Figure 3-13). The median refill rates and distribution of refills remain nearly constant over this period. The steady refill rate is despite the fact that macro-economic conditions have improved in the region during this period. The net price of LPG was mostly stable (Figure 3-2) while both the Indian (Anand, 2018) and Karnataka state (CRISIL, 2019) economies experienced >5% Gross Domestic Product growth in the 2013-2018 period.
Figure 3-13 Boxplot of annual LPG cylinder sales by years of experience. Only those who enrolled before 2017 (consumers for at least two years as on 31 Dec 2018) & whose full purchase history since first (installation) cylinder purchase in known are considered. Only when consumers have completed an entire year, that year’s purchase data is considered. The mean value is indicated by a black dot. The mean and median values are printed above and below the box-plots respectively.

While the overall change in LPG consumption in terms of refills/year does not seem to change with years of experience, I also wanted to examine the data I had at a finer resolution as I also had data on length of time between refills. I plotted the distribution of the gap (in days) between consecutive refill purchases for PMUY consumers. A decreasing time between refills would indicate increasing usage with experience. I selected above average PMUY consumers, who have purchased 3 to 5 cylinders (50-75 percentile of PMUY distribution in consumption) in the first one year and plot their refill purchase distribution (Figure 3-14). I then compared this with that of general consumers with a similar purchase trend in the first year. There is a slight decrease in the time between refills as consumers consume more, but not enough to result in an increase in the number of cylinders purchased per year (see, Figure 3-14). If
I had made assumptions regarding similar trends for PMUY consumers, on average, the median value of the purchasing gap would reduce by about 50% to 60 days (i.e. 6 cylinders annually) after the purchase of the 14th refill.

Figure 3-14 PMUY consumers and general consumers’ LPG purchase patterns. Violin plot of the gap between consecutive purchases of LPG cylinder. Only consumers who purchase 3-5 cylinders in the first year are considered. The second cylinder indicates the first refill, i.e. the gap between the purchase of the first (installation) cylinder during enrollment and the first refill. The bottom and top 1% of outlier refill purchase gap values are not used for analysis. The median and 75 percentiles for PMUY first year cylinder purchase are 3 & 5 cylinders respectively.

I found that the distribution of the refill gap (in days) is similar for both PMUY and general consumers. Notably, to achieve a 50% reduction in the median gap between cylinders requires over 15 purchases. If the average PMUY customer starts at between 2 and 3 cylinders/ year, this implies it would require more than 3 years of experience to double the number of cylinders consumed. In other words, I should not expect a major jump in consumption level, sans additional incentives, in the short term.
However, this is based on averages, which can mask both increases and decreases of refill patterns by individual consumers over the years. To address this, I also did a comparative mapping of how consumers have changed their consumption over three years.

The largely unchanging distribution of annual consumption for general consumers masks the varying patterns of annual consumption when individual consumers are tracked (Figure 3-15). Counter-intuitively, only a minority of consumers increased their consumption (number of LPG cylinders purchased annually) in their second year of use. This suggested that policy interventions to encourage regular use should also target general consumers.

Figure 3-15 Year 1 vs. Year 2 LPG purchase trend. Relative change in annual LPG consumption in the 2nd year compared to the 1st year by general consumers based on year of enrollment. Only those who enrolled before 2017 (consumers for at least two years as on 31 Dec 2018) & whose full purchase history since first (installation) cylinder purchase in known are considered. Only when consumers have completed an entire year as customers, that year’s purchase data is considered.
I found only 8.4% of consumers have actually had steady consumption (Figure 3-16). Only 45% of consumers have moved up or down by 1 cylinder or remained steady over the first 3 years. Roughly 75% of consumers have purchases that stay the same or fluctuate by 1-2 cylinders a year.

![Figure 3-16](image)

*Figure 3-16  Heat map of relative LPG purchases over the first three years The heat map of relative consumption over the first three years for all general consumer who has completed at least 3 years. LPG consumption (annual purchase of 14.2 kg cylinder) for 45% of consumers have either remained stable or shifted by ±1 cylinder year-on-year basis.*

I also plotted via a row-wise heat map to check how the purchase trends change over a three year period (Figure 3-17). If there was a strong experience effect (at least in the first couple of years), the green zone (a continuous increase over three years) should have had a higher proportion of consumers, but that is not the case here.
The row-wise heat map for all consumers who have completed at least 3 years. Out of all consumers who had no change in annual consumption (0 relative change in Y2 compared to Y1), 33% of them again had 0 relative change in Y3 compared to Y2. The green zone (area bordered with a dashed green line) represents consumers who have had consecutive increase over the three-year period. The brown zone represents consumers whose LPG consumption has reduced over the first three years of enrollment.

While I was not able to directly assess multi-year consumption trends for PMUY customers, the data on general customers is indicative of what the trends may look like over time for PMUY. Given the very low base year consumption level that PMUY consumers are starting from, it is unclear what impact experience will have on increasing their refill rates substantially in the near future. If they follow the pattern of the general consumers, however, they will likely remain at low levels of consumption absent additional interventions. Notably, the first-year median consumption levels have been declining (Figure 3-13). Those who enrolled as LPG consumers earlier (e.g., in 2014) used more LPG to cook during their first year as consumers than later enrollees (e.g., 2017). This may have to do with earlier consumers being either more motivated or having more wealth than later adopters.

![Heat map of relative LPG purchases over the first three years](image-url)
3.5.4 Role of non-household factors in LPG consumption

What factors determine LPG consumption?

I attempt to explore the interactive relationship among the increase in the number of consumers, pricing (distributor price, bank subsidy and net price) and seasonal factors. Notably, these are all non-household factors, as I did not have any socio-economic details of the LPG consumers in our database. I only consider thirty-six months of data from January 2016 to December 2018 (last full month of data). I only have complete data from all three distributors for the area from January 2016, and I applied a lag of one month while estimating the number of effective consumers. Based on the available data, I had six possible explanatory/predictor variables to best explain the pattern of monthly LPG refill sales (the dependent or response variable), as detailed below:

a. Upfront amount paid by a consumer (distributor price)
b. The effective price of refill after adjusting for a subsidy (net price)
c. Govt. Subsidy on a refill cylinder deposited to the bank (bank subsidy)
d. Total number of PMUY/PMUY consumers
e. Total number of non-PMUY/General consumers
f. Total number of registered consumers
g. Season-Climate
h. Season-Agricultural

I ran several linear regression models to best explain monthly normalized (per 1000 registered consumers) LPG sales by distributor and what drives the observed fluctuations in sales patterns (Figure 3-18). I found that a standard deviation increase in distributor (upfront) price reduces normalized monthly sales by 0.27 standard deviation (SD). I also saw a comparable effect of seasonal factors in explaining the variation in refill sales. A shift from ‘no cropping’ season to cropping or harvest season increases monthly refill sales by 0.22 or 0.26 SD respectively, everything else remaining equal. Refill rates in summer, when
agricultural activity is limited, are ~10% lower than rates during cropping and harvest seasons when people are busy with agricultural work. During the cropping season, people are busy preparing fields, planting, and weeding. They place a high value on their time and meals tend to be quick, which is conducive to cooking with LPG. Later, during the harvest season, people have cash in hand, making LPG purchases easier (S. K. Singh, 2014). In contrast, during the summer, people have more time and less income. The climate is hot and dry, so people have easy access to dry biomass as well as crop residues from after the harvest period. During the cropping season, which coincides with the monsoon, wood is wet and crop residues have been consumed (Rajakutty & Kojima, 2002). Notably, there are three active distributors in Koppal and the regression results indicate that customers procuring from one distributor purchase fewer cylinders than those procuring LPG from the other two, other predictors remaining constant. Based on several interviews, I found that the worst performing distributor (D3) provides home delivery to all villages in its coverage area, while the other two do not, which appears counter-intuitive as home delivery should facilitate purchases (Giri & Aadil, 2018; Jain et al., 2018). Whether the comparatively higher normalized monthly sales for D1 and D2 is due to greater sales acumen of the distributors or better socio-economic/ behavioral perspectives of the consumers under the catchment area of these distributors cannot be determined, given the limitations of the data.

As the first two potential predictor variables change monthly, I grouped the refill and consumer data by month. I also converted the two season-linked categorical variables as factors using the base ‘is.factor’ function in R (R Core Team, 2018) to prepare for running a regression with both numeric continuous variables and categorical variables. I then ran a stepwise forward regression using R function ‘ols_step_forward_p’ from package ‘olsrr’ (Hebbali, 2018). Forward selection is a strategy that starts with no predictors in the model, iteratively adds the most contributive predictors, and stops when the improvement is no longer statistically significant (Kassambara, 2018).

I use standard regression diagnostics to evaluate if the proposed model meets key general regression model assumptions and to investigate whether or not there are observations with a large undue influence on the analysis. I use ‘gvlma’ function to check if the relationship between predictors and response is
roughly linear (global stats) and heteroscedasticity of residuals, and the ‘vif’ function to test for multicollinearity (i.e. a linear relationship between explanatory variables). In both tests, the regression model satisfies all key assumptions. Considering that this is a time-series dataset, I also tested the assumption that there is ‘no autocorrelation of residuals’. The Durbin-Watson test using function ‘dwtest’ in package ‘lmtest’ (Zeileis & Hothorn, 2002) tests the null hypothesis that there is no auto-correlation (i.e. the variation is random). I failed to reject the null hypothesis with a 95% confidence level as the p-value (0.6314) > 0.05. Notably, the predicted model is able to explain 75% of the variation of the monthly LPG sales around the mean. The results also suggested that seasonal vouchers may be useful to boost sales in the lean period for both general and PMUY rural consumers.
3.6 Limitations, recommendations, and future research agenda

Here, I should note the limitations of the database. I relied on multiple data sets. Some are national in scope but have limited detail. Another is more detailed covering 25,000 LPG users, but lacks socio-demographic details and represents only a single district. The conclusions drawn from the latter...
dataset, which include comparisons of refill rates between PMUY and general consumers as well as seasonal variations in consumption, though instructive, should not be generalized beyond the study area.

In addition, I only looked at trends after the initial eighteen months of the program. Energy transitions take time and it would be premature to pass judgment on PMUY at this stage (Smith & Jain, 2019); though it is a good time to take stock and suggest course corrections. Despite these limitations, there are a number of key implications of this work for policy and research. Given our results, it is reasonable to ask if PMUY should have weaker incentives for enrollment. The fact that 24% of PMUY beneficiaries nationally purchased no refills during the first year (A. Jindal, personal communication, December 4, 2018) also lends some credence to this concern. While universal clean cooking energy access is a worthy goal enshrined in the Sustainable Development Goals, should taxpayers subsidize LPG connections for households who are not willing or able to buy refills and are therefore likely to default on their loans and remain at risk from HAP exposure? Based on their auditors’ recommendations, the OMCs are securing more than Rs. 3 billion in preparation for loan defaults. This has a high opportunity cost in developing countries like India (S. Kumar, 2018).

However, from a health perspective, individual household gains will only come with widespread adoption as household reductions in pollution concentrations and exposure are dependent on both in-house and community level emissions reductions (World Health Organization, 2014). Despite issues in targeting and refills, PMUY has clearly started an unprecedented number of households along the path to clean cooking. In that, it marks a significant departure from a market-based business-as-usual approach and addresses the upfront cost burden that has prevented the poorest households from beginning the clean cooking transition process in the past at a scale to potentially have community-level effects.

The low refill rates (and a large fraction of non-returning customers) would suggest that more effective incentives are needed for PMUY beneficiaries to become frequent LPG users and benefit from lower HAP exposure. One option would be to offer vouchers with seasonal discounts during summer months when demand drops. Other options might include behavior change strategies (Kar & Zerriffi, 2018) to “nudge” (Raihani, 2013) poorer consumers to substitute solid fuels with LPG more often.
Moreover, I found those general rural consumers also lag behind the desired level of LPG use and should not be ignored for post-purchase interventions for a successful cooking energy transition.

Finally, the use of this novel dataset provides several new insights on the clean cooking energy transition, which would have been difficult to obtain through standard tools such as self-reported surveys and would have been prohibitively expensive to achieve via thermal sensors at this scale (Graham et al., 2014). Datasets consisting of distributor-level transactions are invaluable sources of information that, properly anonymized, should be made accessible to researchers and policy analysts. This not only promotes transparency but could facilitate objective program evaluation and potential design changes to this program in order to improve targeting and effectiveness.
4. Transition stages, and the transtheoretical model of change

4.1 Introduction

In this chapter, I tested the CI-CHANGE model—specifically whether and how people move from one stage to another using the transtheoretical model (TTM) of behavior change. It is the most influential theory (by citations, at least) in health psychology (Michie et al., 2014) to study behavior change, and I opted for it as the starting point of examining clean cooking transition through the theoretical lens (Kar & Zerriffi, 2018). The underlying hypothesis is that the transition from solid fuel to clean fuel is driven by a change in psychological variables or behavioral determinants as described in TTM (see, Chapter 2).

I also argue the case that the role of affordability while important is more nuanced than it is implied in the literature. For example, in Ecuador where LPG is heavily subsidized (15 kg of LPG for less than 5 USD), even relatively high-income LPG users in rural areas with decades of usage still engage in stacking (Gould et al., 2018). I acknowledge that unlike self-regulatory behaviors like smoking cessation, cooking energy transition involves external factors at the household level (dependence on male family members), market environment (price), and natural environment (availability of free substitute solid fuels) (van der Kroon et al., 2013). Also, while affordability remains a valid concern, it is a black box in some ways. While there are input objective factors such as distributor price, subsidy, household income, household wealth index, cost of substitute fuels, other competing expenses (both cooking and non-cooking) are well-understood (Kar & Zerriffi, 2018; Lewis & Pattanayak, 2012; Malakar, 2018; Puzzolo et al., 2016; van der Kroon et al., 2013), how these determinants interact towards the output subjective factor of affordability is not well-understood and nuanced. Also, there is the difference between perception and reality of input factors, past experience, hearsays, incomplete information often distort the reality on say, price of substitute fuels and people often take decisions characterized by biases and heuristics (Kar & Zerriffi, 2018). So, psychological variables such as value for money (perception of affordability) may be more reflective of the reality of decision-making than the objective numbers. In this context, if I consider affordability as a subjective construct, how important it is compared to other
subjective behavioral constructs in psychology literature for fuel choices? But as I argue that affordability is subjective, I will use a more objective input indicator of affordability like household wealth index as a proxy metric of affordability.

To my knowledge, there has been no direct comparison of a standard behavioral index (psychological variable) with household wealth index towards estimation of the relative importance of wealth in such cooking related household decisions that indicates a knowledge gap in the existing literature. As the Indian PMUY model of LPG promotion and distribution to poor households is also under consideration to be emulated by other developing countries (Jindal, 2019), these questions around affordability and behavioral determinants are not just academically interesting but immensely timely and policy-relevant for intervention planning.

Past studies (see (Kowsari & Zerriffi, 2011; Wilson & Dowlatabadi, 2007) on household energy decision making have drawn from many of these domains to explain individual and household behavior. However, even when the behavioral aspects of cooking energy transition were researched, the focus has primarily been on uptake or purchase of a new cooking technology (Goodwin et al., 2015) sans research directed at strategies towards long term (multi-year), and sustained usage (Ruiz-Mercado et al., 2011). There are only few studies where formal frameworks were applied, such as the COM-B model and theoretical domains framework (Michie, West, Campbell, Brown, & Gainforth, 2014; Tombor & Michie, 2017) in Guatemala (Thompson, Diaz-Artiga, Weinstein, & Handley, 2018) or application of a modified version of the Sani-FOAM model in Uganda (Namagembe et al., 2015). For this study, I tested the behavior change stages of the CI-CHANGE framework (Kar & Zerriffi, 2018) to seek new insights on ‘how’ transition from solid to clean fuels takes place in reality.
4.2 The transtheoretical model (TTM) of change

The “transtheoretical model” (TTM) is a prominent theoretical behavior change framework that is used to explain, predict and motivate long-term individual behavior change that is desirable from a health perspective (ex. smoking cessation) (Prochaska & Velicer, 1997) and has been applied to pro-environmental behavior changes (ex. sustainable transportation) (Redding et al., 2015). TTM suggests that “there is a common structure or pattern to behavior change across very diverse problems and populations” where a shift from old behavior to desired long-term behavior change entails individuals to progress through a series of five distinct stages in a gradual, iterative manner over the long term (Prochaska, 2008). In TTM parlance, these stages are named as precontemplation, contemplation, preparation, action, and maintenance.

People at the ‘precontemplation’ (PC) stage do not have any intention to adopt the desired behavior in the near future. TTM researchers based on smoking cessation studies have used an arbitrary guideline of the six-month timeframe for ‘near future’ as it was assumed that most people do not plan for behavior change beyond this period (Prochaska, Velicer, Rossi, Goldstein, & et al, 1994). People at ‘contemplation’ (C) stage, are “more aware of the pros [advantage] of changing [existing behavior] but are also acutely aware of the cons [disadvantage]”, and intend to change in near future, but not now (Prochaska & Velicer, 1997). This phase is marked by “chronic contemplation or behavioral procrastination” as people are not able to make up their mind on whether the advantages of using CCS outweigh the disadvantages (Prochaska & Velicer, 1997). Users who are in the third stage of ‘preparation’ (P) have developed strong intentions to change behavior and have followed up by taking significant action in order to prepare for behavior change in the “immediate future” (Prochaska & Velicer, 1997). The fourth stage, as per TTM is when “people have made specific overt modifications in their lifestyles” to achieve the desired behavior (Prochaska & Velicer, 1997), known as ‘action’ (A) stage. The TTM framework, often applied to pro-health behaviors, views that “not all modification of behavior count as an action. An individual must attain a criterion that scientists and professionals agree are sufficient to
reduce the risk of the disease” (Prochaska, 2008). The fifth stage is called the ‘maintenance’ stage, in which users “are working to prevent relapse but they do not apply change processes as frequently as” in action stage (Prochaska & Velicer, 1997). So, permanent behavior change wherein exclusive CCS usage becomes the desirable habit, is not an event but the final stage of a temporal process (Prochaska & Velicer, 1997). At any point, an individual is in one of these five stages, and they have to move through the stages as they adopt a healthy behavior and make it a habit (Prochaska & Velicer, 1997).

The ‘decisional balance’ drives the movement across these stages. Decisional balance reflects the individual’s relative weighing of the pros (perceived advantaged) and cons (perceived disadvantages) of changing from the current undesired (from health perspective) behavior to the target desired behavior (Prochaska, 2008). TTM framework has also included the concept of self-efficacy (SE). SE construct is related to an individual's belief about his/her capacity to "organize and execute courses of action required to produce given levels of attainments" across relevant situations/ events, without which they have “little incentive to act” (Bandura, 1998). Such situation-specific self-confidence in her ability to initiate/continue the desired behavior increases as one moves from preparation to maintenance stage (Prochaska & Velicer, 1997). SE for the desired behavior increases as the person progresses through the stages of change towards the desired behavior. To conclude, progress from undesired to desired behavior is associated with and driven by positive changes in decision balance (pros increase, cons decrease) and self-regulation.

4.3 Framing the stages of change in the context of clean cooking

The desired target health behavior is using clean cooking fuels (i.e. LPG) regularly to cook food for the family. Adaptation of the TTM model to the desirable cooking energy transition process leads to a more structured view of the desired [pro-health and pro-environment] cooking energy transition process
from the lens of individual behavior change. For the purpose of this paper, ‘regular’ usage\textsuperscript{16} is defined as using LPG on average for at least 30 minutes in a day to cook food for the family on a daily basis.

The ideal usage behavior from a health perspective is regular LPG usage, which involves cooking almost exclusively with LPG (Johnson & Chiang, 2015; Pillarisetti, Mehta, & Smith, 2016). As there were negligible numbers of households purchasing ten numbers of [14.2 kg LPG] cylinders (exclusive use) annually for domestic cooking purpose (Kar et al., 2019), it is widely considered to be ‘aspirational’ (Barrett, 2015) in the near term (in line with air quality guidelines (World Health Organization, 2014)). Instead, I use an arbitrary ‘interim’ level of desired health behavior of limited use, defined as average usage of LPG for at least 30 minutes per day (including both morning and evening cooking sessions) to cook food for the family due to practical reasons. This level was decided after extensive field interviews in a balancing act of health significance and a feasible sample size.

I required at least 40 samples in action and maintenance stage (i.e. total 80 households) to detect at least a medium effect for any regression model (general linear model- f\textsuperscript{2}) (see, 4.9 on sample size). I also considered the field staffing and budgets, and the access to villages (physical as well as the willingness of community/ community leaders to participate) around the project site. All in all, though we aimed for the metrics of ‘one hour every day’ during the pilot survey, we ended up with the standard of 30 minutes per day as a practically feasible starting point. Expert interviews with OMC officials suggest that 15 hours of usage per month (180 hours/ year) would result in the consumption of about 4 [14.2 kg] cylinders in a year for a typical family size of five, based on the LPG stove efficiency levels (~60%) and LPG energy content. It demonstrates a reasonable level of commitment by rural households to switch to LPG as a near-primary cooking fuel for daily cooking.

A cook is considered to be in the ‘maintenance’ stage, when she (rarely, males are main cooks in our field site) is cooking with LPG regularly [\textit{action}] for the last twelve months [\textit{time}], and intends to

\textsuperscript{16} see, Chapter 5 for a detailed discussion on the various definitions of ‘regular use’ used in the thesis and why this specific definition was chosen for this chapter
continue the same in the future [future intention]. A subject is in the ‘action’ stage when they are using LPG regularly, but for less than twelve months, and intends to continue the same in the future. A cook is considered to be in the ‘preparation’ stage, when she has purchased the LPG stove, does not use it regularly now, and intends to use it regularly from the next month. A cook at the ‘contemplation’ stage may or may not purchase LPG stove (action-neutral), does not use it regularly now but expresses an intention to use LPG regularly within the next six months. A cook is at the precontemplation stage, may or may not have purchased LPG stove, does not use LPG regularly now, and when asked about future plans, does not express interest to start using LPG regularly within the next six months.

In the definition of stages for this chapter, I have combined both past actions as well as a future intention for two reasons. One, past critiques, see (West, 2005), point out that “the stage definitions represent a mixture of different types of construct that do not fit together coherently” such as action, time and intention. So, we include future intention, action (or, lack of it), and time while constructing the definition of stages. Two, for LPG usage, there is significant dependence on the supply chain and external actions in rural areas, physical access issues LPG home delivery person, if any, sales outlet operating hours, sudden cash crunch, etc.). This is unique for our case unlike behaviors commonly studied by TTM such as smoking cessation or safe sex behavior where the role of externalities is limited (e.g. rarely cigarettes or condoms would be out of stock in the market or too expensive to buy).

Second, for this study, a twelve-month period of existing desired behavior is considered as suitable for the maintenance stage when the standard timeline typically considered in literature is of six months (Prochaska & Velicer, 1997). Past studies (see, (Rakowski et al., 1996) have also adopted a 12-month timeframe diverging from the standard when appropriate; these time boundaries have also been critiqued as “arbitrary lines in the sand” (West, 2005). LPG consumption in a rural area has strong seasonal characteristics due to the seasonality of income and availability of (competing) solid fuels (Giri & Aadil, 2018; Singh, 2014) hence a 12 month period covers the entire spectrum of seasonality and associated consumption variance.
Third, for defining the precontemplation stage, I considered two cases- either respondent explicitly confirms that she does not plan to use LPG regularly in future, or when she refuses to answer a question on her future LPG usage plan. As ‘precontemplation’ is defined as when “people are not intending to take action in the foreseeable future” (Prochaska & Velicer, 1997), lack of response to future plans to the question is assumed to indicate lack of intention to use LPG in future.

4.4 Research questions and hypotheses

In this chapter, I focus on two key questions:

1. *Is cooking energy transition associated with distinct stages of varying perceptions about the advantages, disadvantages, and confidence to cook with clean fuels?*

   While TTM critiques have argued that an increase in pro scores and decrease in con score across stages should be treated as a correlation (Armitage, 2009; Prochaska, 2006), it does, at the minimum, signify distinctness of stages from a policy planning perspective. If it holds true for clean cooking interventions, it should spark a serious conversation around feasibility and modalities around stage-specific interventions as done successfully in the case of smoking cessation based on the stages of change concept (Prochaska, Redding, & Evers, 2008).

2. *In comparison to psychological variables, what is the role of household affluence in the transition process?*

   I plan to compare the relative influence of behavioral determinants (as per TTM), compared to an objective measure of affordability (say, household wealth index) towards progression across stages. If it is determined that affordability/ household wealth matters far more than any behavioral issues, then deliberations on subsidy level/ other incentives should take a more central stage. However, it should be recognized that as drastic increases in subsidy or rapid
increase in income levels may not be feasible in the target low-income, rural communities of developing economies, behavioral interventions at given price levels could still be helpful.

I tested three specific hypotheses borrowed from published research on TTM. First, progress from precontemplation to action involves approximately one standard deviation (SD) increase the pros of changing. This is known in TTM literature as the ‘strong’ principle of progress across the stages (Hall & Rossi, 2008; Prochaska & Velicer, 1997). Second, the ‘weak’ principle is that the progress from precontemplation to action involves approximately half (0.5) standard deviation (SD) decrease in the cons of changing. In other words, the effect size for pros and cons in the transition from PC to A stage would be 1.0 (high) and 0.5 (medium) respectively. Hedge’s g is generally used in TTM literature instead of Cohen’s d to estimate effect size (Hall & Rossi, 2008; Prochaska & Velicer, 1997).

Notably, while it is acknowledged that wherein “self-efficacy scores correlate highly with [ordered] stages of change” (Herrick, Stone, & Mettler, 1997) [emphasis added by me], I do not have any widely accepted standard mathematical relationship for the SE scores, unlike pros and cons. Hence, I used the standard definition of ‘large’/ ‘high’ effect size (Evans, 1996) which would be 0.80 for standardized mean difference (Cohen’s d or Hedge’s g) or 0.50 for correlation (r) (Ellis, 2009). So, using the ‘SD’ based effect size for consistency with the other two hypotheses, the third hypothesis that progress from precontemplation to maintenance involves >0.79 SD change in self-efficacy score. I also presumed that all these effects would be statistically significant at a 95% confidence level.

Further, cookstove literature suggests an important role of affordability in the decision making the process for clean cooking fuels, unlike self-regulatory behaviors where TTM has been generally applied. Hence, we hypothesize that there is at least a moderate correlation between household wealth index and stages of change. Mathematically, the fourth hypothesis for this paper is that progress from precontemplation to maintenance involves >0.49 SD change (Ellis, 2009) in the household wealth score.
4.5 Methods

4.5.1 Survey plan and data collection

There were three main considerations for the study design with regard to sample size when survey planning was carried for (study area: Koppal). First, ensure that at least 30 respondents were there in each of the five groups (stages) as a common rule of thumb to proceed with ‘normal’ approximations for the unknown population (people under a given stage) distribution, though there are calls to “retire the n ≥ 30 rule” (Hesterberg, 2008). Second, as the TTM hypotheses were primarily concerned with the difference in pro and con scores between precontemplation and action stages, we estimated the target group-wise sample size with a focus on these two stages. I aimed to detect a ‘medium’ effect by using Hedges’ g (Hofmann, Sawyer, Witt, & Oh, 2010), as an alternative with Cohen’s d, in line with past landmark TTM studies (Hall & Rossi, 2008). As past studies (Hall & Rossi, 2008; Prochaska et al., 1994) show an effect size of 1 for pros and 0.5 for cons, we use the benchmark of 0.5, i.e. ability to detect an effect size of at least 0.5 (Hedges' g ≥ 0.5). I also assumed standard power (probability of detecting this expected effect) of 0.8, with a standard 0.05 significance level (probability of a false positive result). Further, I assumed that to find every one respondent in the action stage would require reaching out to four respondents in PC stage, such that the allocation ratio is 0.25 (loosely based on pilot test experience).

It should be noted that while the survey was being conducted in June-August 2017, the majority of households in the study area did not have LPG. This changed dramatically over the next year as many of the PC households took LPG connections under PMUY (see, Chapter 3). As of December 2018, stakeholders suggest that over 90% of all rural households in the study area have access to LPG. This is in line with the national average of LPG access (PPAC, 2019). So, for the precontemplation stage, a modified version of definition could also be households who did not invest in getting LPG connection, unlike their general consumer peers.

I then estimated the sample size required for these groups using G*Power-2 online software (Faul, Erdfelder, Lang, & Buchner, 2007) with two scenarios. One, if the pro/con scores have a normal
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distribution, the standard case with a two-tail t-test without TTM assumption, wherein we get n_{PC}= 160, and n_{A}= 40. Two, if the scores do not have a normal distribution, then for Wilcoxon-Mann-Whitney test using A.R.E method and with an allocation ratio of 0.25, n_{PC,W}= 184, and n_{A,W}= 46. Finally, while there was no upper cut-off for individual groups, for logistics/ financial considerations the initial upper limit for the total number of surveys was around 300.

Four surveyors along with a survey lead (who also participated in data collection) were trained for three weeks for this purpose. The survey was conducted in Kannada, the local language, on an Android tablet using the FluidSurvey™ platform. The surveys were carried out between June 2017 and November 2017. Notably in a matter of coincidence, during this survey period, the PMUY program was launched in Koppal and was at its peak in terms of mass-communications around the program and the benefits of LPG.

The survey questions were initially pilot-tested in 12 households in the study area and modified accordingly. For example, we found that respondents were not able to answer the question on stages when asked as originally formulated, and hence, split it into two separate questions on current action and future intention.

4.5.2 Decisional balance and self-efficacy

The survey team asked respondents how important they considered the items reported in Table 4-1, three items of pro (perceived advantages) and four items of the con (perceived disadvantages) to make decisions about executing the desired behavior (see Annexure 1 for individual survey questions). I identified seven items based on the literature review (Kar & Zerriffi, 2018; Lewis & Pattanayak, 2012), structured the questions based on standard TTM format (UBMC, 2019) followed by pilot testing. Similarly, I also asked questions on their confidence level for seven items of self-efficacy (perceived situation-specific confidence to continue with the desired behavior). The data was then transformed into a T-score with a mean of 50 and standard deviation of 10 for item-independent consistency and inter-
comparison with other TTM studies (Hall & Rossi, 2008; Prochaska et al., 1994). A brief description of these fourteen items is detailed in Table 4-1.

*Table 4-1 List of pro, con and self-efficacy indices in the survey*

<table>
<thead>
<tr>
<th>Item Type</th>
<th>Name</th>
<th>Item Descriptor (as in Survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro</td>
<td>Convenient</td>
<td>Using LPG on a regular basis makes cooking quick and easy to use</td>
</tr>
<tr>
<td>Pro</td>
<td>Social Status</td>
<td>Using LPG regularly is a symbol of social status or modernity</td>
</tr>
<tr>
<td>Pro</td>
<td>No Smoke</td>
<td>Using LPG regularly makes my kitchen smoke free and clean</td>
</tr>
<tr>
<td>Con</td>
<td>Safety risk</td>
<td>Regular usage of LPG increases risk of accident</td>
</tr>
<tr>
<td>Con</td>
<td>Refill hassle</td>
<td>Getting LPG refills frequently (every three months or earlier) is inconvenient (far away, unreliable supply)</td>
</tr>
<tr>
<td>Con</td>
<td>Low Value for money</td>
<td>If free wood is available, refill of LPG regularly to cook food is a waste of money</td>
</tr>
<tr>
<td>Con</td>
<td>Affordability</td>
<td>Using LPG regularly is expensive and I cannot afford it</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Food Taste</td>
<td>Family members don't like the taste of food cooked in LPG</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Price increase</td>
<td>Increase in cost of LPG refill</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Accident</td>
<td>Incident of LPG accident in the nearby village</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Refill Delay</td>
<td>Delay in getting LPG refills</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Gender dynamics</td>
<td>Male members in family object to spending money on LPG refills</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Social network</td>
<td>Peers are not using LPG regularly</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>Technical knowledge</td>
<td>Cannot operate LPG stove properly</td>
</tr>
</tbody>
</table>
Typically, multivariate analysis for published TTM studies contains correlated variables (Hall & Rossi, 2008; Rakowski et al., 1996; Redding et al., 2015). Principal Component Analysis (PCA) is used to identify a narrower set of linearly uncorrelated variables called principal components. Due to the low number of indices, the standard methods of using PCA is not used for the study. However, subscale internal consistencies (Cronbach’s alpha) were measured and found to be satisfactory (Section 4.6.2).

4.5.3 Wealth

I use three stand-alone but complementary indices to estimate household wealth. One, using the standard method of using the principal component analysis approach to create a simplified household wealth index based on household self-report of land and non-land assets (Filmer & Pritchett, 2001). Respondents were specifically asked questions on household assets that a family has purchased (excluding items gifted or provided by the government as part of public welfare). The twenty-one items are a mix of productive (e.g. Tractor) and non-productive (e.g. Color TV) assets. Two, an alternative approach of quantifying wealth as a check on the aforementioned wealth index, which I named as the ‘objective wealth’ score where consumption levels are integrated to asset ownership. The presence and absence of these items lead to a score of 1 and 0 respectively, i.e. uniform weightage. The total scores are then converted to a z score of (non-land) asset ownership. Further, as the price of irrigated land is twice of non-irrigated land in the project area (which is a dry land), the land area weighted by the type of land is used to develop the score, which again is converted to a z score of (land) asset ownership. Moreover, the annual household expenditure levels for eight items ranging from private schools for children to fruits/bakery items are recorded, added and then converted to z-score of consumption. The three z-scores for (non-land) asset ownership, (land) asset ownership and consumption expenditure are then totaled and then categorized as ‘objective wealth’. Third, I also had a provision on the survey instrument to record the subjective perception of the surveyors about the respondent household wealth based on visual inspection of household assets. The surveyors were female volunteers who lived in rural communities in the same
study area (rural Koppal) and hence, had a reasonable competence to segregate a household as rich, middle-class or poor by their own community standard. It is considered a ‘subjective wealth’ index. The subjective wealth is considered as quality control on the wealth index/ objective wealth. All the quantitative wealth scores were also converted to T scores (with mean of 50 and standard deviation of 10) for beta regression model comparison with decisional balance scales.

4.5.4 Model fit

I used logistic ordinal regression, a standard tool in literature, to identify the best model to explain the stages of change. For the purpose of uniformity across scales, the Pro, Con, SE and Objective Wealth is scaled to mean= 50, and standard deviation (s.d.) = 10. The TTM stages are defined as ordered in ascending order: PC, C, P, M, A, while Subjective Wealth is also ordered in ascending order: Poor, Middle Class, Rich.

4.6 Results

4.6.1 Stages of change

After a survey of n=402 households, a disproportionate distribution of respondents across the five stages was recorded. The number of respondents was in the precontemplation stage was almost 10 times that of people in the contemplation stage, 212 vs 23 (Figure 4-1). In spite of exceeding the target sample households by 33%, we could not find 30 respondents in the contemplation stage in our study area. In PC, the number of people who explicitly expressed that they do not have any interest in regular LPG usage in near future and those who opted not to answer the question of future intention are about equal. Data for five households out of the 402 were dropped due to inconsistency between current behavior and future plan. Out of the rest, 386 households had provided an answer to all questions. As part of the survey protocol, respondents were reminded that they could choose to not answer any question at any time.
4.6.2 Decisional balance

As discussed earlier, the decisional balance is the combined effect of the pros and cons of the desired behavior change at a given stage of the change process.
4.6.2.1 Internal consistency

The subscale internal consistencies (Cronbach’s alpha) were reasonable for Pros (three-item $\alpha = 0.64$), Cons (four-item $\alpha = 0.77$) and Self-efficacy (SE, seven-item $\alpha = 0.97$). Hence, in spite of not doing PCA and basing the questions on published literature, the quality of the survey is not compromised. The overall pro, con and SE scores for individual respondents are calculated by averaging the individual scores for their respective indices or attributes. Hence, while the individual scores for each attribute are discrete and ordinal (1-5, Likert response format), the overall score for Pro, Con and SE are continuous and interval numbers (Likert scales). However, in line with past studies, I treat Likert scale responses as an interval variable for the purpose of regression and other statistical analyses (Carifio & Perla, 2007; Sullivan & Artino, 2013).

4.6.2.2 Decisional Balance score

4.6.2.2.1 Pros and Cons: Effect size of the transition

The overall score for pros increases across the stages while the cons decrease in line with TTM’s broad principles of decisional balance (Figure 4-2). The Shapiro–Wilk test of normality was carried out for the pro and con scores for respondent in stages PC and A. For both pro and con scores in both PC and A stages, I failed to reject the null hypothesis that the distributions of the data are not significantly different from a normal distribution. Hence, I used the Mann-Whitney-Wilcoxon Test to examine whether the population distributions for PC and A stage people are identical without assuming them to follow the normal distribution.

The Wilcoxon rank sum test with continuity correction was performed for the total pro scores of respondents that indicated a statistically significant difference between the two groups ($W = 2922$, p-value = 3.204e-05). However, the effect size for a pro increase from PC to A stage is less than what is hypothesized. Hedges's $g$ estimate is 0.62 (medium) is less than the 1 (large). Post-hoc analysis for the calculated effect size of 0.62 and a real sample size of 199 and 47 for PC and A groups with a 0.05 significance level for a two-tailed test leads to the power of 0.94 for this dataset.
The Wilcoxon rank sum test with continuity correction was performed for the total con scores of respondents that indicated a statistically significant difference between the two groups (W = 7278.5, p-value = 2.474e-09). The effect size for a con decrease from PC to A stage is more than what is hypothesized. Hedges's g estimate is 1.02 (large) is more than 0.5 (medium). Post-hoc analysis for the calculated effect size of 0.62 and real sample size of 199 and 46 for PC and A groups with a 0.05 significance level for two-tailed test leads to the power of 0.99 for this dataset.
4.6.2.2 Stages of change: Pros scores

The pattern of change in scores for Pro (perceived advantages of regular cooking with LPG) shows an increase from precontemplation to action stage for the three indices as well as the overall score (Figure 4-3). I found that the average Pro score at the precontemplation stage is already high enough. It is in line with findings in the literature on the aspirational aspects of cooking with LPG (Smith & Dutta,
So, the target population need not be convinced about the Pros of LPG as even consumers without LPG are reasonably convinced about LPG’s benefits.

Figure 4-3 Change in individual Pro items across different stages. The blue line indicates the fitted line for the Pro score across the five stages. The shaded band is the pointwise 95% confidence interval on the fitted values by stage.

4.6.2.2.3 Stages of change: Cons scores

The pattern of change in scores for Cons (perceived disadvantages of regular cooking with LPG) shows a sharp decrease from precontemplation to action stage for all the four indices as well as the overall score (Figure 4-4). Unless the con score reduces for each individual item, it will be difficult for people to
jump up to a higher stage (towards regular LPG use). Hence, the interventions need to focus on the cons and messaging around it to change both the reality and the perceptions around it respectively.

![Con Items Variation Across Stages](image)

**Figure 4-4** Change in individual Con items across different stages. The blue line indicates the fitted line for the Pro score across the five stages. The shaded band is the pointwise 95% confidence interval on the fitted values by stage.

4.6.2.2.4 Stages of change: Self-efficacy scores

More interestingly, the SE has a sharp decline from the preparation to the action stage (Figure 4-5). Overall, the change in SE from PC to A is 0.08 (negligible effect size) and statistically non-significant ($W = 4532.5$, $p$-value = 0.7431). It is much less than the hypothesized $g$ value of >0.79, which
leads to the conclusion that SE does not increase steadily and significantly across the stages of change, unlike the Pros and Cons.

Figure 4-5 Change in overall self-efficacy score distribution across different stages
Moreover, this phenomenon is replicated for all the seven indices for SE (Figure 4-6). It indicates that respondents in the action and maintenance stage are more aware and wary of the decision environment which reduces their level of confidence in doing something which they are already doing. This is a unique, hitherto undiscovered, phenomenon that should be explored more in future research.

Figure 4-6 Change in individual self-efficacy items across different stages. The blue line indicates the fitted line for the Pro score across the five stages.
4.6.3 Wealth across stages

In Figure 4-7, I plot the wealth index based on (purchased) asset ownership by households across the stages of change. I also added a layer of wealth perception as a secondary data check. On expected lines, the wealth index increases across the stages. The Shapiro–Wilk test of normality was carried out for both the standard ‘wealth index’ and the customized ‘objective wealth’ scores for PC and A stages. For both wealth scores in PC stage, we fail to reject the null hypothesis that the distributions of the data are not significantly different from a normal distribution. Hence, we use the Mann-Whitney-Wilcoxon Test to examine whether the wealth indicators for the population distributions for PC and A stage people are identical without assuming them to follow the normal distribution.

Figure 4-7 Wealth index and wealth perception across stages of change
The Wilcoxon rank sum test with continuity correction was performed for the ‘wealth index’ scores of respondents that indicated a statistically significant difference between the two groups (W = 3228.5, p-value = 0.0009698). However, the effect size for a wealth-index increase from PC to A stage is less than what is hypothesized. Hedges's g estimate is 0.3 while the hypothesized value was >0.79. Post-hoc analysis for the calculated effect size of 0.47 and real sample size of 199 and 47 for PC and A groups with a 0.05 significance level for a two-tailed test leads to the power of 0.77 for this dataset. The two-tailed test was done on a conservative basis, though we would expect wealth to increase along the stages. For the one-tailed test, the power increases to 0.86.

The Wilcoxon rank sum test with continuity correction was performed for the ‘objective wealth’ scores of respondents that indicated a statistically significant difference between the two groups (W = 3805.5, p-value = 0.04725). However, the effect size for ‘objective wealth’ score increase from PC to A stage is less than what is hypothesized. Hedges's g estimate is 0.47 while the hypothesized value was >0.79. Post-hoc analysis for the calculated effect size of 0.47 and real sample size of 199 and 47 for PC and A groups with a 0.05 significance level for a two-tailed test leads to the power of 0.40 for this dataset. The two-tailed test was done on a conservative basis, though we would expect wealth to increase along the stages. For the one-tailed test, the power increases to 0.53. Considering the low power, we do not use this ‘objective wealth’ score for any data analysis and depend on the standardized ‘wealth index’ as described in the literature.

Moreover, many households who can afford LPG (say, ‘top 25’ by wealth index quartiles) are in the PC, C and P stages (Figure 4-8).
4.6.4 Regression models

I ran multiple logistic ordinal regression models (Figure 4-9) to best explain the stages (dependent variable) using the standard TTM framing (pros, cons), and including other factors (such as wealth indices) to better reflect the externalities that must be navigated to perform the desired behavior. We find that in comparison to the objective wealth index (model 2), the cons (psychological variable) matter three times more.
Figure 4-9 Logistic Ordinal Regression for stages of change

For ordinal logistic regression, we assume that there is a latent variable whose value must decrease over the stages (threshold/ cut-off values). While the composite latent variable whose decrease in value helps movement across the stages is unknown, we view that as the perceived cost of using LPG. As the perceived cost (different from the cash expense involved in refill purchase) reduces, people move across the stages. This cost is not just the out-of-pocket expense of using LPG, but also takes into account the opportunity cost of LPG purchase in terms of convenience, alternative expenses, etc. As this value (cost) decreases, using LPG becomes the desired option for a rural household.
4.7 Discussion

4.7.1 TTM shows that cooking transition is a staged journey

TTM is a valuable way to visualize the clean cooking transition. I found that the pros and cons of regular LPG usage broadly change, across the stages as defined by adapting the TTM literature. It is remarkable that a self-regulatory behavior change theory primarily developed in a western context and often used to study addiction (Prochaska et al., 1994) has fit reasonably well with a problem (which has been projected as a wealth & behavior problem) in a developing country context.

4.7.2 The distribution which is not in sync with existing TTM literature

The difficulty in finding respondents in the preparation stage may be explained by the fact that the desired behavior of regular LPG usage, is actually a staged behavior by itself. Behavior science makes distinction among behaviors of different durations and different levels of familiarity: unfamiliar dot (one time LPG connection, purchase of stove and the installation cylinder), short-term unfamiliar span (learning about LPG usage during user trials in initial days) and long-term familiar path behavior (effortful span behavior turning into the spontaneous habit of regular LPG usage over time) (Fogg & Hreha, 2010). Studies across a wide range of human behaviors have demonstrated that enablers, barriers, and triggers for these three different types of behavior vary, and hence, strategies targeting short-term span behavior would be very different from long-term path behavior (Prochaska & Velicer, 1997). The desired behavior as formulated is actually a mix of dot, span and path behavior. So, when someone who is presently reluctant to engage in dot behavior is asked about the plan to conduct path behavior, it becomes a leap too far.

4.7.3 Reversal of the strong and weak principles of TTM

The proponents of TTM suggest that “perhaps twice as much emphasis should be placed on raising the benefits as on reducing the costs or barriers” (Prochaska & Velicer, 1997). The survey data
indicates that this is not a valid guide for our case. TTM studies were primarily conducted on self-regulatory behavior wherein people control their behavior (smoking cessation etc.) and are generally not dependent on uncertain/ out of control external factors to perform the desired behavior. [However, there may be external conditions that could increase the temptation to fall back to undesired behavior (lack of restriction to smoking in public).] For LPG usage, there is significant dependence on the supply chain and external actions in rural areas, physical access issues, LPG home delivery person, if any, sales outlet operating hours, sudden cash crunch, etc.). This is unique for our case unlike behaviors commonly studied by TTM such as smoking cessation or safe sex behavior where the role of externalities is limited (e.g. rarely cigarettes or condoms would be out of stock in the market or too expensive to buy). Hence, unless the cons of desired behavior are significantly reduced for households at the P (preparation) stage, the transition from preparation to action stage would not happen.

4.7.4 Drop in self-efficacy from preparation to the action stage

People who are actually using LPG regularly are more aware of the externalities (“the daily struggles” as per a community leader) of LPG usage compared to people who plan to use it regularly. Hence the sharp drop from preparation to the action stage. People who are able to resist the temptation to go back to solid fuels, improve their self-efficacy quotient and progress to the maintenance stage.

4.7.5 Study limitations

First, I acknowledge that there are significant critiques (West, 2005) and limitations (Armitage, 2009) of TTM, yet I opted to adopt a standard yet imperfect theory in the cookstove domain characterized by very limited efforts at theorizing the behavior change aspects. Second, suggestion of psychological variables driving fuel choice decisions instead of objective metrics (like cost) is, on its face, contradictory to a strong narrative in existing literature that cost, household wealth or some related affordability
parameter plays the most important role in the decision making process regarding use of clean cooking solutions, including LPG (Khandelwal et al., 2017; Lewis & Pattanayak, 2012; Puzzolo, Pope, Stanistreet, Rehfuess, & Bruce, 2016).

Second, as the information collected is self-reported, there are risks of biases. As using LPG regularly may be viewed as a desirable behavior, there is a likelihood of over-reporting consumption, i.e. social desirability bias. I attempted to minimize the recall errors by focusing on time spent (a more frequently used unit in daily lives) instead of fuel quantity-typically see, (NSSO, 2014) asked in a unit of kg.

1) Due to resource constraints, we did not do exploratory or confirmatory analyses. The standard method of applying a series of exploratory PCAs with varimax rotation on each set of items followed by confirmatory structural equation measurement modeling was not conducted.

2) Due to resource constraints, we only used 3 items of Pro and 4 items of Con. Future studies should increase them further.

The study suggests that:

1) Unlike self-regulatory behaviors where the performance of a behavior is largely a question of individual agency, the desired behavior in our case is dependent on many factors. These factors would continue to persist, and as going back to traditional cooking is low-hanging fruit (easy, quick, free), there would always be a significant temptation (and incentives) to go back to the undesired behavior.

2) As even people in the precontemplation stage have high pro scores, resources should be directed at reducing the cons and increase self-efficacy, especially in order to move people from the preparation to the action stage.

3) While wealth matters (statistically significant), the perceived disadvantages matter even more. So, behavioral interventions are necessary to ensure that 60 million Ujjwala consumers become regular LPG users.
4) A key insight from TTM applications for health and pro-environmental behaviors is that it is in order to nudge people to move across stages, there should be customized intervention. In other words, someone at PC and someone at P should get different sets of communication messaging/incentives to move to C and A respectively. As the decisional balance driven stage-wise movement is validated for LPG use, future research should explore the practical options of identifying and administering stage based communications for millions of poor women.

5) TTM suggests ten pathways to help people make the staged journey towards the desired behavior. While these strategies have not been tested explicitly for our study, it would be helpful to map them to the existing strategies, or lack of it, undertaken in Ujjwala and other programs to incentivize greater use of LPG.

4.8 Ujjwala modality and communication strategy

TTM is found to be partially applicable in the context of regular LPG usage in rural India at least as far as the increase in pros and decrease in cons is concerned. It allows me to argue (in the absence of new contradictory data) that TTM’s pathways to change across stages may have relevance in this context, though it was not explicitly studied. TTM includes ten pathways to change behavior (independent variables) that people need to apply or be engaged in, to move between stages (Prochaska & Velicer, 1997). It is hence useful to review what these pathways are, and to what extent the PMUY (Ujjwala) program conforms to it.
**What TMM Recommends:** information based awareness generation for *consciousness-raising* in target population leading to increased awareness about the causes, consequences, and alternatives related to particular problem behavior.

**The Ujjwala Reality:** Currently the entire communications is how the Ujjwala program has helped women get empowered and how it is helping to transition to “smokeless kitchens”. It needs to talk about the benefits of regular cooking with LPG and disadoption of solid fuels.

**What TMM Recommends:** An emotionally driven campaign (ex. role-playing and dramatic relief) to produce dramatic relief in the form of anxiety about problem behavior/ hope about embracing alternative positive behavior.

**The Ujjwala Reality:** While the govt. has aggressively pursued publishing personal testimonies of women who are using LPG, they tell an emotional, simple, feel-good narrative of how LPG has transformed their lives. However, there needs to be more focus on the struggles with a focus on self-efficacy aspects (how they handled and overcame the objections from male members, complaints about the taste of food) to help reduce the cons.

**What TMM Recommends:** Facilitating self-reevaluation combining both cognitive and affective assessments of one’s self-image with and without a particular problem behavior, “such as one’s image as a couch potato and as an active person” making target individuals realize that healthy behavior if an important part of who they are and who they want to be (Prochaska & Velicer, 1997).

**The Ujjwala Reality:** Considering the sheer scale (60 million women spread across a vast country), individual stage-relevant interventions would be very challenging. While the communications do explicitly focus on “empowered women”, it needs to explicitly include the aspect of getting empowered to decide which cooking fuel would be used and why regular cooking would contribute to a healthier family.

**What TMM Recommends:** Environmental reevaluation combines both affective and cognitive assessments of how one’s problem behavior impacts one’s social and natural environment, such as the
effect of passive smoking and how this person can serve as a negative/positive role model for others by continuing/abandoning a problem behavior.

**The Ujjwala Reality:** The LPG Panchayats do bring to fore the impacts of household air pollution, and ask the regular users of LPG to share their experiences. There should be concentrated efforts to communicate the aspect of children’s health consequences if LPG is not used regularly, especially pneumonia deaths in children below 5 years.

**What TMM Recommends:** **Self-liberation** is both the belief that one can change (embrace desired behavior/abandon undesired behavior) and making a commitment to act on that belief.

**The Ujjwala Reality:** Organizing public pledges in public meetings/ LPG panchayats would be useful especially for the male members of the house to commit to regular LPG purchases. Similar initiatives were taken for ‘Clean India’ program.

**What TMM Recommends:** **Social liberation** strategies which give indication that the society (community leaders or government as its representative) encourages/advocates change in problem behavior by highlighting appropriate policy/advocacy/action (ex. easy access to condom vending machines), especially for socially marginalized or economically weaker segments of society to overcome problem behavior.

**The Ujjwala Reality:** While the program and the purported women empowerment is directed targeted at the economically marginalized, it is useful to ensure that external factors don’t impede behavioral intention to use LPG. For example, if home delivery is not possible, a village camp on a monthly basis to sell LPG near home as well as promote benefits of regular LPG usage through banners, etc.

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What TMM Recommends: **Counterconditioning** requires the actual learning of healthier behaviors that can substitute for problem behaviors.

**The Ujjwala Reality:** While this is not a major concern for younger women, it is a big stumbling block for aged cooks. Generally, with age, the ability to learn new technology diminishes (Venkatesh, Thong, & Xu, 2012). Training by a woman volunteer/ woman distributor staff to provide tips on safety and heat management for new users.

What TMM Recommends: Proactively **manage the environment** by providing stimuli that support desired change and reduce risks for relapse in form avoiding situations associated with negative behavior (ex. visit parties where there would be peer pressure to smoke) and venturing into new situations (ex. set up meetings in smoke-free zones).

**The Ujjwala Reality:** There are not many efforts made in this direction. Incentivize people to break their home stoves. While it can be rebuilt easily, not having a stove on sight can reduce the temptation. Also, creating a local supply network of agricultural residues would provide an alternative and commercially advantageous usage instead of cooking.

What TMM Recommends: A **contingency management** plan where rewards (ex. recognition) and punishment are in-built as consequences for taking steps in a particular direction which encourages movement in the desired direction.

**The Ujjwala Reality:** While punishment (making solid fuel collection illegal) is not desirable, high use consumers can be rewarded with small gifts if they exceed a certain number of cylinders along with public recognition.

What TMM Recommends: Building an effective **social network** that can lead to “helping relationships that combine caring, trust, openness, and acceptance as well as support for the healthy behavior change” (Prochaska & Velicer, 1997).
The Ujjwala Reality: LPG panchayats are a great beginning, and should be repeated in a village with dedicated funds. Cooking events with games/prizes such as ‘find which stove from taste’ can help overcome the self-efficacy challenges.

The first five processes of change are classified as experiential processes and are more effective for early-stage transitions (before action). The last five are labeled behavioral processes and more effective in action/maintenance stages. Stage-specific interventions are more effective for self-regulatory behavior change (Prochaska et al., 2008). TTM critiques have also supported the role of “individualized interventions” over uniform generic interventions (Bandura, 1998). The aforementioned ten ‘processes of change’ could alter two self-assessment or mental constructs (dependent variables).

4.9 Sample size calculation

4.9.1 If normal distribution of pro/con score

t-tests - Means: Difference between two independent means (two groups)

**Analysis:** A priori: Compute the required sample size

**Input:**
- Tail(s) = Two
- Effect size d = 0.5
- α err prob = 0.05
- Power (1-β err prob) = 0.8
- Allocation ratio N2/N1 = 0.25

**Output:**
- Noncentrality parameter δ = 2.8284271
- Critical t = 1.9720175
- Df = 198
- Sample size group 1 = 160
- Sample size group 2 = 40
Total sample size = 200
Actual power = 0.8036475

4.9.2 If non-normal distribution of pro/con score

t-tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method
Analysis: A priori: Compute the required sample size

Input:

Tail(s) = Two
Parent distribution = min ARE
Effect size d = 0.5
α err prob = 0.05
Power (1-β err prob) = 0.8
Allocation ratio N2/N1 = 0.25

Output:
Noncentrality parameter δ = 2.8193616
Critical t = 1.9720964
Df = 196.72
Sample size group 1 = 184
Sample size group 2 = 46
Total sample size = 230
Actual power = 0.8011153
Post-hoc Power Calculations

Non-parametric post-hoc

PRO score

t-tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method

Analysis: Post hoc: Compute achieved power

Input:
- Tail(s) = Two
- Parent distribution = min ARE
- Effect size d = 0.618341
- α err prob = 0.05
- Sample size group 1 = 199
- Sample size group 2 = 47

Output:
- Noncentrality parameter δ = 3.5439928
- Critical t = 1.9712953
- Df = 210.544
- Power (1-β err prob) = 0.9415381

CON score

t-tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method

Analysis: Post hoc: Compute achieved power

Input:
- Tail(s) = Two
- Parent distribution = min ARE
- Effect size d = -1.019688
- α err prob = 0.05
- Sample size group 1 = 199
Sample size group 2 = 47

Output:
Noncentrality parameter $\delta$ = -5.8442945
Critical t = -1.9712953
Df = 210.544
Power (1-\(\beta\) err prob) = 0.9999427

4.9.3 Wealth index score: Two-tail

t tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method

Analysis: Post hoc: Compute achieved power

Input:
Tail(s) = Two
Parent distribution = min ARE
Effect size d = 0.4745406
\(\alpha\) err prob = 0.05
Sample size group 1 = 199
Sample size group 2 = 47

Output:
Noncentrality parameter $\delta$ = 2.7198075
Critical t = 1.9712953
Df = 210.544
Power (1-\(\beta\) err prob) = 0.7725959

WEALTH INDEX score: Single-tail

t tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method

Analysis: Post hoc: Compute achieved power
Input:

Tail(s) = One
Parent distribution = min ARE
Effect size d = 0.4745406
α err prob = 0.05
Sample size group 1 = 199
Sample size group 2 = 47

Output:

Noncentrality parameter δ = 2.7198075
Critical t = 1.6521231
Df = 210.544
Power (1-β err prob) = 0.8568330

Objective wealth score: Double tail

t tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method
Analysis: Post hoc: Compute achieved power

Input:

Tail(s) = Two
Parent distribution = min ARE
Effect size d = 0.3004081
α err prob = 0.05
Sample size group 1 = 199
Sample size group 2 = 47

Output:

Noncentrality parameter δ = 1.7217751
Critical t = 1.9712953
Df = 210.544
Power (1-β err prob) = 0.4029440
Objective wealth score: Single tail

t tests - Means: Wilcoxon-Mann-Whitney test (two groups)

Options: A.R.E. method

Analysis: Post hoc: Compute achieved power

Input: 
- Tail(s) = One
- Parent distribution = min ARE
- Effect size d = 0.3004081
- α err prob = 0.05
- Sample size group 1 = 199
- Sample size group 2 = 47

Output: 
- Noncentrality parameter δ = 1.7217751
- Critical t = 1.6521231
- Df = 210.544
- Power (1-β err prob) = 0.5284548
5. Cooking fuel choices, the theory of planned behavior and survey biases

I covered two distinct but related topics in this chapter. First, I used the expectancy-value model from the theory of planned behavior (TPB) to elicit information about the behavioral determinants of clean cooking fuel choice and then rank them to identify the behavioral barriers. I also tested if the key postulates in the relationship among beliefs, intentions, and behavior as per TPB holds true. The TPB has been developed in western, educated, industrialized, rich, and democratic (WEIRD) societies, while I have applied this theory in the context of Indian, low-educated, agrarian, low-income and democratic conditions, in accordance with the CI-CHANGE model (Chapter 2).

Second, as I depended on self-reported survey data to evaluate and rank behavioral determinants, I delve into the reliability of standardized survey tools in the context of our target communities. While surveys are the standard data gathering tool in the cooking transition literature, the challenges and strategies to tackle survey biases are mostly lacking. I cross-checked the data from survey tools with objective measures, and also compared the direct and indirect responses to questions elicited as per the TPB framework.

5.1 Literature review on behavioral beliefs and survey biases

5.1.1 Beliefs, intention, and behavior

A major challenge for researchers and policy-makers has always been how to prioritize the multitude of factors that affect the household fuel decision choices. Past work has identified more than 30 factors that have been broadly classified by some researchers as internal household characteristics (household internal opportunity set), external socio-cultural and natural environment and external institutional-market environment (van der Kroon et al., 2013). Also, during the discussion on the
principles and approaches around the CI-CHANGE framework (Chapter 2), I made the case that human
decision choices are influenced by impressions of reality driven by effortless and associative perceptions
and intuitions (Kahneman, 2003; Evans, 2008). The worldview that people hold and the action that they
take is often distorted by heuristics, biases, anomalies, mood and past habits (Evans, 2008; Kahneman et
al., 1991; Tversky & Kahneman, 1974). The influential ‘theory of planned behavior’ (TPB) postulates
that behavioral intent to perform the desired behavior can be improved by influencing attitudinal,
normative and control beliefs and provides a quantitative mechanism to rank the importance of these
beliefs/ factors.

5.1.1.1 Attitudinal beliefs

Based on experience, observation or exposure to information, be it true or false, rational or
irrational, people form expected outcome expectancy or behavioral beliefs (Fishbein & Ajzen, 2011).
TRA’s expectancy-value model postulates that attitude is the product of the strength of the attitudinal
belief that performing a behavior will lead to a particular outcome (ex. increase in social status) and the
level of desirability (ex. how important is it to have my social status increase) of the particular outcome
(Ajzen, 2012). Users generally consider belief strength/ feasibility and corresponding attribute evaluation/
 desirability for only five to eight salient beliefs that are “readily accessible in memory” to determine the
attitude at a particular point in time (Fishbein & Ajzen, 2011). Hence, it is important to know which of
these salient beliefs are negative and then design interventions specifically targeting them instead of
attempting to focus on thirty-one factors. For example, if safety concerns/ accidents (ex. from LPG usage)
emerge as a strong negative salient behavioral belief (Puzzolo et al., 2016), then there is scope to improve
the attitude towards LPG by addressing only those concerns directly. As people already consider LPG to
be aspirational (Smith & Dutta, 2011), crowding the safety message in LPG marketing initiatives with the
status increase is akin to “preaching to the choir” and risk losing the emphasis on the issue that people
needed to know to increase favorability of their attitude. Past TRA studies across a broad range of human
behavior report mean correlation of 0.53 between revealed attitude from the expectancy-value index and
direct attitude measure (Fishbein & Ajzen, 2011). It indicates that identifying and targeting the few negative salient beliefs held by people exposed to a new promotion by changing the communication message can significantly improve attitude towards the target behavior (ex. purchase of CCS). This is in line with the recent attention to “create strategic communications that appeal specifically to the” target audience of CCS promotion initiatives (Barnes et al., 2015). Scholars have also distinguished between instrumental (ex. useful vs. harmful) and experiential (ex. boring vs. interesting) attitudes about the behavior of interest. Some scholars also stress the role of “hedonic motivation” (Venkatesh et al., 2012) or affect (Triandis, 1977), which describes as the pleasure/ emotions derived from using technology or any behavioral action.

Here it is also important to differentiate between user’s attitude towards personally using CCS in a stacked fashion and exclusive CCS usage. While desirable long-term behavior change from health perspective entails exclusive CCS usage, the evidence is missing regarding the desire to exclusively use CCS at the time of purchase. The vast majority of clean cooking interventions in the past has shown that households that have purchased CCS, they have continued to stack CCS with TCS (Gould et al., 2018; Quinn et al., 2018; Ruiz-Mercado & Masera, 2015). It may well be the case that factors such as social status, novelty and aesthetics drive purchase decisions more than a strong desire to move away from TCS for economic or health reasons (Jürisoo & Lambe, 2016; Puzzolo et al., 2016). Hence, at this stage, the pre-purchase behavior of interest may be either occasional or exclusive CCS usage. Net positive attitude (increase in pros, in TTM parlance, or perceived advantages) towards the behavior of interest is only the first step in the process.

5.1.1.2 Normative beliefs

Normative beliefs are perceptions held by a person on whether there is a social pressure to engage or not engage in the target behavior. This perceived pressure by salient referents- some people whose views and action matter, like close family members, influential peers, opinion leaders, etc.- often plays an important role in the decision-making process (Fishbein & Ajzen, 2011). TRA postulates that these
beliefs translate into perceived norms about the target behavior as the product of the strength of the individual's normative beliefs and the user's level of "motivation to comply" with perceived expectations of the salient referents (Ajzen, 2012). On similar lines, diffusion literature emphasizes the role of "well-established interpersonal ties" as women users would seek the advice of peers and opinion leaders whose suggestions “matter” (perceived injunctive norms). If the target consumer perceives CCS as a risky innovation, they tend to follow the behavior (perceived descriptive norms) of their peers (Rogers, 2003). Past CCS interventions have leaned on “social support” as a BCT strategy to improve injunctive norms (Goodwin et al., 2015). In order to target the descriptive norms of the late majority segment of the population, the social norm approach (SNA) from sociology domain may be adopted. SNA suggests that telling people about what other people do, usually in the form of what the majority of people do, is effective in changing behavioral intention (Burchell, Rettie, & Patel, 2013). Also, word of mouth (WOM) from early adopters has been demonstrated as one of the most influential channels of communication for consumer products (Allsop, Bassett, & Hoskins, 2007).

5.1.1.3 Control beliefs

Control beliefs are beliefs about personal, technological and environmental factors that can help or impede their attempts to carry out the behavior in relevant situations. TRA postulates that these self-efficacy beliefs translate into perceived behavioral control (PBC) about the target behavior as the product of the individual's belief strength that controls factor (impede/ facilitate behavior) would be present and its power, i.e. the importance of the factor to facilitate or impede the performance of behavior (Fishbein & Ajzen, 2011). PBC is strengthened when people gain mastery experiences (i.e. personal experience of success in overcoming similar obstacles through persistent efforts), vicarious experiences (observing people similar to oneself succeed in target behavior), and social persuasion (getting verbally motivated that one has the capability to successfully perform the target behavioral action) (Bandura, 1998). So, actions such as individualized hands-on training during the demonstration, arranging a visit to existing customer homes, and confidence-boosting messages to potential customers could make users perceive
that CCS is “easy to use”. Some researchers consider that TTM's self-efficacy is about personal control (confidence in own ability to maintain the desired behavior in a difficult situation) while TPB’s PBC is viewed as external control, where the situation is difficult because of a “lack of opportunities or resources in the environment” (Armitage & Arden, 2002). However, for the thesis, control beliefs are considered similar to self-efficacy and include beliefs about personal, technological and environmental factors that can help or impede their attempts to carry out the desired behavior in relevant situations (Bandura, 2012; Fishbein & Ajzen, 2011).

5.1.1.4 Behavior-Intention-Belief linkage

Hence, designing interventions that target unfavorable accessible behavioral, normative and control beliefs should increase the likelihood of preparatory action for desired behavior (Fishbein & Ajzen, 2011). On similar lines, another widely cited theory- the unified theory of acceptance and use of technology (UTAT-version 2 developed for consumer technology adoption) confirms the role of ‘performance expectancy’, ‘social influence’ and ‘effort expectancy’ on similar lines for technology acceptance and continuance behavior (Venkatesh et al., 2012). These strategies should also upgrade the behavioral intention of the user from "stacked CCS usage" to "exclusive CCS usage" to ensure that the target behavior of the CCS customer matches the desired behavior of the CCS promoters. Efforts are made by the user to achieve internal target behavior, not the external agency/ change agent's desired behavior.

In order to capture the perceptions around these factors and create a framework to prioritize these factors, the standardized expectancy-value approach has been used by TPB scholars. Three behavioral constructs, attitudes, perceived norms and perceived behavioral control contribute to strengthening or weakening an individual’s intention to perform the target/ desired behavior (Fishbein & Ajzen, 2011). Attitude is the product of the strength of the attitudinal belief that performing a behaviour will lead to a particular outcome (ex. likely/ unlikely increase in social status from using LPG) and the level of desirability (ex. increase in social status is good/bad) of the particular outcome (Ajzen, 2012) based on
TPB’s expectancy-value model. Perceived norms are determined by the strength of the normative beliefs weighted by the motivation to comply (Ajzen, 2012). This includes both injunctive (perception of what others would say about the respondent’s LPG use) and descriptive (perceptions of others cooking habits) norms. Perceived behavioural control (PBC) is determined by a person's subjective probability that a control factor is present (ex. fuel supply reliability would be high/ low), weighted by the power of each control factor (availability of reliable fuel supply is very important/ does not matter) (Fishbein & Ajzen, 2011). Notably, the effect of all other factors is hypothesized to mediate via these three TPB constructs (Sniehotta et al., 2014).

The above discussed behavioral determinants and the mathematical model for prioritizing them are useful only if behavioral beliefs lead to the performance of the actual target behavior. Behavioral beliefs culminate in the formation of intention18 (see, Figure 2.1) to perform the target behavior. Researchers have highlighted two main issues where intention does not well predict behavior. First, if there is measurement error in terms of the target behavior. A well-framed behavior is considered to be composed of elements- the action to be performed, the target at which the action is directed, the context in which the action is performed, and the time interval in which the behavior is performed (Fishbein & Ajzen, 2011). Sometimes, studies have a measurement error in terms of lack of consistency in these four elements while eliciting self-reports of intention and behavior.

Second, the person should have control over performing the behavior if the intention to perform the behavior is to be realized. TPB suggests that if there are no actual barriers (ex. no supply of CCS) that prevent the cook from performing the behavior (purchase and use CCS) and possess non-behavioral abilities, opportunities, and resources are available to carry out the task, then strength of behavioral

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18 Behavioral intentions are “instructions that people give to themselves to behave in certain ways” (Sheeran, 2002; Triandis, 1977)
intention is correlated to the likelihood of the behavioral action\(^\text{19}\) (Fishbein & Ajzen, 2011; G. C. Moore & Benbasat, 1996). Unlike self-regulatory behaviors such as cessation of smoking, there are several on-ground factors that can prevent a person from following up on the behavior related to clean cooking. TPB researchers claim that such difficulties would be captured (for a well-informed person who is fully aware of the challenges) in the perceived control beliefs which not only affect intention but also mediate between intention and performance of the behavior.

5.1.2 Role of survey bias

The reliability of any findings from a study based on the TPB framework depends on the accuracy or truthfulness of the survey responses or self-reports by the target community. In fact, irrespective of the theoretical frameworks and methods, the majority of studies that have studied cooking energy transition to date have primarily depended on self-reports by stove users (surveys or interviews). So, our understanding of this topic related to cooking energy choices and the stated underlying decision-making factors is contingent on the accuracy of the survey responses. Yet, the cookstove literature is largely silent on the role of survey biases or the effect of survey settings, other than briefly acknowledging its presence in some studies (Duflo et al., 2012; Jain et al., 2018). One notable exception is to study the Hawthorne effect-a change in cooking fuel choices in the presence of outsiders. When surveyors come to record self-reports of use or measure air quality, people tend to use cleaner cooking solutions more in front of them (Simons, Beltramo, Blalock, & Levine, 2017). There are some recent efforts to capture the difference, if any, between self-reported (subjective) and observed behavior, through use of thermal sensors (objective) which capture frequency and duration of use of cooking devices (Pillarisetti et al., 2014; Simons et al.,

\(^{19}\) However, past intervention efforts across a wide range of (largely self-regulatory) human behaviors suggest that even medium-to-large effect (effect size Cohen’s \(d = 0.66\)) on behavioral intention have an only low-to-medium effect \((d = 0.36)\) on actual behavior (Gollwitzer & Sheeran, 2006).
However, due to logistics and cost, sensors are generally deployed to a sub-sample of surveyed sample households (A. Kofi Amegah, 2018).

In contrast, in the field of social and health psychology, where researchers primarily depend on surveys to find out about people’s perceptions and past behavior (Fisher, 1993), there is a rich literature on this issue. Contrary to popular misconception, biases are prevalent not only for “taboo” or stigmatized behavior like sexual health or addiction, but a wide range of human behaviors like voting and attending church (Epstein, 2006; Fisher, 1993; Orne, 1962). Past studies have explored the gaps between self-report and actual data where independent objective data was available, such as voter turnout- see, table 2 in (Epstein, 2006) and income levels-see, table 1 in (J. C. Moore, Stinson, & Welniak, 2000). In addition, there is a rich literature on the cause, effect and strategies to minimize biases where objective data is not generally available such as sexual health (Catania et al., 2002), social workers’ client satisfaction (LaSala, 1997), alcohol and marijuana use (R. A. Johnson, Gerstein, & Rasinski, 1998), and patient satisfaction (Mazor, Clauser, Field, Yood, & Gurwitz, 2002). Wrong answers have been considered to be the “gravest threat” to the value of findings based on self-reports (Epstein, 2006). Someone can honestly provide a wrong answer to a question due to recall error- misremembering a fact from past (Das, Hammer, & Sánchez-Paramo, 2011) or due to unconscious distortion (Epstein, 2006). At other times, there could intentional falsification of data driven by the basic human tendency of impression management (Fisher, 1993) or, simply a “natural reticence” to confide certain things to anyone (Warner, 1965). The quality of the survey responses also depends on the mode of administering the questions (Bowling, 2005), and the data collection setting (Milewski & Otto, 2017).

Next, I discuss two common survey biases which concern researchers in the field of sociology and psychology, namely, social desirability bias (Nederhof, 1985; Stuart & Grimes, 2009; Turner, 1998) and

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20 Here, I am avoiding discussion on issues which are generally within researcher control- such as acquiescence bias, or question order bias; I also do not discuss non-response issues which could be consequential in some cases (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003)
demand characteristics (Nichols & Maner, 2008; Orne, 1962). I argue that these two biases could be relevant for the problem at hand but are currently under-emphasized in the cookstove literature. I also discuss why these biases could get amplified due to the prevalent mode of data collection, namely face-to-face interviews in presence of bystanders, in the target communities of the developing world (Lupu & Michelitch, 2018).

5.1.2.1 Social Desirability Bias

Social desirability refers to efforts made by a survey respondent to make oneself “look good in terms of prevailing cultural norms when answering to specific survey questions” (Krumpal, 2013). As a result, surveys under-report socially undesirable (e.g. using drugs) behavior and over-report socially desirable (e.g. voting) behavior for “ego-defensive or impression management reasons” (Fishbein & Ajzen, 2011; Fisher, 1993; Stuart & Grimes, 2009; Tourangeau & Yan, 2007). In other words, social desirability bias refers to the tendency of research subjects to give socially desirable responses instead of choosing responses that are reflective of reality, i.e. distort the truth in ways that will be viewed favorably by others (Orne, 1962; Stuart & Grimes, 2009).

Interestingly, social desirability bias is not just manifested for stigmatized or illicit behavior like violence and sexual health (Catania et al., 2002; Turner, 1998), but generally for a range of behaviors which one may not consider as particularly problematic. Examples range from reporting income (J. C. Moore et al., 2000), attending religious service (Presser & Stinson, 1998), and voting (Epstein, 2006). Unlike intrusive questions around sexual behavior, in the case of clean fuel choices is no issue with the sensitivity of a question, but sensitivity about response choices.

PMUY has led to the biggest promotion blitz around LPG enrollment and benefits- with posters of the smiling Indian Prime Minister with an LPG cylinder everywhere from train stations to public toilets to village roads (Barua & Agarwalla, 2018). Such promotions raise awareness and inform the study population about the benefits of LPG. Information, education, and communication (IEC) based strategies
should give a boost, temporary or permanent, to their willingness to use LPG more often (Lewis et al., 2015). However, such a campaign could also lead to an adverse unintended outcome - social desirability bias while reporting LPG use. While not using LPG regularly may be the norm in the target communities (see, chapter 2 on the LPG purchase trends) for a host of reasons, I argue that reporting the same to an “outsider” surveyor could be perceived as undesirable by a respondent for two reasons. First, to project a favorable self-image to a stranger and avoid embarrassment (Fisher, 1993), and second, avoid the political spotlight or, worse, backlash (Lupu & Michelitch, 2018) for truthfully reporting low LPG use. Recently, in one incident, a video of an LPG consumer who still used firewood to prepare food for a politician during election campaign led to a political uproar and put the media spotlight on them (Srivastav, 2019).

5.1.2.2 Demand Characteristics

Demand characteristics are defined as “ready complacency and cheerful willingness to assist the investigator in every way by reporting” what the respondent taking part in a study/ experiment perceives the surveyor/ researcher wants to hear is known (Nederhof, 1985; Orne, 1962). Survey participants make effort to be “good subjects” in what they perceive as what researchers what to prove, i.e. catering to the “demand” of researchers (Nichols & Maner, 2008; Orne, 1962). Researchers in WEIRD studies often go to great lengths to hide from participants the purpose of research or the hypotheses driving the research questions, so that the respondents are unaware of the best answers that the researchers are hoping for, in some ways (Orne, 1962). In the context of cookstove interventions, when ‘outsider’ survey teams reach villages, they typically have a preliminary discussion with community leaders on the purpose of the project before they are allowed to work in the community. Sometimes, the partner organization is well-known in the community for their past work on clean cooking solutions (Lewis et al., 2015). Typically, it is communicated without the finesse of wording around research hypotheses, that they are interested in promoting clean fuels and intend to learn about fuel choices in the community and its determinants. If using clean cooking fuels is known by the community as the main goal of a project, respondents may
perceive that the survey team would like to see higher LPG usage. As a result, visit by researchers to kitchens for collecting data leads to significant uptake in the use of clean cooking solutions, while people reverse to the old methods when the outsides leave the premises (Simons et al., 2017). Hence, I argue that the survey participants in cookstove generally have enough information to become “good subjects”.

5.1.2.3 Mode of questioning: Face-to-face interviews & bystander effect

There is not much guidance in the cookstove literature on how to navigate or tackle the social desirability bias and demand characteristics. However, the vast literature around biases in sociology and psychology (Epstein, 2006; Fisher, 1993; Krumpal, 2013; Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Presser & Stinson, 1998; Tourangeau & Yan, 2007) strongly recommends that providing anonymity could avoid systematic misreporting due to biases (Fisher, 1993; Nederhof, 1985; Tourangeau & Yan, 2007). Typically, participant anonymity in terms of not collecting identifying information from participants such as name and address (Stuart & Grimes, 2009) and self-administered questionnaires where the respondent answers questions without the presence of the surveyor or others (Nederhof, 1985) are suggested as a strategy to minimize these biases. Research in domains such as social psychology, health psychology, and consumer marketing often focus on western, educated, industrialized, rich, and democratic (WEIRD) societies where computerized or paper-based self-administration of surveys are increasingly becoming the norm (Tourangeau & Yan, 2007). TPB and TTM have been originally developed and often self-administered in WEIRD societies in the lab (Redding et al., 2015) and field (Rakowski et al., 1996) conditions.

Unfortunately, in the rural areas in the developing world, self-administered surveys are not feasible due to low education levels and lack of reliable home address or telephone directories (Lupu & Michelitch, 2018). Hence, cooking energy transition studies mostly depend on the face-to-face interview of the survey respondent by the surveyor, in which the surveyor visits potential respondent’s home, explains the purpose, received verbal consent, reads the questions to the respondents and then record their
answers. If the questions are read out from an electronic device and then the response is keyed into such a device, in contrast to paper-based questionnaires, it is described as face-to-face computer-assisted interviewing (Tourangeau & Yan, 2007).

Past literature in several domains suggests that face-to-face interviews lead to higher social desirability bias than self-administered surveys (Bowling, 2005; Lyons et al., 1999). Face-to-face interviews increase the chance of misreporting sensitive responses, such as self-assessment of health (see, Table 3 in (Lyons et al., 1999)), drug use (see, Table 2 in (Tourangeau & Yan, 2007)), attending religious services (Presser & Stinson, 1998), and adolescent problem behavior (Turner, 1998), though there are exceptions (for review, please see (Newman et al., 2002)).

Moreover, typically the surveys in target communities in developing countries are administered in front of the respondent house or space immediately near the main entrance to the house. A “central criterion” for minimizing bias during face-to-face interviews is that it should be done in private (without bystanders) to allow anonymity of the respondents (Milewski & Otto, 2017). However, often other family members and even neighbors (both children and adults) gather when the actual survey is being conducted by ‘outsiders’ in target communities (Diop, Le, & Traugott, 2015; Lupu & Michelitch, 2018; Ralis, Suchman, & Goldsen, 1958). So, in effect, the respondent is sharing the answer publicly with not only the surveyor but bystanders or third parties such as her husband (Lupu & Michelitch, 2018).

5.1.2.4 Strategies to detect survey bias

I argue (and subsequently tested) that there are two possible strategies to detect, and if possible estimate the extent of survey bias in responses in the given context. First, ask indirect questions where the respondent is less conscious of the social desirability of the question. Projective questions (“most people”/“a typical consumer” vs. “you”) are sometimes used in psychology literature as indirect questions (Fisher, 1993). Alternatively, if I assess salient attributes of an object (e.g. “is LPG safe?”) individually, overall those responses should have a close relationship with a direct question (e.g. “is LPG good for you?”)
(Fishbein & Ajzen, 2011). For indirect questions around LPG’s attributes, such as whether LPG leads to the cleanliness of the kitchen, I assume that respondents are likely to provide truthful answers. I argue that respondents are more conscious about questions related to future intentions (public commitment to action, in effect) and past behavior (revealing past action). Second, comparing independent objective measures of a survey item with a self-reported value even for a smaller sample is recommended whenever possible (Epstein, 2006). Past studies have indicated that observed behavior often varies from self-reports for socially desirable behavior (Fishbein & Ajzen, 2011).

The survey self-reporting biases would be tested in two ways in this chapter. One, comparison of the composite scores for the various components of attitude, norms and control factors and the scores of these three behavioral determinants from direct elicitation. Two, a comparison of the self-reporting of the performed target behavior (extent of LPG use) should vary with actual observed behavior.

5.2 Research questions

5.2.1 Ranking of behavioral beliefs

5.2.1.1 Research Questions

In light of the above discussion, I seek to identify the factors (beliefs) which act as barriers to regular use of LPG as per the TPB framework and test the relationship between behavioral indices. I also intend to check, if there are any survey biases in the response by comparing the direct and indirect scores of the three key TPB behavioral determinants, namely, attitude, perceived norms and perceived control.

The research question (RQ1) which I aim to answer for this study is as follows: Which low-scoring behavioral beliefs need to be influenced to encourage regular use of LPG? More specifically, I intend to explore the following:

RQ1a. Which attitudinal beliefs in terms of both outcome likelihood and the level of desirability have relatively low scores related to regular LPG use?
RQ1b. Which normative beliefs in terms of both the opinions of influential people and respondents’ ‘motivation to comply’ have relatively low scores related to regular LPG use?

RQ1c. Which control beliefs in terms of both the presence of a control factor and its power to influence behavior have relatively low scores related to regular LPG use?

RQ1d. To what degree do beliefs related to regular LPG usage differ when measured through indirect vs. direct behavioral determinants related to attitudes, norms and control beliefs?

The RQ1d attempts to test the presence of bias, if any, by comparing the direct and indirect scores.

5.2.1.2 TPB Principles

The research question (RQ2) which I aim to answer for this study is as follows: Does the relationship among attitude, norms, control, intention, and behavior as stated in TPB hold true for clean cooking? More specifically, I intend to explore the following:

RQ2a. To what extent does attitude, norms and control factors influence intention to use clean cooking fuels regularly?

RQ2b. To what extent does the stated behavioral intent match state or observed behavior regarding the regular use of clean cooking fuels?

RQ2c. To what degree does self-reported LPG usage match direct measurements of LPG consumption from purchase data?

The RQ2c attempts to test the presence of bias, if any, by comparing the self-reported behavior with the observed behavior of interest.
5.3 Methodology

5.3.1 Data sources

I conducted two distinct surveys to answer the research questions in the villages around Kanakagiri in Koppal district. Study S1 (PW) was used to study RQ1. Study S2 (EPA) was conducted to address RQ2.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Study</th>
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<tr>
<td>RQ1a. Which attitudinal beliefs in terms of both outcome likelihood and the</td>
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<td>level of desirability have relatively low scores related to regular LPG use?</td>
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<td>RQ1b. Which normative beliefs in terms of both the opinions of influential</td>
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<td>related to regular LPG use?</td>
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<tr>
<td>RQ1c. Which control beliefs in terms of both the presence of a control factor and</td>
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<td>its power to influence behavior have relatively low scores related to regular</td>
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<td>LPG use?</td>
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<tr>
<td>RQ1d. To what degree does self-reported LPG usage match direct measurements of</td>
<td>S1</td>
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<tr>
<td>LPG consumption from purchase data?</td>
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<tr>
<td>RQ2a. To what extent does attitude, norms and control factors influence</td>
<td>S2</td>
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<td>intention to use clean cooking fuels regularly?</td>
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<tr>
<td>RQ2b. To what extent does the stated behavioral intent match the stated or</td>
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<td>observed behavior regarding the regular use of clean cooking fuels?</td>
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<tr>
<td>RQ2c. To what degree do beliefs related to regular LPG usage differ when measured through indirect vs. direct behavioral determinants related to attitudes, norms and control beliefs?</td>
<td>S2</td>
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5.3.2 Study 1

Under Study 1 (PW), a one-time survey was conducted in 402 households\(^{21}\) across 12 villages in Koppal. It was funded by the Peter Wall (PW) Institute at the University of British Columbia. The survey was conducted in the period between July and September 2017. The villages were chosen through convenience sampling. Our project partner- SAMUHA- an NGO based out of Koppal district, had ongoing welfare programs in many villages in this area. During internal deliberations, it was decided that due to a good rapport with the community leaders in these villages, it would be quicker and easier to roll out the survey in these villages. Enumerators were instructed to select households along random walks, as is often the protocol for doing surveys in the developing world (Lupu & Michelitch, 2018), though, in practice, they often avoided narrow or dirty lanes. The survey was administered in Kannada (local language) on UBC’s survey platform (Fluid Survey\(^{TM}\)) on Android tablets.

5.3.3 Study 2

Study 2 (EPA) involved two rounds of surveys in 205 households across four villages in Koppal. These households were part of an existing project which was funded by the United States Environmental Protection Agency (EPA) who got LPG. The first round was conducted in the period between June and August 2017 using a brief ten-minute survey, while the second survey conducted in October-November 2018. All these households had an LPG stove provided under the project either before the first survey or by the end of 2017. All our survey respondents live in the catchment area of an LPG distributor whose sales transaction records were available. So, for the second round of the survey, there were only two items. One, one question on how many LPG cylinders (14.2 kg) they have purchased and two, consent to use their LPG purchase data. Similar to Study 1(PW), Study 2 (EPA) survey was also administered in Kannada (local language) on UBC’s survey platform (Fluid Survey\(^{TM}\)) on Android tablets.

\(^{21}\) The same survey was also used to collect data for Chapter 4. Some households were excluded due to Transtheoretical model based group quota, for details please refer to section 4.5.1
5.3.4 Definitions of target behavior: regular LPG use

The target behavior is formally defined as **regular use** (*action element*) of LPG (*target element*) to cook food for the family (*context element*) over the next one year (*time element*). While I use the word ‘regular usage’ of LPG in both EPA and PW survey, I use two operationally different definitions. For EPA survey (Study 2), I use the purchase of 4 cylinders (1 cylinder = 14.2 kg of LPG) in a year as regular use. In the four EPA survey villages, even the households without LPG had reasonable understanding/knowledge on how much cooking with LPG would translate into how many cylinders due to past information campaigns and strong peer network effect. In sharp contrast, I found, during pilot testing, that people in PW villages with low LPG coverage did not understand the linkage clearly. Gas volume to time conversion involves complex assessment with a multitude of factors such as power levels (high power would lead to high consumption), stove efficiency, etc. With lived experience, the sense of that conversion was easy. So, I reached out to LPG experts who suggested that 4 cylinders in a year would work out to roughly 30 minutes/day use on average, and thus it was set as the operational definition for the PW survey (Study 1).

5.3.5 Methods for analysis

5.3.5.1 Data analysis for RQ1

For RQ1, I do descriptive analysis in terms of presenting the response spread for each attribute of the three behavioral determinants- attitude (RQ1a), norms (RQ1b) and behavioral control (RQ1c) with a ranking of the attributes in terms of strength. I measured 12 component attributes for indirect attitude, 6 component attributes for indirect norms, and 6 component attributes for indirect control measures. For each attribute, the intensity of the behavioral belief related to regular LPG use and its value\(^\text{22}\) were measured on Likert scales.

\(^{22}\) The values are perceived likelihood (for attitude), motivation to comply (for norms) and power (for control).
I then multiply these values to derive the composite scores for attitude, norms and control factors respectively for each individual attribute and then rank the attributes in descending order. [Attributes with lower composite score suggest scope for improvement and hence should be prioritized during intervention planning.] The spread of the belief score, value score and the composite score for the three behavioral determinants are then plotted separately for visual and descriptive analysis to answer RQ1a (attitude), RQ1b (norms), and RQ1c (perceived control).

For RQ1d, the indirect attitude, norms, and control scores are calculated in the following manner. As there are 12 attributes of attitude (factors identified in Chapter 2 CI-CHANGE model based on a literature review) each with a maximum possible score of 20, i.e. 240 points, I compress it to a scale of 5 (max value) by dividing the total indirect attitude score by 48. The pairwise t-test is used for direct and indirect measures of attitude, norms and control were carried out, in addition to the skewness and kurtosis to assess the normality of the distributions.

<table>
<thead>
<tr>
<th>Behavioral Belief</th>
<th>Scale</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudinal belief (Outcome belief)</td>
<td>1-5</td>
<td>1. Clean</td>
</tr>
<tr>
<td>Outcome favorability</td>
<td>1-4</td>
<td>2. Healthy</td>
</tr>
<tr>
<td>Attribute wise attitude score</td>
<td>(1-20)</td>
<td>3. Comfortable</td>
</tr>
<tr>
<td>$\text{Attitude}_n$</td>
<td></td>
<td>4. Easy operations</td>
</tr>
<tr>
<td>Attitudinal belief x Outcome desirability</td>
<td></td>
<td>5. Less time</td>
</tr>
<tr>
<td>(for n$^{th}$ attribute)</td>
<td></td>
<td>6. Safe</td>
</tr>
<tr>
<td>Total Attitude Score=</td>
<td>12-240</td>
<td>7. Tasty</td>
</tr>
<tr>
<td>$\Sigma \text{Attitude}_n$</td>
<td></td>
<td>8. Socially Respectable</td>
</tr>
<tr>
<td>for, n= 1 to 12</td>
<td></td>
<td>9. VFM$^{23}$ (free solid fuels)</td>
</tr>
<tr>
<td>Final Indirect Attitude Score</td>
<td>1-5</td>
<td>10. VFM (commercial</td>
</tr>
<tr>
<td>(Compressed Scale- divide the score by 48)</td>
<td></td>
<td>11. VFM (other competing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12. Same cooking style</td>
</tr>
<tr>
<td>Normative belief (presence of control factor)</td>
<td>1-5</td>
<td></td>
</tr>
</tbody>
</table>

---

$^{23}$ VFM: Value for money
Motivation to comply 1-3
1. Financial decision maker: suggest use
2. Other family members: suggest use
3. Peers: suggest use
4. Opinion leaders: suggest use
5. Peers: self-use
6. Opinion leaders: self-use

Attribute wise norm score (1-15)
Normn =
Normative belief x Motivation to comply
(for n attribute)

Total Norm Score=
\[ \sum \text{Norm}_{n} \text{ for, n= 1 to 6} \]

Final Indirect Perceived Norms Score (Compressed Scale- divide the score by 18)
1-5

Control belief (presence of control factor) 1-5
1. Operate stove properly
2. Repair service available
3. Autonomy
4. No price hike
5. Refill Available
6. Affordable

Power of control factor 1-3

Attribute wise control score (1-15)
Controln =
Control belief x power of control factor
(for n attribute)

Total Perceived Control Score=
\[ \sum \text{Norm}_{n} \text{ for, n= 1 to 6} \]

Final Indirect Perceived Control Score (Compressed Scale- divide the score by 18) 1-5
6-90

Table 5-1 Direct and indirect behavioral indices

5.3.5.2 Data analysis for RQ2

For RQ2, I use partial correlations instead of the traditional structural equation modeling. During preliminary data analysis, I found severely skewed distribution to the direct responses on intention, attitude, norms, and control. Hence, I measured the relationship between the key factors as hypothesized in the CI-CHANGE model using the partial correlation factors. Partial correlation is a measure of the strength and direction of a linear relationship between two continuous variables whilst controlling for the effect of other covariates.
In the EPA survey (Study 2) I elicited information on experiential (feel) and instrumental (useful) aspects of attitude to perform the target behavior. As per TPB, these may be considered as immediate predictors of direct attitude (Fishbein & Ajzen, 2011). So, I use the mean value of these two indicators as a direct attitude score. Similarly, I estimate the direct perceived norms score by calculating the average of descriptive (what others do) and injunctive (what others say) regarding the target behavior on a scale of 5. I then normalized the composite scores of the attributes of attitude, norms, and control to a scale of 5.

For RQ2c, the score distributions (self-report vs. purchase records) for LPG use were tested for normality using the Shapiro Wilk normality test. If both the distributions for comparison are found to be normal, the pairwise t-test would be used to assess if the means for the two categories are statistically significant, else the pairwise Wilcoxon signed rank test with continuity correction would be used. For RQ3b, I compared the skewness of the responses to direct and indirect questions surrounding attitude, perceived norms and perceived control from the PW survey after checking for normality as detailed above.

5.4 Results and discussion

Out of 402 respondents, 369 respondents have answered all questions related to behavioral beliefs. I only present the results from those survey respondents.

5.4.1 Distribution of behavioral determinants

5.4.1.1 Distribution of Attitudinal Scores (RQ1a)

The belief strength variation across the twelve attributes for attitude is presented in Figure 5-1. The belief strength regarding the outcome for the target behavior (regular LPG use) is positive (‘definitely yes’ or ‘probably yes’ options) for all attributes. However, the majority of respondents are not confident (‘definitely yes’) that food cooked with LPG would be tasty or that regular use of LPG would lead to social respect. About 8% of respondents also fear that LPG is probably not a safe cooking option. 16% of respondents also expect that the use of LPG would lead to a change in cooking style. Counterintuitively,
about 50% of respondents think LPG is value for money (VFM). Technology adoption literature has found that perceived ‘value for money’ or ‘price value’, which plays an important role in consumer purchase decisions, is defined as the cognitive trade-off between the monetary expenses of use and the perceived benefits of the product/service (Venkatesh et al., 2012). There were three different standards against which cost of LPG (4 cylinders per year= Rs.3200/ year) was compared for the VFM attribute—free solid fuels (zero cost), commercial cooking fuels (electricity for induction stoves or kerosene) and other competing needs (education, health care) where the alternative is not free and/or the free option is not easily accessible. LPG was considered by more than 90% to be probably or definitely value for money across the three reference standards.

**Figure 5-1** Distribution of behavioral belief strength scores for attitude attributes. On a five-point scale Likert scale, respondents provide response on the outcome likelihood if the desired/target behavior is performed.
The outcome favorability variation is presented in Figure 5-2. About 60%-80% of respondents consider that healthy family, clean kitchen, comfortable and easy stove operations, safety and time savings to be ‘extremely important’. 33% of respondents stated that whether cooking style remains the same when switching to regular LPG use ‘does not matter’. Generally, ‘no change in cooking style’ is the desirable attribute associated with cooking as cooks tend to generally avoid change (Khandelwal et al., 2017). Again, counterintuitively, 28% of respondents stated that ‘value for money’ for LPG stove ‘does not matter’.

Figure 5-2 Distribution of value (favourability) scores of different attitude attributes. On a four-point scale Likert scale, respondents provide response on how important a probable outcome is
The composite attitude score for different attributes is calculated by multiplying the expectancy (belief strength about the likelihood of outcome) on a 1-5 scale and its value (outcome favorability) on a 1-4 scale as per the TPB expectancy-value model (Fishbein & Ajzen, 2011). The variation in composite attitude score on a 1-20 scale for the different attributes is presented in Figure 5-3. First, there is strong positive attitude among respondents, on the aspects of LPG being a clean, healthy, comfortable, easy-to-handle, and faster cooking option with the median score maxing out at the highest score possible (20). More than 60% of respondents perceive that regular cooking with LPG will lead to these outcomes and they also value these outcomes highly. In contrast, attitudinal attributes of ‘value for money’ and ‘no change in cooking style’ have lower scores (median around 10).

**Figure 5-3 Distribution of composite score for attitude attributes. The red dot shows the mean value while the distribution of composite scores is shown as boxplots**

The TPB framework has helped to identify that VFM for LPG remains a major challenge along with the perceived changes in cooking style when there is a switch to LPG. Composite scores of taste and safety are also bringing down the overall attitudinal score associated with the target behavior. These scores for attributes of attitude around regular use of LPG provides four key insights. One, overall the data
points are clearly in line with the past findings that LPG is an aspirational fuel (Cecelski & Matinga, 2014; Smith & Dutta, 2011). For eight out of twelve attributes, the median composite score is 15 or more out of 20. Developing behavioral communications around these high-scoring attributes would likely not be very useful as people are already positively convinced about these characteristics/attributes. Two, the VFM scores of LPG use with three different reference frames are remarkably similar. If VFM is be viewed as a behavioral metric for affordability, the composite lower attitudinal scores for VFM are not surprising. However, I expected to find a lower score for VFM belief strength, i.e. I expected more respondents stating that LPG is not value for money. I also expected to find the higher score for VFM outcome favorability, i.e. more respondents stating that VFM is ‘extremely important’. Puzzlingly, it is a reverse trend. The survey first asked respondents about LPG’s VFM against the three standards (three separate questions), and then asked if ‘value for money’ matters. Three, respondents have a high level of attitudinal concern (lowest composite score) regarding the change in cooking style. While many respondents think that LPG use would lead to a change in cooking style (how they manage current kitchen operations- from a selection of vessels to preparatory kitchen activities), they also claim that such change does not matter. Four, only 38% (lowest out of all 12 attributes) respondents stated ‘definitely yes’ for the outcome belief strength. It is apparently a contradiction of having high aspiration about the use of LPG (overall score), yet not expecting that LPG’s use leads to greater social respectability in the community. LPG has been considered traditionally as a sought-after & prestigious object to own (Lewis & Pattanayak, 2012; Puzzolo et al., 2016). A plausible explanation could be that due to the mass scale uptake of LPG under the ongoing Ujjwala scheme, it has lost its earlier sheen of being a property of rich & powerful people. So, while the LPG is aspirational at an individual level, it is not perceived by respondents as a mechanism to lift up LPG users’ status in the community.
5.4.1.2 Distribution of Perceived Norm Scores (RQ1b)

The belief strength variation across the six attributes for perceived norms is presented in Figure 5-4. The majority of respondents were not sure whether opinion leaders would like them to use LPG or whether opinion leaders used LPG regularly in their own homes. Notably, while 32% of respondents have claimed that peers have strongly recommended the use of LPG, only 12% of respondents have reported that their peers actually do so themselves. 59% of respondents (primary/secondary cooks) perceive that their family members (including the financial decision maker of the household) would definitely want them to use LPG regularly.

![Distribution of normative belief strength scores for attributes of perceived norms.](image)

On a five-point scale Likert scale, respondents provide response on perceived normative beliefs regarding the desired/target behavior in question.
The power (motivation to comply) variation across the six attributes for perceived norms is presented in Figure 5-5. More than 90% of respondents stated that they have no motivation (‘neutral/ does not matter’) to do what opinion leaders or peers suggest or what fuel choices they make (as perceived by the respondent). 43% of respondents have said that they have to comply with what FDM suggests, while 25% of respondents stated that the opinion of other family members (like children, in-laws who stay with them) strongly matters (‘definitely do’).

![Perceived Norms: Motivation Variation](image)

Figure 5-5 Distribution of value (motivation to comply) scores of different normative attributes. On a three-point scale Likert scale, respondents provide response on how important it is to comply with the perceived norms of salient referents

The composite norms score for different attributes is calculated by multiplying the expectancy (belief strength about social norms) on a 1-5 scale and its value (motivation to comply) on a 1-3 scale as per the TPB expectancy-value model (Fishbein & Ajzen, 2011). The variation in composite perceived norms scores variation on a scale of 1-15 for the different attributes is presented in Figure 5-6. The
median score for injunctive norms related to family members (including financial decision maker) is only 8 out of the maximum possible score of 15. The descriptive and injunctive norms for external salient referents are 4 or less. The TPB framework of ranking by attribute median scores indicates that external salient referents like peers and opinion makers have the lowest scores which discourage regular LPG use.

![Indirect Norms:Composite Score Distribution](image)

**Figure 5-6** Distribution of a composite score for perceived norms attributes. The red dot shows the mean value while the distribution of composite scores is shown as boxplots. FDM is a financial decision maker.

The composite score for attributes of perceived norms around regular use of LPG provides three key insights. First, contrary to published literature (Miller & Mobarak, 2013; Shrimali, Slaski, Thurber, & Zerriffi, 2011), opinion leaders do not matter much in terms of people’s motivation to comply with their opinion/ preference about respondents’ fuel choices or their own fuel choices. Interestingly, even at the peak of a national level campaign, villagers seem to be unaware of whether local village level political or community leaders support regular LPG use. Second, the role of peers as a motivational force is limited as >90% of respondents report that they are not necessarily going to follow what the peers would say. Notably, contrary to the social network theory findings in this space (Jagadish & Dwivedi, 2019), ~70%
women respondents state that they are unaware of what opinion their peers have about regular LPG use. Third, I find that in addition to financial (mostly, male) decision-makers in a household, other family members like children also play an important part. While consumer companies nowadays proactively target children as decision influencers (Swinyard & Peng Sim, 1987; Wang, Hsieh, Yeh, & Tsai, 2004), there are little efforts in the cookstove space on similar lines. The fact that majority of women respondents are motivated to comply with the perception about other members of the family outside the typical ‘husband-wife’ decision-making process, not only creates an additional intra-household communication target but an opening for successful behavioral intervention via children. Contrary to literature (Ramirez, Dwivedi, Ghilardi, & Bailis, 2014), there is no signal that external salient referents can influence behavior by statements (injunctive norms) or action (descriptive norms).

5.4.1.3 Distribution of Perceived Control Scores (RQ1c)

The belief strength variation about the presence of control factors across the six attributes for perceived control is presented in Figure 5-7. More than 80% of respondents trust that the government would not increase (net) price of LPG, would maintain infrastructure for repair services, and there would be no shortage of refill supply. 82% are also confident of their own ability to operate a gas stove on a regular basis. Only 70% of respondents are confident that LPG would be affordable (even if there is no price hike). Notably, only 31% of (women) respondents are confident that they have sufficient decision autonomy regarding the choice of fuels.

24 During field work, I interviewed a mother ruling that her ten-year-old son does not like the taste of roti made on LPG stove. She said, “What is the point of cooking food, if children don’t like it. I cook for them, and will do whatever it takes to feed them well”
Figure 5-7 Distribution of control belief strength scores for attributes of perceived control. On a five-point scale Likert scale, respondents provide response on perceived control beliefs regarding the desired/target behavior in question

The power (ability of the control factor to drive or impede LPG use) variation across the six attributes for perceived control factors is presented in Figure 5-8. On expected lines, the majority of respondents have said that availability of repair service, refill availability, price stability and affordability are essential (‘definitely necessary’) to regular LPG use. Only 22% of respondents said that decision autonomy was essential while 19% stated that it was not necessary. As in the survey, the question on whether they have decision autonomy was asked first, and then how important is decision autonomy, there could be a plausible question order bias.
Figure 5-8 Distribution of power strength for control factors. It shows the value (power of control factors to facilitate/hinder target behavior) scores of different normative attributes. On a three-point scale Likert scale, respondents provide response on how important it is to comply with the perceived norms of salient referents.

The composite control score for different attributes is calculated by multiplying the expectancy (belief strength about the presence of control factors) on a 1-5 scale and its value (the ability of the control factor to drive or impede LPG use) on a 1-3 scale as per the TPB expectancy-value model (Fishbein & Ajzen, 2011). The composite perceived control score variation on a 1-15 scale for the different attributes is presented in Figure 5-9. The median score (and interquartile range) for repair service availability and stove operations ability is highest at 15 (maximum possible score). The median perceived control scores for refill availability, price hike and affordability are also 15. Notably, the median composite score for autonomy is only 8 (out of 15). The TPB framework of ranking by attribute median...
scores indicate that decision autonomy is a bigger issue than affordability as a control barrier to regular LPG use.

Figure 5-9 Distribution of composite score for perceived control attributes. The red dot shows the mean value while the distribution of composite scores is shown as boxplots

The composite score for attributes of perceived control around the regular use of LPG shows three insights. First, respondents perceive access conditions to be satisfactory in terms of refill and repair service availability. I have observed first hand and through numerous interviews, that refill supply at the study area was steady (there was always sufficient stock). However, the doorstep home delivery facility was not available in the surveyed villages. Second, I attempted to tackle the questions around affordability directly and using a price hike as a proxy indicator, such that the price hike would lower affordability. While 88% of respondents stated that they think the price would not be hiked over the next
one year, only 70% were confident that LPG would remain affordable. As affordability is a mix of both demand (household wealth) and supply (price of LPG cylinder) side metrics, some households are concerned that LPG may not be affordable in the near future even if the price does not go up. Notably, about 90% of households did not expect a price hike in the near future, which indicates the need for the government to control price hikes, especially in the face of global fluctuation in petroleum prices. Third, there was a major issue in terms of women’s decision autonomy regarding LPG purchase decisions, which is in line with the literature (Khandelwal et al., 2017; Malakar, 2018; Miller & Mobarak, 2013), which drags down the overall score of perceived control over the target behavior. Interestingly, 19% of women said that decision autonomy or lack of it would not be a factor in the fuel choice decision-making process. Also, women were most comfortable with LPG stove operations, at least they did not think it to be a major impediment to stove use.

5.4.1.4  Direct vs. indirect estimates of behavioral determinants (RQ1d)

The direct attitude questions had a more negatively (left) skewed distribution compared to the indirect attitude scores (see, Figure 5-10). I find that the direct questions lead to a heavier tail (positive kurtosis value) while the indirect questions lead to a more normalized distribution (negative kurtosis value). The skew and kurtosis for indirect attitude score histograms are -0.32 and -0.45 respectively. For experiential attitude, the skew and kurtosis are -1.12 and 0.21 respectively. For instrumental attitude, the skew and kurtosis are -1.28 and 0.56 respectively. The difference between direct attitude score (4.6) (average of experiential and instrumental attitude) and indirect attitude score (3.6) is also statistically significant (Wilcoxon signed rank test, p <0.001).
Similar trends are also observed for perceived control (Figure 5-11). The skew and kurtosis for indirect perceived control score histograms are -0.77 and -0.05 respectively. For the direct perceived control score, the skew and kurtosis are -1.54 and 3.31 respectively. The difference between direct perceived norms score (4.5) and indirect perceived norms score (4.0) is also statistically significant (Wilcoxon signed rank test, p < 0.001).
Figure 5-11 The score distribution for direct and indirect perceived control response as elicited from survey respondents.

Similar trends were also observed for perceived norms (Figure 5-12) where the indirect scores are closer to reality than the direct scores, though none truly represent the left-tail heavy distribution of actual behavior. The skew and kurtosis for indirect descriptive norms score histograms are 3.61 and 18.63 respectively. The skew and kurtosis for direct injunctive norms score histograms are -0.80 and 1.54 respectively. The skew and kurtosis for indirect injunctive norms score histograms are 0.33 and -1.23 respectively. The difference between direct descriptive norms score (3.74) and indirect descriptive norms score (1.24) is also statistically significant (Wilcoxon signed rank test, p <0.001). The difference between direct injunctive norms score (4.28) and indirect injunctive norms score (2.13) is also statistically significant (Wilcoxon signed rank test, p <0.001). Indirect descriptive and injunctive norms also provide a truer representation of the reality that directly elicited responses. A plausible explanation is that there are
serious survey biases where direct questions are asked where it is easy for the respondent to gauge what responses would be most satisfactory to surveyors from an organization that promotes clean cooking.

5.4.2 Relationship between behavioral determinants

5.4.2.1 Intention-Behavior linkage and its predictors (RQ2a, RQ2b)

As per the theory of planned behavior, attitude, norms, and control were expected to be positively correlated with intention. I do not find such a relationship nor was there evidence of a relationship between intention and target behavior. In fact, I find that there is no statistically significant relationship between behavioral intention and its predictors- attitude, norms and behavioral control (Figure 5-13). Moreover, the literature suggests a positive correlation between the determinants of intention (attitude and
norms) and stated intention (Ajzen, 2012; Sniehotta et al., 2014), but the data indicates a negative relationship. However, I do find that habit (not included in TPB and critiqued for it widely) and actual behavior have a statistically significant relationship, which is in line with social psychology literature (Gardner, 2015; Sniehotta et al., 2014; Verplanken, Aarts, & Van Knippenberg, 1997).

One reason for this anomaly could be that 99% of respondents self-reported plans to regularly use LPG in the project area to surveyors who represent an organization that promotes clean fuel. So, there is not enough variability in the intention scoring to meaningfully establish the relationship with its predictor variables or its relationship with the observed/ self-reported target behavior. However, in the case of norms and attitudes, their predictor variables are positively related (statistically significant) with their behavioral predictors (see, Figure 5-13).

![Figure 5-13 Partial correlations among psychological variables/ key components of TPB](image)
5.4.2.2  *Self-report Vs. purchase data (RQ2c)*

During the first round of survey in July-September 2017, respondents were asked if they would use 4 (or more) cylinders or less than 4 cylinders over the next one year (binary purchase behavior). In the second round (in November 2018), participants were asked how many cylinders they purchased in the last year (self-report behavior). I then cross-checked the self-reported data with the sales record (purchase behavior).

I find that the difference in mean between the self-report behavior (3.53 cylinders\(^{25}\) per year) and purchase record linked behavior (1.73) is statistically significant (p<0.001). Even considering ±2 as recall error (Das et al., 2011) (i.e. a household purchasing 2 cylinders reporting 4 cylinders by mistake), >33% still over-reported, clearly indicating response bias (see, Figure 5-14). Only 15% of consumers accurately reported consumption. Considering that many past studies (NSSO, 2014) have depended on surveys for even more complex fuel use units (such as kg of wood) where recall errors would be even higher, it calls into question the wisdom of depending on survey data without at least some additional checks. Kitchen performance test in a smaller subset of study households (Rob Bailis, Smith, & Edwards, 2007) or the use of sensors (A. Kofi Amegah, 2018), when purchase sales data are not available or accessible could be relatively more objective substitutes involving physical measurements. However, some form of survey biases such as the Hawthorne effect may still persist depending on the mode of ‘objective’ data collection (Simons et al., 2017).

\(^{25}\) 1 cylinder has 14.2 kg of LPG
If I consider the results as a whole, there is a striking disparity between the direct behavioral determinants and observed behavior. The direct questions have a heavier tail for a higher score, i.e. if it were true, and attitude/norms/ control drives intent, and subsequently actual behavior, the distribution of target behavior would also be right-skewed. Data shows that the target behavior (in EPA villages) follows a distribution that is left-tail heavy (see, Figure 5-15) and in the study area in general (see, Figure 3.4). If I assume that it would be similar in PW villages where direct and indirect scores are available, it suggests that direct questions provide a misleading impression of reality, and indirect measures are comparatively more reflective of the reality.

Figure 5-14 Difference between LPG use self-report and purchase records for all LPG consumers under EPA project
5.5 Limitations

While I have highlighted the role of survey biases, I here note two unique factors that may have amplified the biases due to the settings. One, in the EPA villages, the survey was administered to participants of a three-year ongoing project. It was explicitly communicated in these villages during community mobilization at the start of the project that the main aim was clean cooking promotion and its allied benefits for the community. Hence, the survey participants had enough information to become “good subjects”. Two, the survey data collection period in June- August 2017 coincided with the huge launch of Ujjwala in the project area. (Ujjwala launched in May 2016 in Uttar Pradesh state in Northern India and then had phased state-wise roll-out.) Under such an environment with a strong political messaging (ruling party’s flagship ‘vote-catching’ scheme), with bystanders looking over the shoulders and listening to responses, I suspect that responses would have above average ‘demand characteristics’.

Figure 5.15 Distribution of LPG cylinder use by purchase data and self-report show left-tail heavy distribution
bias in terms of verbally responding the questions around use during interviews. I was sometimes asked at the end of the survey “are you happy?” which is treated in the literature as the effort of the research subject (respondent) to be a “good subject” in the “experiment” (Orne, 1962). The fact that 99% of households expressed their intention to use LPG regularly in the EPA survey is not normal, to say the least.

I originally planned to capture intention for the PW survey dataset. Unfortunately, I made a mistake of using wrongly worded question26 for the stated intention for PW respondents. As the households of the PW survey were not easily accessible for follow up (required to collect their LPG consumer number, self-report and consent to match it with their purchase data), I was unable to track their self-reported consumption and actual purchase behavior. So, while the PW survey provided interesting insights on the ranking of behavioral attributes, the available data was insufficient to test the relationship of intention with behavior (forward linkage) and with attitude, norms, and control factors (backward linkage).

The operational definitions of target behavior were also insufficient from a theoretical perspective TTM’s definition of a health behavior “action” (Prochaska & Velicer, 1997). It views that “not all modification of behavior count as an action. An individual must attain a criterion that scientists and professionals agree is sufficient to reduce the risk of the disease” (Prochaska, 2008). Strictly going by that definition, the target behavior should have been defined as using LPG regularly as the exclusive/near-exclusive fuel and where usage is significant enough to have an effect on health outcomes. Now, we have calculated the total energy requirement for a typical rural low-income household with five members (see, Chapter 2, supplementary information Note 5). It suggests that 10 or more cylinders suggest

26 In my original survey, I used the word “plan” to elicit intent. While it was technically correct, during translation in Kannada for the training of surveyors it was not easy initially. So, I replaced it with “like” and proceeded with the training. For the EPA survey, I switched it back from “like” to “plan” before surveys began, but forgot to do so for PW survey.
exclusive use, while 5- cylinders suggest primary use. The word *primary* suggests that more than 50% of the useful cooking energy is provided by LPG in the cooking mix.

Now, the problem in practical terms was there were simply not enough people in the exclusive use category to roll out this definition with sufficient samples across the spectrum. In fact, finding such consumers in the survey villages were near impossible, and in some cases, the consumers we could find with 8-9 cylinder purchases were running tea stalls/ small village restaurants. So, we use a more generic term- “*regular use*” in the two surveys.

Moreover, while I use the word ‘*regular usage*’ of LPG in both PW (n= 402) and EPA (n= 205) surveys, I use two operationally different definitions. For EPA survey, we use purchase of 4 cylinders (1 cylinder = 14.2 kg of LPG) in a year as regular use, in the four villages where due to past efforts and strong peer network effect, the 40 households without LPG had reasonable understanding/ knowledge on how much cooking with LPG would translate into how many cylinders. While the respondents (primary or secondary cook) in the rest of the EPA households were clearly aware of how their purchase numbers were linked to the extent of cooking. In sharp contrast, I found, during pilot testing, that people in PW villages with low LPG coverage did not understand the linkage clearly. It was also a complex assessment as it involved a multitude of factors such as power levels (cooking with low flame would lead to lower gas consumption). With lived experience, the sense of that was easy in EPA villages, in contrast to the PW villages. So, I used a different operational definition of regular usage for PW villages. Regular use is defined as cooking with LPG for 30 minutes per day on average. We reached out to LPG experts who suggested that 4 cylinders in a year would work out to roughly 25-40 minutes/ day use on average. I decided on the 30-minute value as more granular numbers like 32.5 minutes (range average) would not have been easily perceptible for the survey respondent.
5.5 Conclusion

I used two distinct survey datasets and a secondary LPG sales database to answer seven research questions. Three questions were related to identifying key attributes to behavioral determinants of regular LPG use, two questions related to the relationships among the key theoretical constructs as laid out in the theory of planned behavior (TPB), and two questions related to the reliability of the survey data. I use the PW single round village survey on behavioral determinants (Study 1, n1= 402) to identify which attributes have relatively low scores (RQ1a-c). When the component indicators of attitude (based on the expectancy-value model) are evaluated, I find that while there was an overall positive attitude towards the target behavior of regular LPG use, the scores related to the cooking style and value for money related to regular LPG use were on the lower side. Regarding social norms, there is a significant scope of improvement related to the opinion leaders and peer scores for both injunctive and descriptive norms. Regarding perceived norms, women (primary/secondary cook) respondents have raised serious concerns about their own decision autonomy and affordability related to regular LPG use. I used the EPA first round village survey (Study 2, n2= 205) to test the relationships among behavior, intention, and precedents to answer research questions RQ2a and RQ2b. I also match the EPA second round village survey on self-report of consumption (Study 2, n2= 205) with the LPG purchase records (secondary data) to find the majority of respondents significantly over-report actual use (RQ3a). I also find that direct responses related to attitude, norms and perceived control are much more skewed than indirect responses (RQ3b). I posit that the way surveys are administered increases the social desirability bias in responses.

This chapter provides two novel insights as an original contribution to the methods in the clean cooking transition literature. First, a quantitative model (expectancy-value model) from social psychology has been applied which leads to a relative ranking of the behavioral determinants to clean fuel choice. It is a novel approach with practical significance for prioritizing behavioral communications, where low scored attributes could be highlighted and addressed. Compared to objective factors like education and income, perceptions are probably more amenable to change in the near term. Second, the mismatch
between self-reported consumption and sales data, and between direct and indirect questions suggest the presence of survey biases. This is a clarion call to the research community as almost all studies in this domain exclusively or primarily depend on surveys, with very limited discussion on the role of biases or around strategies to minimize them.
6. Conclusion

In this concluding chapter, I first discuss the summary of the key findings and policy recommendations. Then, I briefly discuss the limitations of the study and the future research agenda. Next, I briefly summarize the boundaries of the study emphasizing that a vast majority of the (cooking) energy poor are currently within the boundary of this dissertation. I then follow-up with a discussion on three transition pathways beyond the study boundaries, namely, urbanization, regulation and massive subsidies which have led to the desired transition in the past. Concluding remarks on the big picture takeaways from my research endeavour.

6.1 Summary of key findings

The focus of this dissertation is limited to stage 1 (clean fuel as primary cooking fuel) transition in the “triple whammy” of (1) rural, (2) low-income communities in (3) developing countries, with two additional conditionalities of (4) reasonable physical access to clean fuels and (5) no role of regulations in the post-uptake period due to political or enforcement issues. The summary of key findings and discussion is detailed below.

Chapter 1: Based on my extensive review of cookstove literature, I found that the bulk of literature is focused on the transition up to the uptake of CCS. Moreover, the key research questions around transition are primarily framed around two narrow issues: ‘who’ are more likely to adopt CCS and ‘under what circumstances’. The first issue is focused on the socio-economic characteristics of households such as income, education, and size (Lewis & Pattanayak, 2012; van der Kroon et al., 2014). The question of ‘under what circumstances’ examines the decision environment, such as whether there is a local market for alternative fuels, availability of electricity, awareness about health and environmental problems of using TCS, and if wood is purchased and at what price (Lewis & Pattanayak, 2012; van der Kroon et al., 2014). Generally, CCS program implementers have more control over some of these aspects such as awareness
creation (Lewis et al., 2015) while other factors can be either out-of-control (e.g. electricity access) or are not amenable in the short term (e.g. market price of alternative fuels). While some researchers have advocated studying the transition problem as a behavior change issue (Barnes et al., 2015; Thompson et al., 2018), there is little empirical evidence around this issue in the post-uptake period.

Chapter 2: Based on a review of published literature, I argued that a clean cooking energy transition necessitates effortful behavior changes by members of the households, such as the cooks, financial decision-makers, and other family members. I borrowed distinct concepts from three different disciplines to be integrated into a conceptual framework. This model was developed to understand cooking energy transition through the lens of behavior change; where conscious (behavior) Change, driven by Intention, which in turn is influenced by (perceived) Control, (past) Habits, Attitude and (perceived) Norms, explain the General [cooking] Energy transition framework hence named as the CI-CHANGE model of behavior change. It combines elements of the Transtheoretical Model (TTM) from the health behavior change psychology domain, Theory of Planned Behaviour (TPB) from the social psychology domain, and the Unified Theory of Acceptance and Use of Technology (UTAUT version 2) from the information systems research domain to identify & prioritize intervention focus areas. This model led to three new testable hypotheses on the how and why of the transition process using behavioral constructs such as perceptions and habits. First, I closely adapted TTM’s principles of change which state that people in two different stages of transition (precontemplation and action) have different perceptions about the advantages and disadvantages of the target behavior (of using LPG as primary cooking fuel).

Chapter 3: This chapter provided evidence that in rural areas, the experience of use does not lead to an increase in consumption and that a vast majority of rural consumers (whether Ujjwala beneficiaries or not) do not use LPG as exclusive cooking fuel. I applied the CI-CHANGE framework to study the clean fuel consumption trend in a target population by taking the example of LPG use in rural households of Koppal district of Karnataka state in India (hereafter, study area). The Indian national government launched
an ambitious program *Ujjwala* in the area in June 2017 in which poor households received an LPG connection with no upfront cost. As *Ujjwala* provided physical access to clean stoves and fuels to rural low-income communities in a developing country like India, it falls under the boundary conditions discussed in Section 6.1.1. I took stock of the situation as on December 2018, on what has been the level of access and use. The LPG sales database contains the entire population of rural LPG consumers in the study area.

I found that general consumers in the study area who enrolled in 2013 and 2014 purchased 6 cylinders per year (median value), while a typical rural household should buy 10-12 [14.2 kg LPG] cylinders per year for the exclusive use of LPG as clean cooking fuel. General consumers who enrolled in 2015 onwards, purchased 4 cylinders of LPG per year (median). *Ujjwala* consumers who enrolled in 2017 onwards and completed one year, purchased 2 cylinders of LPG per year (median). The available data of general consumers (no *Ujjwala* completed 2 years as of December 2018) who have completed two or more years suggest that there has been no change in the consumption (median value) in later years compared to the first year. The mean value also does not show any significant and consistent trend over the years. Notably, there is a significant shift at the individual consumer level within stable distributions. Out of consumers who have completed three or more years of LPG ownership, only one-third of them have stable consumption patterns over the first three years; ‘stable’ is defined as either maintained the same consumption or changed the first year consumption over the next two years by ± 1. For the rest of consumers, there are mixed trends, i.e. both increase and decrease have been recorded.

I also find that seasonality plays as important a role in stacking decisions compared to the price of LPG cylinder. There is a strong seasonal influence on income, and access to substitute solid fuels in the target population (Rajakutty & Kojima, 2002; S. K. Singh, 2014) which is observed in the study area. Moreover, and intriguingly, I find the individual distributors are major predictors wherein switch from one to another can increase monthly sales by 100 units (median sales across distributors is 386), everything else remaining equal. Based on several interviews, I found that counter-intuitively the worst performing distributor (D3) provides home delivery to all villages in its coverage area, while the other two did not provide it. There are a few possible explanations of this phenomenon. First, D1 and D2 may have greater
sales acumen than D3. Second, the service/market area of D1/D2 is markedly different than D3, i.e. consumers of D1/D2 have enhanced socio-economic profile or have more positive behavioral perspectives related to regular LPG use. Also, while D3 provides delivery, it is sometimes limited to delivering the cylinder to the village centre/entrance and not necessarily to the door-step level. Given the limitation of the socio-economic profile of the consumers, it is difficult to explain or hypothesize in more detail.

Chapter 4: This chapter provides evidence that the switch from solid fuels to clean fuels is not a binary (0/1) process of change, but a transition journey which may be viewed as a five-stage process. I grouped the surveyed respondents into five categories after adapting TTM’s stages of change definition to cooking energy transition. I found that people sans LPG stove considered regular LPG use as a two-stage behavior change (the first one has to purchase LPG stove and then the issue of use arises), and hence, did not contemplate regular LPG use when they did not have an LPG stove. This condition makes the target behavior for transition unlike other one-stage health behaviors (e.g. stop smoking) where TTM is applied. Between the precontemplation (no stove, no intention to perform target behavior) and action (has a stove, started performing target behavior recently) stages, the perceived advantages (pros of target behavior) and perceived disadvantages (cons) increase and decrease significantly in line with TTM hypotheses. Notably, the effect size for the cons decrease from precontemplation to action stage is even more than what is hypothesized. Hedges's g (effect size) estimate is 1.02 (large) is more than the hypothesized 0.5 (medium). However, there was no statistically significant difference in self-efficacy (SE-perceived situation-specific confidence to continue with the desired behavior). People who were actually using LPG regularly were more aware of the externalities (“the daily struggles” as per a community leader) of LPG usage compared to people who planned to use it regularly. Unlike self-regulatory behaviors studied using TTM, where the performance of a behavior is largely a question of individual agency, the desired behavior in our case is dependent on many factors. These factors would continue to persist, and as going back to traditional cooking is low-hanging fruit (easy, quick, free), there would always be significant temptation to go back to the undesired behavior for the target population facing the ‘triple whammy’. Also, as expected, the household
wealth index score of respondents in the precontemplation and action stage differ significantly. However, logistic ordinal regression of the pros, cons, self-efficacy, and wealth index suggests that while wealth matters (statistically significant) in the transition through the five stages, the perceived disadvantages such as inconvenience in getting LPG refills matter even more.

Chapter 5: This chapter provides a demonstration of a framework to rank the diverse determinants of transition along with the evidence that there is considerable survey bias in self-reports. I matched the EPA second round village survey on self-report of consumption (n1= 205) with the purchase records to find the majority of respondents significantly over-report actual use. When the component indicators of attitude (based on the expectancy-value model) are evaluated, I found that while there was overall positive attitude towards the target behavior of regular LPG use, the scores related to taste of food, and social respect from LPG use were on the lower side while safety and cleanliness scored more highly. Regarding social norms, financial decision-makers opinion matters the most. Also, on average, the respondent (primary/secondary women cooks) perception is that the (predominantly male) financial decision makers are not very enthusiastic about regular LPG use. Regarding perceived norms, women (primary/secondary cook) respondents raised serious concerns about their own decision autonomy related to regular LPG use. I also found that direct responses related to attitude, norms and perceived control were much more skewed than indirect responses. I also found that surveys which are administered by interview and those implemented during interventions increase the social desirability bias in responses.

6.2 Policy insights and recommendations

Three over-arching new policy-relevant insights emerge from my dissertation.

One, policy interventions in the post-purchase period are necessary for the target low-income, rural communities across developing countries if clean cooking energy transition is the ultimate goal. In Chapter 3, I found that consumers, irrespective of the mode of uptake, were using far less than what was
required to make LPG an exclusive cooking energy source. Also, many consumers have purchased less LPG than the previous year, strongly suggesting that there was no auto-mode of increased consumption with time, experience, familiarity or even general economic progress at the state or national level. As there was significant seasonal variation in sales, seasonal discount vouchers could be used to attract consumers in the lean periods when they have less income and more access to free LPG substitutes like dry solid fuels.

Also, the current initiative by the government to promote conversion from 14 kg to 5 kg cylinder (Jindal, 2019) could also be helpful. As most people without monthly fixed salary and often dependent on daily/weekly wage, purchase on a weekly/bi-weekly basis, saving up the money for a big LPG cylinder is more challenging in practical terms (Khandelwal et al., 2017). However, there are also risks involved in terms of three times (5 vs. 14.2 kg) more frequent visits to the distributor, if home delivery is not available. Analysis of the refill patterns before and after the switch could establish the efficacy, or not, of the cylinder switch empirically.

As shown in Chapter 4, the self-efficacy (confidence to use LPG regularly under adverse conditions) is low even for regular users of LPG, including those who are using it for more than one year. Post-purchase interventions targeting the cons (perceived disadvantages) of regular LPG use as highlighted in Chapter 4 should be an urgent priority.

Two, policy interventions that focus on behavioral determinants could be useful for progress in stable access and affordability environment. As shown in chapter 4 that while the household wealth index was an important determinant for transition, perceived disadvantages to use were found to be more important in determining the transition process. Also, survey results in Chapter 5 indicate that weak perceptions about decision autonomy (of female cooks in a patriarchal society) and fuel procurement hassles discourage consumers from using LPG regularly. Campaigns should focus on the issues of decision autonomy and encourage women LPG user groups. The LPG Panchayats organized by the government is a good beginning in that direction to establish greater awareness and experience sharing-tools recommended by TTM towards transition.
Three, the comparison of self-reports with purchase data in Chapter 5 shows significant over-reporting by users. So, purchase data should be made accessible for objective evaluation, while survey methods should be complemented with objective measurements to minimize social desirability bias in results. (Here it should be noted that while purchase data is expected to a quick assessment of LPG consumption trends of a large consumer base in a reliable manner, whether LPG is used as primary cooking fuel at individual household level cannot be confirmed without household level details on family size, food preferences, and solid fuel use assessment.) Over-reporting of LPG consumption or severely skewed distribution in responses to direct questions signal a larger serious issue on the reliability of self-reported surveys through face-to-face interviews in presence of bystanders, as is the norm in the developing countries. Finally, the use of this novel dataset provides new insights into the clean cooking energy transition. For example, counter-intuitively, I found that experience/ familiarity with LPG does not increase consumption with time. It would have been difficult to obtain such insights reliably through standard tools such as self-reported surveys (recall errors and bias) and would have been prohibitively expensive to achieve via thermal sensors at this scale (Graham et al., 2014). Datasets consisting of distributor-level transactions are invaluable sources of information that, properly anonymized, should be made accessible to researchers and policy analysts. This not only promotes transparency but could facilitate objective program evaluation and potential design changes to this program in order to improve targeting and effectiveness of policy changes like cylinder switch (from 14.2 kg to 5 kg).

6.3 Study limitations and future research agenda

Based on the data availability, data analyses and findings of my work, I discuss some key limitations and propose future research efforts as a follow-up to this dissertation using existing data and new research efforts to build upon the existing findings.

First, there is mostly qualitative discussion in the literature on the role that the physical location of a consumer plays in terms of access. However, one recent study shows that population density and
urbanization play important roles in the transition process (Shupler et al., 2019). For example, distance from the nearest sales point is considered to be a key factor (Khandelwal et al., 2017; Puzzolo et al., 2016). Access to the highway and proximity of a community to the public transport routes could also encourage use. The physical location could also matter in terms of the peer effect. Social network theory suggests that if a community already has regular LPG users, newer users may be more inclined to use it more often (Jagadish & Dwivedi, 2018, 2019). While this has been tested using qualitative research, the dataset of LPG sales records provides an interesting approach to these hypotheses using a big data-set spanning years and thousands of consumers if the home address of these consumers is considered.

Chapter 3 analyses had been limited to sales data without consideration to the address of the consumers. While the quality of the address is poor (spelling mistake, first 10 letters deleted to avoid identification as per research ethics guidelines), even if a majority of consumer’s village location is detectable, it would be useful. The role of the distance of a village from the highway and from a distributor physical outlet are important parameters in literature but never been tested with an actual sales dataset. The effect of the base (existing consumers) on the magnitude and pace of the diffusion of innovation (new LPG consumer) after accounting for the proximity of the sales outlet (distributor office), distance from the highway and availability of public transportation would be an interesting line of research.

Second, there is a scope to make a key theoretical contribution to the field of health and social psychology by integrating the TPB (pros, cons, and self-efficacy) and TTM (norms, attitude, control, intention) constructs. Proponents of TTM suggests that the stages of change are the outputs or manifestations of the decision-making process associated with distinct perceptions (Prochaska & Velicer, 1997). On the other hand, TPB framing of intentions, attitudes, norms, and control could be viewed as the drivers of the change from one stage to another. The integration of these two theories as outlined in the CI-CHANGE model (Chapter 2) provides the unique ability to check if TPB constructs act as inputs to the outputs of TTM constructs.

The survey for Study S1 has data on psychological constructs of TTM (pros, cons, and self-efficacy) and TPB (norms, attitude, control, intention). There are no studies, to the best of my knowledge,
wherein both TPB and TTM constructs are captured in a single survey dataset. Correlations between these variables from the existing dataset will be an interesting theoretical contribution to how much aligned these two theories are in terms of capturing people’s perceptions about a target behavior. Moreover, analyzing the difference in TPB attributes among people in different (TTM) stages would also be an interesting line of research.

Third, I did not have any panel data to study “transition”- i.e. I did not track a cohort over time and see how their behavioral determinants changed over time. Here, it should be also be noted, that the vast amount of studies in the cookstove and other domains from where I draw upon the conceptual pieces are dependent on cross-sectional data, often due to lack of resources to conduct large scale longitudinal studies (Fishbein & Ajzen, 2011). In fact, most studies on clean fuel transition also depend on cross-sectional studies, with few notable exceptions like the PURE study (Shupler et al., 2019), and the CEEW study on cooking energy patterns in India (Jain et al., 2018).

Critics suggest that cross-sectional studies weaken the claims on the role of behavioral determinants towards facilitating the transition (Sniehotta et al., 2014; West, 2005). For example, the correlation between the perceptions (Pros/ Cons) and stages of change may be moderated by other variables beyond what TTM proposes. On the other hand, the proponents of TTM and TPB push back that in real-life conditions, careful application of these theories in a variety of settings has led to real-world changes (Ajzen, 2015; Prochaska, 2006). While stage-specific interventions were successful in WEIRD contexts in addiction behaviors, there is a need for substantial research to develop the implementation strategy for stage-specific interventions, or even to prove that stage-specific interventions are more useful than generic interventions. Given the divergence between the settings where healthy psychology theories are typically applied and the cooking energy transition environment, it is useful to do pilot programs to test their effectiveness before making sweeping recommendations on changing policies at a large scale.

Hence, I propose a longitudinal study involving a randomized control trial for stage-specific interventions as the follow-up research to this study. One can randomly identify X respondents in each of the five TTM stages and then assign them into three groups of (X/15) each per stage. The first group will
receive stage-specific behavior change interventions, the second group will receive generic behavior change interventions and the third group would receive no intervention. Then, LPG use (sales data) by these respondents/households could be tracked over a five-year period with repeat measurement of TTM and TPB variables at the end of five years. It should provide interesting insights into the comparative advantages of stage-specific over generic interventions if any. Moreover, a panel dataset could also help determine if the movement of people across stages (at the end of five years) is associated with a change in TTM variables. Further, the stage-specific interventions should draw upon the ten strategies listed in the TTM literature (Prochaska & Velicer, 1997) to encourage progression to the maintenance stage. Moreover, there is also an opportunity to further explore the implementation science framework in order to better understand the transition challenges in real world conditions (Rosenthal et al., 2017).

Fourth, there is a need to further explore the interaction effect that (objective) wealth, or lack of it, has on the subjective cons score which captures perceptions around affordability. Hence, future research should involve running advanced regression models that compare the cons score (without wealth) and using wealth x cons as an interaction effect. The current dataset is limited by the number of non-wealth cons indicators (only two) to conduct such rigorous analysis. Hence, future research should add more cons indicators.

Fifth, the countries which are hot-spots of cooking energy poverty, particularly in Asia, such as India, Bangladesh, and Pakistan are known for patriarchy- wherein, the male members often act as key decision-makers (Khandelwal et al., 2017; Miller & Mobarak, 2013). This study had focused exclusively on women cooks, irrespective of whether they were the main decision-makers about fuel use, especially LPG purchase decisions. Here, the key consideration was that it was the (female) cook who would be the user of the technology. Unless she agrees to the change and goes through repeated behavior change actions (change in the cooking style, flame management, posture, etc.) the transition would not be possible. Moreover, the theoretical framework was created based on theories of behavior change that focused on self-regulatory individual behavior. There is no available theoretical framework to analysed gendered differences in behavioral constructs to explain and predict household level decision-making- a glaring gap.
in the psychology literature. Moreover, given the resource constraints in the study, logistically the choice was to either do 200 surveys of households where both primary decision-makers and primary cooks are interviewed (assuming gendered role of male and female) or conduct 400 surveys of primary cooks. It was a trade-off decision with valid arguments on both sides. With 400 surveys of cooks, there were statistically sufficient numbers for individuals at five different TTM stages of change to detect a medium effect size with sufficient power (power= 0.8). On the other hand, if men are key to the fuel purchase decisions, not being able to capture their attitudes, norms and control perceptions leads to a partial vision into the household decision-making process. While there are explicit social norms questions of whether “family decision maker” and “other family members” support use of LPG as the primary cooking fuel, it does not have the richness or accuracy of capturing perceptions directly from the male decision maker. For example, even if the male household head opposes the female cook’s wish to cook with LPG, the social desirability bias may prevent the woman cook from opening up to an outsider (surveyor) about the sensitive (marital) differences in front of others (bystander effect). (It should be noted that local female volunteers were used to minimize the survey biases, but it still persists as shown in survey bias results between indirect and direct attitude, norms, and control scores in Chapter 5.) Hence, future research should focus on developing and testing a household fuel choice theory. While I have called the CI-CHANGE conceptual framework as the household fuel choice, it is (strictly speaking) cook’s fuel choice theory. There is a need to not just capture different perceptions of key decision-makers (including children) but better theorize the decision-making process- who has veto power, how members negotiate with each other etc. Marriage counselling theories on negotiations could be an interesting reference point for the future household fuel choice theory.

6.4 Study boundaries

In this study, the primary focus is on behavior change to achieve clean cooking energy transitions. For the dissertation, I aimed to clearly define the target population (rural poor), the target behavior (LPG
as primary fuel) and the target phenomenon (choice of fuel), where I argue behavior change interventions are likely to be particularly useful.

First, the target population for this study was situated within the ‘triple whammy’\textsuperscript{27} of rural, low-income households in developing economies as the environment within which the problem-at-hand (insufficient clean cooking transition, albeit, at different stages in different countries) was situated. Rural households with comparatively (to urban households) easy access to solid fuels in farmlands & forests have a temptation to switch to solid fuels easily and free of (monetary) cost. Low income households in developing economies have the affordability problem: limited fuel subsidy by the government coupled with low purchasing power by households with several competing needs like medical treatment and education. Notably, ten countries contribute to 71% of the world’s population without access to clean cooking. Except for China (per capita GDP: 18,120 USD\textsuperscript{28}) and Indonesia (13,177 USD), the other eight economies are either lower middle-income (e.g. India- 7796 USD) or low-income (democratic republic of Congo- 817 USD) economies wherein 27%-91% of households living on less than 3.2 USD\textsuperscript{29} a day at 2011 international prices. Almost the entire Indian population of (cooking) energy poor- who do not use LPG or electricity based cooking devices as primary cooking fuel- live in rural India, with the exception of migrant workers in urban areas. All the major (cooking) energy poverty hotspots in Asia (with the exception of China and Indonesia) and Africa have low (<40%) urbanization rates. However, it should be noted that, in addition to the current urban/rural ratio, the projected rate of urbanization over time should also be considered from policy perspective. So, about 70% of the world’s energy poor (barring China, Indonesia, and a few countries in Latin America) are likely to be within the boundary conditions of the target population at least in the near term.

\textsuperscript{27} “Three simultaneous deleterious blows with compounded effect” (Thomas M., 2000)
\textsuperscript{28} Purchasing power parity adjusted for 2018
\textsuperscript{29} World Bank poverty threshold is $3.1 http://www.oecd.org/iaos2018/programme/PosterSession_MassarovaAlena.pdf
Second, the target phenomenon was voluntary cooking fuel choices, i.e. the target households had a real choice of using both clean and/or solid fuels in two ways. First, I assume that there was no law that makes solid fuel choice as illegal (i.e. no external coercion to switch to clean fuels), and even if there was law, the enforcement was not strict enough to be effective in preventing people from using solid fuels. Second, there is reasonable physical access to clean fuels. In other words, I considered physical access as a precondition to discussing transition through the lens of behavior change. If there is no access or very limited access to fuels or sales and repair service for stoves, no behavior change (or, even affordability enhancement) strategies could possibly work.

Third, the target behavior is using clean cooking fuels as the primary cooking fuel. While exclusive use of clean cooking fuels is highly desirable, especially from a public health perspective (M. A. Johnson & Chiang, 2015), this may be an overly ambitious target in the short term for the target population. An interim target of using clean fuels as the primary cooking energy source, which would be more achievable (within the reach) in the near to medium term, is displacing solid fuels with clean fuels as the primary cooking energy source (Barrett, 2015). Moreover, while discussing clean cooking technologies, I implicitly assumed that commercial stoves and fuels have low emissions in real-world conditions, and have high manufacturing quality which will result in rare product breakdowns. Past studies show that this may not be the case for improved biomass cookstoves or unbranded clean stove components (Palit & Bhattacharyya, 2014; Shrimali, Slaski, Thurber, & Zerriffi, 2011).

6.5 Beyond boundaries: Alternative pathways to transition

This dissertation has attempted to examine the transition process solely from the perspective of behavior change for the population within the boundary of the study. However, it is important to acknowledge that for any behavior change or technology adoption, having laws that force/push for changes (regulations), lack of solid fuel choices (urbanization), and low cost (fuel subsidies) would act as an enabling environment (Verplanken & Wood, 2006). So, while behavior change interventions are the
likely pathways within the boundary conditions, there is a need to also advocate for the alternative pathways to transition that go beyond these boundaries.

There are two recent examples of regulation to ban solid fuels which provide interesting glimpse into the role of regulations in the transition process- China banned coal for heating in rural households in the Beijing Municipality in 2016 (Barrington-Leigh et al., 2019) and a ban on firewood harvesting in Kenya in 2018 (Okonda, 2018). In China, the policy intent is to substitute coal with a subsidized electrical heat pump, which even after the subsidy was costlier than coal on a per unit basis. However, for households in relatively wealthy villages/ districts, the benefits of “health, comfort, and convenience” outweighed the additional cost from electric heating and the switch was successful in terms of elimination of coal use. In the low-income households where the ban was enforced, the switch was partial, wherein the average coal consumption declined by 50% but people were dissatisfied with their energy choices (Barrington-Leigh et al., 2019). This suggests that regulations that put pressure on people to switch to cleaner fuels will be better enforced when people can afford the switch. In Kenya, the firewood ban led to a sharp increase in alternative fuel prices, and an unheard of “environmental crime”- rural households reporting that their firewood stocks were being stolen (Njagi, 2019; Okonda, 2018). The banning of forest tree chopping has led to greater pressure on farm trees, which leads to the unintended effect on the tree canopy- “which attracts rainfall and acts as a wind break”- getting thinner on the farm land (Njagi, 2019). These two recent examples of regulations suggest that while regulations can be effective and enforceable under certain conditions, adverse household level finances and unintended effects can be a challenge. Also, the role of regulations is oft highlighted in the behavior change literature- self-regulatory behavior change efforts like smoking cessation are often helped by favourable “upstream” interventions that disrupt old environmental clues, such as ban on smoking indoors in USA (Verplanken & Wood, 2006).

To summarize, regulation of solid fuel use could be used in conjunction with careful behavior change interventions, but just focusing on the former without adequate planning may not be effective for the target population.
There are two prominent examples of fuel subsidy being an independent driver of the transition to clean cooking fuels. In Ecuador, the government has been providing subsidy for the last two decades to ensure that LPG (15 kg cylinder) price fixed at 1.60 USD. At current international LPG prices, it is equivalent to a price subsidy of about 80%, or, about 1% of the country’s GDP (Gould et al., 2018). (Ecuador’s per capita GDP is 11,500 USD after adjusting for purchasing power parity at 2011 USD). As of 2018, about 94% of the households have moved to LPG as the primary cooking fuel (IEA, 2018), and an ongoing unpublished study indicates that about 55% of rural households are using LPG as exclusive cooking fuel. Second, in India, when rural households were provided an LPG toolkit (device, first cylinder, and accessories) at no cost (like Ujjwala) and provided free (14.2 kg) LPG cylinders every month, they exclusively cooked with LPG for 90% of the monitoring period (Pillarisetti et al., 2019). It clearly suggests that all the behavioral challenges associated with a change in cooking style, taste, texture matter/ emerge as factors only when people have to pay for it. I argue that this evidence is not in conflict with the findings from this dissertation on the applicability of behavior change interventions. When affordability is not a factor (LPG and solid fuels are at comparable cost), the resistance to switching to clean fuels disappear as cons in the form of perceptions about affordability greatly reduce, so people move to the action and maintenance stage. In other words, the other cons around safety and change in cooking style take a backseat once the fuel is free, and the “aspirational” (Smith & Dutta, 2011) aspect of LPG gains prominence. In order to establish the role of behavioral communications in practice, there is need to demonstrate how perceptions about affordability can be altered without changes in objective reality (i.e. improve perception about affordability without increasing subsidy), and test if it leads to change in fuel use?

Urbanization has been traditionally associated with a clean cooking fuel transition (Barnes, Krutilla, & Hyde, 2004; Shupler et al., 2019) for three main reasons. First, it has a better “on demand” supply in comparison to rural areas (Puzzolo et al., 2016). (My dissertation boundary conditions assumed

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30 “excuses” as one OMC official described to explain reluctance to buy LPG
reasonable access to clean fuels without discussing the nuances around reliability in the supply side). Second, urban households have a higher income (i.e. greater spending potential) than rural areas, on average. As a result, the opportunity cost to gather (non-monetized) fuelwood is also higher (Heltberg, 2004). Third, urban areas often do not have access to non-monetized fuel and given a choice of a low-priced polluting fuel (wood or charcoal) and a high-priced non-polluting fuel, they often chose the latter (Barnes et al., 2004). So, one may argue that moving from low cost to high cost fuel (urban) is easier than moving from zero cost to high cost fuels (rural). The findings from the impact of urbanization on energy access are in sync with the framing of the CI-CHANGE model to explain the transition process.

Urbanization leads to reduced access to solid fuels (Shupler et al., 2019), which in turn reduce the temptation of households to switch to solid fuels- as it would be difficult to access and/ or require cash to purchase solid fuels. The reduction of temptation to return to the old “undesirable” habits in the form of structural changes is an integral component of habit change (Verplanken & Wood, 2006).

To conclude, there is existing evidence that regulation, fuel subsidy and urbanization, help change people’s behavior without explicit behavior change efforts. It is in sync with the sufficiency assumption of TPB literature that all external factors that promote or impede behavior lead to a change in beliefs, which via intentions, lead to behavioral actions. Further, multiple studies have shown that change in structural factors such as regulation in conjunction with behavior change strategies has been more effective than these activities, i.e. whole was greater than the sum of its parts, for behaviors like smoking cessation (Fishbein & Ajzen, 2011; Verplanken & Wood, 2006). However, the key question for future research is whether behavior change interventions in the post-stacking period be effective without changes in these (objective) structural factors. The behavior change theories have mostly been applied to behaviours such as smoking cessation and voting, where cost and settings do not play any major role. My working hypothesis is that that behavior change strategies (to change perception) should be employed along objective structural drivers (like fuel subsidy) to maximize the likelihood of the transition process, especially if the fuel subsidy is not competitive to the competing solid fuels. In most developing countries.
where fuel subsidy is provided, with the exception of Ecuador, the cost of subsidized clean fuels is significantly higher than that of competing solid fuels.

6.6 Concluding remarks

As the body of knowledge on cooking energy transition stands today, the three structural pathways- urbanization, fuel subsidy, and regulation- to clean cooking energy transition is well-established. I argue that in absence of these three factors (thereby meeting boundary conditions), explicit behavior change interventions in the post-uptake period are a plausible pathway to get people to clean cooking fuels in countries like India. However, the relative merit and costs associated with effective behavior change interventions (compared to diverting those funds to increase fuel subsidy) are unknown. In some ways, this dissertation was an application of theories of “problem” (better understand & predict the problem behavior) to establish that behavior change theories can play an important role to explain and predict transition behavior. While stage-specific interventions targeting weaker beliefs should be attempted based on the findings in this dissertation, it does not fully lead to formulation and validation of the theories of “action” (pathways to behavior change) (Ajzen, 2015; Sniehotta et al., 2014). So, attempts to highlight the role of behavior change should not be interpreted as an attempt to minimize the role of these three important factors.

Notably, in the vast majority of developing and under-developed economies, the fuel subsidy to make LPG competitive to solid fuels and enforcement of regulations will be challenging. While governments can theoretically spend 1% to 48% of their budget (top 10 countries with population sans access to clean fuels) needed to subsidize LPG as the primary fuel, it may be politically infeasible to cut budgetary allotments from other sectors. On the other hand, it is plausible that the financial (not just economic) benefits from the transition to clean fuels could compensate for the same in the long run for some countries. If governments realize and monetize the expected public health cost savings by avoiding household air pollution linked diseases towards direct fuel subsidy, it would be a welcome step.
Further, the specific conclusions drawn from the Koppal sales dataset and survey results though instructive, should be carefully applied elsewhere due to the context dependence of perceptions and behavior. For example, while the survey data shows that safety and cleanliness already have positive attitude scores unlike value for money, the relative ranking of these factors may change with location or past experience of the respondents. However, the big picture insights around the stage-wise difference in perceptions and self-confidence or the presence of survey biases may be applicable under similar conditions with varying degree. Moreover, energy transitions take time and it would be premature to pass judgment on PMUY at this stage (Smith & Jain, 2019); though it is a good time to take stock and suggest course corrections such as introducing incentives and strategies that focus on post-uptake regular LPG use.

However, the challenges of decision autonomy of the (woman) cook, low prioritization of clean cooking in household budgets (sometimes, over tobacco and liquor), economic non-viability of home delivery infrastructure in rural areas (Puzzolo et al., 2016; van der Kroon et al., 2013) are manifestations of systematic impediments involving equity and other larger issues which are generally beyond scope of CCS interventions. For example, I estimated that the expenses on addictive products like tobacco and liquor (Pawar et al., 2015) could be close to the cost of LPG (four cylinders) required for primary use in many rural households. So, just focusing on affordability dilutes the complexity of the situation. CCS like LPG is often considered as “a technical, cheap, easy, and noncontroversial fix to what in fact is serious, complex, deeply structural and thus highly political problems” (Khandelwal et al., 2017). Ultimately, the non-use of LPG stove is not just an issue of education, or, information, or cost, but it also signals to deep-rooted societal issues such as lack of women’s decision autonomy in budgeting.

To conclude, this dissertation shows that there is a serious need to focus on post-uptake interventions and monitoring in order to accrue the envisaged health, societal and environmental benefits within the boundary conditions. I demonstrate that using the behavior change framework can provide insights into the five-stage transition process, which now needs to be followed up with rigorous stage-specific pilot interventions. I also highlight the need for objective data considering the likelihood of respondent biases in traditional surveys. However, while evidence-based practical behavior change
interventions would further the transition process, it will take time to win the battle against deep-rooted structural challenges like patriarchy in the absence of influential drivers like urbanization, fuel subsidies, and regulations.
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