Global Dual and Poly-Tobacco Use in Adults and Implications for Tobacco Control

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Daniel Tzu-Hsuan Chen

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Imperial College London

Department of Primary Care & Public Health

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List of Abbreviations

ATP	Alternative Tobacco Products
AIC	Akaike Information Criteria
CI	Confidence Interval
DIC	Deviance Information Criterion
DHS	Demographic and Health Survey
ENDS	Electronic Nicotine Delivery System
GATS	Global Adult Tobacco Survey
GDP	Gross Domestic Product
GYTS	Global Youth Tobacco Survey
GEE	Generalized Estimating Equation
HIC	High-Income Countries
HDS	Health Development Surcharge
HTP	Heated Tobacco Products
ICC	Intra-Class Correlation Coefficient
ITC	International Tobacco Control Policy Evaluation Project
LMIC	Low- and Middle-Income Country
LIC	Low-Income Country
MRP	Maximum Retail Price
MTP	Multiple Tobacco Product
MPOWER	Monitor, Protect, Offer Cessation Help, Warning Label, Enforce Ban, Raise Tax
MCMC	Markov Chain Monte Carlo
NRT	Nicotine Replacement Therapy
NHIS	National Health Interview Survey
NATS	National Adult Tobacco Survey
OR	Odds Ratio
PATH	Population Assessment of Tobacco and Health
PPP	Purchasing Power Parity
QIC	Quasi-Likelihood Information Criteria
RRR	Relative Risk Ratio
SDG	Sustainable Development Goals
SES	Socioeconomic Status
SLT	Smokeless Tobacco
ST	Smoked Tobacco
UAE	United Arab Emirates
US	United States
UMIC	Upper-Middle-Income Countries
USAID	US Agency for International Development
WHO	World Health Organization
WHO FCTC	Who Framework Convention of Tobacco Control

Declaration of Originality

I hereby declare the work presented in this thesis is my own, developed with guidance from my supervisors, Dr. Filippos Filippidis and Professor Christopher Millett. All else is appropriately referenced. The series of research papers yielded from this PhD thesis were fully referenced, and the co-authors that contributed to the work of the published papers were fully acknowledged at the beginning of each chapter.

Copyright Declaration

Abstract

Background

Dual (using two tobacco products) and poly-tobacco product use (using more than two) account for a considerable proportion of global tobacco users. Although the global prevalence of tobacco use has declined from 33.3% in 2000 to 24.9% in 2015 and is projected to decline further in response to global tobacco control efforts, there is a growing diversity of new and alternative tobacco products in certain areas across the globe. This has contributed to the high prevalence of concurrent use of multiple tobacco products and the possibility of transitions between products, potentially increasing the health burden associated with tobacco use in areas of high prevalence of use, such as the lower-middle income countries (LMICs). Therefore, improving understanding of dual and poly-tobacco use is essential for tobacco control policy and practice.

Objectives

To first systematically review existing epidemiologic evidence on current dual and poly-tobacco use among adults globally. Then, building upon the conceptual model of multiple tobacco product (MTP) use to further assess potential associations with individual and country-level factors among adults in LMICs using the latest wave of the Demographic and Health Survey (DHS). Following that, conduct an in-depth case study on Bangladesh, one of the LMICs with the highest prevalence of tobacco users globally, using the International Tobacco Control Policy Evaluation Project (ITC)-Bangladesh dataset to longitudinally investigate the patterns and factors related to transitions of different tobacco use patterns and products within different user subgroups. Lastly, to give suggestions based on the above findings to inform tobacco control regulations.

Methods

A systematic review was conducted to identify studies published up to June 30, 2020, with measures of nationally representative prevalence of current dual or poly-tobacco use among adults. Next, data from 19 LMICs was obtained from the most recent wave of the DHS study, collected between 2015 and 2016, comprising 235,975 men aged 15–49 years. The prevalence was estimated using available sample weights. To estimate the associations of individual and country-level factors with tobacco use, a range of person, product, and context/situation factors

were examined with multilevel models. For the longitudinal analyses, a balanced panel of 3,245 tobacco users from 2009 to 2015 in four waves of the ITC Bangladesh survey was used. Generalized Estimating Equation (GEE) models in longitudinal data analysis were utilised to evaluate predictors for transitions of cigarettes, bidis, and smokeless tobacco (SLT) use. However, only male adults were included for analyses of transitions of exclusive cigarette and exclusive bidi users, as the prevalence of both products among female adults was significantly lower in all waves of the survey.

Results

Twenty studies with nationally representative prevalence data on current dual or poly-tobacco use in the adult population across 48 countries were included in the systematic review. Dual tobacco use was generally higher in Southeast Asia; poly-tobacco use was prevalent in Europe as well as in Southeast Asia. Factors associated with dual and poly-tobacco use were older age, low academic achievement, low-income status, being divorced, living in urban areas, high frequency of media use, and being a migrant. MPOWER scores were inversely associated with single tobacco use, but not with dual and poly-tobacco use. Longitudinal transition analyses revealed that age, place of residence, and psychosocial factors such as attitudes toward tobacco use and intent to quit were the most important factors associated with cigarette, bidi, and SLT use transitions in Bangladesh.

Conclusions

Findings suggest that dual and poly-tobacco use are common among men, especially in LMICs in Southeast Asia. The related individual and contextual-level factors explored in this thesis could aid researchers and policy makers in identifying specific target populations, products, or consumer characteristics linked to dual/poly-tobacco use, and products transitions. This thesis highlights the need for global tobacco control regulations to be expanded and strengthened in all aspects to address all tobacco products and explicitly consider dual and poly-use to further reduce tobacco-related inequality, disease and economic burden globally.

Acknowledgments

The work in this thesis spans the most significant period of my life so far. It has influenced both my future career goals and who I am as a person. Throughout this adventure, I've made lasting friends and learnt from some of the brightest minds. I will be forever grateful to my supervisors Dr. Filippos Filippidis and Prof. Christopher Millett, and my wonderful colleagues in PHPE — some of the brightest minds and most compassionate researchers I have ever met.

I'm extremely thankful to Filippos for his mentoring, advice, and support during my PhD. The numerous learning opportunities he provided have enriched my studies at Imperial. It has been an honour to learn from and collaborate with him in the field of tobacco control. His ingenuity and integrity as a person, scholar, and mentor will always be an inspiration to me.

The Department of Primary Care and Public Health at Imperial College will always be my intellectual home, and I hope to be able to continue and pass on what I've learned in the coming years as I pursue my future profession. Special thanks to my dearest friend and colleague, Dr. Kiara Chang, who was extremely helpful and caring throughout my time at Imperial.

My aspirations for this work and the published papers that come from it is that it may provide some additional knowledge for tobacco control and health care professionals to better understand the global impact of tobacco use. I also hope that my passion and true interest in the field has produced a piece of original research that is interesting to read, and above all useful. However, none of this would have been possible without the hard work of my co-authors, and the advice from Prof. Geoffrey Fong and Dr. Nigar Nargis form the ITC team in Waterloo, Canada. I'd also like to thank my examiners, Dr. Matthew Harris and Prof. Lekan Ayo-Yusuf for serving as examiners for my thesis viva.

During my studies abroad, I was fortunate to receive support from the *Taiwan Governmental Scholarship of the Ministry of Education*, as well as an early career researcher award from *Dr. Oxford Biotech Factory Co.* in 2017, allowing me to pursue my PhD training without concern. Lastly, this journey wouldn't have been possible without the support of my incredibly supportive parents; my caring friends; and my greatest supporter and companion, Leopold; plus, all the people who have cheered me along the way. Thanks to all of you.

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Chapter 1: Introduction

1.1 Current Landscape of Global Tobacco Use

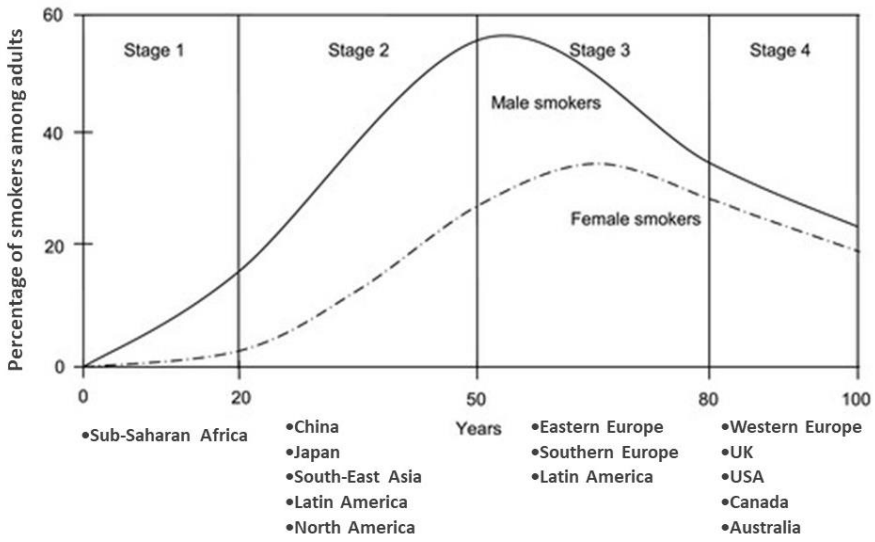
Tobacco use is the leading cause of mortality and disability across the globe. It is responsible for over 8 million deaths annually and has been notably linked to a variety of malignancies, including lung cancer, pancreatic cancer, laryngeal cancer, and cervical cancer[1]. Tobacco smoking is also a significant risk factor for non-communicable diseases and a variety of chronic illnesses, such as stroke, coronary heart disease, and especially respiratory diseases[1]. The negative health consequences are not limited to direct users of tobacco products. Secondhand smoking is estimated to be responsible for more than 1.2 million fatalities worldwide each year[2], including 168,800 deaths among children[2] and increased risks of infant mortality[3]. Most deaths from second-hand smoke in adults are caused by ischemic heart disease, asthma, and lung cancer and in children most of these deaths are caused by lower respiratory infections[2].

It is projected that the death toll accountable from tobacco use will increase to 10 million per year by the year 2030 if regulatory policies are not reinforced[4]. Tobacco use continues to be a key driver of health disparity, accounting for 80% of estimated deaths in low- and middle-income countries (LMICs)[4]. Health inequalities arising from tobacco use reflects its relationship with socioeconomic status (SES), income, ethnicity, migration and deprivation such that use is much more common among those who can least afford it[5].

The “tobacco epidemic” can be illustrated by a four-stage model that describes the evolution of smoking/tobacco use in the global population across time[6]. This conceptual framework enables comparisons of a nation’s progression in the tobacco epidemic in relation to other countries (see Figure 1 below). The first stage is characterised by predominant smoking among men. In stage two, the prevalence of smoking increases dramatically in men and gradually in women. The third stage is characterised by a discernible downturn in smoking prevalence among men and a more gradual decline in women. In the fourth stage, both men and women show a further decline in smoking. Most high-income and some developed countries in North and West Europe, the US, and Canada have evolved to this stage. From the lens of the “tobacco epidemic”, economically developed Western countries are in an advanced stage of the epidemic

with declining prevalence of tobacco use, while in LMICs such as China, India, Middle-Eastern, or other African or Southeast Asian countries that host a significant portion of a culturally diverse population and are still at an early stage, the public health burden of tobacco use is expected to rise in these nations without concerted global effort to curb the tobacco epidemic.

Figure 1: The four stages of the tobacco epidemic, adapted from Lopez et al.



The WHO Framework Convention of Tobacco Control & The MPOWER package

Global tobacco control measures have progressed during the past years, including the adoption and implementation of the WHO Framework Convention of Tobacco Control (WHO FCTC). Through comprehensive tobacco control regulations, these instruments empower governments with evidence-based solutions for reducing the burden of tobacco-related disease and mortality[7]. The WHO FCTC was adopted by the World Health Assembly in May 2003 and entered into force in February 2005 as the first global public health treaty. Currently, 182 Parties worldwide have ratified the FCTC, covering more than 90% of the world population.

The WHO FCTC was founded on the premise that the tobacco pandemic is a global issue requiring international collaboration. The treaty asserts the right of all people to the greatest level of health. It is obliged by international law to comply with the treaty terms by implementing measures targeted at lowering the supply and demand for tobacco products[8].This have contributed to the decrease in smoking prevalence, especially in high-income countries[9]. The global prevalence of cigarette smoking has declined from 25.7% in

2000 to 19.8% in 2015[10]. The prevalence of tobacco use has similarly declined from 33.3% in 2000 to 24.9% in 2015[10]; however, this trend has not been consistently observed across regions and countries ―the developing LMICs, which bear the major burden of tobacco-related diseases have not been very successful in achieving large magnitudes of reductions[11]. There are currently more than 80% of the world's smokers living in LMICs[12], with great proportion being male users[5]. East Asia, Southeast Asia, Eastern Europe, and Central Asia have some of the highest rates of male tobacco smoking[10]. In 2020, the highest prevalence of tobacco use in the world, was reported in Southeast Asia and it was around 27.9%[10]. The male/female smoking rate ratio was 4.7, and the average prevalence of tobacco use among both sexes was 46% and 9.7%, respectively[10].

To assist Parties adopt and implement the WHO FCTC at the national level, the WHO has developed specific implementation recommendations for the treaty's Articles as well as the MPOWER technical support package, which includes tools for monitoring FCTC progress and effectively managing and improving its implementation. The MPOWER package, an acronym representing six evidence-based control approaches, to help nations implement tobacco control policies[7]. The six strategies were: **Monitor** tobacco use and prevention policies; **Protect** people from tobacco smoke; **Offer** help to quit tobacco use; **Warn** about the dangers of tobacco; **Enforce** bans on tobacco advertising, promotion, and sponsorship; and **Raise** taxes on tobacco. While some of these demand-reduction initiatives have experienced increased acceptance by FCTC parties over the last decade[4], there are still several barriers to decreasing tobacco use at the population level. Given the various stages of the tobacco epidemic and tobacco control in different countries, it is vital to consolidate the knowledge base on the effectiveness of policies in reducing tobacco use collectively as governments move toward smoke-free nation targets.

Apart from the health consequences, the economic costs of lost productivity and higher healthcare expenditures are well-established negative effects of tobacco use[13, 14]. These impacts highlight the need of coordinated global tobacco control efforts, which is an essential and important step as countries work toward the 2030 Sustainable Development Goals (SDGs)[15], particularly SDGs target 3A, which calls on all nations to strengthen implementation of the WHO FCTC.

1.2 The Rise of Alternative Tobacco Products

With the ratification of the WHO FCTC, tobacco control efforts across the globe have achieved great progress in reducing tobacco use and ensuring that people in many regions of the world are protected from the health risks of tobacco[9]. However, emerging non-cigarette products, collectively referred to as "alternative tobacco products" (ATPs)[16, 17], have proliferated in different markets in recent years posing serious health concerns.

Aside from manufactured cigarettes, which are the most common form of tobacco used worldwide, other types of smoked and smokeless tobacco are widely used in different regions of the world[18]. Cultural, social and economic factors may influence popularity of alternative tobacco products in certain regions[19]. Emerging APTs include *hand-rolled cigarettes* (i.e., "roll-your-own" most popular in European countries), *pipes*, *cigars*, as well as *bidis* (small hand-rolled cigarettes wrapped in leaves, particularly prevalent in India, Bangladesh and South Asian countries), *kreteks* (clove-flavoured cigarettes most common in Indonesia), and *waterpipes* (also known as *hookah* or *shisha*, most common in the Mediterranean region and the Middle East). There are other smokeless products, such as *chewing tobacco*, which is most prevalent in Southeast Asia, and *snuff* (made of ground or shredded tobacco and may be moist or dry— moist snuff is taken orally and dry snuff is inhaled by nose or mouth) or *snus* (oral moist snuff in packets most common in Northern Europe).

There are also growing concerns over the expanded market for novel tobacco products in the 21st century, such as electronic nicotine delivery systems (ENDS), also known as electronic cigarettes, and heated tobacco products (HTPs) that have attracted younger users[7]. For the purposes of my thesis, these two types of novel products will not be addressed in the studies included. The electronic delivery systems, which heat "e-liquids" that may or may not contain nicotine but not tobacco, are not regarded as a tobacco product in many countries other than the United States (US), and thus not included in tobacco product regulation[20]. HTPs, although recognised as a novel tobacco product, are however not widely popular until recent years in middle- and higher-income countries[21]. Thus it use was not monitored consistently in the literature to allow global analysis. This thesis focuses primarily on cigarettes and ATPs, and the important role they play in tobacco control and the industries' strategy.

Most studies evaluating the harm of tobacco use have focused on manufactured cigarettes due to their higher prevalence than ATPs. However, evidence has also shown significant adverse health effects linked with the use of ATPs. Waterpipe (hookah), Cigar, and kreteks use are largely associated with an increased risk of tuberculosis, abnormal lung function, acute lung injury, as well as cancer of the lungs, oral, oesophageal, head and neck and the stomach[17, 22]. Bidi smoking delivers significant levels of toxins such as carbon monoxide, nicotine, and tar that adversely affect normal lung function[23]. Moreover, smokeless tobacco (SLT) use is also related to a myriad of negative health effects[24]. The health outcomes of SLTs vary by region, possibly due to the availability of different forms of products (chew, snuff or snus) within countries and societal trends of the product use in the country of residence. In studies conducted in the US and Asia, it has been associated to an increased risk of oral cancer, as well as oesophageal and pancreatic cancer in studies conducted in Northern Europe[24].

1.3 Global Dual and Poly-Tobacco Use

1.3.1 The Characteristics of Dual and Poly-Tobacco Use

As the tobacco market landscape rapidly changes, the proliferation of ATPs opens avenues for cigarette smokers to use other tobacco products or smoke cigarettes in combination with ATPs. Referred to as dual (concurrent use of two products) or poly-tobacco users (use of three or more products) in this thesis, smokers concurrently using two or more than two tobacco products have become increasing common.

The Increasing Diversity and Growing Market

Increasing dual and poly-tobacco use is likely due to the rise of the variety, marketing, and availability of non-cigarette tobacco products. Younger dual/poly-users, for example, were found to be more exposed to tobacco product marketing than cigarette only users[25]. Although cigarette sales and use have dropped over the last decades[10], sales of non-cigarette tobacco products such as cigars and loose tobacco, moist snuff, SLTs and ENDS have grown over time[26-28].

Cigarette smoking in conjunction with one or more tobacco products accounts for the vast majority of adult dual and poly-tobacco use[29]. According to a study in the US, 37.8% of

adult tobacco users (10% of the US adult population) were using two or more tobacco products concurrently, with the most common combinations being dual use of cigarettes with ENDS (23%); hookah (6%); cigarillos (5%)[29]. This phenomena, however, is more prominent in low-income countries[30], especially among the male population. Approximately 63.6% of males in Southeast Asia were currently using at least one tobacco product, with 7.5% being dual-users of cigarettes and ATPs[30]. In comparison to European countries, cross-county analysis showed a higher prevalence of poly-use among males in Southeast Asia, the Western Pacific, and Africa, with larger variability of product use among smokers in lower SES areas[31, 32]. As a result, dual and poly-tobacco use has become a global public health concern.

Health Impact of Dual & Poly-Tobacco Use

With the increasing diversity of ATPs, cigarette smokers who additionally use other tobacco products may be faced with increased health risks compared to those using single tobacco product. For example, people who use one tobacco product are potentially diversifying their tobacco product use to maintain levels of nicotine[33]. Study reported the levels of serum cotinine are found to be similar for dual users of smokeless tobacco and cigarettes as for people who smoke daily[34].

Although the long-term health consequences of dual and poly-use are not yet well understood[35, 36], the use of multiple tobacco products has been linked to increased nicotine dependency compared to single product use, which might impact cessation intentions and success[37, 38]. Additionally, cigarette smokers who are dual/poly-users may smoke as many as or more cigarettes per day than exclusive cigarette smokers[39-41], leading to increasing exposures to tobacco toxicants[34, 42] and placing them at greater risk of cardiovascular disease than exclusive cigarette smokers[43].

ENDS may be used concurrently by cigarette smokers as a mean to help them quit smoking[44, 45]. Whilst ENDS may be less hazardous than combusted cigarettes[46], they are addictive and are not without harm. However, the use of ENDS is not within the scope of my thesis, given that they contain nicotine but are not necessarily regarded as "tobacco products". Nevertheless, the health risks and regulatory policies regarding dual use of cigarettes and ENDS may be an important area of study in the field.

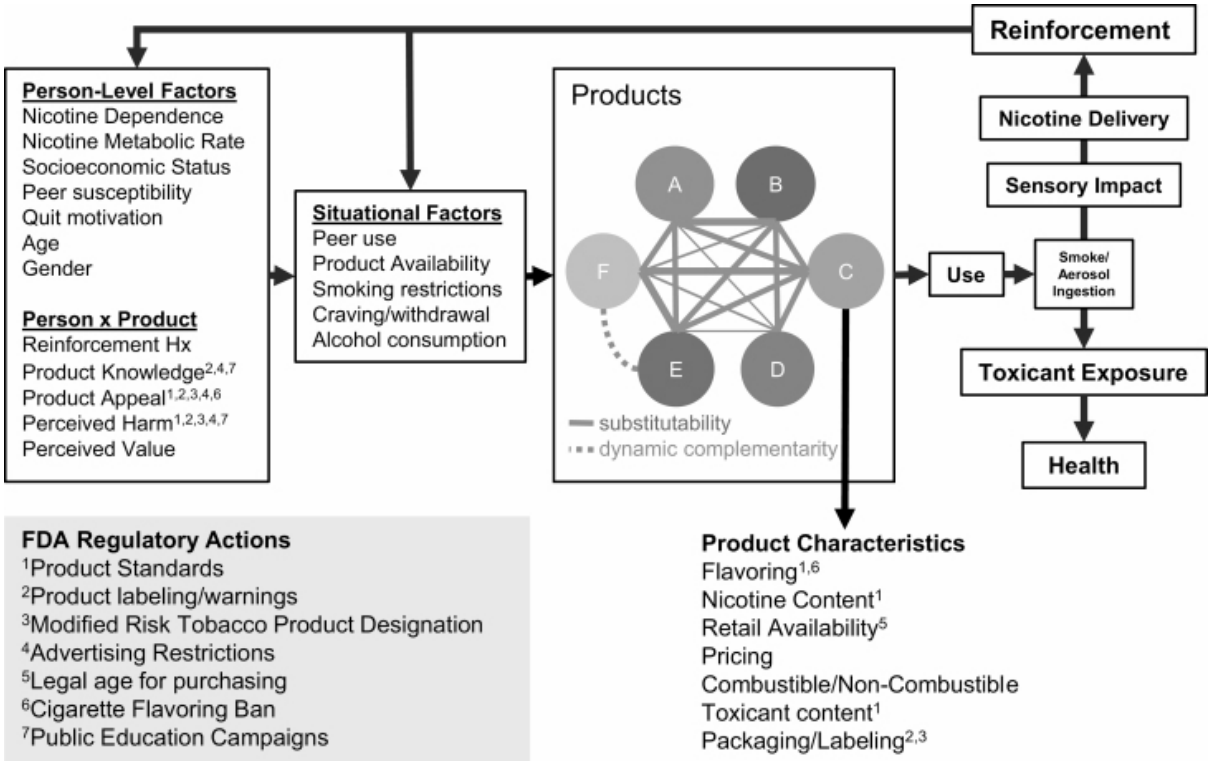
1.3.2 The Conceptual Model of Multiple Tobacco Product Use by Pacek et al.

Conceptual Framework

To understand the factors that influence the use of multiple tobacco products, Pacek et al. presented a conceptual framework – the conceptual model of multiple tobacco product (MTP) use [35, 47]. In Figure 2 below, the MTP model shows the person, product (represented by circles A–F in the Products box), and context/situational factors (and interactions between these factors) that interact in the process of transition/substitution (solid lines) between products. This model can be a useful illustration when considering various potential factors and characteristics in the evaluation of dual and poly-tobacco use, which is also the primary framework upon which the research questions in this thesis are based.

The framework is intended to help researchers understand the dynamics that lead to MTP use, as well as how/when MTPs are used and/or discontinued. The variables depicted in the Figure below are non-exhaustive examples of characteristics that impact MTP use within each category listed. Given the focus of this thesis, I would mainly focus the MTP model on dual tobacco-product use, and the use and transition of products among current tobacco users in the following chapters. The MTP model may also be used to better understand how different regulatory measures target certain factors in order to better understand where such actions might have an impact and how such actions on one STP affect the consumption of other tobacco products[47]. This conceptual framework incorporates and synthesises concepts from several health behaviour theories (eg, the Health Belief Model[48], Reasoned Action[49], Planned Behaviour Theory[50]), and also modern literatures such as marketing[51] and behavioural economic[52] literature.

Figure 2: Conceptual framework of factors contributing to multiple tobacco product use, reprinted from Pacek et al.



Conceptual model of multiple tobacco product use and the levels at which Food and Drug Administration of the U.S. (FDA) regulatory actions have their impact. In the proposed conceptual model, the magnitude of substitution (solid lines) between products varies as a function of Person, Product (represented by letters A–F in the Products box), and Context/Situational factors (and interactions between these factors). Reinforcement histories with single tobacco products update Person and Context/Situational factors. Dynamic complementarity between products (dotted line) exists when one product is used in contexts/situations in which there are costs associated with using another product. FDA regulatory options are displayed in the grey inset and components of the conceptual model targeted by these actions are indicated with superscripts.

Transition of Tobacco product Use

One key concept of the MTP model is that current tobacco users may, under the influence of various people, products, or contextual/situational factors, adopt the use of other commercially available products and transition completely (substitution) or partially (in combination of the use of current products) to the use of other products. In practice, some proportion of current tobacco-product users who adopt the use of an alternative product will "transition" between different products and become dual or poly-tobacco users[35]. This transition of tobacco product use is also an important aspect I plan to investigate in this thesis.

Tobacco product use transitions (or substitution) have been previously explored in tobacco economics studies to understand tobacco demand and price relationships[52-54], and in behavioural pharmacology studies to investigate the influence of consuming one nicotine-containing product on the use of other products under varied levels of craving and product availability[55, 56]. However, from a wider perspective, population-based evidence on transitions of different tobacco use pattens and products is still lacking[47]. Therefore, this is also one of the main areas this thesis aimed to explore.

Established Factors Associated with Dual & Poly-Tobacco Use

According to the framework, person, product, and contextual/situational factors, together with their interactions affect tobacco product use. The framework facilitates the understanding of the mechanisms that lead to multiple tobacco products use, and how the factors influence the initiation and termination of use in an individual (see for illustrated framework by Pacek et al.). The section below includes a brief review of selected variables associated with each of these factors in the three broad categories.

- Person-level factors

On the personal (individual) level, tobacco use behaviours are affected by various sociodemographic – particularly SES, income, age, gender, ethnicity, migratory background[57], and other psychosocial factors such as stress and mental health status[58-60]. To date, limited work has examined sociodemographic factors associated with multiple tobacco use, and most of the studies have been done in the US. Poly-tobacco use was found to be more prevalent among young adults whose parent had a high school or lower educational attainment than those whose parent's educational attainment was college or higher[5, 61]. Adult poly-tobacco users in the US were more likely to be male than female and non-Hispanic white than other ethnic minority according to studies[40, 62, 63]. As poly-tobacco use patterns differ across sociodemographic sub-populations, and the user profiles also vary across wide range of tobacco products, it is important to capture these differences among users with different SES backgrounds, which likely have implications to tackle health inequality.

- Product characteristics

On the market, tobacco products exhibit a variety of distinct characteristics, including, but not limited to, flavours, nicotine content, packaging, advertisements, and marketing of products. Each of these elements further interacts with the person-level and determines the attractiveness of a product, risk perceptions, and how an individual user consumes each product, which greatly impacts selection or patterns (single, dual, or poly-use) of tobacco use behaviours[47].

- Contextual/situational factors

On a contextual level, smoking is also influenced by social norms on the interpersonal-level and country-level tobacco control interventions (i.e., smoking bans, cigarette prices, etc.) or the society's social support for tobacco control regulations[64, 65] on the socio-political level[65-68]. Other contextual factors including, peer influences, product availability, and country-specific tobacco control measures (smoke-free laws, cigarette pricing, warning labels and packaging etc.) may all impact tobacco use. For example, smoking bans are not only shown to protect non-smokers from second hand smoke, but also to motivate tobacco users to quit, as well as prevent the transition or initiation of smoking[8]. Strong, comprehensive smoking bans can also assist reduce cigarette use among current smokers and develop strong social norms against smoking at the contextual level. Many other tobacco control initiatives, particularly those that have a large population impact, such as price and anti-advertising campaigns, are expected to have comparable direct and indirect impacts on tobacco use that work through society, community, and other contextual factors[69].

- Interactions between individual and contextual factors

The impact of broader factors on multiple tobacco use patterns also plays an important role in multiple tobacco product use, but is rarely explored in the literature. LMICs or economically developing countries such as Southern or Southeast Asian, Africa, and Southern American countries are characterised by considerable ethnic diversity. Population residing in these societies are heterogeneous, comprising people from different countries of origin, with different cultural norms, health profiles, and a more vulnerable status to being affected by the combined effects of individual-level SES factors and differences in smoking behaviours between countries.

Interactive factors such as neighbourhood environment and cross-border tobacco marketing, as well as migrant status, could represent another important underpinning of interaction between individual and contextual factors influencing social inequalities in smoking[70]. Increased knowledge of whether there is a socioeconomic gradient in smoking among these population could aid preventative measures that consider these integrative factors.

1.3.3 The Impact on Tobacco Control Policies

Given the different stages of the tobacco epidemic and tobacco control regulations in different countries, integrating knowledge of the factors mentioned above regarding personal, product and contextual-level characteristics, and cross-country variations in tobacco use, may provide important information to strengthen regional tobacco control policy integration and reinforce their impact in effectively combating the tobacco epidemic.

Evidence suggests that tobacco control measures had unequal impacts on smoking behaviour across different social classes[71]. It's likely because conventional tobacco control strategies don't always aim at the most vulnerable members of society, as characterised by race/ethnicity, gender, income[72, 73]. A review of tobacco control interventions on socioeconomic inequalities in smoking found strong evidence that increases in tobacco prices have a pro-equity effect on socioeconomic disparities in smoking. However, results for mass media campaigns and smoking cessation support services were inconclusive. It appeared that these measures studied were less effective at reducing inequalities in smoking without making specific efforts to reach disadvantaged populations and communities including migrant population[57, 74].

It's possible that targeted tobacco control measures in these populations might help reduce smoking inequities, but there are still efforts to be made in designing support programmes that are specifically tailored to those with low SES. Tobacco control policies are usually multi-faceted with several interventions developing in parallel across different jurisdictions. Therefore, implementation gaps may exist across borders or jurisdictions, which reflects a broader challenge in delivering effective measures to tackle smoking inequalities among the high-mobility migrant population[74]. Reducing inequalities in tobacco use is critical, thus public health initiatives and policies aiming at reducing smoking should pay special attention to this.

Furthermore, most tobacco control policies across the globe tend to focus mostly on manufactured cigarettes[75]. This might lead to inconsistencies in regulatory policy for poly-tobacco users, as these users are prone to use ATPs with or without the concurrent use of cigarettes, that fall outside of regulatory authority. As a result, establishing evidence regarding the use of dual and poly-tobacco use is essential, and it might have implications for tobacco control policy and practices, as well as reinforcing regulations on ATPs. As proposed in the MTP model, regulations and policy actions at different points may have their impact on influencing multiple tobacco product use among tobacco users[47]. Product characteristics are influenced by policy and regulatory decisions, which interact with person-level factors to affect use. For example, introducing or raising a tobacco tax increases the price of tobacco products, which would in turn impact both the users' perception of the value of the product and its use as an alternative or substitute product. Based on this concept, regulatory actions can affect dual and poly-tobacco use by exerting influence on the framework variables. However, research on the effects of regulatory policies on dual and poly-tobacco product use is still in its infancy. Thus it should be a priority to explore how regulating one or more products affects the use of other products in a representative group of multiple tobacco product users.

This thesis focuses on some of the challenges posed by multiple (dual/poly-use) tobacco product use to the reinforcement of effective regulations. In relation to the MPOWER measures, for example: concurrent use of different tobacco products increases the complexity of monitoring tobacco use; smokefree legislation may be less effective as smokers may use alternative products to circumvent bans and may also deter cessation; emerging novel products may impede the reinforcement of product regulation on warning labels and advertisements; and last but not least, it makes the tobacco tax structure difficult to cover all products and be less effective in reducing consumption of tobacco products.

1.4 Statement of Problems

Comparing to other research areas in the tobacco control regulation, disproportionately small percentage of research has focused specifically on the question of dual and poly-tobacco use. Furthermore, existing research on dual and poly-tobacco use has important limitations. The definitions of the term "dual-use" and "poly-use" varies widely in different studies. Varying

definitions may cause inconsistency across research, reducing the comparability of prevalence estimates and introducing discrepancies across prevalence reported.

Next, the global extent of prevalence and the determinants of dual and poly tobacco use is poorly described. Recent studies on dual/poly-use employed a variety of surveys. Most of them were specific to the US populations (e.g., the National Adult Tobacco Survey [NATS]; the Population Assessment of Tobacco and Health [PATH], and the National Health Interview Survey [NHIS]) and few of them were international studies (e.g., the Global Adult Tobacco Survey [GATS], the Eurobarometer and the Demographic and Health Survey [DHS]). Although these large-scales surveys are designed to be nationally representative, prevalence estimates of tobacco product use obtained from each survey still vary based on survey methodology [76] and many of them do not necessarily contain information on dual/poly-use, making the estimate of global prevalence challenging.

To improve tobacco control science, it is important to disaggregate product use characteristics by SES or differentiate dual and poly-use product combinations to facilitate the evaluation of the prevalence of product use across sociodemographic sub-groups and their potential influence on health inequalities, especially in LMICs. For example, it's unclear if socioeconomic inequalities in smoking have the same impact on the growing migrant population in LMICs as they do on other disadvantaged groups. As a result, using nationally representative data to gain a better understanding of the socioeconomic gradient in tobacco use among the disadvantaged, may help guide the development of national preventative measures that target health inequities in these populations. Furthermore, discerning the sociodemographic profiles and product-related features that lead to dual/poly-tobacco use, as well as the transitions of use between different products may also aid in the development of preventative treatments and tobacco control policies to curb dual and poly-tobacco use and eventually decrease population-level harm associated with tobacco use.

1.5 Research Aims and Objectives

The thesis aims to first systematically review existing epidemiologic evidence on current dual and poly-tobacco use among adults globally. Then explore the patterns of poly and dual tobacco product use among the predominant smoking population of adult male respondents in LMICs

in different geographical regions using the latest wave (wave 7 survey 2013-2018) of the Demographic and Health Survey (DHS) to examine potential correlates of the patterns of poly-tobacco use at the individual and the country level as well as the migrant population. Next, an in-depth case study of poly-tobacco use was conducted using International Tobacco Control Policy Evaluation Project (ITC)- Bangladesh dataset. The survey consists of 4 waves (2009 to 2015) with a longitudinal cohort which will be longitudinally investigated for factors related to transitions of different tobacco use pattens and products within population subgroups.

The specific objectives of this thesis are:

- Assess available prevalence estimates of global dual and poly-tobacco use
- Review definitions of dual and poly-tobacco use in the literature
- Estimate the prevalence of dual and poly tobacco use among men in LMICs and their potential associations with individual and country level factors
- Explore the association between migration and tobacco use among men in LMICs
- Examine transitions of dual and poly-tobacco use in a longitudinal sample of male smokers in Bangladesh and the associated factors of transitions from one product to the other

Chapter 2: Systematic Literature Review

To investigate the global patterns and prevalence of dual and poly-tobacco product use, a systematic literature review of published evidence was conducted. The findings of the systematic review are presented, followed by an overview of the studies identified and the evaluation of common definitions of dual and poly-use in the literature. Finally, the gaps in the literature are explored, as well as the ways in which these deficiencies will be addressed in this thesis. The study was carried out between 2018 and 2020, and published in 2021 *in Nicotine and Tobacco Research*[77]. I am the primary and the first author of the published research paper derived from this thesis chapter. However, the paper derived from this thesis chapter is based on collaborative work. The co-authors of the published paper mentioned above are outlined as follows: my PhD supervisors, Filippidis FT, and Millett C, helped to conceive the study idea, design and implement the searches. The second and third co-authors, Girvalaki C, and Mechili EA contributed to screening the studies and extracted data. All authors reviewed the manuscript, provided comments, and were involved in the interpretation of data and revision for critical intellectual input.

2.1 Global Patterns & Prevalence of Dual and Poly-Tobacco Use

In recent years, the increasing variety, availability, and expanding market of alternative tobacco products such as waterpipes (hookah)[38] and cigars[78], as well as smokeless tobacco (SLT) products[27], has resulted in a rise in the prevalence of concurrent use of various tobacco products[38]. The dual and poly-use of tobacco products among smokers has become an important field of interest in both health behaviour studies and tobacco control science[36]. As a result, gaining a better knowledge of the epidemiology of dual and poly-tobacco use is critical. As it may provide researchers better understanding on the public health burden of these phenomena, and also have significant implications for policy and practise in developing effective tobacco control regulations for alternative tobacco products.

However, knowledge on worldwide patterns and trends of dual and poly-tobacco use among smokers in various countries and economic contexts is presently limited, and the definitions used to describe concurrent use of multiple tobacco products in the literature are not unified.

Furthermore, the number of dual/poly-use prevalence studies has increased in recent years; however, they have not any systematic analyses.

A large number of studies were performed in developed nations, with an emphasis on the subnational level (e.g., college students, young adults or current smokers), or users with specific characteristics (e.g., among cancer patients or those with substance abuse histories) rather than at a nationally representative level. This is particularly relevant in the research of dual and poly-tobacco use when the national prevalence of use is of interest, especially in comparing patterns of use between studies and across countries.

The objective of this study was to systematically review existing epidemiologic data on current dual and poly-tobacco use among adults across the world through a systematic review of existing literature in order to: (i) assess the best available prevalence estimates and (ii) analyse the literature's definitions of dual and poly-tobacco product use.

2.2 Methods

A systematic review of literature published up to June 30, 2020 was carried out to address the aim of the study. The evaluation was designed using the PRISMA methodology[79] as a reference. Quantitative studies with measures of prevalence of current dual (concurrent) or poly (multiple) tobacco use with a focus on any nationally representative samples of the adult population worldwide were included. Prevalence estimates of each country were extracted manually and stratified by the World Health Organization (WHO) regions and World Bank income classifications.

2.2.1 Search strategy

With language limits set to English, Ovid for Medline, Embase, and Global Health databases were searched using Ovid on Imperial College Library computers. For the search terms, the adjacency operator, "adj1," was used to limit the terms next to "tobacco," "smoking," "nicotine," "cigarette," "combustible," or "smoke/smoking" in any order, as well as synonyms and other variations describing use of multiple tobacco products, such as "alternative," "poly,"

"concurrent," and "dual." Table in Appendix 1 shows an example of the search method employed. Additionally, the reference lists of included publications and review papers were hand-searched. The Google Scholar function was also used to manually identify new publications.

2.2.2 Eligibility Criteria

Inclusion criteria

Studies were eligible for inclusion if they meet the Population, Outcome, and Study design criteria of the PICOS framework[80] as follows:

(i) Population: nationally representative study sample of the adult population (defined as greater or equal to 18 years old).

(ii) Outcomes: any measure of the prevalence of "current" dual tobacco use (concurrent use of two tobacco products) or poly-tobacco (concurrent use of more than two tobacco products). It is important to note that "tobacco products" in this study refer to products containing tobacco including manufactured cigarettes, roll your own tobacco (considered as the same category as manufactured cigarettes), pipe tobacco, cigars, cigarillos, smokeless tobacco and herbal tobacco products for smoking. The use of vaporizers, e-cigarettes, and other Electronic Nicotine Delivery Systems (ENDS) were not evaluated in the current study as it is not by definition categorised as a tobacco product.

(iii) Study design: quantitative studies with prevalence estimates of tobacco use.

Exclusion criteria

Studies that met the following criteria were eliminated from the investigation based on the preceding criteria:

(i) Population: prevalence estimates of subgroups that were not representative of the overall adult population in the studies. For example, adolescents or tobacco users from a particular socioeconomic background or with pre-existing physical or mental health problems.

(ii) Outcomes: studies with mixed estimates, in which the prevalence of the various tobacco products used could not be extracted, or studies lacking measurements of the prevalence of

dual or poly-tobacco use. Studies that reported concurrent use of non-tobacco drugs (i.e., drugs, marijuana) as well as ENDS such as e-cigarettes were excluded as well, since they include nicotine rather than tobacco.

(iii) Study design: studies that weren't categorised as original research were excluded. Studies for which complete text could not be retrieved, despite consulting a medical library or contacting the relevant author, were excluded as well.

2.2.3 Data Extraction

Study Selection

Duplicates were eliminated from the results of the literature searches. With the assistance of the other two co-authors (CG and EM), we screened separately in pairs to evaluate the titles to find possibly suitable articles for this review. Publications that were not relevant were excluded. The abstracts of publications that were thought to be possibly eligible were retrieved after examination. The full text of the articles that were considered relevant was downloaded and reviewed in pairs in a thorough manner. Disagreements about study eligibility were settled via discussion among the three of us or with the help of my PhD supervisor (FTF) as the fourth reviewer.

Data Extraction

The following information of the eligible studies were extracted: (1) authors and years of publication; (2) study design; (3) sample size; (4) name of the survey or dataset; (5) country surveyed; (6) age of the population; (7) year of the survey conducted; (8) prevalence of each tobacco product assessed; (9) prevalence of different combinations of tobacco products used; (10) operationalized definition of dual and poly-tobacco use; (11) prevalence of dual and poly-tobacco product use.

Current tobacco product use was defined as past 30-day use in the study. I also sought for additional unpublished data from the relevant authors where the prevalence of particular tobacco products could not be derived from data provided in the article. When there were several publications with prevalence statistics from the same sample or research within a nation, only the latest estimate for the nation was included in our study.

Data Analysis

Countries were categorised as: African countries, American countries, Southeast Asian countries, European countries, Eastern Mediterranean countries, and Western Pacific countries according to WHO regions. I further present results in four country groups based on national income levels, as defined by the World Bank[81]: high-income countries (HIC), upper-middle-income countries (UMIC), lower middle-income countries (LMIC), and low-income countries (LIC).

Weighted prevalence estimates of individual tobacco products and combinations of different tobacco product use are presented. Single tobacco product use and poly/multiple tobacco product use among the adult population of every country in eligible publications were reported as well. Wherever possible, weighted prevalence was selected and used to ensure that it is nationally representative. The most current prevalence estimate typical of each nation is given when several estimates were available.

2.3 Results

There were 6,315 publications identified. After 3,824 duplicate citations were removed, 2,491 possibly eligible studies were screened. The flow chart of study selection is shown in Figure 3 as below along with the reasons for excluding articles. During selection, 2,270 papers did not match the inclusion criteria, and 221 articles were identified as potentially suitable; their abstracts were retrieved and evaluated for final review inclusion. After final decisions, the study includes a total of 20 studies[19, 29-31, 38, 39, 82-95] from 48 nations, comprising about 53% of the world population, providing nationally representative prevalence data on current dual or poly-tobacco product usage in the adult population. Among all selected studies, nineteen of the investigations were conducted in a cross-sectional manner, except for one which is longitudinal[29]. The characteristics of the included studies are summarised in Table 1 below.

Table 1: Summary of the included studies by country and region

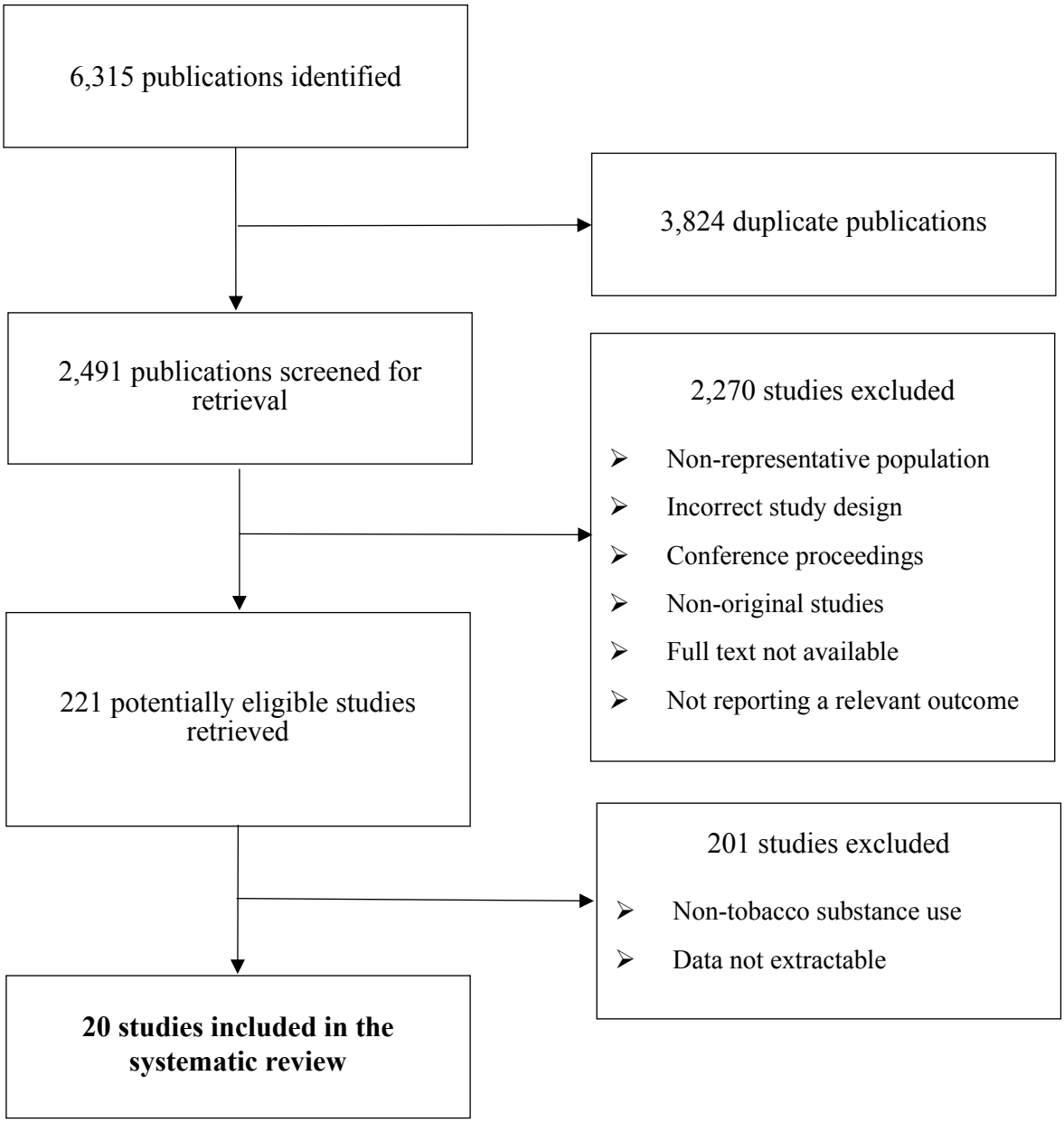
Region, Country	Authors, Year of Publication	Survey Year/Period	Survey Name	Sample Size	Dual/Poly tobacco Use	
					Dual use	Poly use
South East Asia Region						
Bangladesh	Sinha D.N. et al., 2016[30]	2007	DHS	10,400	✓	
	Palipudi K.M. et al., 2012[19]	2009	GATS	9,629	✓	
	Agaku I.T. et al., 2014[31]					✓
	Zaman M.M. et al., 2014[84]	2010	N/A	4,312(men)	✓	
Indonesia	Agaku I.T. et al., 2014[31]	2011	GATS	8,305		✓
	Sinha D.N. et al., 2016[30]	2012	DHS	43,852	✓	
India	Sinha D.N. et al., 2016[30]	2005/6	DHS	109,041	✓	
	Singh A. et al., 2014[83]	2009/10	GATS	69,296	✓	
	Palipudi K.M. et al., 2014[19]				✓	
	Agaku I.T. et al., 2014[31]					✓
	Jawad M. et al.,2 014[82]				✓	
Maldives	Sinha D.N. et al., 2016[30]	2009	DHS	6,443	✓	
Nepal	Sinha D.N. et al., 2016[30]	2011	DHS	10,826	✓	
Timor-Leste	Sinha D.N. et al., 2016[30]	2009/10	DHS	11,463	✓	
Thailand	Palipudi K.M. et al., 2012[19]	2009	GATS	20,566	✓	
	Agaku I.T. et al., 2014[31]					✓
Western Pacific Region						
China	Palipudi, K. M. 2012[19]	2010	GATS	13,354	✓	
	Agaku, I. T. 2014[31]					✓
Malaysia	Agaku I.T. et al., 2014[31]	2011	GATS	4,250		✓
Philippines	Palipudi K.M. et al., 2012[19]	2009	GATS	9,701	✓	
	Agaku, I. T. 2014[31]					✓
Viet Nam	Palipudi K.M. et al., 2012[19]	2010	GATS	9,925	✓	
	Jawad M. et al., 2014[82]				✓	
	Agaku I.T. et al., 2014[31]					✓
Eastern Mediterranean Region						
Egypt	Palipudi K.M. et al., 2012[19]	2009	GATS	20,924	✓	
	Jawad M. et al., 2014[82]				✓	
	Agaku I.T. et al., 2014[31]					✓
African Region						
Nigeria	Agaku I.T. et al., 2014[31]	2012	GATS	9,765		✓
European Region						
Poland	Palipudi K.M. et al., 2012[19]	2009	GATS	7,840	✓	
	Agaku I.T. et al., 2014[31]					✓
France	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,059		✓
Belgium	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,051		✓
Netherlands	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,014		✓
Germany	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,552		✓
Italy	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,036		✓
Luxembourg	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	501		✓
Denmark	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,019		✓
Ireland	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,008		✓
United Kingdom	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,331		✓
Greece	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	999		✓
Spain	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,004		✓
Portugal	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,009		✓
Finland	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,003		✓
Sweden	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,016		✓
Austria	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,031		✓
Cyprus	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	506		✓
Czech Republic	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,003		✓
Estonia	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,000		✓
Hungary	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,021		✓
Latvia	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,024		✓
Lithuania	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,021		✓
Malta	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	500		✓

Slovakia	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,000		✓
Slovenia	Agaku I.T. et al., 2014[31]	2012	Eurobarometer	1,017		✓
Bulgaria	Agaku I.T. et al., 2014[31]	2011	Eurobarometer	1,006		✓
Ukraine	Palipudi K.M. et al., 2012[19]	2010	GATS	8,158	✓	
	Agaku I.T. et al., 2014[31]					✓
Romania	Agaku I.T. et al., 2014[31]	2011	Eurobarometer	4,517		✓
Russian Federation	Palipudi K.M. et al., 2012[19]	2009	GATS	11,406	✓	
	Jawad M. et al., 2014[82]				✓	
	Agaku I.T. et al., 2014[31]					✓
Turkey	Palipudi K.M. et al., 2012[19]	2008	GATS	9,030	✓	
	Agaku I.T. et al., 2014[31]					✓
American Region						
Mexico	Palipudi K.M. et al., 2012[19]	2009	GATS	13,617	✓	
	Agaku I.T. et al., 2014[31]					✓
Uruguay	Palipudi K.M. et al., 2012[19]	2009	GATS	5,581	✓	
	Agaku I.T. et al., 2014[31]					✓
Brazil	Agaku I.T. et al., 2014[31]	2008	GATS	39,425		✓
Argentina	Agaku I.T. et al., 2014[31]	2010	GATS	6,645		✓
United States	Mumford E.A. et al., 2006[89]	1992/93,1995/96,1998/99,2000,2001/02	TUS-CPS	374,335	✓	
	BackingerC.L. et al., 2008[85]	1995/96, 1998, 2000, 2001/02	TUS-CPS	552,804	✓	
	Tomar S.L. et al., 2010[39]	2006	TUS-CPS	67,293(men)	✓	
	Mushtaq N. et al., 2012[90]	2010	BRFSS	170,114	✓	
	Grinberg A. et al., 2016[87]	2010/11	TUS-CPS	85,545	✓	
	Lee Y.O. et al., 2014[38]	2012	NATS	3,627	✓	✓
	Sung H.Y. et al., 2016[92]	1998, 2000, 2005, 2010	NHIS	117,816	✓	✓
	Wang Y. et al., 2017[94]	1998, 2000, 2005, 2010	NHIS	123,399	✓	
	Roberts M.E. et al., 2017[91]	2013/14	PATH	32,320	✓	✓
	Kasza K.A. et al., 2017[29]	2013/14	PATH	32,320		✓*
	Weaver S.R. et al., 2016[95]	2014	TCORS	5,717	✓	
	Syamlal G. et al., 2017[93]	2014-2016	NHIS	59,690※		✓*
	Jones D.M. et al., 2018[88]	2015/16	TCORS	12,065	✓	
	Creamer M.R. et al., 2019[86]	2018	NHIS	25,417		✓*
Total						
48 Countries	**20 Studies**	**1996-2018**	**11 Datasets**	**2,165,464**		

* referred as multiple tobacco product use in corresponding studies. ※ sample restricted to working adults.

Abbreviations: DHS: Demographic and Health Surveys; GATS: The Global Adult Tobacco Survey; NSDUH: National Surveys on Drug Use and Health; NATS: National Adult Tobacco Survey; TCORS: Tobacco Products and Risk Perceptions Survey; NHIS: National Health Interview Survey; TUS-CPS: Tobacco Use Supplement-Current Population Survey; PATH: Population Assessment of Tobacco and Health; BRFSS: Behavioral Risk Factor Surveillance System; N/A: locally conducted survey w/o survey name.

Figure 3: Flow diagram of the study selection



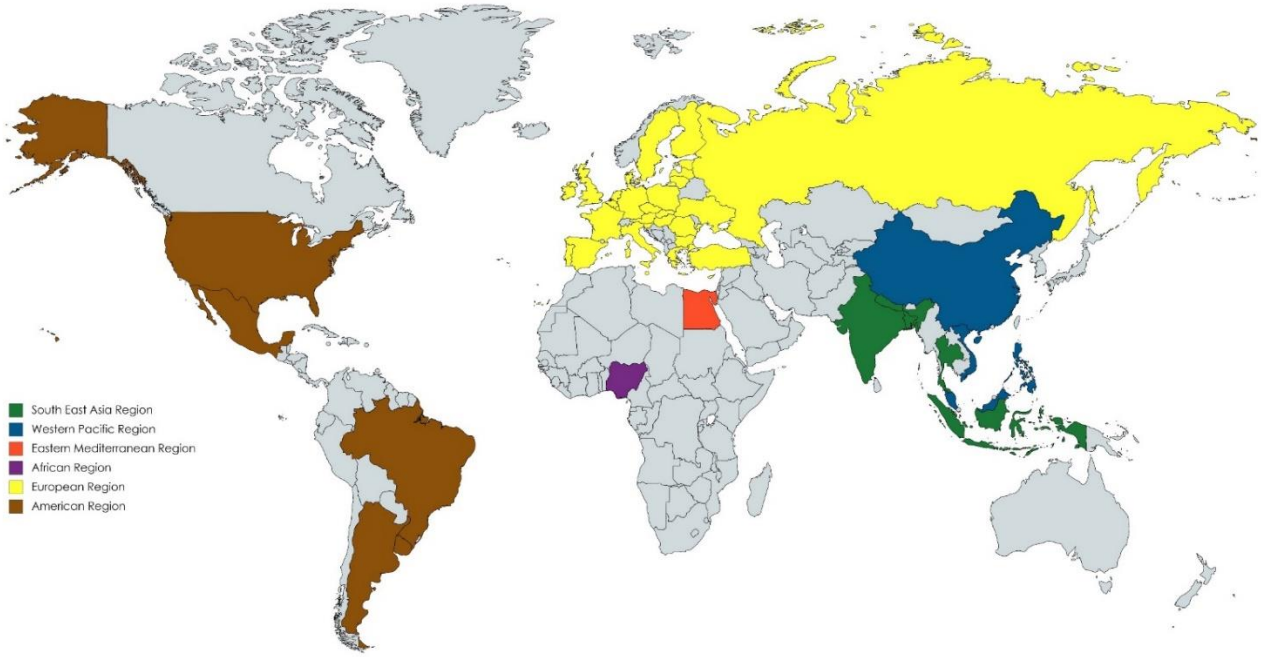
Data from all six WHO areas were included in the current study. Thirty of the countries featured are in Europe, seven in Southeast Asia, five in America, four in the Western Pacific, one in the Eastern Mediterranean, and one in Africa. We obtained prevalence estimates from 1992 to 2018 in the US and from 2005 to 2012 in the other countries, with a total sample size of 2,165,464. Of all, fourteen of the twenty studies are national representative surveys from the United States[29, 38, 39, 85-95], with almost one-third of them analysing the National Health Interview Survey (NHIS); six non-US studies[19, 30, 31, 82-84] largely employed the Global Adult Tobacco Survey (GATS). Only males were included in two studies[39, 84] with available prevalence estimates. All of the studies reported on dual (concurrent) or poly (multiple) tobacco product use, with three studies[38, 91, 92] reporting both.

2.3.1 The Epidemiology of Dual & Poly Tobacco Use

A graphical map of the 48 nations included in the review is shown in

Figure 4 as below. All 20 studies included information on current single tobacco use as well as a variety of other tobacco products among adults. As the prevalence estimates of single tobacco product use of the studies reviewed was not the main aim of the study, the results are presented in Appendix 2.

Figure 4: Map of the countries included in the review



The first objective of the study is to assess prevalence available in the literature.

Table 2 below presented the most recent estimates of dual and poly-tobacco product consumption in each nation, stratified by the WHO region. As listed below, the most recent prevalence data of dual use of smoked and smokeless tobacco products varies from 0.2% in Ukraine and Mexico[19] to 17.9% among males in Nepal[30]. When prevalence stratified by sex was available in studies from four Southeast Asian countries (Indonesia, Maldives, Nepal,

and Timor-Leste), the proportion of dual users among males was at least twofold higher than that among females[30]. As for specific combinations of product use, five nations reported the combination of dual cigarette and hookah/waterpipe use[29, 82], which was 6.0% in the United States, 2.6% in Russia and Vietnam, 0.4% in Egypt, and 0.3% in India during 2009, 2010.

On the other hand, adult poly-tobacco use was reported in six studies with data from 45 countries[19, 30, 31, 82-84]. According to the findings of these studies, prevalence ranged from 11.9% in Denmark and 11.4 % in the United Kingdom in 2012 to 0.8% in Mexico in 2009 and 0.9% in Argentina in 2010[31]. From 1992 to 2016, eleven studies in the United States[38, 39, 85, 87-92, 94, 95] assessed the prevalence of dual use, while six studies estimated the prevalence of poly use from 1998 to 2018[29, 38, 86, 91-93].

Table 2: Prevalence estimates of current dual & poly-tobacco use among adults by country and region

Region, Country	Income level	Survey Year	Current Dual/ Poly-Tobacco Use[1,2] (%)	
			Dual Use#	Poly Use*
South East Asia				
Bangladesh[19, 31]	LIC	2009	6.8	8.8
Indonesia[30, 31]	LMIC	2012	M:0.2; F:0.1	4.6
India[ж][19, 31, 82, 83]	LMIC	2009/10	5.3	6.5

Maldives[30]	UMIC	2009	M:1.5; F:0.03	—
Nepal[30]	LMIC	2011	M:17.9; F:1.5	—
Timor-Leste[30]	LMIC	2009/10	M: 2.6; F:0.8	—
Thailand[31]	UMIC		0.4	5.9
Western Pacific				
China[19, 31]	UM	2010	0.4	2.1
Malaysia[31]	UM	2011	—	5.4
Philippines[19, 31]	LMIC	2009	0.7	1.8
Viet Nam※[19, 31, 82]	LMIC	2010	0.1	3.5
Eastern Mediterranean				
Egypt※[19, 31, 82]	LMIC	2009	1.9	2.7
African				
Nigeria[31]	LMIC	2012	—	1.5
European				
Austria[31]	HIC	2012	—	10.6
Belgium[31]	HIC	2012	—	9.0
Bulgaria[31]	UMIC	2011	—	5.1
Cyprus[31]	HIC	2012	—	10.8
Czech Republic[31]	HIC	2012	—	9.1
Denmark[31]	HIC	2012	—	11.9
Estonia[31]	HIC	2012	—	7.9
France[31]	HIC	2012	—	10.4
Finland[31]	HIC	2012	—	9.8
Germany[31]	HIC	2012	—	9.5
Greece[31]	HIC	2012	—	10.5
Hungary[31]	UMIC	2012	—	7.8
Italy[31]	HIC	2012	—	5.3
Ireland[31]	HIC	2012	—	7.1
Luxembourg[31]	HIC	2012	—	8.7
Latvia[31]	HIC	2012	—	10.0
Lithuania[31]	HIC	2012	—	5.9
Malta[31]	HIC	2012	—	9.1
Netherlands[31]	HIC	2012	—	9.3
Poland[19, 31]	HIC	2009	0.3	2.4
Portugal[31]	HIC	2012	—	6.2
Romania[31]	UMIC	2011	—	1.7
Russian Federation※[19, 31, 82]	HIC	2009	0.4	6.0
Spain[31]	HIC	2012	—	9.0
Sweden[31]	HIC	2012	—	5.2
Slovakia[31]	HIC	2012	—	4.7
Slovenia[31]	HIC	2012	—	5.2
Turkey[19, 31]	UMIC	2008	—	3.7
Ukraine[19, 31]	LMIC	2010	0.2	3.4
United Kingdom[31]	HIC	2012	—	11.4
American				
Argentina[31]	UMIC	2010	—	0.9
Brazil[31]	UMIC	2008	—	3.1
Mexico[19, 31]	UMIC	2009	0.2	0.8
Uruguay[19, 31]	HIC	2009	—	5.0
United States※[29, 86]	HIC	2018	4.0¶	3.7

Note:

1.Current use was determined as participants who had smoked or used the product in the previous 30 days.

2.Table summarises prevalence estimates weighted from various studies and surveyed years, and therefore, figures may not be directly comparable between each usage groups.

3.Table presents most recent prevalence estimates available of each country and product use.

dual use: smoking + smokeless tobacco; * poly use: consuming two or more tobacco products; — data not available;

¶ dual use of cigarettes+smokeless tobacco; ※ percentages of cigarette + hookah/waterpipe dual use: India=0.3%; Viet Nam=2.6%; Egypt=0.4%; Russian Federation=2.6%; United States=6.0%.

Abbreviations: M: male; F: female; LIC: Low Income Countries; LMIC: Lower-Middle Income Countries; UMIC: Upper-Middle Income Countries; HIC: High Income Countries

Table 3 below highlights the most recent prevalence estimates from fourteen studies published in the United States over the last two decades on the prevalence of various tobacco products among adults[29, 38, 39, 85-95]. According to studies, the prevalence of various combinations of two tobacco products, such as cigarettes and smokeless tobacco, cigarettes and cigars or cigarillos, has varied over the last decade across different studies[29, 38, 95]. In 2013-2014, estimates of poly-tobacco use (i.e., the use of three or more tobacco products) were very high among current adult tobacco users, with an estimated prevalence of 15.3%[29]. Multiple tobacco product use (i.e., the use of two or more tobacco products) was also found to be very common in populations of the same demographic, with a prevalence of 37.8%[29].

Table 3: Prevalence estimates of current tobacco product use among adults in the US

Authors, Year of Publication	Survey Year	Single Product Use (%)				Dual Tobacco Use (%)			Poly Tobacco Use (%)	
		Cigarette	Cigar	Hookah/ Waterpipe	Smokeless Tobacco	Cig+SLT	Cig+hookah/ waterpipe	Cig+cigars	Any≧2 products††	Any≧3 products‡‡
Mumford E.A. et al., 2006	2001/02	21.9	—	—	1.6	0.32	—	—	—	—
Backinger C.L. et al., 2008[a]	2001/02	20.55	—	—	—	2.15*	—	3.49	1.19	—
Tomar S.L. et al., 2010[b]	2006	19.8	—	—	2.1†	6.6†	—	—	—	—
Mushtaq N. et al., 2012	2010	M:19.07; F:15.14	—	—	M:5.78; F:0.82	M:1.62; F:0.35	—	—	—	—
Grinberg A. et al., 2016	2010/11	16.7	—	M:0.8; F:0.4	—	—	3.4	—	—	—
Lee Y.O. et al., 2014[c]	2012	24.2	8.2	5.5	Snus:4;Chew: 5.7	2.8	4.2	5	—	2.4
Sung H.Y. et al., 2016	2010	19.3	2.5	—	Snuff:2;Chew: 1.1	2.2†; 1.5‡	—	5.2	7.6	—
Wang Y. et al., 2017	2010	24.2	5	—	—	2.1†; 1.5‡	—	5	—	—
Roberts M.E. et al., 2017[d]	2013/14	22.5	3.6	2.2	3.3	—	—	—	10.3	—
Kasza K.A. et al., 2017[e]	2013/14	22.5	3.6	2.2	3.3	4	6	4	37.8¶	15.3¶
Weaver S.R. et al., 2016[f]	2014	16.6	1.8	1.2	2.1	3.5	2	2.7	—	—
Syamlal G. et al., 2017[g]	2014-2016	15.4	—	—	3	—	—	—	4.6	—
Jones D.M. et al., 2018	2015/16	13.6	—	—	—	0.8	—	—	—	—
Creamer M.R. et al., 2019	2018	13.7	3.9§	1	2.4	—	—	—	3.7	—

Note:

1.Current use was determined as participants who had smoked or used the product in the previous 30 days.

2.Table summarises prevalence estimates weighted from various studies and surveyed years, and therefore, figures may not be directly comparable between each usage groups.

3.Table presents most recent prevalence estimates available of each country and product use.

Abbreviations: cig: cigarettes; SLT: smokeless tobacco; M: male; F: female.

*snuff and chewing tobacco combined; †snuff; ‡ chewing; ¶ prevalence estimates among tobacco users; § cigars, Cigarillos and filtered cigars combined; — data not available;

†† consuming two or more tobacco products; ‡‡ consuming three or more other products

a: Cig+pipe: 0.78%; Cig+snuff: 0.97%; Cig+chewing: 1.36%. b: Prevalence estimates restricted to males. c: Cig+snus: 2.6%. d: Cigarillo: 4.4%; pipe: 0.9%. e: Cigarillo: 4.4%; filtered cigars: 2%; pipe: 1.1%; snus: 0.8%; dissolvable: 0.1%; cig+cigarillos: 5%; cig+filtered cigars: 3%; cigar+cigarillos: 3%; cigar+SLT: 1%; cigar+hookah: 1%; cigarillos+hookah: 1%; cigars+cigarillos+flitered cigar: 1%; cig+cigars+cigarillos: 3%; cig+cigarillos+hookah: 2%; cig+cigarillos+filtered cigar: 1%; cig+cigar+cigarillos+filtered cigar: 1%.

f: Cigarillo: 2.8%; Cig+cigarillos: 9.4%; Cig+snus:1.2%. g: Prevalence estimates restricted to working adults.

2.3.2 Definition of Current Dual & Poly-Tobacco Use

The second objective is to review definitions of current dual and poly-tobacco product use in the literature. Among the reviewed studies, the definition of current/recent use was generally similar. In all six non-US studies, current use was defined as respondents who used the specified tobacco products "daily" or "occasionally" (some days) according to the World Health Organization (WHO) Global Tobacco Surveillance System[96], or "everyday", "weekly" or "monthly" according to the Eurobarometer[97]; as for the fourteen US studies included, current use was defined as any use in the previous 30 days. For the purpose of this review, I used a broader definition for current (monthly) tobacco use to capture both daily and non-daily users, including any use in the past 30 days across surveys. Regarding definitions for current adult dual tobacco use, also known as "concurrent tobacco use" [85, 88-90], it was typically determined in one of five ways in the literature:

1. Current use of one smoked and one smokeless tobacco product[19, 83, 84].
2. Current use of cigarettes and one other tobacco product[38, 85, 95].
3. Current use of cigarettes and smokeless tobacco products[88-90].
4. Current use of any two tobacco products[91, 92].
5. Current use of at least one smoked and one smokeless tobacco product[30].

Several studies, however, characterised current dual usage as a specific mix of two tobacco products, such as current use of cigarettes and a waterpipe/hookah[82, 87], cigarettes and snuff[39, 94], or cigar/chewing tobacco[94]. On the other hand, poly-tobacco use was repeatedly described as the use of two or more tobacco products[29, 31, 86, 92, 93], or in some research, three or more items[38, 91], which included dual use. Moreover, the term "Multiple tobacco product use" [29, 86, 91, 93] is a common term used to describe this pattern of use. The Table 4 below provides an overview of the definitions used in the studies reviewed.

Table 4: Summary of definitions of dual and poly-tobacco use

Definitions	Authors, Year of Publication
Dual /Concurrent Tobacco Use	
Smoking + Smokeless Products[a]	Zaman M.M. et al., 2014; Singh A. et al., 2014; Palipudi K.M. et al., 2014
Cig + One Other Product[b]	Lee Y.O. et al., 2014; Weaver S.R. et al., 2016; Backinger C.L. et al., 2008
Cig + SLT[c]	Mumford E.A. et al., 2006; Jones D.M. et al., 2018 Mushtaq N. et al., 2012
Any Two Products	Sung H.Y. et al., 2016 ;Roberts M.E. et al., 2017
Cig + Hookah/Waterpipe	Grinberg A. et al., 2016; Jawad M. et al., 2014
Cig + Snuff	Tomar S.L. et al., 2010
Cig + Cigar/Snuff/Chew	Wang Y. et al., 2017
≧1 Smoking Product + ≧1 SLT[d]	Sinha D.N. et al., 2016
Poly /Multiple Tobacco Use	
Any≧2 Products[e]	Sung H.Y. et al., 2016[#]; Agaku I.T. et al., 2014[#] Syamlal G. et al., 2017*; Kasza, K.A. et al., 2017* Creamer M.R. et al., 2019*
Any≧3 Products[f]	Lee Y.O. et al., 2014; Roberts M.E. et al., 2017*

Note:

a Use of one smoked and one smokeless tobacco product

b Current use of cigarette and one other tobacco product

c Current use of cigarettes and smokeless tobacco

d Use of at least one tobacco smoking product and at least one smokeless tobacco product concurrently

e Consuming two or more tobacco products

f Consuming three or more other products

Poly tobacco use including dual use

* Also referred as multiple tobacco product use

Abbreviations: cig: cigarette, SLT: smokeless tobacco

2.4 Discussion

Summary of Main Findings

This systematic review identified 20 studies spanning 48 countries that reported nationally representative prevalence estimates on current adult dual (concurrent) or poly (many) tobacco product usage. The majority of the studies were conducted in the United States and were cross-sectional in nature, with a limited number of data sources used to obtain the prevalence data. In summary, our results revealed significant differences in dual and poly-tobacco use prevalence by location and economic level.

Dual-tobacco use was more common in Southeast Asia, whereas poly-tobacco use was more common in Europe and Southeast Asia. In comparison to other higher-income nations, the prevalence of both was found to be greater in LICs and LMICs. Contextual factors, such as cultural, societal, and economic variations may affect regional variations in the frequency of dual and poly-tobacco use[18, 98]. For instance, smokeless tobacco (SLT) use, is very common and deeply ingrained in the culture of Southeast Asian nations, accounting for over 90% of global users[99, 100] and contributing to the region's high incidence of dual SLT and smoking product use[101].

Although high levels of poly-tobacco use have been observed in low-income countries, the proliferation of alternative tobacco products in some higher-income European countries as a result of a combination of cultural and economic factors opens another avenue for traditional cigarette smokers to either switch to cheaper tobacco products[102] or smoke cigarettes in combination with other products[97], which would potentially lead to increased levels of poly-tobacco use.

Despite the fact that some research indicate that dual use is linked to quitting smoking[103], there is sufficient evidence suggesting that concurrent users of several tobacco products are more likely to acquire tobacco-related illness [43]and are less likely to quit than single product users[1]. Moreover, when compared to exclusive smokers, population-based studies found no substantial reductions in tobacco-related toxicant exposure among dual users[39, 42].

2.4.1 Implications for Regulations and Policies

The study results provide an overview of the magnitude of global prevalence on dual and poly-tobacco use. Improving dual and poly-use monitoring in health surveys and associated studies is critical for tracking trends and patterns. Incorporating questions on alternative tobacco products and dual and poly-use into all regular tobacco surveys is an essential first step. To enable analysis and inform regulation, global data on product types, and the magnitude, duration, and frequency of different product use should be recorded ideally in a standardised manner to aid international monitoring and cross-country comparisons.

Furthermore, to promote research and monitoring for improved communication and understanding of these phenomena, the global tobacco control community and health authorities such as the World Health Organization should agree on a uniform operational definition of dual and poly-tobacco use. Researchers will be able to examine how tobacco control strategies influence transitions from single-product use to dual or poly-tobacco usage and vice versa by analysing data from longitudinal studies.

2.4.2 Limitations of The Review

At the time of the publication of this study, this was the first systematic review attempting to quantify the prevalence of dual and poly-tobacco use in various countries across the globe. Despite the fact that the review only included English language publications, this review found studies spanning the adult population of nations in all six WHO regions and at all income levels. However, when data comes from a limited number of nations, these may not be representative of the corresponding WHO regions or income levels. For example, there was only one prevalence estimate for each country representing the Eastern Mediterranean and the African region. Other countries in these regions were not recorded due to the limited studies and sources of data in these regions. Another potential limitation is that stratification of prevalence by sex was only provided in a few research.

Furthermore, since this study only included the most recent data for each nation, estimates may not be directly comparable between countries, therefore, the estimated prevalence should be interpreted with caution. Additionally, this review excluded dual and poly-use of drugs, other

substances and e-cigarettes. Therefore, it cannot capture the entire range of complexity of poly-tobacco use. Finally, this study relies, as all survey studies, on self-reported assessments which makes findings subject to potential misreporting.

2.4.3 Gaps in The Literature

Regardless of the increasing evidence on the significance of dual and poly-tobacco use, our analysis found that published studies were based on mere 11 national surveys, nearly half of which were conducted in the United States. In comparison to the vast amount of studies on smoking and tobacco use across the globe, this is a relative minor quantity. During the systematic review's screening procedure, a significant number of research on teenage populations was noted, including studies on dual-use with ENDS such as e-cigarettes. The small number of data sources could be due to the fact that questions about dual/poly-tobacco use are rarely asked in routine tobacco use surveys, or it could be due to researchers' lack of interest in the subject, as only a few studies have looked at datasets with dual or poly-tobacco use as an outcome of interest. In any case, demographic data on the use of various tobacco products by the adult population has been found to be insufficient.

Moreover, among the literature identified, definitions of dual and poly-tobacco use differed greatly. Varied definitions induce discrepancy across studies, makes prevalence estimates difficult to compare in different settings. Prior research has shown that different dual use definitions may have a 50-fold difference in prevalence estimates[104]. Therefore, tobacco use regulation may be strengthened by reaching an agreement on a consistent and generally accepted operational definition of "dual" or "poly-tobacco use."

2.4.4 What This Review Adds

This systematic review provides prevalence estimates of dual and poly-tobacco use among adults across 48 countries. Such data is critical for tobacco control policy and smoking behavioural research that aims to offer effective regulation and a more comprehensive understanding of tobacco use on alternative tobacco products, as well as dual and poly-use. The systematic review indicates that dual and poly-tobacco use is common in certain parts of the globe.

Given the increasing evidence on the health implications of such use patterns, dual and poly-tobacco use should be given greater attention in terms of regulation and research, particularly in areas with higher levels of use.

The issue of varied definitions of dual and poly-tobacco use is another important issue of this thesis. This chapter highlighted that discrepancies across research are often caused by different operational definitions, indicating the way surveys define current tobacco use has an effect on the reported prevalence of dual use. To avid ambiguity and conflations of the definitions, I have adopted the more general and distinct definition of dual and poly-tobacco use in the literature for the following chapters of this thesis— individuals currently using two different tobacco products were deemed dual tobacco users, while poly-tobacco users were defined as concurrently using three or more tobacco products at the time of the survey.

This study's strength is that it is not only the most thorough evaluation of worldwide prevalence estimates of dual and poly-tobacco use, but it also covers all six WHO regions, including countries which account for nearly 53% of the world's population. Nevertheless, this review emphasises the need for the global tobacco control community and health authorities to agree on a consistent operational definition of dual and poly-tobacco use in order to propel research and improve surveillance of dual and poly-use in health surveys for better communication and understanding of dual and poly-tobacco use.

The review highlights that this phenomenon remains understudied in the fields of tobacco regulatory science and health behaviour research. Routinely collected data on dual and poly-tobacco use with comparable/unified operational definitions can facilitate research comparisons and strengthen our understanding of potential determinants (e.g., socioeconomic factors, personal and country-level factors) related to dual and poly-tobacco use in population health and tobacco control policy research.

As a starting point for these issues, this chapter also recognises important factors within the conceptual model of multiple tobacco product (MTP) use such as the [35, 47] that warrant further investigation in the field of dual and poly-tobacco use, which is the primary focus of the remaining chapters of this thesis.

Chapter 3: Dual & Poly-Tobacco Use in Low-and Middle-Income Countries

3.1 Research Overview

Following the previous chapter of a systematic literature review and narrative synthesis of prevalence data on global dual and poly-tobacco product use, this chapter expands on the research context of this thesis by using multiple cross-sectional data to explore the patterns of dual and poly-tobacco product use among adults in different geographical regions. Overall, this chapter consists of two studies with data on tobacco use collected in different participating countries of the Demographic and Health Survey (DHS).

In the first phase, patterns of multiple tobacco use among current tobacco users in multiple low- and middle-income countries (LMICs) were analysed to explore potential correlates of the patterns of poly-use at the individual and the country level. This phase served as a springboard to investigate further the contextual, behavioural, and psychosocial factors that impact dual and poly-tobacco use outcomes in developing countries, which bear the highest health burden of tobacco use, and also in settings such as the underprivileged migrant population. Under similar research constructs, the second phase of the study focused on understanding the factors associated with being a multiple product user among migrants within these countries.

The aforementioned studies in this chapter, were conducted between 2018 and 2020 and there were two papers published in 2020 and 2021 in *Preventive Medicine*[105], and the *European Journal of Public Health*[106], respectively, that derived from this chapter. Although I am the first author of these studies, designing and conducting the analysis, the work involved in this chapter and the papers published were a collaborative effort. The contributors were my primary and secondary PhD supervisors, Filippidis FT, and Millett C. Both contributed to the study's design and methodology, reviewed the study, and were involved in data interpretation and revisions for important scientific input.

3.2 Background & Research Questions

3.2.1 Study Rationale

The World Health Organization Framework Convention on Tobacco Control (WHO FCTC), which came into force in 2005, enacted a set of universal standards stating the dangers of tobacco and encouraging stringent regulations on tobacco control across the globe[7]. This universal effort has contributed to a decrease in smoking prevalence among the signatory countries, and was particularly successful in high-income countries[107]. However, low- and middle-income countries (LMICs), on the other hand, which bear the greatest burden of tobacco-related disease, have not been as successful in reducing smoking prevalence.

Whilst manufactured cigarettes continue to be the most popular tobacco product among adults worldwide[107], the emergence of alternative tobacco products such as waterpipe, smokeless tobacco, and cigars provides another option for traditional cigarette smokers to switch to or smoke cigarettes in conjunction with alternative products[108]. The tobacco industry has exploited countries with limited capacity to counter its influence and implement comprehensive tobacco control measures, thereby exacerbating smoking disparities between countries[109, 110]. Results from my literature review indicated that there were substantial regional and socioeconomic differences in the profile of dual and poly-tobacco users[31]. Males in Southeast Asia, the Western Pacific, and Africa, for example, are more likely to be poly-tobacco users than those in Europe, with more product diversity found among smokers in economically disadvantaged areas with low SES[19]. Moreover, such burden is also seen prominent among culture diverse populations, such as migrants in economically developing countries, especially South Asian migrant workers expatriated from India, Pakistan, and Bangladesh and The United Arab Emirates (UAE)[58].

As the number of people who use two or more tobacco products at the same time (i.e., dual and poly-users) has increased in recent years, a growing body of research addresses the complex and dynamic factors impacting dual and poly-use. The conceptual model of multiple tobacco product (MTP) use emphasises the importance of taking into account various factors from *person level* such as socioeconomic status (SES), peer susceptibility, cultural background, *product characteristics* such as price, marketing, and advertising, and *situational factors* like product availability, smoking restrictions, and interactions between these factors. The MTP

model also suggests that both individual and contextual (country-level) factors play an important role when an individual chooses which tobacco product to use[35, 47]. As various products become available on the market, the aforementioned characteristics affect the extent to which substitutive and complementary relationships arise, which has an impact on dual and poly-use behaviour and health[47].

In the previous chapter's literature review, I discovered the majority of studies were conducted in the Western higher income countries and focused more on specific subpopulations (i.e., college students, pregnant women, or people in the military) or particular combinations of dual-tobacco use. Such findings may be useful in addressing the correlates and health effects of multiple product use among a targeted group of people, but the results were less representative of the general population and have limited implications for understanding the broad range of person, product, and situational factors related to dual and poly-use, as well as the effects of tobacco regulation.

It is this chapter's intention to build upon established factors associated with dual and poly-tobacco use and continue research to investigate the prevalence and correlates of multiple tobacco use disparities, as well as the use patterns among different population, especially in the following areas to expedite understanding of the effect of individual and contextual factors on tobacco use among the high-risk and vulnerable groups.

3.2.2 Dual & Poly-Tobacco Use Among Males in LMICs

LMICs account for more than 80% of all smokers worldwide[12], with men accounting for the vast majority[5]. Several studies have previously investigated the sociodemographic factors that influence the concurrent use of different tobacco use, with an emphasis on developing countries[19, 31, 72, 111, 112]. However, evidence on concurrent dual and poly tobacco use is scarce and knowledge on poly-tobacco use among smokers in LMICs is still limited. Furthermore, little study has been done to date on dual and poly-use and use patterns as a function of demographic and other characteristics such as media exposure, level of urbanisation, and occupation[47]. Given that patterns of tobacco product use and outcomes have been shown to significantly differ by income levels/SES and by sex[5], additional research is needed to explore whether the same holds true for dual and poly-user within LMICs. Similarly, while a

small number of studies have examined disparities in dual and poly-tobacco use[113], such data is limited and further research is needed.

With the high prevalence of dual and poly-use tobacco use in LMICs and disproportionately high in high-risk populations, such as male users, those of low socioeconomic status, and people with behavioural health conditions, multiple tobacco product use is a particularly important public health issue in LMICs. Understanding sociodemographic differences in tobacco use, including the concurrent use of various products, as well as regional or transnational variations, can help to improve regional integration of tobacco control strategies and consolidate their impact across and within nations. Nevertheless, there is currently minimal research on dual and poly-tobacco use and its relationship with these factors. Research in these diverse samples will better inform policies that affect the wider population and help address disparities and factors to reduce global multiple tobacco use.

For the first phase of this study, the aim is to estimate the prevalence of dual and poly tobacco use among men in 19 LMICs using the latest data from the DHS and assess potential associations with individual and country-level factors.

3.2.3 Dual & Poly-Tobacco Use Among Male Migrants

The other aim of this chapter was also to investigate the impact of broader social factors on multiple tobacco use patterns. According to the MTP model[35, 47], multiple tobacco use is determined by person, product, and context/situation factors, but also higher-level social and cultural factors. The role of concurrent contextual factors such as neighbourhood environment and tobacco industry marketing as well as disparity group were hypothesized by Leventhal[114] to play an interactive role on tobacco use. Phenomena such as migration represent an interactive factor between person and contextual level, which is especially relevant in understanding tobacco use behaviour in LMICs.

Previous studies suggested factors like neighbourhood environment, tobacco retail outlets, product availability or tobacco product use norms, can help explain population-level prevalence of multiple tobacco products use[115]. People with migratory status are more likely to be exposed to the aforementioned factors because they are exposed to different environments,

which would then in turn affect their smoking behaviours. Under such influence, migrant population may tend to diverge away from that of their original home population or converge with that of the host population over time (also known as acculturation) resulting in a more complex behaviour of tobacco use[116].

Despite the fact that tobacco use is increasing and disproportionately prevalent among these vulnerable populations, migrant status is often associated with poorer socioeconomic level and health[59]. There is currently minimal research on dual and poly-tobacco use in these groups. Studies of migrant populations in developing nations, showed greater tobacco use and other inequality-related factors put migrants at a higher risk for non-communicable disease and other health issues[9]. Such vulnerable population may be at increased risk of dual and poly-tobacco use because they have a lesser incentive to quit, stronger addiction and are targeted by the tobacco industry[117].

Given the fact that migrant populations in the LMICs account for around 60% of the world's migratory population[118], with the majority being male[119], it is therefore within the chapter's scope to look at the effect of migration, a broader social factor, on these populations' use of multiple tobacco products. Understanding this link might be crucial to enforcing tobacco control measures and designing more targeted interventions to reduce disparities in tobacco use and health outcomes among culture diverse migrants. Following the previous investigation, the goal of this phase is to look at the link between migration and tobacco smoking among men in LMICs.

3.3 Materials & Methods

This section outlines the methods of data collection used and data management performed on the DHS data made available for this research. This includes the variables generated for the outcome of interest, the selection of independent variables associated with the outcomes, and the new derived variables as predictors of the outcomes. The analyses that were utilised and the regression models that were created for descriptive and correlation analysis will then be presented.

3.3.1 Research Approval & Registration

The research proposal was approved by the DHS in September 2018 and access was granted for survey datasets under the registered project entitled: “Trends and Patterns of Global Poly-tobacco Use in Adults”. Ethical approval for the study protocol was obtained from the Head of Department on April 2019 and the Imperial College Joint Research Compliance Office (JRCO) in December 2019 (protocol number: 19IC5630).

3.3.2 Sampling Procedures

Data was acquired via the DHS institution website, where the data has already been processed and made publicly available to apply and analyse. Fully anonymised data was downloaded and was securely stored on a password protected external drive.

The DHS Surveys & Study Populations

Data from the Demographic and Health Surveys (DHS) were used for the studies in this chapter. The DHS data contains nationally representative household surveys performed in more than 90 developing countries across Africa, South & Southeast Asia, Oceania, Latin America & the Caribbean and parts of Eastern Europe[120]. The DHS project was initiated in 1984 and is primarily sponsored by the US Agency for International Development (USAID). It has been implemented in multiple countries to collect data on a wide range of demographic and health-related factors through its cooperation with national level agencies to conduct surveys inside a country and are intended to be administered every five years.

The DHS employs a two-stage cluster sampling process, first with enumeration levels and then selected households; these data are considered to be representative of the population of the country. The surveys include a household questionnaire, a women's questionnaire and a men's questionnaire, with eligible respondents in the reproductive age group (15 to 49 years old) sampled. The household questionnaire is used to determine the eligibility of all household members for the individual women's and men's surveys. Face-to-face interviews with chosen household members were conducted by trained interviewers using standard questions that were translated into relevant local languages. To ensure data quality, procedures were standardised across all nations investigated, and stringent quality control methods were used. Survey

weights are generated to account for unequal selection probabilities as well as survey non-response. The results of the survey represent the whole target population with weights applied. A complete description of the data collection, cleaning and weighting processes can be found in official reports[120]. A number of nations include questions in the individual questionnaires assessing tobacco use. For purposes of this study, self-reported tobacco use behaviours among male respondents were examined, as well as a variety of information on social determinants that were also collected. The dataset supporting the studies herein is available in the DHS repository, https://dhsprogram.com/data/available-datasets.cfm. A geographic map of the countries included in the studies is presented in

Figure 5 below.

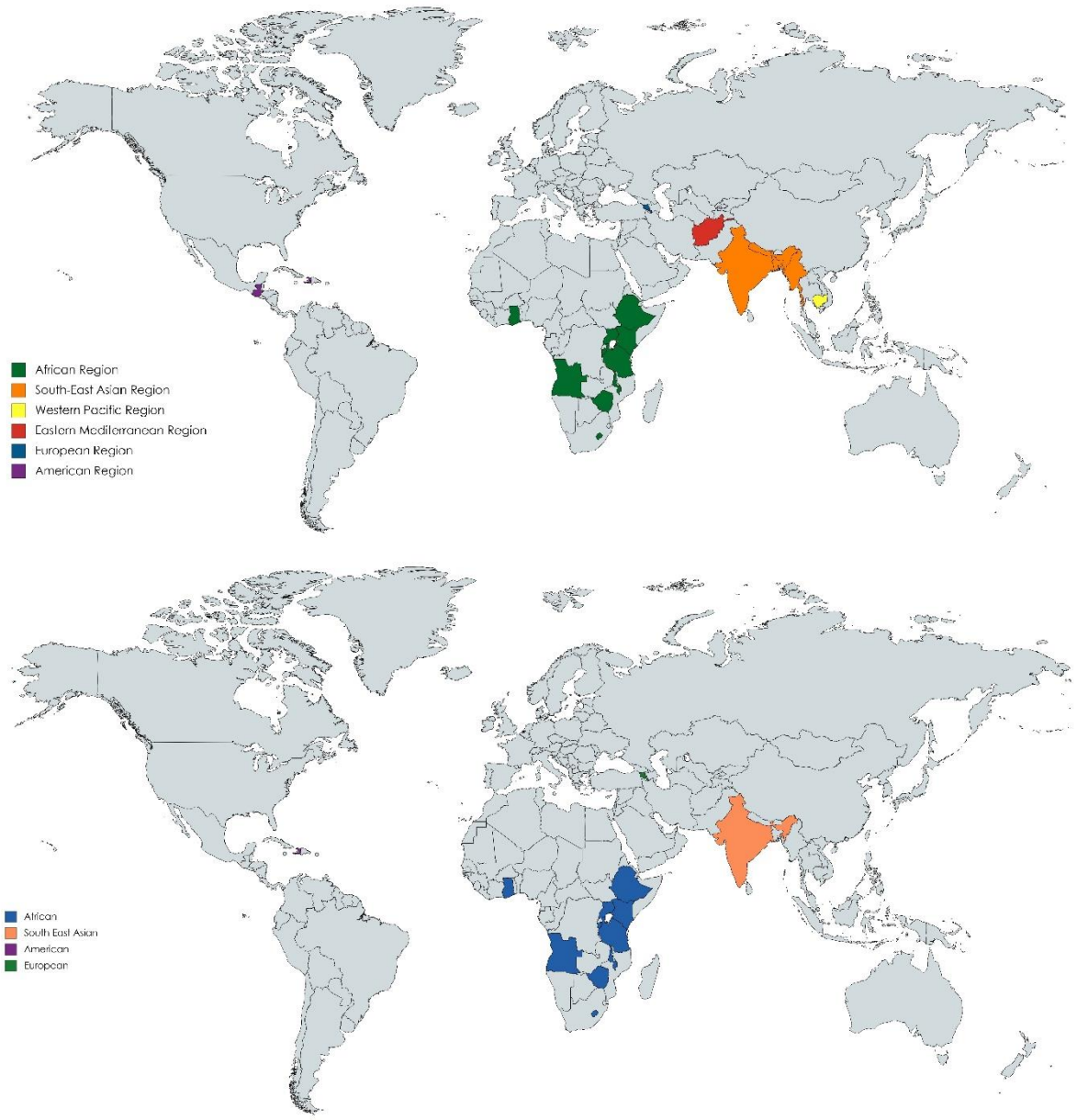
(i)Male adults in 19 LMICs

The first study examined data from 19 LMICs from the most recent data available in the DHS surveyed during 2015 and 2016. Nations from all WHO regions, including the African (Ethiopia, Kenya, Tanzania, Zimbabwe, Malawi, Lesotho, Burundi, Ghana, Uganda and Angola), American (Guatemala and Haiti), Southeast Asian (India, Nepal and Myanmar), European (Armenia), Eastern Mediterranean (Afghanistan), and Western Pacific (Cambodia and Timor-Leste) regions were included. The data on current tobacco use was analysed from 234,537 male respondents aged 15 to 49 years old (India: 15-54 years old).

(ii)Male migrants in 15 LMICs

The second phase of the study uses the same sets of data for analysis with questions on migration status in order to better understand the connection between migration and tobacco smoking among males in low- and middle-income countries. Data from 15 LMICs collected between 2015 and 2018 in the latest Demographic and Health Surveys (DHS) wave were used in this analysis. Countries included were from the WHO Western Pacific and Southeast Asian region (India, Nepal, and Cambodia), African region (Ethiopia, Kenya, Tanzania, Zimbabwe, Malawi, Lesotho, Burundi, Ghana, Uganda, and Angola), Europe (Armenia) and the American region (Haiti). A total of 154,425 male respondents aged 15 to 49 years old (India: 15-54 years old) were surveyed. All 15 nations analysed in this phase were included in the previous 19 LMICs analysis, except for Myanmar, Timor-Leste, Afghanistan, and Guatemala.

Figure 5: Map of the countries included in the Demographic and Health Surveys analysis



Note: The 19 LMICs studied in the first phase are shown in the top of the figure, and below the 15 LMICs in the second phase

3.3.3 Questionnaires & Main Variables

Outcome Variables

Current single dual and poly-tobacco use are the main outcome variable of the study. In the majority of the countries studied, respondents were first specifically asked "Do you currently smoke cigarettes?" Those who replied "yes" to this question were considered as current manufactured cigarette smokers, whilst those who responded "no" were defined as current non-smokers. Those who replied yes to this question were next asked to report the type(s) of tobacco that they smoked or used. In some countries, respondents were first asked whether they currently smoked cigarettes or tobacco ("Do you currently smoke cigarettes or tobacco?"). There are some slight variations in the wording of this question across the countries (i.e., use "consume" instead of "smoke"). Similarly, those who responded in the affirmative to this question were classified as current users, and were then asked to report the type(s) of tobacco that they smoked or used ("What do you smoke?/ What type of tobacco do you smoke?"). The list of products recorded are presented as below.

According to the respondents' questions, a multinominal outcome variable was derived. Dual tobacco users are those who concurrently use two tobacco products at the time of survey, while poly-tobacco users are those who reported current use of three or more tobacco products at the same time. On the contrary, single tobacco users were those who consume only one tobacco product at the time of the survey. Non-users were those who were non-smokers and did not used any other tobacco products.

Tobacco Products Surveyed

A common set of tobacco use questions was included in the individual surveys in the majority of the countries. However, not all of the countries documented the same set of variables for the different types of tobacco products in their survey. In countries where certain types of tobacco product were common (e.g., bidis, water pipes etc.), variables for these types of products may have been included in the dataset; whereas in some countries, these may have been excluded if less prevalent. There are some slight variations in the wording of this question across the countries, however, the questions evaluating current tobacco use are mostly comparable throughout the nations.

Overall, a total of 11 different tobacco products (in bold) were surveyed across the countries.

- **Cigarettes** and **chewing tobacco** collected in all countries
- **Snuff** and **pipes** collected in all countries except for Myanmar
- **Cigars** in countries except for Cambodia, Kenya, Zimbabwe, Lesotho, Ghana, Guatemala and Afghanistan
- **Gutkha/paan masala with tobacco**, **khaini** and **bidis** survived only in India
- **Betel quid with tobacco** in Nepal, Timor-Leste, Tanzania and Burundi
- **Kreteks** in Timor-Leste, Tanzania and Burundi
- **Water pipes (hookah)** surveyed in countries except for Cambodia, Myanmar, Timor-Leste, Zimbabwe, Lesotho, Ghana, Angola, Guatemala and Afghanistan.

Independent Variables

The majority of the individual-level variables used in analyses were from the existing DHS dataset. For the purpose of the analysis, I recoded some variable values to reduce the number of small and zero-cell counts to interpret the data. These variables include education level, marital status, occupation, and media use. I performed initial single-variable logistic regressions to determine significant relationships between variables. All variables that were significantly related to the dependent measures of interest were then included in final analyses. Country-level variables were generated from external validated sources.

In this chapter, the associated factors of current dual and poly-tobacco use on several behavioural, social, and demographic variables were compared to current single use. The information collected included established factors in the literature associated with dual and poly-tobacco use[77] and was also based on the MTP model[35, 47], which takes into account individual factors and contextual determinants at the individual-level and the country-level in the adoption of multiple tobacco product use. Details of the variables used in analyses in this chapter are listed below.

- Individual-level factors:

The individual-level variables consist of a range of sociodemographic characteristics selected based on previous research and the MTP model showing differences in tobacco use across these factors[34, 37, 39, 84, 121-124]. These are:

- age (continuous variable)
- education level (no education, primary, secondary, higher)
- marital status (never married, partnered [married or living with partner], widowed, divorced [separated or no longer living together])
- residential area (urban or rural)
- occupation (unemployed, professional, service, agriculture, household or manual)
- wealth index (divided into quintiles from 1 [lowest] to 5 [highest])
- media use (dichotomised as low or high frequency media use)
- migration status (described below).

The household wealth index (asset index), which indicates ownership of a variety of home objects and amenities, was constructed by the DHS individually for each country using household asset data from the respondents and was used as a proxy for SES. The wealth index was calculated using factor analysis of a number of essential household items held by the respondents (refrigerator, television, vehicle, and washing machine) and access to electricity, similar to previously published methodologies. The generated scale's reliability was considered highly satisfactory, as evidenced by the high internal consistency of responses to scale items (Cronbach $\alpha = 0.83$)[125]. For each asset held by each family, a score was assigned, and the scores were summed together. Individuals were ranked based on the household's score when they were questioned. The index scores employed in the analyses were then ranked into quintiles ranging from one (lowest) to five (highest) within each nation in order to categorise the respondents of their household wealth level. This wealth index has been created by the DHS developers, and was used in a significant number of countries surveyed, and is comparable with economic status metrics[126].

Frequency of mass media exposure was assessed by four factors to see if respondents read newspapers/magazines, watched television, listened to the radio, or used the internet at least once a week (1 [less than once a week; 2 [at least once a week]). The frequencies of all four variables were added together to create an additive score, which was then recoded into a binary variable indicating low (scoring 1 to 4) and high frequency (scoring 5 to 8) of media use.

Finally, in the second phase of the study, migration status was examined as the main independent variable. It should be noted that, in the DHS studies, migration status was only

available among male respondents in certain countries. Migration status for men was assessed based on the number of times the respondent reported that they slept away from home in the last 12 months. The specific question was “in the past 12 months, have you slept or lived away from home for more than 1 month?” (none, 1-4, 5 or more). Owing to the small number of observations for some responses, the categories based on the number of days slept away from home had to be reduced to two groups. A binary variable was further created to describe the respondents’ migration status (migrant or non-migrant). If respondents answered affirmatively, indicating that they had slept or stayed away from home for any amount of time (none, or ≥1 times) for more than one month in the previous 12 months, they were considered to have a migration status.

The rationale for using the migration status variable has been established in previous studies using the DHS data but in limited capacities[127]. While little research has examined the association between labour migration and health[128], interactive factors of individual and the surrounding context experienced by migrant workers such as social exclusion and decreased social support, poor living and working conditions, and reduced access to health care may influence the prevalence of smoking and multiple tobacco use among men[35, 47, 128]. While the male respondents may be away from home for a variety of reasons, including visits to family or friends, hospital stays, or vacations, however being away from home is frequently associated with labour migration in LMICs[118].

- Country level factors:

These are:

- MPOWER score
- National wealth index

In the first phase of the study, two additional indicators were included as country-level variables: the MPOWER score and the national wealth index. They were accessed online from the 2017 WHO report on the global tobacco epidemic[129] and the World Bank[130]. Data extracted were matched to correspond to the surveyed countries and years of the DHS datasets.

The MPOWER package is a combination of six cost-effective and high-impact strategies proposed by WHO in line with the FCTC to help countries in decreasing tobacco product demand at the national level[131]: (i)**M**onitoring tobacco consumption ; (ii)**P**rotect from tobacco smoke; (iii)**O**ffer help to quit tobacco; (iv)**W**arn of dangers of tobacco; (v)**E**nforce bans on tobacco advertising, promotion and sponsorship; and (vi) **R**aise taxes on tobacco. To match to the surveyed countries and years analysed in the study, data on the MPOWER scores were extracted from the 2017 WHO report on the global tobacco epidemic, which include documentation of global tobacco control data from up to 2016[129]. The score was determined by the number of MPOWER key components applied at the highest level in each country, which composites a score ranging from 0 (the lowest) to 6 (the highest).

The World Bank database was utilised to get country wealth indices corresponding to the surveyed countries and years.[130]. The purchasing power parity (PPP) of a country is its GDP per capita in international dollars, was adjusted for inflation and expenditures to generate the indicators. The PPP per thousand dollars of each nation for the survey year was used in the research.

3.3.4 Statistical Analyses

For nationally representative estimates, all analyses were weighted according to the cluster sampling design of the surveys using strata and primary sampling unit at the country level[132]. To accommodate for the DHS's complex multistage sample design, Stata's "svyset" and "svy" commands were used. All analyses were conducted using Stata 13.0.

Descriptive Analyses

Descriptive data analyses estimated the proportion of the population within each of the 19 countries that reported current use of different tobacco products, as well as the prevalence of single, dual and poly-tobacco use patterns. Similar analyses were conducted separately for the subsample of 15 countries with male migrants. Weighted estimates of prevalence of single, dual and poly-tobacco use for each country together with 95% confidence intervals (CI) were calculated.

Multilevel Regression Models

Then, to examine the association between the independent variables and current tobacco use patterns (non-smokers, single, dual and poly tobacco users), multilevel regression models for categorical outcomes were conducted to produce less biased results[132]. Multilevel models account for the existence of hierarchical data structures by estimating group effects simultaneously with the effects of group-level predictors, which in this case are the different countries and the country-level variables the respondents were grouped/nested within. For the purpose of the analyses, two-level regression models for categorical responses (multinomial regression) were used to estimate the factors associated with different use patterns at the individual (level 1) and country level (level 2).

In the first phase of the study, age, education, marital status, occupation, residential area, wealth index, and media use were the level 1 variables; national wealth and MPOWER score were the level 2 variables. Multilevel analyses were constructed through a stepwise approach. Firstly, in model 1, an intercept-only model was estimated to quantify the cross-country variation in tobacco use patterns. Then in model 2 and model 3, the country-level variables and the individual-level variables were entered into the model respectively to examine separately the single level effect of individual and contextual factors on tobacco use patterns. Lastly, in model 4, the integrated model, a multilevel regression model adjusted for all variables was fitted. To quantify residual components at each level in the hierarchy, the intra-class correlation coefficients (ICC) were computed to reflect the residual variance at the country-level as a proportion of the overall variance (the country-level variance + individual-level variance)[133]. A higher ICC value indicates a greater variation in the country-level residuals, as well as a higher degree of unobserved cross-national variables that influence tobacco use outcomes, therefore suggesting that the multilevel approach is necessary[133].

In the second phase, the association between migration status and tobacco use pattern (non-smokers, single, dual and poly tobacco users) was investigated similarly using multilevel regression models for categorical responses (multinomial regression) with a random intercept at the country level adjusting for all individual-level variables. However, the two country-level variables (national wealth and MPOWER score) were not included in this phase as they were not the main focus of analysis at this point. Lastly, an additional binary logistic multilevel model was fitted to examine relationships of migration status and tobacco use with non-user as reference.

The Bayesian Markov Chain Monte Carlo (MCMC) estimation approach was used to fit all regression models to provide less-biased estimates for multivariate nominal models[134]. The "runwlwin" command was used to connect the MLwiN software from within Stata[135]. The MLwiN 3.04 is a software package specialized for fitting multilevel models developed by Centre for Multilevel Modelling, University of Bristol[136]. For all the models analysed, both age and age squared were included to allow for a non-linear association between age and the respective outcome. All comparisons were made against non-tobacco use, and all estimates are weighted and nationally representative within each country.

3.4 Study Results

3.4.1 Dual & Poly-Tobacco Use Among Male Adults

Data from 235,975 males aged 15 to 49 years (India: 15-54) surveyed between 2015 and 2016 from 19 LMICs were analysed. The section below presents the results of the descriptive analyses and regression modelling respectively.

Cross-Sectional Prevalence of Tobacco Use

Cigarettes were the most popular tobacco product across all countries. Armenia (59.4%), Lesotho (41.3%), and most Southeast Asian nations had the highest overall prevalence of current cigarette smoking among male adults. Other smoked tobacco products such as pipes, cigars, waterpipes, kreteks and bidis were most prevalent in Southeast Asian, European, and Eastern Mediterranean nations, compared to Africa, where prevalence was low. Lesotho had the greatest overall prevalence of current pipe usage at 6.1%; Myanmar had the highest cigar use at 14.3%; India had the highest bidi use at 14.3%; and Timor-Leste had the highest kretek use at 23.1%. Men's use of smokeless tobacco such as chew, snuff, betel quid with tobacco ranged from almost none in Armenia and Africa to a high frequency in Asian nations including Afghanistan, Nepal, Timor-Leste, and India.

The patterns of current dual or poly-tobacco use among male adults were shown to differ considerably in different nations as illustrated in Figure 6. Table 5 below presents the weighted prevalence of current tobacco use among male adults by different products and use patterns in

19 countries. Highest prevalence of poly-tobacco use was seen in Timor-Leste (6.3%), Nepal (3.2%), and India (1.9%). Region wise, the average prevalence of current dual or poly-tobacco use among men was highest in Southeast Asia (15.2%), Afghanistan in the Eastern Mediterranean (7.1%), and Cambodia the Western Pacific (4.1%); alternatively, the lowest average prevalence was seen in the African (2.2%) and Central America (0.7%) regions.

Table 5: Weighted prevalence of current tobacco use among male adults by different products and use patterns in 19 LMICs

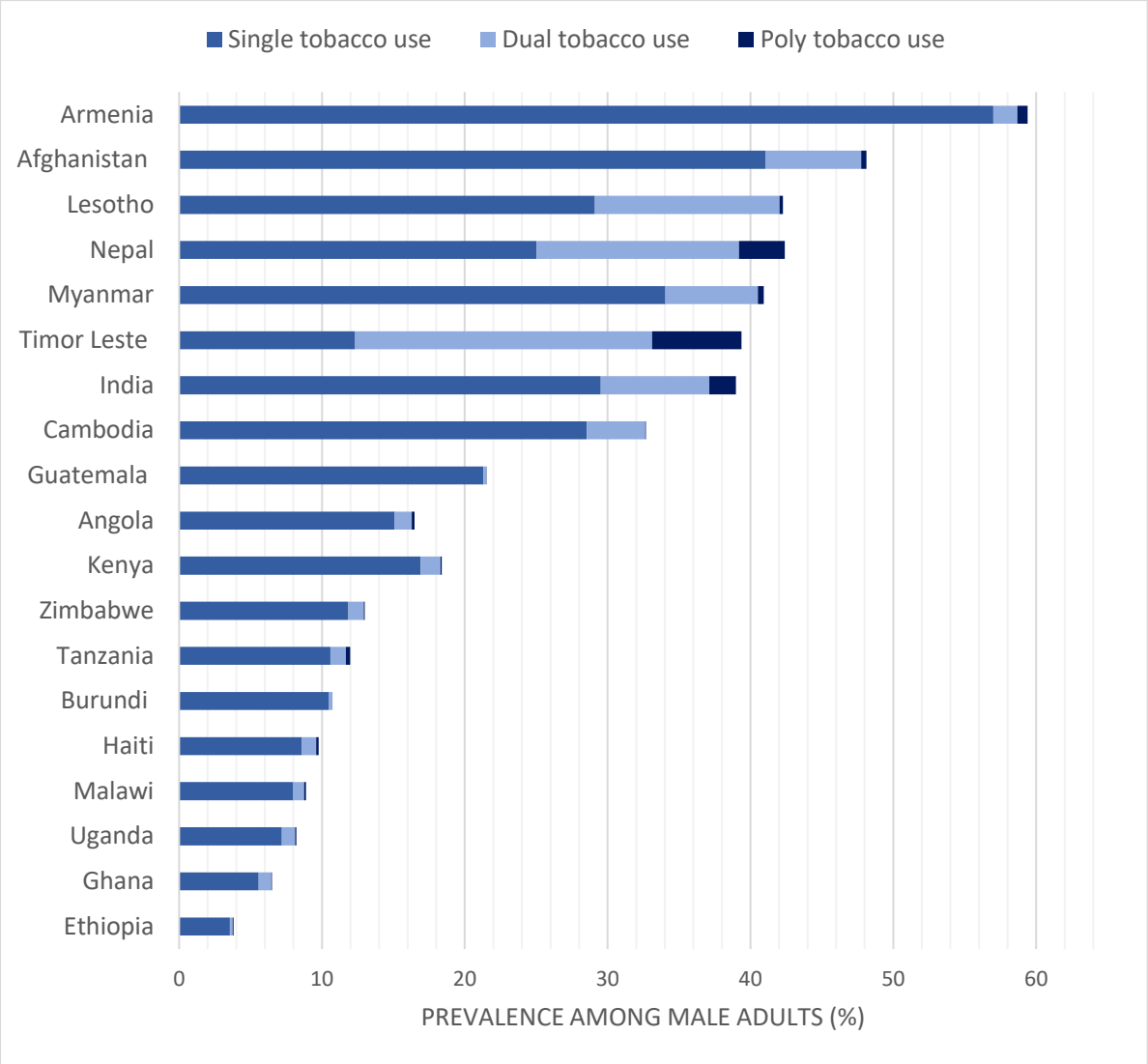
			Prevalence of tobacco use (%) and 95% confidence interval											
Country	**Year of survey**	**Number of male respondents**	**% cigarette**	**% pipe**	**% cigar**	**% chew**	**% snuff**	**% betel quid w/ tobacco**	**% water pipe (hookah)**	**% kreteks**	**% others**	**% Single [a]**	**% Dual [b]**	**% Poly [c]**
Cambodia	2014/15	5,190	31.85 30.21-33.52	0.05 0.01-0.32	—	1.93 1.42-2.61	3.01 2.5-3.61	—	—	—	0.04 0.01-0.23	28.55 26.97-30.19	4.08 3.42-4.86	0.05 0.01-0.2
India *	2015/16	112,122	13.68 13.25-14.12	0.19 0.15-0.24	0.48 0.41-0.56	2.33 2.14-2.55	0.09 0.06-0.12	—	0.64 0.56-0.72	—	0.46 0.4-0.52	29.53 29.03-30.04	7.59 7.32-7.87	1.87 1.75-1.99
Myanmar	2015/16	4,737	31.74 29.86-33.69	—	14.34 12.9-15.91	1.21 0.81-1.8	0.94 0.62-1.41	—	—	—	0.08 0.03-0.22	34.04 32.28-35.84	6.48 5.68-7.39	0.42 0.25-0.72
Nepal	2016	4,063	16.39 14-17.42	1.43 1-2.04	0.19 0.08-0.46	25.75 23.6-28.02	2.04 1.32-2.71	16.04 14.32-17.93	1.28 0.88-1.86	—	0.68 0.26-1.75	25.02 23.1-27.03	14.17 12.63-15.88	3.22 2.61-3.97
Timor-Leste	2016	4,622	36.67 33.03-37.6	1.04 0.7-1.55	2.62 1.87-3.68	2.01 1.43-2.82	—	7.92 6.79-9.22	—	23.14 20.6-25.89	1.67 1-2.75	12.32 0.11-0.14	20.79 18.64-23.12	6.26 5.16-7.58
Ethiopia	2016	12,688	3.34 2.6-3.98	0.05 0.02-0.14	0.08 0.05-0.14	0.17 0.09-0.3	0.45 0.16-0.58	—	0.05 0.02-0.13	—	0.01 0-0.04	3.56 2.93-4.33	0.18 0.1-0.32	0.07 0.03-0.18
Kenya	2014	12,819	16.59 15.6-17.62	0.17 0.11-0.26	—	0.89 0.71-1.12	1.28 1.04-1.58	—	0.29 0.15-0.57	—	0.75 0.52-1.07	16.91 15.94-17.92	1.4 1.11-1.75	0.07 0.04-0.15
Tanzania	2015/16	3,514	11.05 9.74-12.52	0.06 0.01-0.22	—	0.06 0.01-0.26	1.71 1.27-2.3	0.05 0.01-0.38	0.03 0-0.22	0.29 0.15-0.57	0.52 0.22-1.2	10.6 9.29-12.06	1.07 0.77-1.49	0.31 0.12-0.79
Zimbabwe	2015	8,396	12.5 11.6-13.44	0.31 0.19-0.49	—	0.01 0-0.05	0.45 0.32-0.65	—	—	—	0.96 0.73-1.25	11.84 11-12.73	1.1 0.85-1.4	0.06 0.02-0.18
Malawi	2015/16	7,478	8.96 7.86-9.61	0.08 0.04-0.18	0.14 0.06-0.34	—	0.22 0.13-0.36	—	0.16 0.06-0.38	—	0.6 0.35-1.06	8 7.23-8.85	0.76 0.47-1.21	0.11 0.04-0.3
Lesotho	2014	2,931	41.34 39.18-43.53	6.13 5.04-7.44	—	1.17 0.82-1.67	0.72 0.47-1.1	—	—	—	6.3 5.25-7.54	29.1 26.93-31.36	12.94 11.37-14.69	0.23 0.11-0.49
Burundi	2016/17	7,552	10.65 9.81-11.56	0.06 0.02-0.16	0.03 0.01-0.11	—	0.04 0.01-0.1	—	0.03 0.01-0.13	0.12 0.06-0.25	0.07 0.03-0.16	10.47 9.63-11.37	0.27 0.16-0.44	0 0-0
Ghana	2014	4,388	4.78 4.07-5.62	0.54 0.29-0.98	—	0.34 0.19-0.62	0.94 0.65-1.37	—	—	—	0.64 0.35-1.17	5.56 4.62-6.2	0.9 0.56-1.44	0.03 0-0.23
Uganda	2016	5,336	7.48 6.61-8.44	0.48 0.19-1.25	0.18 0.08-0.41	0.1 0.06-0.19	0.73 0.5-1.05	—	0.22 0.08-0.56	—	0.14 0.06-0.34	7.2 6.43-8.05	0.92 0.56-1.5	0.09 0.02-0.31
Angola	2015/16	5,684	15.05 13.45-16.03	0.07 0.02-0.24	0.01 0-0.05	0.48 0.23-1	2.44 1.85-3.21	—	—	—	0.03 0.01-0.14	15.1 13.89-16.41	1.19 0.84-1.68	0.2 0.06-0.72
Guatemala	2014/15	11,145	21.47 20.32-22.66	0.04 0.01-0.11	—	0.03 0.01-0.07	0.15 0.08-0.26	—	—	—	0.06 0.03-0.15	21.31 20.17-22.5	0.2 0.12-0.32	0.01 0-0.04
Haiti	2016/17	11,886	7.6 6.91-8.34	0.36 0.24-0.53	0.42 0.29-0.61	0.04 0.02-0.09	2.23 1.83-2.72	—	0.07 0.03-0.15	—	0.45 0.3-0.66	8.59 7.82-9.42	1.01 0.8-1.27	0.17 0.09-0.31
Armenia	2015	2,755	59.41 57.05-61.73	0.03 0-0.23	1.57 1.09-2.28	—	0.07 0.02-0.29	—	1.39 0.94-2.06	—	0.05 0.01-0.33	57.01 54.64-59.35	1.69 1.21-2.36	0.71 0.39-1.28
Afghanistan	2015/16	10,760	21.94 20.53-23.41	1.49 1.01-2.18	—	17.69 15.95-19.57	14.24 11.96-16.89	—	—	—	0.23 0.14-0.39	41.04 38.93-43.19	6.72 5.61-8.01	0.36 0.13-1.01

Note:

* India: % for gutkha/paan masala w/ tobacco = 14.92 (14.5-15.35); % for khaini (snus): 12.36 (11.99-12.75); % for bidis: 14.31 (13.93-14.70); — indicates product not surveyed in corresponding country.

a Single tobacco use: individuals currently using only one tobacco product. b Dual tobacco use: individuals concurrently using two different tobacco products. c Poly tobacco use: individuals concurrently using three or more tobacco products.

Figure 6: Prevalence of tobacco use patterns among male adults in 19 LMICs.



Note: all the percentages are estimated from the weighted analysis.

Determinants & Factors associated with Tobacco Use

Table 6 presents the results of the multilevel regression model of different tobacco use patterns among male adults. Models 1 to 3 represents the intermediate steps before building the full integrated model 4. The intercept only model (model 1) indicates a strong degree of country-level variance in single, dual and poly tobacco use, with high ICC values ranging from 50% to 63%, meaning a large proportion of residual variance is attributable to the country-level variance, thus the multilevel approach is warranted. In model 4, the Individual and country-level variables are included in the integrated model. The integrated model demonstrated a balanced goodness of fit and model complexity with lower ICC and deviance information criterion (DIC) values[133].

Individual factors, such as higher education (Relative Risk Ratio [RRR]=0.55; 95%CI: 0.46-0.66), household wealth (RRR=0.16; 95%CI: 0.14-0.19) and residing in rural regions (RRR=0.78; 95%CI: 0.71-0.85) were linked with reduced relative risks of poly-tobacco use after controlling for both country and individual-level variables. On the other hand, being divorced (RRR=2.29; 95%CI: 1.61-3.15), working in manual (RRR=2.42; 95%CI: 2.11-2.79) and service (RRR=2.34; 95%CI: 2.01-2.70) sector and those reporting high frequency of media use (RRR=1.39; 95%CI: 1.22-1.58) showed higher relative risks of being poly-tobacco users. In comparison to non-tobacco users, the direction and magnitude of association for the individual-level variables were similarly comparable for dual and single tobacco users.

On the country level, national wealth did not appear to be related with being dual or poly-tobacco users. However, the implementation of additional MPOWER regulations at the highest level was negatively related with single use (RRR=0.74; 95%CI: 0.72-0.77), but positively associated with dual and poly-tobacco use (RRR=1.54; 95%CI: 1.16 - 1.91) when compared to non-users.

Table 6: Multilevel regression of tobacco use patterns among male adults in 19 LMICs

	Relative risk ratio (RRR) with 95% confidence interval											
	Model 1 (intercept only model)			Model 2 (country level model)			Model 3 (individual level model)			Model 4 (integrated model)		
	Single Use	Dual Use	Poly Use	Single Use	Dual Use	Poly Use	Single Use	Dual Use	Poly Use	Single Use	Dual Use	Poly Use
Fixed effects												
Intercept	0.25*** (0.22-0.29)	0.04*** (0.03-0.06)	0.00*** (0.00-0.01)	0.08*** (0.0-0.013)	0.00*** (0.00-0.01)	0.00*** (0.00-0.00)	0.01*** (0.01-0.01)	0.00*** (0.00-0.01)	0.00*** (0.00-0.01)	0.00*** (0.00-0.01)	0.00*** (0.00-0.01)	0.00*** (0.00-0.01)
National Wealth[a]				1.22*** (1.01-1.34)	1.35*** (1.21-1.51)	1.62*** (1.19-2.20)				1.03 (0.91 - 1.17)	1.05 (0.85 - 1.29)	1.17 (0.91 - 1.47)
MPOWER[b]				0.95 (0.88-1.05)	1.42*** (1.19-1.59)	1.55** (1.25-1.92)				0.74*** (0.72 - 0.77)	1.34*** (1.16 - 1.69)	1.54*** (1.16 - 1.91)
Age							1.17*** (1.16-1.18)	1.22*** (1.2-1.24)	1.27*** (1.24-1.30)	1.17*** (1.16-1.18)	1.22*** (1.20-1.24)	1.27*** (1.24-1.31)
Age-squared							1.00*** (1.00-1.00)	1.00*** (1.00-1.00)	1.00*** (1.00-1.00)	1.00*** (1.00-1.00)	1.00*** (1.00-1.00)	1.00*** (1.00-1.00)
Education (ref. no school)												
Primary							0.96* (0.93-1.00)	0.96 (0.9-1.02)	1.14* (1.02-1.28)	0.96 ** (0.93-0.99)	0.96 (0.90-1.01)	1.14* (1.02-1.28)
Secondary							0.79*** (0.76-0.82)	0.78*** (0.74-0.83)	0.85** (0.76-0.95)	0.79*** (0.76-0.82)	0.78*** (0.74-0.83)	0.85** (0.76-0.95)
Higher							0.59*** (0.56-0.62)	0.52*** (0.48-0.57)	0.55*** (0.46-0.66)	0.59*** (0.56-0.62)	0.52*** (0.48-0.57)	0.55*** (0.46-0.66)
Marital status (ref. never married)												
Partnered							1.11*** (1.07-1.14)	1 (0.95-1.06)	0.91 (0.81-1.02)	1.11*** (1.07-1.15)	1.00 (0.94-1.06)	0.91 (0.81-1.02)
Widowed							1.52*** (1.35-1.71)	1.36*** (1.12-1.63)	1.34 (0.9-1.86)	1.52*** (1.35-1.71)	1.36** (1.11-1.65)	1.34 (0.91-1.86)
Divorced							2.60*** (2.40-2.80)	2.86*** (2.48-3.28)	2.27*** (1.60-3.14)	2.61*** (2.41-2.82)	2.86*** (2.45-3.29)	2.29*** (1.61-3.15)
Occupation (ref. not working)												
Professional							1.29*** (1.22-1.37)	1.37*** (1.24-1.51)	1.45*** (1.15-1.80)	1.29*** (1.22-1.37)	1.37*** (1.23-1.52)	1.47*** (1.16-1.83)
Service							1.63*** (1.56-1.70)	1.84*** (1.7-1.97)	2.32*** (2.01-2.68)	1.63*** (1.56-1.70)	1.83*** (1.7-1.97)	2.34*** (2.01-2.7)
Agriculture							1.59*** (1.53-1.66)	1.63*** (1.52-1.74)	1.81*** (1.58-2.07)	1.59*** (1.53-1.66)	1.63*** (1.52-1.74)	1.82*** (1.58-2.09)
Household							1.90*** (1.70-2.11)	2.23*** (1.71-2.88)	1.75 (0.7-3.55)	1.89*** (1.7-2.10)	2.22*** (1.69-2.85)	1.72 (0.78-3.3)
Manual							1.86*** (1.79-1.94)	2.08*** (1.95-2.23)	2.42*** (2.12-2.76)	1.86*** (1.79-1.94)	2.08*** (1.95-2.22)	2.42*** (2.11-2.79)
Wealth index (ref. 1st quintile)												
2nd							0.79*** (0.77-0.82)	0.79*** (0.75-0.84)	0.66*** (0.6-0.73)	0.79*** (0.77-0.82)	0.79*** (0.75-0.84)	0.66*** (0.60-0.73)
3rd							0.66*** (0.64-0.69)	0.57*** (0.54-0.61)	0.46*** (0.41-0.51)	0.66*** (0.64-0.69)	0.57*** (0.54-0.60)	0.46*** (0.41-0.51)
4th							0.55*** (0.53-0.58)	0.44*** (0.41-0.47)	0.30*** (0.26-0.33)	0.55*** (0.53-0.57)	0.44*** (0.41-0.46)	0.3*** (0.26-0.33)
5th							0.42*** (0.4-0.43)	0.28*** (0.26-0.30)	0.16*** (0.14-0.19)	0.42*** (0.40-0.43)	0.28*** (0.26-0.30)	0.16*** (0.14-0.19)
Place of residence (ref. urban)												
Rural							0.86*** (0.83-0.88)	0.78*** (0.75-0.82)	0.78*** (0.71-0.85)	0.86*** (0.83-0.88)	0.78*** (0.75-0.82)	0.78*** (0.71-0.85)
Media Use (ref. no use)												
Low use							1.08*** (1.04-1.12)	1.32*** (1.24-1.40)	1.34*** (1.2-1.51)	1.08*** (1.04-1.12)	1.32*** (1.24-1.40)	1.35*** (1.19-1.51)
High use							1.00 (0.96-1.04)	1.29*** (1.21-1.38)	1.40*** (1.22-1.58)	1.00 (0.96-1.04)	1.29*** (1.21-1.38)	1.39*** (1.22-1.58)
Random effects												
Country-level variance												
Variance (SE)	4.01 (2.2)	3.3 (1.22)	5.57 (3.21)	1.14 (0.45)	2.49 (0.93)	3.22 (1.39)	1.32 (0.53)	2.89 (1.02)	5.11 (1.89)	0.96 (0.34)	2.88 (1.04)	5.08 (1.90)
ICC (%)	54.92	50.04	62.85	25.8	43.9	49.5	28.71	46.73	60.82	22.66	46.66	60.69
DIC	357976.78			357974.36			337262.21			337164.37		

Note 1: Non-tobacco use as the base category, reported in Relative Risk Ratio, RRR. 2: The low DIC together with the decreased ICC in the model indicates balanced goodness of fit and model complexity
*p<0.05; **p<0.001; ***p<0.001 a National Wealth: purchasing power parity (PPP) / thousands $. b MPOWER: numbers of the MPOWER measures implemented to the highest level

3.4.2 Dual & Poly-Tobacco Use Among Migrants

Data of 154,425 male adults from 15 countries aged 15 to 49 years (India: 15-54) surveyed between 2015 and 2016 were analysed. The section below presents the results of the descriptive analyses and regression modelling respectively.

Cross-Sectional Prevalence of Tobacco Use

Among the total sample, one-fifth (20.7%, n=32,160) of the male respondents were categorised as migrants. Except for African countries, the prevalence of using dual or poly- tobacco products was relatively high among migrants compared to non-migrants in the countries surveyed. In Southeast Asia region, Nepal and India had the highest prevalence of dual and poly-tobacco use among migrants: 15.9% dual-use and 3.3% poly-use in Nepal; 10.4% dual-use and 3.2% poly-use in India. Table 7 presents the weighted prevalence of tobacco use patterns among male migrants in each country.

Determinants & Factors associated with Tobacco Use

After controlling for individual-level demographic and socioeconomic factors, the multilevel models revealed that male migrants were generally at higher risks of tobacco use. Table 8 presents the associations of migration status with different patterns of tobacco use. After adjusting for individual-level sociodemographic variables with country-level random intercept, the multinomial regression models (model 1) indicated that in comparison to non- migrants, male migrant respondents were at higher risk of single (RRR=1.22; 95%CI: 1.19-1.26), dual (RRR=1.41; 95%CI: 1.34-1.48) and poly (RRR=1.71; 95%CI: 1.57-1.86) tobacco use. The association was consistent for any tobacco use (RRR=1.28; 95% CI: 1.25-1.35) vs. non-users in the binary logistic model (model 2).

Table 7: Weighted prevalence of current tobacco use among male migrants by different use patterns in 15 LMICs

Country	Year of survey	Number of male migrants (%)	Prevalence of tobacco use (%) and 95% confidence interval		
			% Single [a]	% Dual [b]	% Poly [c]
Cambodia	2014/15	960 (34.6)	36.8 (33.1-40.7)	2.1 (1.3-3.4)	0.1 (0.1-1.8)
India	2015/16	18,730 (16.2)	31.2 (30.1-32.2)	10.4 (9.4-10.9)	3.2 (2.8-3.6)
Nepal	2016	1,070 (28.9)	29.1 (25.3-33.3)	15.9 (13.5-18.6)	3.3 (3.2-4.9)
Ethiopia	2016	1,563 (22.3)	2.3 (1.7-3.2)	0.2 (0.1-0.4)	0 (0 - 0)
Kenya	2014	2,189 (35.1)	15.7 (13.8-17.9)	1.2 (0.8-1.7)	0.2 (0.1-0.5)
Tanzania	2015/16	671 (36.9)	13.1 (101-16.9)	0.7 (0.3-1.9)	03 (0.1-1.1)
Zimbabwe	2015	1,246 (24.6)	10.4 (8.5-1.6)	1.4 (0.8-2.3)	0.2 (0.1-1.0)
Malawi	2015/16	934 (29.4)	9.5 (7.3-12.3)	0.3 (0.1-0.8)	0.5 (0.1-2.4)
Lesotho	2014	378 (33.9)	31.9 (26.8-37.4)	10.1 (9.5-14.9)	0.3 (0.1-1.2)
Burundi	2016/17	900 (30.6)	10.3 (8.4-12.6)	0.1 (01-0.8)	0 (0 - 0)
Ghana	2014	810 (31.5)	4.8 (3.3-6.9)	1.9 (0.6-5.4)	0.2 (0.1-1.3)
Uganda	2016	844 (29.9)	6.2 (4.8-8.1)	1.3 (0.5-3.4)	0 (0 - 0)
Angola	2015/16	642 (41.9)	16.9 (13.6-21.1)	2.6 (1.1-6.0)	0.3 (0.1-2.4)
Haiti	2016/17	912 (22.5)	10.6 (8.4-13.2)	1.5 (08-2.8)	0.6 (0.2-1.5)
Armenia	2015	320 (35.7)	62.7 (56.5-69.5)	3.8 (2.1-7.1)	0.7 (0.1-3.5)

Note:

a Single tobacco use: individuals currently using only one tobacco product.

b Dual tobacco use: individuals concurrently using two different tobacco products.

c Poly tobacco use: individuals concurrently using three or more tobacco products.

Table 8: Multilevel regression of tobacco use patterns among male migrants in 15 LMICs

	Relative risk ratio/ odds ratio with 95% confidence interval			
	Model 1			Model 2
	Single Use [a]	Dual Use [b]	Poly [c] Use	Any [d] Use
Migration status (ref. non- migrants)				
Migrants	1.22***	1.41***	1.71***	1.28***
	(1.19 - 1.26)	(1.36 - 1.49)	(1.57 - 1.86)	(1.26-1.32)
Number of observations				
Level 1		155,425		
Level 2		15		

Note : both models 1 and 2 were adjusted for age, education level, marital status, residential area, occupation and household wealth using multilevel regression models for categorical responses (model 1) and binary outcomes (model 2). Non-tobacco use as the base category for both models, reported in Relative Risk Ratio in model 1; Odds Ratio in model 2.

a Single tobacco use: individuals currently using only one tobacco product.

b Dual tobacco use: individuals concurrently using two different tobacco products.

c Poly tobacco use: individuals concurrently using three or more tobacco products.

d Any tobacco use: individuals currently using nay tobacco products.

*p<0.05; **p<0.001; ***p<0.001

3.5 Discussions

Summary of Main Findings

The examination of tobacco use among male adults in LMICs reveals that the prevalence of current dual and poly-tobacco use varies substantially worldwide for the male population, although in some regions of the world multiple product use was much less prevalent than single product use. Similar findings were discovered among male migrants. Older age, low academic attainment, low-income status, being divorced, residing in urban areas, high frequency of media use, and being a migrant were all linked to dual and poly tobacco use. Among country-level variables, national wealth was not associated with dual and poly tobacco use; however, a mixed association was discovered between implementation of MPOWER measures and tobacco use.

3.5.1 Characteristics and Patterns of Dual & Poly-Tobacco Users

Among countries in the WHO Western Pacific region, Southeast Asia region, as well as Afghanistan in the Eastern Mediterranean region, males used dual and poly-tobacco more frequently. In average, dual or poly-use, at around one in seven (15.2%) using, is highest in South Asian men; and almost one in twelve (7.1%) men using in the Eastern Mediterranean; and one in twenty-five men (4.1%) using in the Western Pacific regions.

Multilevel regression accounting for both individual and country-level variables revealed considerable country-level variation in tobacco use, highlighting the variations between countries. At the individual-level, significant negative associations were found between dual/poly-use status and the respondents' socioeconomic factors. That is, the risks of dual and poly-use are lower among men in households with higher levels of household wealth and education attainment. This highlights the disparities in tobacco use across wealth quintiles and education levels, which are similar in trend across the countries for men. The largest disparities in tobacco use for men were for poly-tobacco users in comparison to non-users, where men in the highest wealth quintile were 84% less likely to be poly-users compared to men in the highest quintile (RRR=0.16; 95% CI: 0.14-0.19 for the highest wealth quintile vs. the lowest). The gradient of disparity followed the same pattern for men of different education levels. These results were similar to established evidence on inequality of tobacco use among the disadvantaged[59]. The risks of dual and poly-use were also higher among those who lived in

urban areas and were more exposed to mass media than those who lived in rural areas and were less exposed to media sources. This may be explained by increased accessibility of points of sale in urban areas and higher exposures to marketing strategies and media portrayal of tobacco product use as unproblematic, fashionable, masculine, or independent may encourage smoking among individuals[91, 137].

The current analysis used the household wealth index as a proxy of SES to separate in quintiles from one (lowest) to five (highest) as measure of the household's relative economic status for each respondent. However, the index was by definition made to measure several housing characteristics into ad hoc indexes to determine a household's economic status and is essentially different from expenditure or income measures that directly reflect the respondents' or households' consumption power[138]. As a result, the current analysis was unable to and did not examine whether dual and poly-use were related to the availability or/and affordability of tobacco products, but this is an important question for subsequent research. Although the wealth index does not yield results directly comparable to an income or expenditure-based index, it has been shown that the wealth index produced a better analysis for some key demographic and social indicators (e.g., health, education, use of public services indicators) than an expenditure or income index and could explain a greater amount of variance between individuals on a set of indicators[138].

On the other hand, at the country-level, findings indicated that there was no link between national income and different tobacco use patterns, which might imply that the prevalence of dual and poly usage is influenced by non-economic variables such as social and cultural features that impact tobacco product consumption and the popularity of the products. However, other contextual-level factors such as cigarette price and taxation that were proven to influence tobacco product consumption[32] were not taken into account in the current study. Future studies should incorporate these factors to explore their associations with multiple tobacco use. In addition, high-income countries were not included in the analysis, which would have shown more variance in national income and smoking prevalence.

Furthermore, results indicated that more MPOWER regulations implemented at the highest level were negatively related with single tobacco product usage, predominantly manufactured cigarettes, among males in the LMICs studied. Given that MPOWER interventions have been

demonstrated to reduce cigarette use, this is to be expected[73, 139]. However, current results indicated that MPOWER scores were further linked to a greater relative risk of dual and poly-tobacco use as compared to non-user. This might be partially explained by regulatory discrepancies between manufactured cigarettes and non-cigarette tobacco products. Policy restrictions on cigarettes are often more rigorous in terms of taxes, warning labels, smoke free laws, and flavour prohibitions[73, 139] in comparison to non-cigarette products. These key measures were very effective in reducing cigarette smoking at the population level, but should be strengthened to address all tobacco products to curb switching and transitioning to alternative tobacco products of lower costs or to circumvent regulation, leading to multiple product use[140, 141].

However, it is important to acknowledge that the MPOWER score calculated in the current study is a composite score constructed by the number of six key tobacco control policies implemented at the highest level in each country (ranging from 0—none at the highest level, to 6—all measures implemented at the highest level) and may be susceptible to composite variable bias[142, 143] that causes both analytical and interpretational challenges when included in a model. In the case of the current study, the MPOWER score was created as a variable that aims to "summarise" multiple related concepts in a convenient or parsimonious way. In particular, summarising means that one intends to model and understand the "average effect" of a group of related ideas on a desired outcome. Even the composite variable demonstrated validity and interpretability, it is expected all composite variables, regardless of how they were constructed, to suffer some degree of information loss whenever the constituent components have very different variances, because a single variable would not be able to sufficiently capture all of them. Therefore, for example, having an MPOWER score of 3 (three out of six components at the highest level) may not be equally the same for all countries with the same score. In a more specific scenario, implementing tobacco taxation to the highest standards and effectively enforcing advertising bans would potentially have a more direct impact on regulating tobacco product use than scoring higher in tobacco use monitoring and enforcing some-free bans, as these policies might need time to reflect on their impact on tobacco use in the long term[13, 144-146].

In order to further test the findings related to MPOWER and poly-tobacco use and the positive relationship discussed, I have conducted an additional analysis to address one of the comments

made by the paper's reviewer as well as my thesis examiner's comments on this point. In the additional analysis, two additional multilevel models were fitted to examine the association between MPOWER measures and two types of dual or poly-tobacco use: dual or poly-tobacco use including cigarettes; and dual or poly-tobacco use of non-cigarette products only. Both models were adjusted for the same set of independent variables mentioned above. By categorising dual- and poly-tobacco users based on whether they used cigarettes in conjunction with other products or all non-cigarette products, one can disentangle the role of conventional cigarettes in the relationship between MPOWER measures and dual/poly-use. Consequently, results indicated that by type of dual/poly-tobacco use found no association between MPOWER implementation and dual or poly-tobacco use including cigarettes (RRR=1.01; 95%CI: 0.99-1.03). However, a positive association was identified for dual or poly-tobacco use of exclusively non-cigarette products (RRR=1.21; 95%CI: 1.20-1.22) (Appendix 3). Thus, the assumption that the differences in the restrictions on manufactured cigarettes (mainly stricter) in contrast to other non-cigarette products is also supported by the fact that the MPOWER score was positively associated with dual or poly-tobacco use of non-cigarette products.

3.5.2 Migration and Dual & Poly-Tobacco Use

LMICs host substantial populations of migrant workers[147] with the majority of whom are male. This could be resulted from accelerated industrialisation within developing nations, resulting in greater labour mobility and migratory movements of men from rural regions to cities with manufacturing jobs within/across nations[118]. The migrant population generally have lower SES, poor health, and greater frequency of tobacco use[59]. Previous research has found that migrant workers had worse health outcomes and a lower quality of life and are more likely to engage in complicated health risk behaviours[5, 59], making them vulnerable to dual and poly-tobacco use.

Results suggest a positive relationship between migrant status and different tobacco use patterns. This is consistent with the proposed MTP model for multiple tobacco use[35, 47], which suggests that higher-level social or cultural factors, in this case, migration status, may have an impact on the substitutive and complementary behaviour of tobacco use. People with migrant status are more likely to be exposed to various neighbourhood environments, tobacco retail outlets, product availability, or tobacco product use norms across various cultural

contexts[115], which may have an impact on their tobacco consumption behaviours. Under such impacts, migrant populations may have a higher likelihood of transitioning/switching between various tobacco products into dual or poly-tobacco user. Acculturation may also be related to changes of migrant's tobacco use behaviour, as migrant population may tend to diverge away from rates of smoking initiation, prevalence, and quitting of their home population or converge with that of the host population over time resulting in a more complexed behaviour of tobacco use[116].

The current study reveals a greater association for dual and poly-tobacco use than for single and any tobacco use. However, it is possible to argue that dual and poly-tobacco use may be an expensive to keep as habit for the disadvantaged migrants. This could be explained by interactions between personal characteristics, availability of products and situational factors of the MTP model[35, 47]; migratory men are prone to dividing their time between areas with varying availability of different tobacco products, switching to more affordable tobacco products, and moving between regions with different restrictions and cultural norms, which increase the risk of multiple tobacco use and overall tobacco consumption.

3.5.3 Implications for Regulations and Policies

Clear regional patterns of different tobacco product use were observed from the research findings, these results were partially similar with previous findings[5, 30]. Cigarettes were the most popular products used globally. In Southeast Asia, Europe, and the Eastern Mediterranean area, one-third to two-thirds of men smoked cigarettes. However, in accordance with previous research, smokeless tobacco products such as *gutkha/paan masala* with tobacco and *khaini* were extremely popular among men in South Asia[5, 84]. These geographical trends were also seen for dual/poly-tobacco use, implying a strong relationship between a wide and varied tobacco market and high prevalence of dual and poly-tobacco use, as in Southeast Asia and Western Pacific regions[72, 111]. Dual and poly-tobacco use is prevalent in most nations examined, particularly among regions where diversified tobacco products were more accessible, posing an obvious and severe health risk to these people.

Dual and poly-tobacco use may represent price-minimisation methods, particularly among individuals with a lower socioeconomic position, or as a way to avoid current regulations

against public smoking restrictions[140, 141]. Furthermore, they may raise health concerns for people who use numerous tobacco products and hinder them from effectively quitting[1]. The findings suggest that men in LMICs, particularly in Southeast Asia, appear to bear a double burden. Importantly, those in the poorest and least educated segments of society bear a disproportionate share of this cost, exacerbating health inequities within countries. As a result, tobacco control policies in these regions must place a greater emphasis on alternative tobacco products in the context of dual and poly-tobacco use to curb the growing tobacco epidemic in LMICs. In many countries, MPOWER policies have been inadequately implemented to non-cigarette tobacco products, and our findings underscore the possible repercussions of this[148].

Furthermore, male migrants in LMICs exhibit a high prevalence of single, dual and poly tobacco use, particularly in the Southeast Asia region and are more likely to face barriers receiving health care and support for cessation[5, 59]. This implies that such vulnerable population may be at increased risk of stronger addiction, lower motivation to quit and being targeted by the tobacco industry[117]. As discussed in the previous section, the migrant population may become more susceptible to pro-tobacco use influences from their higher mobility and varying situational factors as they are more likely to split their time between places with varying availability of different tobacco products, switch to more affordable tobacco products, and move between regions with varying restrictions and cultural norms. This adds challenges to implementing effective policies for reducing tobacco use among these vulnerable populations and interventions to provide them with consistent support to quit.

Thus, tobacco control policies should specifically address migrant populations with culturally appropriate programming and focus on preventing and reducing multiple tobacco use and overall tobacco consumption to relieve the health burden among population with diverse background[149]. Bespoke agreements between authorities and borders to protect these vulnerable populations from tobacco-related health risks and increase access to tobacco-dependence services can be applied to protect the migrant population. Other policies, such as unified efforts to raise tobacco taxes to reduce cross-border purchases and comprehensive clean indoor air policies in all settings to prevent users from switching between products to avoid regulations, have been shown to be effective in reducing tobacco use in vulnerable populations [150].

The considerably higher levels of dual/poly-tobacco use among certain regions and migrants in the LMICs may reflect the social and contextual effect of living in a less stringent environment with respect to tobacco control efforts. This highlights that tobacco control regulations need to be reinforced to address non-cigarette tobacco products within these nations[148] in order to reduce dual and poly-tobacco use. It also highlights the importance of disaggregating smoking prevalence by ethnicity and migration status in order to inform applicable policies and preventative and smoking cessation programmes for specific target populations[151].

3.5.4 Strengths & Limitations

This chapter presents an up-to-date analysis of dual and poly-tobacco use among men in LMICs. It also gives a more detailed view of underprivileged male migrants, which few studies have looked into[19, 31, 112, 128]. Furthermore, this chapter adopted a multilevel approach to the analysis by taking into account the effect of clustering in individual outcomes when respondents are from different countries. Such method is imperative in making accurate inferences about the population of groups[134], especially when examining a heterogeneous sample within different cultural contexts, such as the studies in this chapter. The large sample sizes analyzed in this chapter reduce uncertainty around estimates, also allowing study findings to reflect less biased associations of the results. Also, the consistent methodology of the surveys enabled me to compare results across countries.

To my knowledge, the DHS datasets were used for the first time to explore the prevalence, correlates, and patterns of dual and poly-tobacco use in a number of LMICs. Using both individual and country-level data from surveys, the current studies were able to expand established knowledge on multiple tobacco use in the literature and expand the research questions to understand the characterization of dual/poly-tobacco use disparities and patterns among different populations. Furthermore, adding to the current literature, advanced methodologies such as multilevel analyses were used to look at the effect of broader social factors on individual use patterns. Such random effects models have been limited in previous studies in the felid of tobacco regulatory studies.

Taking into account the MTP model's person, product, and situational factors[35, 47], the application of multilevel analyses on DHS data was an appropriate method to focus on both how multiple-tobacco use and use patterns at the person level (for example, sociodemographic characteristics) relate to geographic, cultural, and population-level socioenvironmental factors in the evaluation of multiple tobacco use across various countries. Such findings can lead to a more comprehensive understanding of dual/poly-tobacco use as well as more precise estimates of the effects of certain factors on different populations. Moreover, this was the first to utilize such methodology to explore relationships of multiple tobacco products among men and migrants in LMICs at the time of publication.

Despite the strengths of the studies, there are several limitations of the DHS data that should be considered when interpreting these results. There are a number of countries that were excluded from the analyses as they did not collect information on current tobacco use. Therefore, results might not be entirely representative of all countries in the particular regions. The DHS questionnaires typically undergo a review every five years or so. This review can result in some questions being changed or dropped, and others added. Caution should be taken when comparing the prevalence of tobacco use across countries, because the surveys may have been conducted at different points in time, and the questions assessing tobacco use may have differed, leading to underestimation of dual and poly-tobacco use. However, to ensure compatibility and reliable measurement of dual and poly-products use, prior to the analysis, questions and responses on all tobacco use was checked for validity, and complete data on tobacco use patterns were included in the data cleansing process.

It should be noted that DHS surveys are not intentionally designed to be tobacco surveys, thus they do not capture detailed information such as smoking duration, frequency of use and the use of all tobacco products. Although questionnaires did not include all tobacco products in all countries, I assumed that all popular products were assessed in each country. For this reason, I did not disaggregate dual and poly-use according to the type of tobacco product used, as there was a total of 11 types of products surveyed, and the availability of products data varied widely across 19 countries. Categorising dual and poly-tobacco use patterns by types of products used would limit the comparability across countries and the interpretation of data in a meaningful way. Additionally, with new emerging tobacco and nicotine products such as heated tobacco and e-cigarettes, the tobacco market in LMICs will be complicated in coming years. These

were not surveyed and assessed in the DHS questionnaires, presumably due to very low prevalence, particularly in LMICs, but may need to be considered in future surveys.

Next, migration status is operationalized as a binary variable of whether the respondent has slept or resided away from home for more than one month in the last 12 months. However, it may also refer to visits to family or friends, hospital stays, or vacations, among other things. Thus, migration status could be at risk of an overestimation. Nevertheless, similar definitions were also used in previous DHS study[127]. Due to the limited information obtained from the survey, detailed data including the amount of time spent in current/previous residences were not available. However, in an LMIC context, it can be reasonably assumed that being away from home is often related to labour or work-related purposes rather than having long holidays.

As previously discussed, the MOPWER score, and media exposure variables were simplified measures of a summary effect, which may be at risk of composite variable bias[143, 152], and may not fully capture the effects of specific tobacco control policies on dual and poly-tobacco use. Another drawback is that the data on tobacco use is self-reported, which may be influenced by reporting or recall bias. As noted in the methods section, only male respondents were analyzed. However, given the current societal trends in the countries examined, it is mostly men who smoke. Thus, the results of this chapter would reflect the majority of tobacco users. [5, 30, 31].

Lastly, due to the analytical approach and the cross-sectional nature of the data, it was not able to study transitions from single to dual and poly-tobacco use and vice versa. This would be the focus of the study in the next chapter, which uses longitudinal data to capture temporal relationships of different tobacco use patterns.

3.5.5 What the Studies Add

Studies in this chapter add to the current literature an updated overview of the prevalence of dual and poly tobacco use in LMICs and the potential factors that impacts different use patterns. Methodologically, the study took into account of both individual and contextual-level (situational) factors with the application of multilevel analyses on DHS data in the evaluation

of different tobacco use patterns (i.e., single product use, dual tobacco use, poly-tobacco product use) across various countries and economic contexts, which few studies have examined.

Understanding the sociodemographic variations such as SES and migration status in tobacco use within and between countries not only provides critical information for addressing inequality in tobacco use within countries, but also aids in improving regional integration of tobacco control policies to strengthen their impact across borders.

This study underlines the importance of considering the role of alternative tobacco products in LMICs. The findings emphasise the need for more comprehensive tobacco control policies to strengthen tobacco control policies and interventions in LMICs, with a special focus on non-cigarette products and inequality in tobacco use among the underprivileged in order to reduce dual and poly-tobacco use.

Chapter 4. Correlates of and Transitions to Dual & Poly-Tobacco Product Use among Adults in Bangladesh

4.1 Research Overview

Following on previous cross-sectional studies on dual and poly-tobacco use in low- and middle-income countries (LMIC), the present chapter focuses on Bangladesh, a developing nation in Southeast Asia that is home to a considerable proportion of the world's smokers. The International Tobacco Control (ITC) Survey in Bangladesh was utilised as a case study in this chapter for a closer look at the trends and patterns of dual and poly-tobacco product consumption among current tobacco users over four ITC waves. This study also looked at the transitions between different tobacco product use throughout time, as well as the relationships between tobacco use patterns and different behaviours and tobacco control factors. This study was carried out between September 2021 and April 2022, in collaboration with the ITC Project team in Waterloo, Canada. Whilst being the primary author of the study and performing and planning the analysis, the work featured in the chapter is the result of a collective effort. The other contributors to the study are outlined as follows: my PhD supervisor, Filippidis FT assisted in conceiving the study idea and study methodology; Nargis N, Fong GT, Huq SM, and Quah ACK from the ITC Project team provided comments, reviewed the study, and were involved in the interpretation of data and revision for critical intellectual input.

4.2 Background & Aims of The Study

4.2.1 Study Rationale

Tobacco smoking is a major issue in LMICs as 80% of tobacco smokers dwell in these regions[7, 153]. Specifically, the Southeast Asian area accounts for nearly two-thirds of the world's smokers[154]. In Southeast Asia, tobacco is consumed in diverse forms, including smoked products, such as *cigarettes* and *bidis* (a cheaper hand-rolled form of smoked tobacco), and *smokeless tobacco* (SLT), which is commonly regarded as more socially acceptable and less harmful than smoked products[155]. Several countries have witnessed an increased prevalence of concurrent use of these products (i.e., dual- and poly-tobacco use) in recent years[77, 156]. This is extremely relevant in Southeast Asian countries such as Bangladesh,

one of the top countries with the highest tobacco production and consumption in the world[7, 153].

Bangladesh is a country with a diverse cultural heritage. Social custom are an integral part of the country's culture and tobacco use is one of the accepted social norms in the country[156]. The dynamic connections between smoking and SLT use, as well as the socio-cultural structures that influence tobacco use, shape the context of high dual and poly-use of the three commonly used tobacco products in Bangladesh (i.e., cigarettes, bidis, SLTs), which makes it easier for users to transition between products, adding considerable health burden of tobacco-related illnesses in Bangladesh. Furthermore, dual and poly-tobacco use reflect patterns of tobacco product substitution/initiation and nicotine seeking behaviour, which in turn can be influenced by underlying person, product, and situational-level factors, as demonstrated in the conceptual model of multiple tobacco product (MTP) use[35, 47]. Therefore, this chapter's aim was to conduct an in-depth case study for a closer look at the trends and patterns of dual and poly-tobacco product use among current tobacco users in Bangladesh to assist in developing comprehensive and multi-faceted approaches to tackle diversified tobacco use in Bangladesh. Not only for the reason that Bangladesh is one of the countries with the highest number of tobacco users globally, but conclusions from this case study could potentially inform policies in other countries, especially in the same geographic region, where hundreds of millions of tobacco users live.

4.2.2 Tobacco Use & Policy in Bangladesh

Tobacco use in Bangladesh

Bangladesh, a South Asian country, is one of the top ten countries in the world, accounting for two-thirds of the world's smokers[7]. According to the most recent Global Adults Tobacco Survey (GATS) data from Bangladesh, in 2017, more than one-third of the adult population (35.3%) aged above 15 in Bangladesh were current tobacco users of smoked and/or SLT products[157]. Cigarettes, bidis, and SLTs are the three major products used in the country. SLT was accounted as the most prevalent type of tobacco product used in Bangladesh (overall prevalence 20.6%), followed by cigarette use (overall prevalence 14.0%) and bidi (5%) in 2017[157].

Bangladesh has recently gone through a health and economic transition; with tobacco use being the leading cause of noncommunicable diseases, it has become a significant burden in Bangladesh[155, 157]. Bangladesh men have shown high prevalence of both smoking (e.g., *cigarettes, bidis*) and use of SLT (e.g., *betel quid with tobacco*, fermented tobacco leaves/power such as *khoini, Zarda, Gul*). However, women usually do not smoke but use SLTs. Bidi smoking is a common practice in Bangladesh. Half of the smokers use bidis, particularly in rural regions and among the disadvantaged urban residents. According to GATS data in 2017, the prevalence of bidi smoking in rural areas (13.5%) is higher than in urban areas (4.7%)[157]. Bidi is the cheapest substitute for cigarette and is often sold in filterless form. It is a crude form of smoking that is smaller in size than a cigarette and is hand-rolled by wrapping dried tobacco flakes onto a dried leaf or paper and tying it with thread.

SLT is common in South Asian countries for both sexes. More than one third of total tobacco consumption in this region is in the form of smokeless tobacco[155]. In Bangladesh, SLT use is considered the predominant form of tobacco use; 18.6% of adults smoke and 20.6% of adults use SLT, with the majority being female users[157]. Traditional values and social norms in South Asia may discourage young men and women from smoking, but there is no such taboo on SLTs[158]. Many adults use SLTs because of its claimed therapeutic efficacy in treating physical illnesses such as toothaches, headaches, and stomach pains[159]. Curiosity, peer pressure, and offers from friends and acquaintances all play a role in the decision to initiation[160]. Some studies suggest that Bangladesh has considerably higher rates of tobacco consumption, including smokeless tobacco, than India and Pakistan[161].

SLT is more common among lower socioeconomic status (SES) groups in Bangladesh, such as the economically disadvantaged, semi-skilled manual workers, unemployed people, and those with less education[156]. National survey in 2009 had reported an overall prevalence of 27.2% of current SLT users in Bangladesh, and 43.2%-47.1% of adults in rural areas were smokeless tobacco users[162]. This study also reported that respondents having less education and a lower socioeconomic status (SES) had higher odds of using both smoking and smokeless products while a marginally positive relationship was noted between living in rural areas and using SLTs[163]. In 2017, the population prevalence of SLT was estimated to be 20.6%, with statistically higher rates in rural areas than in urban areas[157]. Results showed that participants from higher SES were more likely to smoke than those from lower SES backgrounds, and that

respondents from rural areas had lower prevalence of tobacco smoking[164]. Consistent with other national studies, large differences were noted in tobacco use prevalence among the divisions of the country with clear disparities in use by sociodemographic and economic characteristics of population subgroups[156, 161, 165].

During the past decade, current tobacco use prevalence has decreased among adults from 43.3% in 2009 to 35.3% in 2017 (from 23% to 18% among tobacco smokers; 27.2% to 20.6% among SLT users; 38.1% to 29.9% among urban respondents; 45.1% to 37.1% among rural respondents). Although the prevalence of tobacco use has declined over the period, the sustained growth of the tobacco market and industry in Bangladesh and the increased purchasing power of the population have led to switching/ transitions between tobacco products[144] and the increased prevalence of concurrent use of multiple tobacco products (i.e., dual and poly-tobacco use) in recent years[77].

Though previous studies have largely focused on cross-sectional patterns of tobacco smoking and smokeless tobacco use among various socioeconomic and demographic sub-groups, attention should be given to further investigating long-term impact of these factors on the transitions of tobacco use and quitting, and whether they were associated with policy implementation. The Tobacco Control Policy Evaluation Project (ITC) Bangladesh survey provides a longitudinal cohort (4 waves from 2009 to 2015) which offered an opportunity to longitudinally explore tobacco use transitions between different patterns of users (e.g., how people transition to and away from single, dual and poly-tobacco use), and uptake of different products within population subgroups.

Tobacco control policy in Bangladesh

Bangladesh is one of the first signatory countries to the World Health Organization (WHO) Framework Convention for Tobacco Control (FCTC). The global treaty was signed in 2003 and ratified in 2004[162]. In 2005, the government passed a comprehensive tobacco control law in line with FCTC- the “Smoking and Tobacco Products Use (Control) Act” and in 2006, it passed rules to facilitate its enforcement. The government amended the Smoking and Tobacco Products Use (Control) Act in 2013, and rules under this law were notified in 2015. It was not until then that smokeless tobacco (SLT) was included in the definition of tobacco

products under the amended Act in 2013[162]. The three most commonly used smokeless tobacco products, *Zarda, SadaPata*, and *Gul* are included in the Act.

To curb tobacco use, the Bangladeshi government has implemented a number of initiatives, including forming taskforce at district and sub district level to strengthen monitoring mechanism on enforcement of tobacco control law, and raising the cigarette tax on a regular basis. However, Bangladesh has been faced with the challenges of securing long-term support for tobacco control activities[157]. To preserve public health and provide sustainable funding for tobacco control to meet Sustainable Development Goal (SDG) target 3 on health and well-being, the government implemented a 1% health development surcharge (HDS) on all tobacco products in the 2013–14 fiscal year[166]. In 2017, rule passed to adopt HDS, and the government published the Health Development Surcharge (HDS) Policy, accordingly. Figure 7 depicts a detailed timeline of tobacco control policies and regulations in Bangladesh, as well as the corresponding time frames for the four waves of the ITC-Bangladesh survey.

Bangladesh started implementing the MPOWER package in December 2008, and the strategy is being implemented through a national tobacco control programme. The MPOWER package is a set of six established strategies aimed at combating the global tobacco epidemic: **Monitor** tobacco use; **Protect** people from tobacco smoke; **Offer** help to quit; **Warn** about the dangers; **Enforce** bans on advertising and promotion; and **Raise** taxes on tobacco[7]. Bangladesh has met goals for monitoring and pictorial health warnings at the highest achievement during the past years[7]. However, Bangladesh lagged behind in compliance and comprehensive policies in controlling tobacco use in other facets. Particularly, policy inadequacies remain for smoking bans and offering cessation services as well as efficient control for SLTs[166].

To protect people from the dangers of tobacco smoke, the government of Bangladesh declared healthcare and educational facilities 100% smoke-free under the Smoking and Using of Tobacco Products (Control) Act, 2005, and in 2013 the Act was amended to extend the list of smoke-free public places including ban on smoking in universities, government facilities, indoor offices, public places, and transport. However, smoke-free rules are not yet applicable to SLTs, and Bangladesh still has to expand the numbers of smoke-free public spaces to cover all public places as completely smoke-free[166].

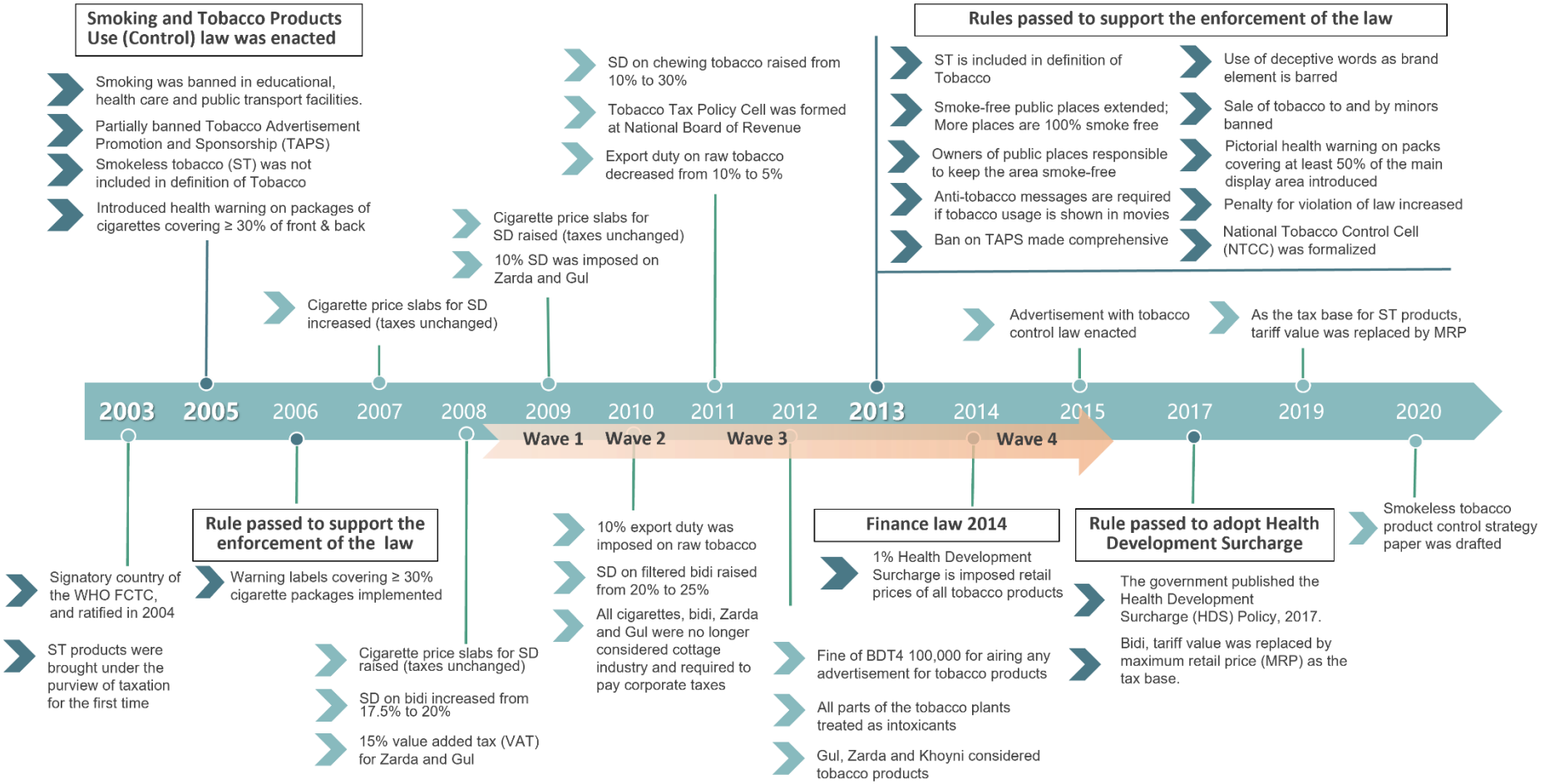
Furthermore, Bangladesh has a high burden of tobacco-related illness. However, clinic-based smoke cessation treatments have not kept pace. Bangladesh currently lacks a dedicated national tobacco cessation service or quit line; nicotine replacement therapy (NRT) and cessation therapies are neither cost-covered in Bangladesh[7]. To provide sustainable services to treat tobacco dependence, cessation programmes on both smoked and smokeless products should be advocated on a constant basis in health professionals' curriculum[166]. As people become more receptive to medical counsel, a comprehensive cessation effort may increase patients' motivation to quit smoking.

Lastly, low levels of excise tax are the main reason for the price differences between LMICs and high-income countries. WHO recommends that the excise tobacco tax should account for 75% of the final retail price[7]. The current cigarette excise system has been in force for decades in Bangladesh. The tiered system at four different rates for low-price, medium-price, high-price and premium brands of cigarettes were applied by The National Board of Revenue of the Bangladesh finance ministry. Between 2009–2010 (wave 1 of the ITC-Bangladesh survey) and 2014–2015 (wave 4), the supplementary duty at four different tiers increased from 32%, 52%, 55%, and 57% of the recommended retail price to 43%, 60%, 61%, and 61% for the four tiers, respectively[167].

However, according to the budget presented in the Bangladesh National Parliament in 2020, in the fiscal year 2021, the supplementary duty on cigarettes for the low-tier and three other tiers is 57% and 65% of the maximum retail price (MRP), respectively. Taxation on SLT remains low in Bangladesh compared to cigarettes. The supplementary duty on *Zarda* and *Gul* is relatively low—only 55% of the MRP. It is advised to continuously decrease the affordability of tobacco products by introducing specific taxes and increasing the present ad valorem tax level and the Health Development Surcharge (HDS) across smoked and smokeless products[168]. Furthermore, tax increases should be comparable across all tobacco products to reduce opportunities for substitution/transition in response to changes in relative prices.

To prevent transitioning and switching between products, and to avoid morbidity and mortality related with dual and poly-use of smoked and smokeless products, it is critical to strengthen tobacco product regulations, stringent tax measures, and cessation support on all smoked and SLT products at the national level.

Figure 7: Timeline of tobacco control policies and the ITC surveys in Bangladesh.



Note: figure adapted from the ITC website and study from Huque et al.[166]

4.2.3 Aims & Objectives

The aim of this study is to conduct an in-depth case study of poly-tobacco use using four waves of the International Tobacco Control Policy Evaluation Project (ITC)- Bangladesh dataset to longitudinally investigate the patterns and factors related to transitions of different tobacco use pattens (i.e., single, dual, and poly-tobacco use) and products (i.e., cigarettes, bidis, and SLTs) within population and user subgroups.

More specifically, the objectives of this study are:

- Provide descriptive overview of the changing prevalence of adult tobacco dual and poly-use of smoking and smokeless products at the country level across waves.
- Track trajectories of tobacco use transitions from Wave 1 to Wave 4 within different subgroups of users.
- Examine transitions of dual and poly-tobacco use in a longitudinal sample of tobacco users in Bangladesh and the associated factors of transitions from one product to the other at the individual level.
- Explore influencing factors related to the initiation, transition, and cessation of different smoking and smokeless products; and identify relevant strategies to reduce tobacco use among the Bangladeshi population to inform tobacco control policy.

4.3 Data & Methodology

4.3.1 Research Approval & Registration

The research proposal was approved by the International Tobacco Control Policy Evaluation Survey (ITC) Project in February 2020, and a subset of the ITC Bangladesh survey data was granted under the registered project entitled: “Correlates and Transitions of Dual and Poly Tobacco Product Use in Bangladeshi Adults Between 2009 and 2015: Findings from The International Tobacco Control (ITC) Study Wave 1 to Wave 4”.

Ethical clearance for the study protocol was obtained from the Head of Department on April 2019 and the Imperial College Joint Research Compliance Office (JRCO) in December 2019

(protocol number: 19IC5630) together with the previous project documented in chapter three. Following the ITC guidelines and the conditions of the ITC External Data Usage Agreement, all data was securely stored on a password protected encrypted external drive.

4.3.2 The ITC-Bangladesh Survey

The study in this chapter is based on data from International Tobacco Control (ITC) Bangladesh surveys. In 2008, the ITC Bangladesh Project was established to assess the impact of tobacco control laws in Bangladesh. The ITC Bangladesh Survey is a face-to-face survey performed in conjunction with the ITC Project team at the University of Waterloo in Canada by the Bureau of Economic Research at the University of Dhaka in Bangladesh[169]. The current study draws on data from all four waves available from the ITC Bangladesh survey, which took place in 2009, 2010, 2011–2012, and 2014-2015, respectively.

A nationally representative probability sample of adult tobacco users and non-users aged 15 and older was recruited utilising a multistage cluster sampling design for the first wave of the survey. In the ITC Bangladesh survey, households were interviewed using structured questionnaires. There were two different categories of eligible respondents in a household: adult smokers, and adult non-smokers, surveyed using the tobacco users' and non-users' questionnaire respectively. All tobacco use-related questions and data were retrieved from the tobacco users' survey, except for data on smokeless tobacco (SLT) use in waves 1 and 2, which were partially recorded and derived from the non-users' surveys.

At the time the initial cohort was surveyed, Bangladesh was divided into six administrative divisions, which are further divided into 64 districts. The national sample was designed to represent the broad national population of Bangladesh. For the national sample, 20 out of the 64 districts covering Bangladesh were selected randomly, Then, 37 upazilas/thanas (smallest administrative units of the local government) were chosen from among these districts. Each upazila/thana selected two villages as clusters with a probability proportional to population size; hence, the total number of clusters from the general population was 74[170-173]. All participants from the groups in the first cohort were called again to complete follow-up questionnaires in 2010, 2011–2012, and 2014-2015 for the subsequent waves. The total retention rate between waves 1 and 2 was 94.0%, while the rates between waves 2 and 3, and

waves 3 and 4 were 90.5% and 87.1%. The details of the ITC Bangladesh Survey are described elsewhere[174].

In this study, the national samples representative of the general population were analysed. The tribal sample, the slum areas, and the border regions sample in the Bangladesh survey were excluded in the current analyses due to the high mobility of these population, the complex data registration history and the un-stratified sampling. For the purpose of the longitudinal analyses, datasets from the four waves were matched and merged to the core dataset to filter out any excluded records. Furthermore, the longitudinal analyses were conducted only among the 3,245 respondents present in all four waves (Table 9).

Table 9: National sample of the ITC-Bangladesh survey (excluding the slums and tribal areas)

Survey waves	**Wave-1**		**Wave-2**		**Wave-3**		**Wave-4**		**Core datasets**	**Data analysed**
	2009		2010		2011-2012		2014-2015		Total respondents	**Respondents present in all 4 waves**
Sample size (N)	Tobacco User	Non-User	Tobacco User	Non-User	Tobacco User	Non-User	Tobacco User	Non-User		
	2,368	2,010	2,401	1,958	2,707	1,516	2,811	1,431	N= 5,511	**N= 3,245**

4.3.3 Measures & Key Variables

Tobacco product types

The types of tobacco products surveyed include cigarette, bidi, and SLT. Information was collected on the status of smoked and smokeless tobacco use of individuals aged 15 years and older using the tobacco users' survey. Respondents were identified as current tobacco users if they reported current use of cigarette or bidi or a combination of these products either in a daily, weekly, or less than weekly basis. If they did not meet this criterion, they were classified as non-users. The criteria were used to include occasional users in the user group who consume tobacco on a regular basis (e.g., monthly). The questions were: "do you currently smoke cigarettes/ bidis?". Those who answered "yes" (wave 1) or "daily/ weekly/ less than weekly" (wave 2, 3, and 4) were categorised as current users.

A similar principle was followed for the identification of SLT users. However, the SLT use definitions in wave 1 and wave 2 of the survey were less explicit. Two variables were included to account for current SLT use: any use in the previous 6 months and general use of SLT at least weekly. Those who gave an affirmative response to both variables were classified as smokeless tobacco users. It is also worthwhile to mention, in wave 1 and wave 2, exclusive smokeless users would include respondents from both the tobacco users', and non-users' survey who reported using SLTs. The relevant questions in waves 1 and 2 were: "In the past 6 months, have you used any smokeless products?" (yes/no) and "I generally use SLT at least weekly."(yes/no) Those who responded both "yes" to the former and latter questions were classified as current SLT users. For waves 3 and 4, the questions were: "Do you currently use SLT?" Responding daily, weekly, or less than weekly (very few responses) to the question indicates current use of SLT.

Current dual and poly-tobacco use

Following definitions of previous studies conducted in this thesis, current dual and poly-tobacco use were operationalised in the same manner. Individuals currently using two distinct tobacco products were deemed dual tobacco users (in the case of the current study, three combinations of use were created: cigarette+bidi, cigarette+SLT, bidi+SLT), whereas poly-tobacco users were characterized as concurrently using all three tobacco products assessed at the time of the survey (cigarette+bidi+SLT). In contrast, single tobacco users were individuals who reported currently consuming only one tobacco product. Therefore, current tobacco product use patterns were classified as below:

- Single product use
    - Exclusive cigarette use
    - Exclusive bidi use
    - Exclusive SLT use
- Dual product use
    - Cigarette + bidi
    - Cigarette + SLT
    - Bidi + SLT
- Poly product use
    - Cigarette + bidi + SLT

- Non-users/ Quitting

Outcome variable: transitions to different tobacco product/patterns

To examine respondents' transitions to various tobacco products/patterns between subsequent waves from wave 1 to wave 4, a set of binary measures was created using the panel data to measure transitions in respondents' tobacco use patterns depending on their use status at wave 1 (exclusive cigarette users, exclusive bidi users, or exclusive SLT users). The measures were dichotomized to indicate transition outcomes, where 1= the presence of transitions and 0 = no transitions occurring.

Among exclusive cigarette users at wave 1, five separate transitional outcomes were investigated. These transitions could be using another product in wave t+1 exclusively, in combination with cigarette use, or quitting. Thus, for exclusive cigarette users, the possible transitions/outcomes (non-mutually exclusive) were as follows:

- Transition to bidis use (i.e., using bidis with or without cigarettes/SLT)
- Transition to SLT use (i.e., using SLT with or without cigarettes/bidis)
- Quitting (transition to non-tobacco users)
- Any transition other than "quitting" (i.e., transition to any other combination of tobacco use other than "exclusive cigarette use").
- Transition to dual or poly use (i.e., using at least two products concurrently, regardless of the combination of products)

Similarly, the same sets of transitional outcomes were investigated for exclusive bidi users:

- Transition to cigarette use (i.e., using cigarette with or without bidis/SLT)
- Transition to SLT use (i.e., using SLT with or without cigarettes/bidis)
- Quitting (Transition to non-tobacco users)
- Any transitions other than "quitting" (i.e., transition to any other combinations of tobacco use other than "exclusive bidi use").
- Transition to dual or poly use (i.e., using at least two products concurrently, regardless of the combination of products)

Transitional outcomes for exclusive SLT users:

- Transition to cigarette use (i.e., using cigarette with or without bidis/SLT)

- Transition to bidi use (i.e., using bidis with or without cigarettes/SLT)
- Quitting (Transition to non-tobacco users)
- Any transitions other than "quitting" (i.e., transition to any other combinations of tobacco use other than "exclusive SLT use").
- Transition to dual or poly use (i.e., using at least two products concurrently, regardless of the combination of products)

Classifying transitional outcomes in this way makes it possible to examine longitudinal transitions of specific tobacco product/patterns over time at the individual level.

Covariates

For the covariates, there are three groups of independent variables: (A) Sociodemographic factors, (B) smoking status and (C) psychosocial predictors of smoking (Table 10).

In order to examine potential covariates that might be associated with individuals' transitions over time, several sociodemographic variables were included in the regression models. In particular, all models accounted for sex, age groups (15-17/ 18-24/ 25-39/ 40-54/ 55+ years), residence area (urban/rural), and housing index (low/moderate/high SES). However, additional sociodemographic factors such as marital status (married/ single or live alone), educational status (illiterate/ 1 to 8 years/ 9 years or more), as well as smoking status (nondaily or daily light/ daily medium/ daily strong), and smoking-related psychosocial factors were included in separate analyses later in the study to investigate in depth possible predictors of transitional patterns of exclusive cigarette users.

To capture the impact of socioeconomic status (SES), the CASHPOR index of housing conditions was constructed and served as the basis for stratification of the population in each survey area by socioeconomic position[175]. The CASHPOR housing index score was created based on housing conditions information such as structural condition of the house, area of the house, number of rooms, main materials of roof, floor, and wall, source of drinking water, toilet facilities, cooking fuel, and possession and use of television and radio. A categorical variable indicating low, moderate, and high SES according to the housing index was then constructed by the original ITC researchers.

To assess the respondents' cigarette smoking status, respondents were classified by current cigarette smoking and smoking intensity: daily light smokers who use less than ten cigarettes per day, moderate smokers who use more than ten but less than twenty cigarettes per day, and heavy smokers who use more than twenty cigarettes per day. This variable was constructed to reflect the ordinal status of cigarette smoking intensity. For analytical purposes, nondaily smokers (i.e., weekly or monthly smokers) and daily light smokers were collapsed into a single category across waves. Thus, three categories of smoking status were included as covariates for the transitional analyses of exclusive cigarette users: nondaily or daily light, daily medium, and daily strong.

A variety of psychosocial factors were assessed in the ITC Bangladesh Survey. Three questions regarding the respondents' quit intention, advice from doctors to quit, and attitude toward smoking were recorded. The respondents were asked whether they intend to quit smoking. Responses included: no plan to quit/ beyond 6 months/ in the next 6 months/ don't know. Respondents were also asked whether they received doctor's advice to quit smoking in the past 6 months (yes/no). Lastly, the respondents' attitudes toward smoking were measured by two statements: "Do you find smoking calming? (yes/no)" and "Do you find smoking important in your life? (yes/no)". Based on these questions, the responses were classified into "positive attitudes" (answered yes in both questions); "negative attitudes" (answered no in both questions), and "neither" (answered a yes and a no for both questions) and "don't know" if this was the answer to one of the two questions.

In order to assess the associations between psychosocial factors of smoking and an individual smoker's likelihood of transitioning to different tobacco products/patterns or quitting, the analysis of transitions of exclusive cigarette users between successive waves used the above three measures as possible predictors of transitions. Each of these measures was used as a categorical predictor of transition. Table 10 below shows the list of covariates mentioned above used to explore to association of transition in the current study.

Table 10: Covariates used to explore to association of transition (ref. category in bold face).

Variable Name	Description	Categories
Sociodemographic		
Sex		**M**/F
Age group		**15-17**/ 18-24/ 25-39/ 40-54/ 55+
Urban/rural	Residence area	**Urban**/rural
Housing index	CASHPOR index for socioeconomic status	**Low**/moderate/high
Marital status		**Married**/ single or live alone
Education	Less educated: 1 to 8 years More educated: 9 years or more	**Illiterate**/ Less educated /More educated
Smoking status		
Cigarette smoking status	Daily light: <=10 cig/day Daily medium: >10~<=20cig/day Daily heavy: >20+ cigs/day	**Nondaily or daily light**/ daily medium/ daily strong
Psychosocial predictors of smoking		
Quit intention	Intention of planning to quit	**No plan to quit**/ beyond 6 months/ in the next 6 months/ Don't know
Attitude toward smoking tobacco	Attitude to smoking (find smoking calming or important)	**Positive**/ neither/ negative/ Don't know
Doctor's advice to quit	Advice from doctor to quit cigarettes in the past 6 months	**No**/ Yes

Perceptions and reasons for transitions among exclusive users

A set of questions were asked of the respondents in order to understand why exclusive cigarette, bidis, and SLT users in wave 1 transitioned to either the initiation of other tobacco products or quitting in subsequent waves.

Respondents were asked about reasons for starting other products: "Why have you started using cigarettes/bidis/SLTs… friends/family smoke cigarettes?, media people smoke cigarettes?, it calms me when I'm stressed?, out of curiosity?, it's a sign of sophistication?, it's a way to occupy time?, the look and feel of the packaging (for bidis and SLTs)?, it's less harmful (for bidis and SLTs)? tastes better (for bidis)?, reduces stress (for SLTs)?, help quit tobacco (for SLTs)?, like the taste (for SLTs)? " The responses to these questions were yes, no, and don't know.

Reasons around quitting tobacco use were assessed with the questions: "Why quit using cigarette/bidis/SLT: concerns for health (pooled responses for concerns of poor health, concerns of future health, and information about health)?, concerns for others?, fewer places

to smoke (work place restrictions for exclusive SLT users)? example for children?, doctor's advice?, price?, warning labels?, family/ friends disapprove (society disapproves for exclusive SLT users)? " The responses to these questions were yes, no, and don't know.

Appendix 4 shows a list of all the questions asked above in relation to perceptions and reasons for transitions in the ITC Bangladesh survey.

4.3.4 Statistical Analyses

In this study, repeated cross-sectional analyses of the four waves were first conducted to examine country-level changes of tobacco use prevalence across waves. Then longitudinal analyses were performed on the balanced panel of respondents present in all waves to examine respondent-level changes in tobacco product use. In the current study, only male adults were included for analyses of transitions of exclusive cigarette and exclusive bidi users, as the prevalence of cigarettes and bidis smoking among female adults was significantly lower (less than 2%) in all waves of the survey.

Repeated cross-sectional analysis

- Country level prevalence of tobacco use

To explore the trends in tobacco use prevalence over time, a repeated cross-sectional analysis of the four waves of the ITC Bangladesh survey was conducted. Data from all current tobacco users from wave 1 to wave 4 was used in the analysis. This descriptive analysis provided an overview of the changes in the prevalence of different patterns of tobacco product use (single, dual, and poly-tobacco use) across different waves at the country level. The prevalence estimates were also analysed after stratification by sex and subgroups of different tobacco products (exclusive cigarette/bidis/SLT, cigarette+bidi, cigarette+SLT, bid+SLT, or poly-use [cigarette+bidi+SLT]).

In addition, tests of trend (ptrend) were performed to see if there were linear trends[176] in the prevalence of different tobacco use patterns over the waves studied. A statistically significant trend was determined using P values of less than 0.05. All cross-sectional analyses were weighted using the cross-sectional ITC sampling weights. Descriptive data is shown as

weighted percentages and 95% confidence intervals (CI). Weighted estimates are presented to ensure that the results are representative of the Bangladeshi population of tobacco users.

- Perceptions and reasons for transition

Repeated data from wave 2 to wave 4 on perceptions and reasons for exclusive cigarette, bidis, and SLT users to either start using other products or quit in the ITC-Bangladesh survey were analysed using cross-sectional ITC sampling weights, respective to the waves analysed. To obtain the pooled percentage of response across all waves, the STATA command "metaprop" was used to perform meta-analyses of the proportion data[177].

This command offers proper techniques for pooling percentage data using the random-effects model and permits computation of accurate binomial and score test-based confidence intervals when the estimated proportion of the sub-group is between 0 and 1[177].

Longitudinal transition analysis

- Product specific transitions in the ITC Bangladesh survey

In order to examine respondent-level changes in tobacco product use and transitional patterns among Bangladeshi adults over time, a balanced panel of 3,245 tobacco users present in all four waves of the ITC Bangladesh survey was used.

A series of analyses were carried out to present the trajectories of tobacco use transitions for wave 1 exclusive cigarette users, exclusive bidis users, and exclusive SLT users who were successfully followed up to wave 4. Separate alluvial diagrams (river plots) were used to visually depict transitions between successive waves. Following a descriptive assessment of the trajectories of tobacco use transitions among exclusive users from wave 1 to wave 4, the logistic Generalized Estimating Equation (GEE) models in longitudinal data analysis were utilised to evaluate predictors for transitions. Analyses of transition timing require complete records going back to the first wave. A respondent observed from wave t, for example, would require data from wave t-1 to assess if a transition had already happened at that time. Therefore, wave 1 was considered the baseline wave to investigate transitions from exclusive product use (exclusive cigarettes/bidis/SLTs) to the initiation of other products (either transfer to exclusive use of other products or in combination with previous products) or quitting in subsequent waves.

A common approach for the analysis of transitions was developed based on this construct. To track changes in tobacco use in exclusive cigarette users, exclusive bidi users, and exclusive SLT users in wave 1, sociodemographic factors such as age group, residence area, and housing index were included as covariates in the GEE models to explore the associations with transitions in use in waves 2, 3, and 4. These analyses used the binary transition outcome, where 1 = the presence of transitions, and 0 = no transitions occurred. In addition, the transitions analysis tested the overall effect of ITC "wave" (a proxy for time) as a categorical variable (wave 1 to wave 4) in all models to see if there was a significant effect of time across waves.

Following the common approaches, psychosocial variables such as quit intention, smoking attitude, and whether or not one received doctor's advice to quit were included as predictors for transition analysis for an in-depth analysis of factors associated with the transition from exclusive cigarette users to bidi users, SLT users, or quitting. The adjusted estimates were presented for each psychosocial measure, controlling for smoking status, wave and the sociodemographic variables mentioned above. Due to the low prevalence of cigarettes and bidi use among females in Bangladesh, all analyses regarding the transitions of exclusive cigarette and exclusive bidi users were based solely on male respondents.

- Transitions of dual and poly-tobacco use in the ITC Bangladesh survey

In addition to the analyses of product-specific transitions in Bangladeshi adults, the aggregate level of transitions of dual and poly-tobacco use (i.e., concurrent use of two or three tobacco products) was also examined. River plots (alluvial diagrams) were developed to graphically represent transitions between non-user, single, dual, and poly-tobacco use in subsequent waves.

- GEE models for longitudinal data analysis

The GEE approach was used to estimate binary logistic regressions accounting for the longitudinal association between repeated measures[178]. GEE methods were used because respondents participated repeatedly in the study. Whereas responses from the same individuals are correlated, it is necessary to account for the statistical dependencies of the repeated data in longitudinal analyses of transitions in tobacco use.

Thus, when looking at multiple repetitive waves, the population-averaged GEE method (also known as marginal models) is more appropriate when inferences of between-subgroup effects are of interest and not the subject-specific individual differences; otherwise, estimations would be under or overestimated[178, 179]. The population-averaged GEE model offers a straightforward interpretation that, looking across the population for a given wave, age group, residence area, and SES, gives the estimated mean response of the likelihood of respondents that would have been expected to make a transition.

The GEE models estimated in the study employed an unstructured working correlation matrix to account for correlations between repeated observations, which is a more appropriate accounting for correlations across time since it assumes that each pair-wise correlation of outcome is distinct from one another[178]. All regression models were estimated using STATA 17 to account for correlation across repeated assessments across time, logistic regression using population-averaged GEE with unstructured correlation structure among outcomes was fit using "xtlogit" with the "pa" and the "corr(unstructured)" option to indicate the within-panel correlation structure. All analyses were weighted using the longitudinal ITC sampling weights. Weighted estimates are presented to ensure that results are representative of the Bangladeshi population of tobacco users. Results are presented as odds ratios (ORs) with 95% confidence intervals (95% CIs).

- Model selection and diagnostic tests

The goodness-of-fit of the models was examined by the quasi-likelihood information criteria (QIC) statistics to compare models[180]. The QIC statistic is analogous to the likelihood-based Akaike information criteria (AIC). The model resulting in the smallest QIC value is preferred. The covariate effects in the model are tested using Wald tests. Since GEE is based on quasi-likelihood, traditional likelihood-ratio tests are not used with GEE models. As a result, the Wald test, a non-parametric approach, may be used for model selection for choosing the best subset of covariates[181].

According to the goodness-of-fit statistics (lower QIC value) and a significant Wald test compared to base variables, the final model and subsets of covariates used for the product

specific transition analyses were selected. The selection process of the models and variables are present in Appendix 5.

4.4 Study Results

4.4.1 Repeated Cross-Sectional Analysis of the ITC-Bangladesh Survey

Sample characteristics

The repeated cross-sectional analyses examined four waves of the ITC Bangladesh survey from wave 1 (2009) to wave 4 (2015). Table 11 describes the weighted estimates of the sample characteristics of respondents surveyed in each wave. Across all waves, there were generally equal proportions of both genders, with slightly higher proportions of adults aged between 25-39. Overall, most respondents were married (above 77%), and came from rural areas of Bangladesh (61%), and the majority of respondents reported moderate (above 32%) to higher (above 35%) SES for housing indices. Although almost half (48%) of the respondents had some education, still a quarter of respondents were illiterate.

Country level prevalence of tobacco use

Table 11 also describes the prevalence of tobacco use across the four waves. The majority of the respondents in the sample were single product users across all waves (above 45.7%). The percentages of dual and poly-product users decreased significantly over the survey period, falling from 14.8% in wave 1 to 8.9% in wave 4 ($p<0.001$) and 2.8% in wave 1 to 1% in wave 4 ($p<0.001$). Among different products, cigarettes were the most common type of tobacco used (above 30.7%) across all waves, followed by smokeless tobacco (around 10%). Bidi users comprised about 5% of the sample.

Table 11: Sample characteristics and tobacco use prevalence of the ITC-Bangladesh surveys

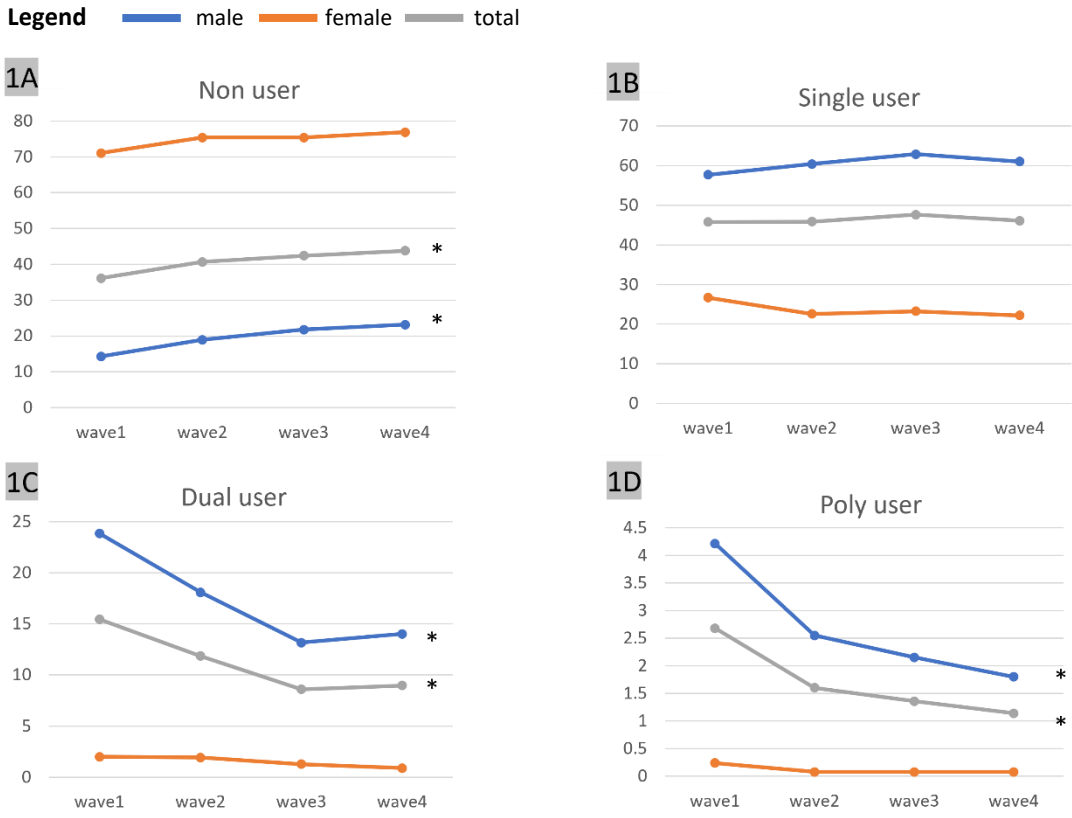
	Weighted Percentages (%) with 95% Confidence Interval			
	Wave 1 (N=4,378)	**Wave 2 (N=4,359)**	**Wave 3 (N=4,223)**	**Wave 4 (N=4,242)**
Surveyed year	**2009**	**2010**	**2011-2012**	**2014-2015**
Sample characteristics				
Gender				
Male	51.4 (49.9 - 52.9)	51.8 (49.9 - 52.9)	50.2 (48.7 - 51.7)	50.1 (48.6 - 51.6)
Female	48.6 (47.1 - 50.1)	48.2 (47.5 - 50.1)	49.8 (48.3 - 51.3)	49.9 (48.4 - 51.4)
Age Group				
15-24	23.2 (22 - 24.5)	21 (19.8 - 22.2)	17.8 (16.7 - 19)	7.9 (7.1 - 8.8)
25-39	36.6 (35.2 - 38.1)	37.3 (35.8 - 38.7)	38.4 (37 - 39.9)	37.8 (36.4 - 39.3)
40-54	22.9 (21.7 - 24.1)	23.4 (22.1 - 24.6)	25.6 (24.3 - 26.9)	27.2 (25.9 - 28.5)
55+	17.3 (16.2 - 18.5)	18.4 (17.3 - 19.6)	18.2 (17.1 - 19.4)	27.1 (25.8 - 28.5)
Residence				
Urban	35.5 (34.1 - 36.9)	35.6 (34.2 - 37)	35 (33.6 - 36.5)	38.5 (37.1 - 40)
Rural	64.5 (63.1 - 65.9)	64.4 (63 - 65.8)	65 (63.5 - 66.4)	61.5 (60 - 62.9)
Housing index				
Low	31.6 (30.2 - 33)	30.2 (28.9 - 31.6)	31 (29.6 - 32.4)	28.9 (27.6 - 30.3)
Moderate	33.4 (32 - 34.8)	32.9 (31.5 - 34.3)	32.4 (31 - 33.9)	35.7 (34.2 - 37.1)
High	35 (33.6 - 36.5)	36.9 (35.4 - 38.3)	36.6 (35.2 - 38.1)	35.4 (34 - 36.9)
Education				
Illiterate	24.7 (23.5 - 26)	19.7 (18.5 - 20.9)	25.9 (24.6 - 27.2)	23.5 (22.2 - 24.8)
1 to 8 years	53.6 (52.1 - 55)	54.9 (53.4 - 56.3)	48.4 (46.9 - 50)	48.3 (46.8 - 49.8)
9 years or more	21.7 (20.5 - 22.9)	25.5 (24.2 - 26.8)	25.7 (24.4 - 27)	28.2 (26.8 - 29.6)
Marital				
Married	80 (78.8 - 81.1)	77.4 (76.1 - 78.6)	81.7 (80.5 - 82.8)	85.9 (84.8 - 86.9)
Single/ live alone	20 (18.9 - 21.3)	22.6 (21.4 - 23.9)	18.3 (17.2 - 19.5)	14.2 (13.1 - 15.2)
Tobacco use prevalence				
Nonuser	36.5 (35.1 - 37.9)	39.6 (38.1 - 41)	43 (41.5 - 44.5)	44.5 (43 - 46)
Single use	45.9 (44.4 - 47.3)	47 (45.5 - 48.5)	47 (45.5 - 48.5)	45.7 (44.2 - 47.2)
Dual use*	14.8 (13.8 - 15.9)	11.9 (11 - 12.9)	8.6 (7.8 - 9.5)	8.9 (8 - 9.8)
Poly use#	2.8 (2.4 - 3.4)	1.6 (1.2 - 2)	1.4 (1.1 - 1.9)	1 (0.8 - 1.4)
Single use				
Exclusive Cig	32.8 (31.4 - 34.2)	31.8 (30.4 - 33.2)	31.1 (29.7 - 32.5)	30.7 (29.4 - 32.1)
Exclusive bidis	3.8 (3.3 - 4.4)	5.2 (4.6 - 5.9)	5.3 (4.6 - 6)	4.7 (4.1 - 5.3)
Exclusive SLT	9.3 (8.5 - 10.2)	10 (9.1 - 10.9)	10.7 (9.8 - 11.7)	10.3 (9.4 - 11.2)
Dual use				
Cig+Bidi	4.7 (4.1 - 5.3)	3.5 (3 - 4.1)	4.5 (3.9 - 5.2)	3.7 (3.2 - 4.3)
Cig+SLT	7.9 (7.1 - 8.7)	6.2 (5.5 - 6.9)	2.8 (2.4 - 3.4)	4.5 (3.9 - 5.1)
SLT+Bidi	2.3 (1.9 - 2.8)	2.3 (1.9 - 2.8)	1.3 (1 - 1.7)	0.7 (0.5 - 1)

Note: * co-use of 2 products, # co-use of ≥3 products, cig: cigarette, SLT: smokeless tobacco

In Figure 8, the prevalence of tobacco use was stratified by sex across waves. An increasing trend of non-users was observed among male respondents from 14.3% in wave 1 to 23.1% in wave 4 ($p < 0.001$); although the majority of non-users were females, the prevalence remained steady at around 75% during the time surveyed (Figure 8A). No significant trends were observed among single product users. The prevalence of single product use among male and female adults fluctuated between 60% and 22%, respectively, across waves (Figure 8B).

In terms of dual and poly-tobacco use, there was a significant decrease in both pattens among males (Figure 8C, 7D). Male dual use decreased from 23.8% in wave 1 to 14% in wave 4, while poly-use declined from 4.2% to 1.8% in the same period. However, the female respondents reported relatively low prevalence in both use patterns (around 2% dual use and 0.01% poly-use) without any specific trends observed over time.

Figure 8: Prevalence of different tobacco use patterns across each wave, stratified by sex (%)

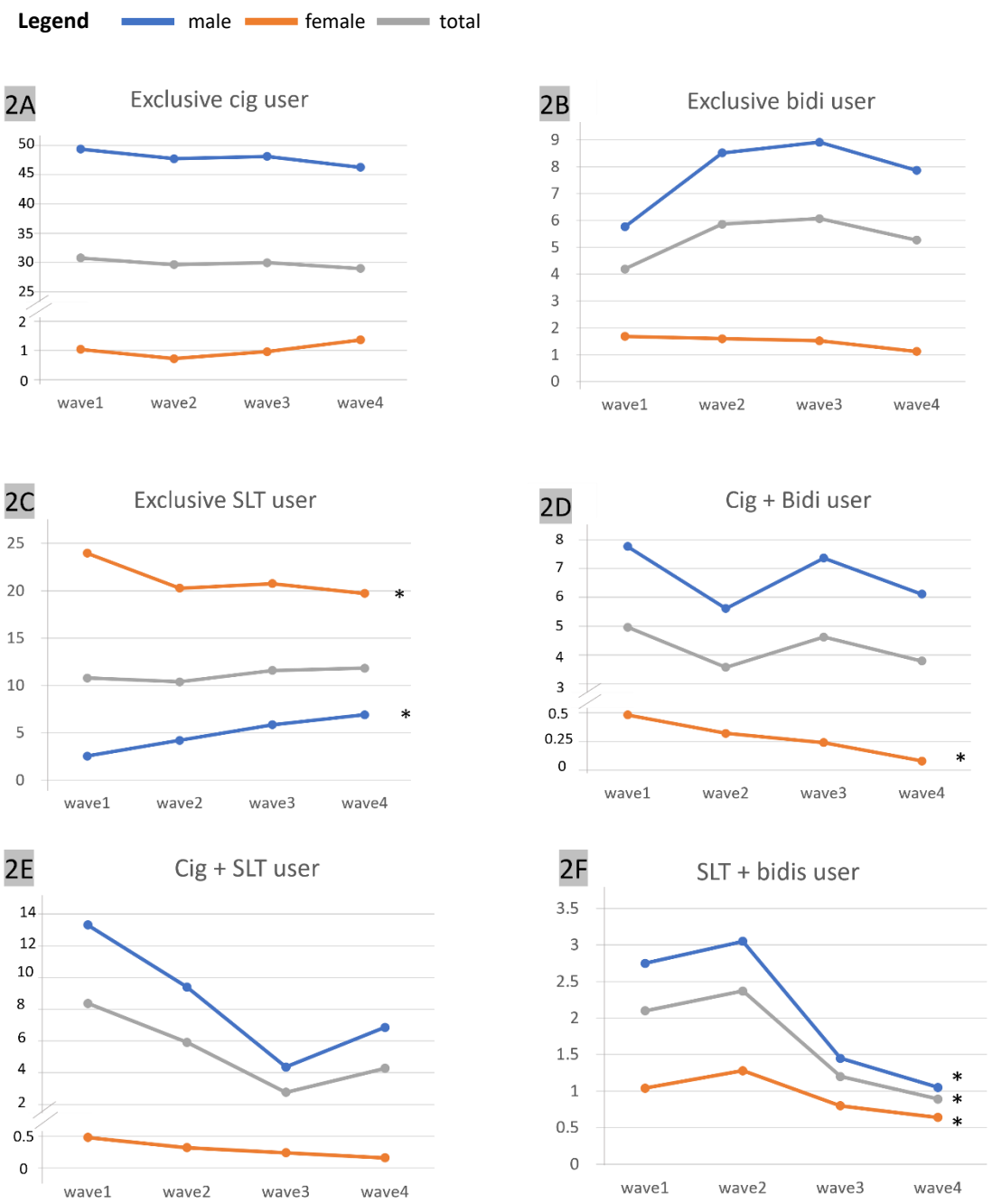


Note: * ptrend >0.05

In Figure 9, product specific prevalence across each wave was stratified by sex. As opposed to exclusive cigarette and bidis use (Figure 9A, 8B), where the majority of users were male users, a great proportion (around 20%) of exclusive SLT users were females all waves (Figure 9C). Additionally, a significant decline in exclusive SLT prevalence over time among female users was detected ($p < 0.05$). Between wave 1 and wave 4, the prevalence gradually declined from 24% to 19.7% ($p < 0.01$). On the other hand, the prevalence of male exclusive SLT users saw a significant increase, rising from 2.5% to 6.9% during the survey period.

Regarding combinations of use, dual of cigarettes and bidis among female users showed a gradual decline in prevalence from 0.5% to 0.1% ($p < 0.01$), while the prevalence of male dual users wavered between 5% and 8% over time (Figure 9D). Similar decreasing trends were observed among dual users of cigarettes and SLT in both sexes (Figure 9E). The prevalence of male cigarettes and SLT dual users dipped from 13.3% in wave 1 to 4.4% in wave 3, and mildly rose to 6.1% in wave 4 ($p < 0.01$); whereas the percentages of female dual users of the same products halved from 13.3% to 6.9% ($p < 0.01$). The prevalence of dual SLT and bidi use dropped by almost 2% among male users and 0.5% among female users throughout the surveyed period. However, no significant trends were detected among both sexes (Figure 9F).

Figure 9: Prevalence of different tobacco product use across each wave, stratified by sex (%)



Note: * ptrend >0.05; cig: cigarette; SLT: smokeless tobacco

4.4.2 Longitudinal Transition Analysis of the ITC-Bangladesh Survey

Sample characteristics

The sample descriptives, including the sociodemographics, smoking status, and psychosocial variables related to smoking, are presented by the type of longitudinal sample in Table 12 below. All samples were weighted with the longitudinal ITC sampling weights. The longitudinal sample reflects the sample population present in all four waves of the ITC Bangladesh survey. Among the exclusive users' samples, only male users were included in the longitudinal sample of exclusive cigarette and exclusive bidi users, as the prevalence of both product use among female adults was significantly lower (less than 2%) in all waves of the survey. The gender and age distributions of the longitudinal samples closely reflect those of the national cross-sectional samples.

The proportion of rural residents was higher in both exclusive bidi users and SLT users compared to other samples. Exclusive bidi users had a notably higher percentage of respondents with lower housing index (lower SES), with 43.8 percent of male bidi users in the lower index group and less than one-fifth (19.3%) of the sample in the higher index group. A similar SES gradient among exclusive SLT users was also observed.

Exclusive bidi and SLT users both have lower proportions (below 8%) of users reporting higher education status (9 years or more) and more married respondents compared to other samples. The majority of the longitudinal sample (76.8%) and the exclusive user sample (75.5%) reported non-daily to daily light use of cigarette smoking, while most of the exclusive bidi users (46.7%) reported daily medium use status of bidis.

Quit intentions were higher among exclusive bidi users compared to other samples. Nearly one-fifth (19.9%) of exclusive bidi users planned to quit within the next six months, while less than 10% of exclusive cigarette users had the same intention. Lastly, compared to other samples, exclusive bidi users have a higher percentage of positive attitudes toward smoking (30.9%) and a quarter of the respondents (24.9%) reported receiving doctor's advice to quit smoking.

Table 12: Sample characteristics of the longitudinal analyses

	Weighted Percentages (%) with 95% Confidence Interval			
	Longitudinal sample W1 (N=3,245)	**Exclusive cig users at W1 (N=986, male only)**	**Exclusive bidi users at W1 (N=115, male only)**	**Exclusive SLT users at W1 (N=350)**
Sample characteristics				
Gender				
Male	51.4 (49.7 - 53.1)	—	—	26.2 (21.8 - 31)
Female	48.6 (46.9 - 50.3)	—	—	73.8 (69 - 78.2)
Age Group				
15-24	22.3 (20.9 - 23.7)	20 (17.6 - 22.6)	2.8 (0.7 - 8)	9.3 (6.7 - 12.9)
25-39	36.5 (34.8 - 38.1)	42.8 (39.7 - 45.9)	19 (12.8 - 27.2)	33.4 (28.6 - 38.5)
40-54	24.1 (22.7 - 25.6)	23.4 (20.9 - 26.1)	36.5 (28.2 - 45.6)	35 (30.1 - 40.1)
55+	17.2 (16 - 18.6)	13.9 (11.8 - 16.2)	41.8 (33.2 - 50.9)	22.4 (18.3 - 27)
Residence				
Urban	30.4 (28.9 - 32)	35.5 (32.6 - 38.5)	8.6 (4.5 - 15.3)	21.8 (17.8 - 26.5)
Rural	69.6 (68 - 71.1)	64.5 (61.5 - 67.5)	91.4 (84.7 - 95.5)	78.2 (73.5 - 82.2)
Housing index				
Low	30.7 (29.1 - 32.3)	30.9 (28.1 - 33.9)	43.8 (35 - 52.9)	38 (33.1 - 43.2)
Moderate	33.8 (32.2 - 35.4)	34.4 (31.5 - 37.4)	37 (28.7 - 46.1)	35.1 (30.3 - 40.3)
High	35.6 (33.9 - 37.2)	34.7 (31.8 - 37.7)	19.3 (13 - 27.5)	26.9 (22.5 - 31.8)
Education				
Illiterate	25.1 (23.6 - 26.6)	17.9 (15.6 - 20.4)	50.8 (41.8 - 59.8)	42.8 (37.7 - 48.1)
1 to 8 years	54 (52.3 - 55.7)	53 (49.8 - 56.1)	41.9 (33.3 - 51)	49.4 (44.2 - 54.6)
9 years or more	20.9 (19.6 - 22.4)	29.2 (26.4 - 32.1)	7.3 (3.6 - 13.7)	7.8 (5.4 - 11.1)
Marital				
Married	81.1 (79.7 - 82.4)	77 (74.2 - 79.5)	90.1 (83.1 - 94.5)	83.4 (79.1 - 87)
Single/live alone	18.9 (17.6 - 20.3)	23 (20.5 - 25.8)	9.9 (5.5 - 16.9)	16.6 (13 - 20.9)
Smoking status				
Nondaily/daily light	76.8 (74.5 - 78.9)	75.5 (72.7 - 78.1)	33.6 (22.9 - 44.6)	—
Daily medium	20.3 (18.3 - 22.5)	22.3 (19.8 - 25)	46.7 (36.2 - 57.6)	—
Daily strong	2.9 (2.1 - 3.9)	2.3 (1.5 - 3.4)	19.7 (12.3 - 29.8)	—
Quit intention				
No plan	38.7 (36.3 - 41.1)	36.6 (33.7 - 39.7)	34.6 (24 - 47.1)	—
Beyond 6 months	36.2 (33.9 - 38.6)	36.8 (33.9 - 39.9)	27.2 (17.7 - 39.5)	—
In next 6 months	9 (7.7 - 10.5)	9 (7.4 - 11)	19.9 (11.7 - 31.6)	—
Don't know	16.2 (14.4 - 18)	17.6 (15.3 - 20.1)	18.3 (10.4 - 29.8)	—
Smoking attitude*				
Positive	24.8 (22.8 - 27)	25 (22.4 - 27.8)	30.9 (20.8 - 43.2)	—
Neither	18.4 (16.6 - 20.4)	18.8 (16.5 - 21.3)	19.7 (11.6 - 31.2)	—
Negative	47.5 (45 - 49.9)	47.8 (44.7 - 50.9)	43.7 (32.2 - 56)	—
Don't know	9.3 (8 - 10.8)	8.4 (6.9 - 10.4)	5.7 (1.7 - 14.8)	—
Doctor's advice to Quit				
No	89 (87.3 - 90.4)	90.7 (88.7 - 92.4)	75.1 (62.9 - 84.3)	—
Yes	11.1 (9.6 - 12.7)	9.3 (7.6 - 11.3)	24.9 (15.7 - 37.2)	—

Note: * Smoking attitude: attitude towards the statement that smoking tobacco (cig/bidis) is calming or important to life, — no data points

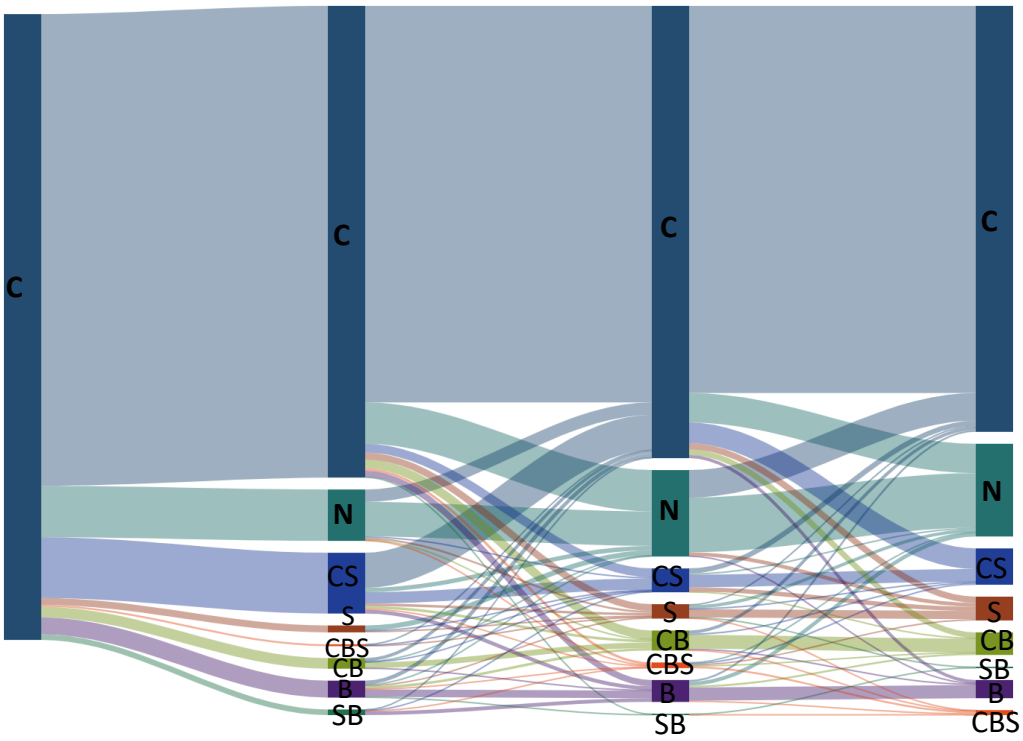
Product specific transitions in the ITC Bangladesh survey

- Transitions of exclusive cigarette users

Figure 10 presents the descriptive diagram illustrating the transitional patterns of tobacco product use for exclusive cigarette users from left to right in wave 1 to wave 4. The width of the knots at each wave indicates the weighted proportion of transitions. The wider the knots, the greater the proportion. According to the diagram, the majority of exclusive cigarette users remained as cigarette user throughout the waves. Exclusive cigarette users were much more likely to remain as exclusive cigarette users at Wave 4 (68.1%). This was significantly higher than the percentage of exclusive bidi users who remained exclusive bidi users (43.4%) (Figure 11) or the percentage of exclusive SLT users who remained exclusive SLT users (44.3%) at the last wave (Figure 12)

A smaller proportion transitioned to non-users or dual users of cigarettes and SLTs. Transitions to SLT+bidis dual use or poly-use of all three products (cigraettes+SLT+bidis) were less observed compared with other transitions (≤4%).

Figure 10: Transitions of exclusive cigarette users in Wave 1 (n=986) to Wave 4.



C: cigarette S: smokeless CB: cig+bidis CBS: cig+SLT+bidis

B: bidis CS: cig+ SLT SB: SLT+bidis N: quitters

According to Table 13, rural respondents were more likely to transition than urban respondents (Transition to bidi use: OR = 3.0, 95%CI = 1.47–6.14; Transition to SLT use: OR = 2.87, 95%CI = 1.9–4.33; Quitting: OR = 1.49, 95%CI = 1.02–2.19; Any Transitions: 3.12, 95%CI = 2.09–4.65; Transition to dual or poly use: OR = 2.64, 95%CI=1.63–3.81). Housing index (SES indicator) was not associated with any transition. Generally, younger people remained as cigarette users and were less likely to transition compared to older people. There were generally significant effects of waves across different transition patterns, indicating a significant time effect.

Table 13: Associations between sociodemographic factors and transitional patterns of Exclusive cigarette users at W1 (N=986) to W4, adjusted for longitudinal weights (male respondents only)

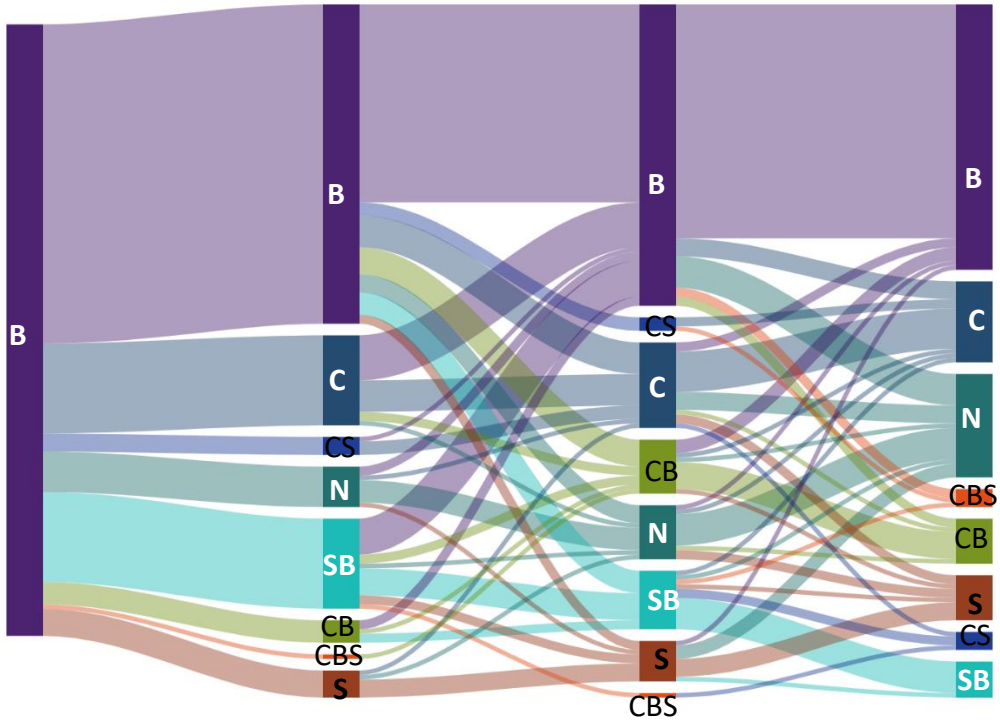
	OR (95% CI)				
	Transition to bidi use	**Transition to SLT use**	**Quitting**	**Any Transitions†**	**Transition to dual or poly use**
N of transitions in wave 2	52	117	80	159	123
N of transitions in wave 3	75	70	136	135	78
N of transitions in wave 4	73	104	146	167	104
Age Group					
55+	1	1	1	1	1
40-54	0.75 (0.49 - 1.15)	1.14 (0.76 - 1.72)	0.62 (0.38 - 1.03)	0.92 (0.66 - 1.27)	1.13 (0.75 - 1.69)
25-39	0.35 (0.19 - 0.62) ***	0.92 (0.59 - 1.43)	0.66 (0.41 - 1.06)	0.58 (0.39 - 0.85) **	0.91 (0.57 - 1.44)
15-24	0.76 (0.31 - 1.86)	0.35 (0.17 - 0.72) **	0.85 (0.48 - 1.5)	0.47 (0.26 - 0.86) *	0.72 (0.36 - 1.46)
Residence					
Urban	1	1	1	1	1
Rural	3.0 (1.47 - 6.14) **	2.87 (1.9 - 4.33) ***	1.49 (1.02 - 2.19) *	3.12 (2.09 - 4.65) ***	2.64 (1.72 - 4.05) ***
Housing index					
Low	1	1	1	1	1
Moderate	1.11 (0.58 - 2.12)	0.98 (0.59 - 1.62)	1.44 (0.9 - 2.29)	1.06 (0.69 - 1.65)	1.09 (0.67 - 1.79)
High	1.16 (0.6 - 2.24)	0.84 (0.5 - 1.39)	1.41 (0.89 - 2.22)	0.92 (0.61 - 1.41)	1.03 (0.64 - 1.65)
Wave					
2	1	1	1	1	1
3	1.79 (1.24 - 2.59) **	0.51 (0.38 - 0.71) ***	1.8 (1.36 - 2.40) ***	0.93 (0.72 - 1.2)	0.69 (0.49 - 0.98) *
4	1.57 (1.1 - 2.26) *	0.8 (0.62 - 1.04)	1.96 (1.43 - 2.69) ***	1.11 (0.9 - 1.37)	0.84 (0.64 - 1.12)

Note: * p <0.05,** p <0.01, *** p <0.001, † any transitions except for transition to quitting.

- Transitions of exclusive bidi users

Figure 11 presents the diagram illustrating the transitional patterns of tobacco product use for exclusive bidi users from left to right in wave 1 to wave 4. Transitional patterns were more volatile for exclusive bidi smokers compared to other exclusive product users. As shown in the diagram, fewer than half of the exclusive bidi users remained their status throughout the waves. There were growing proportions of users transitioning to non-users or exclusive SLTs throughout the survey period. The proportions of exclusive bidi users who transitioned to exclusive cigarette use were rather stable across all waves (around 15%). However, transitions from exclusive bidi use to exclusive cigarette use (13.2%–14.7%) were much more frequent than from exclusive cigarette use to exclusive bidi use (2.8%–3.2%) (Figure 10). Dual use of SLT and bidis decreased over time, while dual use of cigarettes and bidis mildly increased. Transitions to poly-use remained low among exclusive bidding users.

Figure 11: Transitions of exclusive bidi users in Wave 1 (n=115) to Wave 4.



C: cigarette S: smokeless CB: cig+bidis CBS: cig+SLT+bidis

B: bidis CS: cig+ SLT SB: SLT+bidis N: quitters

Results from Table 14 indicated that among exclusive bidi users, age and residential area were not related to transition. However, a higher housing index (SES indicator) was related to the quitting (OR = 3.64, 95%CI = 1.08–16.01), but the opposite for transitioning to exclusive cigarette use (OR = 0.48, 95%CI = 0.24–0.99) and any transitions (OR = 0.46, 95%CI = 0.22–0.96). There were generally no time effects in the transitions among exclusive bidi users.

Table 14: Associations between sociodemographic factors and transitional patterns of exclusive bidi users at W1 (N=115) to W4, adjusted for longitudinal weights (male respondents only)

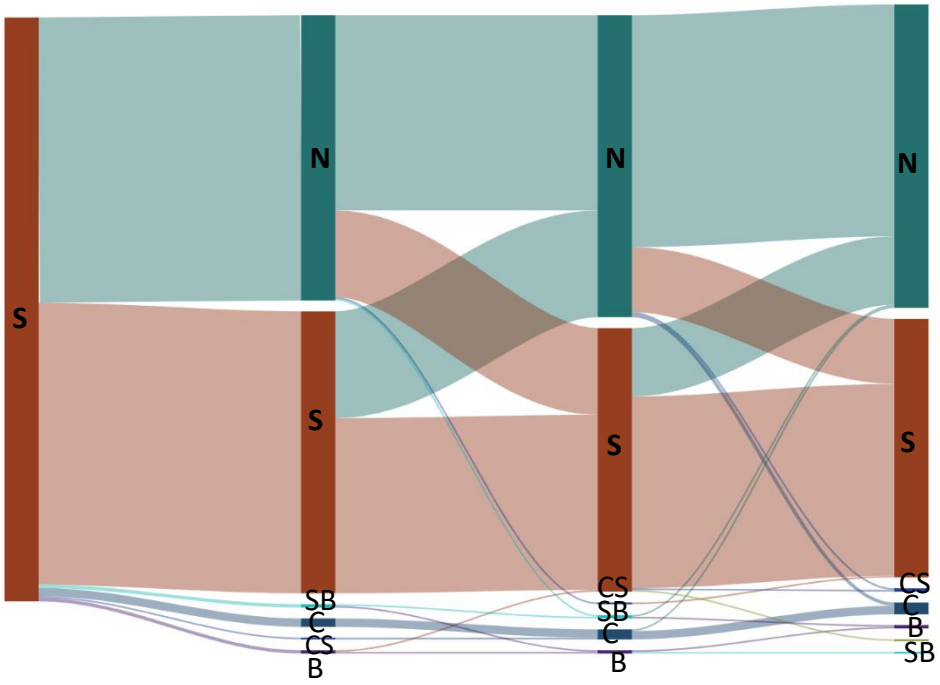
	OR (95% CI)				
	Transition to cig use	**Transition to SLT use**	**Quitting**	**Any Transitions†**	**Transition to dual or poly use**
N of transitions in wave 2	30	22	8	47	26
N of transitions in wave 3	35	15	9	46	25
N of transitions in wave 4	36	17	16	45	23
Age Group					
55+	1	1	1	1	1
40-54	1.01 (0.43 - 2.36)	0.91 (0.39 - 2.09)	0.68 (0.27 - 1.75)	1.11 (0.69 - 1.79)	1.32 (0.69 - 2.55)
25-39	1.71 (0.71 - 4.17)	0.6 (0.2 - 1.79)	0.51 (0.11 - 2.4)	1.13 (0.53 - 2.39)	0.88 (0.33 - 2.32)
15-24	1.88 (0.6 - 5.86)	0.28 (0.04 - 1.99)	1.92 (0.58 - 6.35)	1.04 (0.39 - 2.75)	0.37 (0.08 - 2.36)
Residence					
Urban	1	1	1	1	1
Rural	0.39 (0.1 - 1.52)	1.57 (0.43 - 5.64)	0.79 (0.15 - 4.11)	0.79 (0.22 - 2.82)	1.44 (0.33 - 6.45)
Housing index					
Low	1	1	1	1	1
Moderate	0.85 (0.41 - 1.76)	1.27 (0.55 - 2.94)	3.0 (0.7 - 12.89)	1.1 (0.56 - 2.15)	0.72 (0.35 - 1.56)
High	0.48 (0.24 - 0.99) *	0.51 (0.18 - 1.42)	3.64 (1.08 - 16.01) *	0.46 (0.22 - 0.96)*	0.52 (0.23 - 1.51)
Wave					
2	1	1	1	1	1
3	1.05 (0.57 - 1.93)	0.77 (0.37 - 1.6)	1.02 (0.42 - 2.49)	1.07 (0.61 - 1.89)	0.61 (0.31 - 1.35)
4	1.13 (0.5 - 2.52)	0.6 (0.28 - 1.28)	2.83 (1.1 - 7.23) *	0.96 (0.5 - 1.86)	0.57 (0.31 - 1.19)

Note: * p <0.05,** p <0.01, *** p <0.001, † any transitions except for transition to quitting.

- Transitions of exclusive SLT users

Figure 12 presents the diagram illustrating the transitional patterns of tobacco product use for exclusive SLT users from left to right in wave 1 to wave 4. The diagram showed that for exclusive SLT users, a large proportion remained as SLT users, and transitions mainly occurred between becoming non-users. Transitions to other product combinations were relatively small throughout the waves (overall ≤ 2%). The most likely transition to dual-use for both exclusive cigarette and exclusive bidi smokers was with SLTs, instead of with another smoking product.

Figure 12: Transitions of exclusive SLT users in Wave 1 (n=350) to Wave 4.



C: cigarette S: smokeless CB: cig+bidis CBS: cig+SLT+bidis

B: bidis CS: cig+ SLT SB: SLT+bidis N: quitters

Results from Table 15 indicate that exclusive SLT users were highly common amongst women and had significantly lower odds to transition to any products/patterns of use. Quitting was more likely among younger respondents (OR = 3.04, 95%CI = 1.29–7.14), those more educated (OR=1.55, 95%CI=1.77–3.12), and less likely for those in rural areas (OR = 0.51, 95%CI = 0.3–0.86) compared to urban residents. Due to the small numbers of transitions to exclusive cigarette use, exclusive bidi use, and any transitions, the estimations for these three models were unstable with wide confidence intervals.

Table 15: Associations between sociodemographic factors and transitional patterns of exclusive SLT users at W1 (N=350) to W4, controlled for sex and adjusted for longitudinal weights

	OR (95% CI)				
	Transition to cig use	**Transition to bidis use**	**Quitting**	**Any Transitions†**	**Transition to dual or poly use**
N of transitions in wave 2	6	4	171	10	30
N of transitions in wave 3	7	4	181	11	29
N of transitions in wave 4	10	4	182	13	26
Age Group					
55+	1	1	1	1	1
40-54	0.84 (0.2 - 3.52)	—	1.5 (0.97 - 2.33)	2.34 (0.24 - 23.21)	0.11 (0.01 - 1.29)
25-39	1.63 (0.36 - 7.3)	0.47 (0.05 - 4.45)	1.44 (0.79 - 2.62)	1.4 (0.16 - 12.05)	0.4 (0.07 - 2.19)
15-24	4.08 (0.76 - 22)	—	3.04 (1.29 - 7.14) *	6.62 (2.58 - 22.29) *	0.94 (0.1 - 8.82)
Residence					
Urban	1	1	1	1	1
Rural	2.93 (0.46 - 18.44)	—	0.51 (0.3 - 0.86) *	8.9 (1.09 - 72.42) *	—
Housing index					
Low	1	1	1	1	1
Moderate	0.21 (0.02 - 2.08)	2.69 (0.41 - 17.73)	0.96 (0.51 - 1.81)	1.02 (0.03 - 35.46)	0.52 (0.09 - 3.02)
High	1.37 (0.3 - 6.18)	0.3 (0.02 - 4.85)	1.34 (0.67 - 2.65)	7.85 (2.05 - 8.31) **	0.81 (0.14 - 4.62)
Wave					
2	1	1	1	1	1
3	—	—	1.17 (0.78 - 1.73)	3.57 (0.24 - 52.48)	0.68 (0.18 - 2.55)
4	1.95 (1.09 - 3.49) *	1.64 (0.28 - 9.83)	1.15 (0.74 - 1.77)	7.82 (1.19 - 51.39) *	1.14 (0.38 - 3.41)

Note: * p <0.05,** p <0.01, *** p <0.001,— no data points, † any transitions except for transition to quitting.

Psychosocial factors related to transitions of exclusive male cigarette users in the ITC Bangladesh survey

Table 16 extends previous results on the analysis of transitions of exclusive cigarette users in Table 13. The three logistic GEE models in the current table present the results of the longitudinal analyses developed to examine psychosocial correlates of transitioning to bidi use, SLT use, and quitting after adjusting for sociodemographic factors and smoking status. The psychosocial variables included in these final GEE models were quit intentions, smoking attitude, and doctor's advice to quit.

With respect to quit intentions, exclusive cigarette smokers with higher quit intentions to quit within the next six months, had significantly lower odds (OR = 0.63, 95%CI = 0.4–0.98) to transition to bidi use, but higher odds (OR = 1.63, 95%CI = 1.34–1.16) to quit.

Similarly, exclusive cigarette smokers with negative attitudes toward smoking tobacco (negative feelings toward either smoking is calming, or smoking is important to life) had significantly lower odds of transitioning to bidi use (OR = 0.39, 95%CI = 0.26–0.88) and SLT use (OR = 0.46, 95%CI = 0.24–0.89) but higher odds (OR = 1.44, 95%CI = 1.3–1.64) to quit. Lastly, exclusive cigarette users receiving doctor's advice to quit had almost 2-times higher odds of quitting (OR = 1.98, 95%CI = 1.68–2.4) compared to those who didn't.

Table 16: Transitional analysis of exclusive cig users at W1 (N=986) to W4, adjusted for longitudinal weights (male respondents only)

	OR (95% CI)		
	Transition to bidis use	**Transition to SLT use**	**Transition to Quitting**
Age Group (ref. 55+)			
40-54	1.65 (0.57 - 4.82)	0.69 (0.28 - 1.72)	0.98 (0.52 - 1.84)
25-39	0.69 (0.23 - 2.11)	1.12 (0.52 - 2.39)	0.85 (0.47 - 1.56)
15-24	3.98 (0.86 - 18.32)	0.28 (0.09 - 0.87)*	1.08 (0.38 - 3.06)
Residence (ref. Urban)			
Rural	2.16 (0.85 – 5.49)	2.42 (1.38 – 4.23)**	2.2 (1.35 - 3.6)**
Housing index (ref. Low)			
Moderate	1.26 (0.43 - 3.71)	0.95 (0.49 - 1.84)	1.13 (0.66 - 1.94)
High	2.28 (0.82 - 6.36)	0.96 (0.49 - 1.88)	1.19 (1.09 - 2.05)*
Education (ref. Illiterate)			
Less educated	1.61 (0.71 - 3.64)	1.51 (0.65 - 3.51)	1.56 (0.87 - 2.81)
More educated	1.28 (0.45 - 3.66)	0.92 (0.37 - 2.29)	1 (0.5 - 1.98)
Marital (ref. Married)			
Single/ live alone	0.55 (0.27 - 1.11)	0.58 (0.25 - 1.39)	0.5 (0.25 - 1.02)
Wave (ref. 2)			
3	1.49 (1.24 - 2.39) **	0.57 (0.38 - 0.71) ***	1.84 (1.26 - 2.31) ***
4	1.37 (1.1 - 2.16) *	0.82 (0.62 - 1.04)	1.91 (1.53 - 2.49) ***
Cig status (ref. nondaily/daily light)			
Daily medium	1.04 (0.59 - 1.82)	1.49 (0.85 - 2.62)	1.27 (0.78 - 2.05)
Daily strong	0.67 (0.16 - 2.83)	1 (0.21 - 4.65)	0.81 (0.29 - 2.27)
Quit intention (ref. no plan)			
Beyond 6 months	0.68 (0.4 - 1.19)	1.08 (0.52 - 2.27)	0.8 (0.47 - 1.34)
In next 6 months	0.63 (0.4 - 0.98)*	0.84 (0.27 - 2.63)	1.63 (1.34 - 1.16)***
Don't know	0.38 (0.22 - 0.64)***	1.13 (0.52 - 2.49)	1.23 (0.48 - 1.77)
Smoking attitude * (ref. positive)			
Neither	0.56 (0.28 - 1.1)	0.19 (0.05 - 0.71)	1.36 (0.19 - 1.67)
Negative	0.39 (0.26 - 0.58)***	0.46 (0.24 - 0.89)*	1.44 (1.3 - 1.64)***
Don't know	0.34 (0.12 - 0.94)*	0.83 (0.35 - 1.95)	1.58 (0.33 - 1.01)
Doctor's advice to Quit (ref. No)			
Yes	0.77 (0.53 - 1.12)	1.37 (0.64 - 2.94)	1.98 (1.68 - 2.4)*

Note: * Smoking attitude: attitude towards the statement that smoking is calming or important to life. * p <0.05,** p <0.01, *** p <0.001

Perceptions and reasons for transition

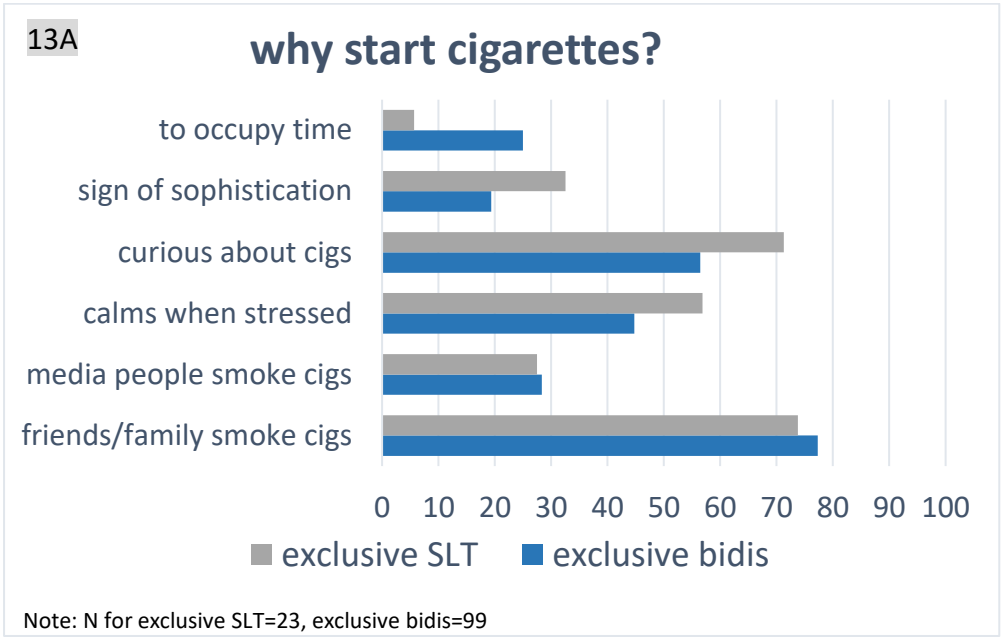
Figure 13A to 12D presents the pooled proportions of perceptions and reasons for exclusive cigarette, bidis, and SLT users in waves 2 to 4 to start using other products or quit. As shown in Figure 13A, the top three reasons for exclusive SLT users to start using cigarettes were the influence of friends and family (74%), curiosity (71%), and because it calms stress (57%). The reasons for exclusive bidi users to start using cigarettes were generally the same, the proportions were 77%, 56%, and 45%, respectively, for the above reasons.

In Figure 13B, the most common two reasons for exclusive bidi and exclusive cigarette users to start SLT were friends and family (86% and 80%, respectively) and curiosity (47% and 45%, respectively). A larger proportion of exclusive cigarette users started SLT because of the better taste (38%), and because they thought that it helps quit tobacco use (32%). More exclusive bidi users started SLT because they thought it's less harmful (37%), and it reduces stress (31%). Only around 6% of both exclusive users started SLT because of the packaging, which is the ranked in the last place among all reasons.

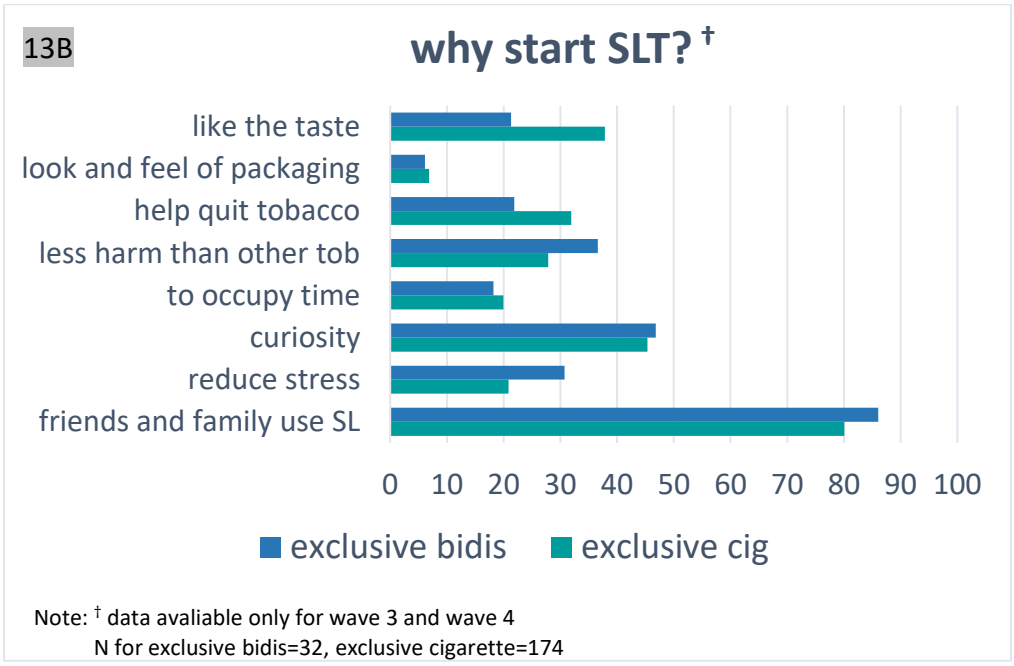
In Figure 13C, the top four reasons for exclusive SLT users to start using bidis were friends and family (83%), curiosity (72%), the impression that bidis taste better (71%), and thinking that bidis are less harmful (52%). Regarding exclusive cigarette users, the major reasons were family and friends (80%), curiosity (44%), calming of stress (43%), to occupy time (27%), and the impression that bidis taste better (27%).

Figure 13D describes the top reasons for exclusive users to quit. For exclusive cigarette users, the majority quit because of their concerns for health (63%), disapproval from family and friends (56%), followed by doctor's advice to quit and concerns for others (41% and 42%, respectively). The lowest ranking of reasons for exclusive cigarette users to quit is because of the smoking bans (9%). As for exclusive bidi users, the chief reasons were because of price and health concerns (32% and 33%, respectively), followed by disapproval of friends and family, concern for others (25% for both reasons), and doctor's advice to quit (23%). Only around 5% of exclusive bidi users quit because of the warning labels and smoking bans. For exclusive SLT users, the majority quit because of their friends and family (30%), and concerns about health (16%). About 10% quit because of the price and their children. Merely 1.5% of exclusive SLT users quit because of the doctor's advice, which was the least reported reason.

Figure 13: Perceptions and reasons for exclusive cigarette, bidis and smokeless tobacco (SLT) users to start using other products or quit from Wave 2 (2009) to Wave 4(2014) of the ITC-Bangladesh survey (pooled %).

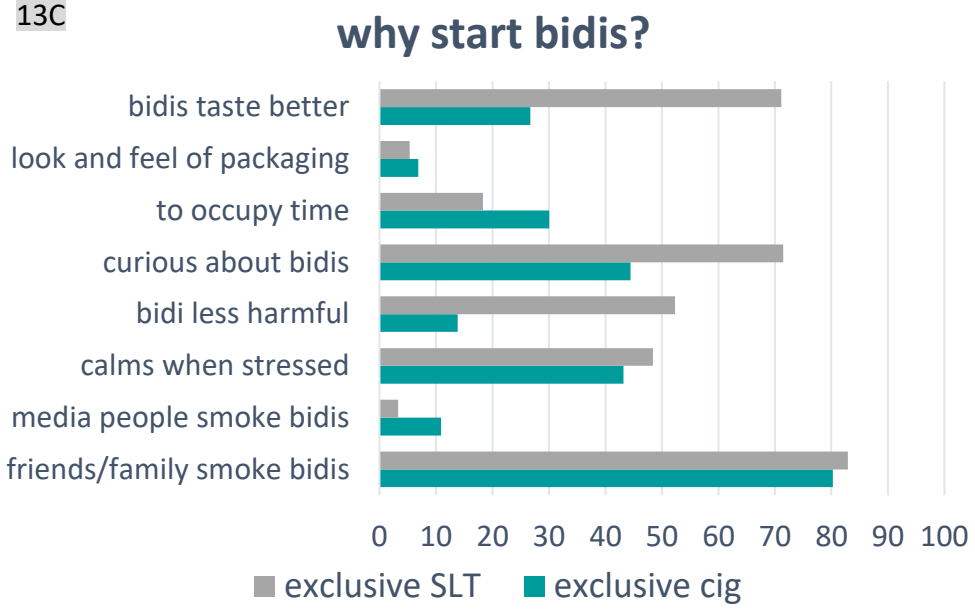


Note: N for exclusive SLT=23, exclusive bidis=99



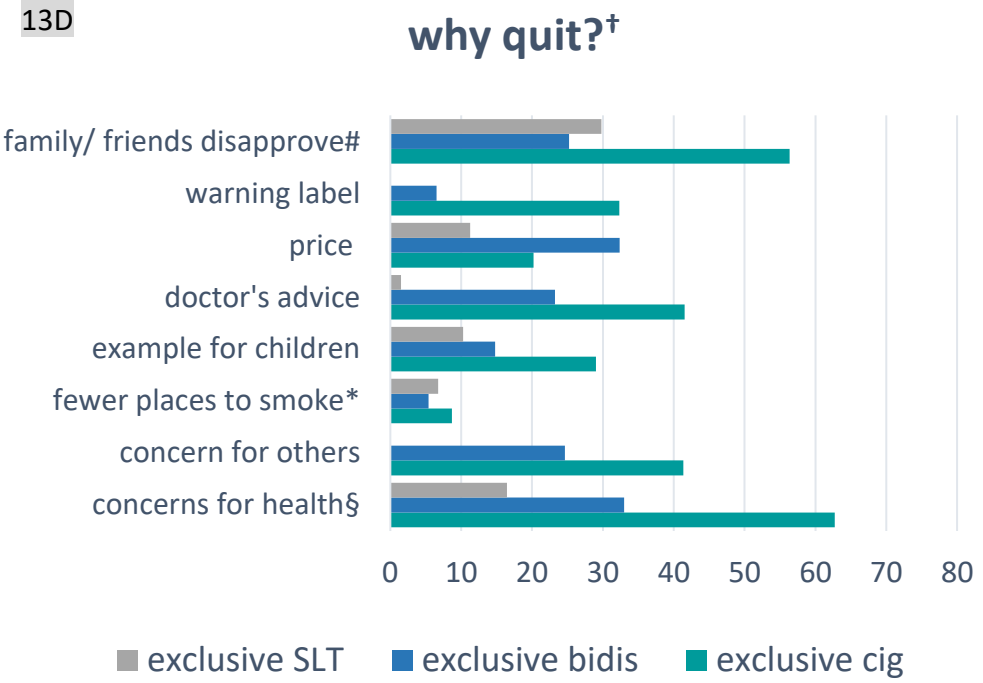
Note: † data avaliable only for wave 3 and wave 4
N for exclusive bidis=32, exclusive cigarette=174

13C



Note: N for exclusive SLT=182, exclusive cigarette=16

13D

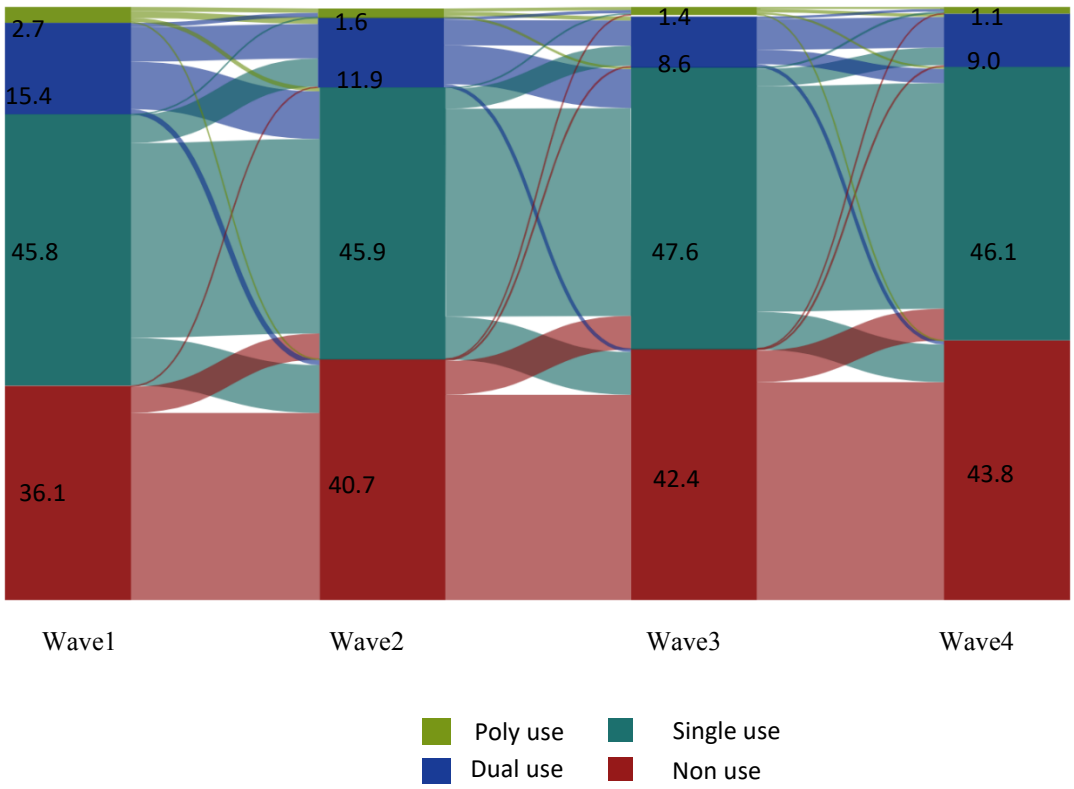


Note: † wave 2 and wave 3 data are only available for exclusive cigarette users;
wave 3 and wave 4 data are only available for exclusive SLT users.
N for exclusive SLT=58, exclusive bidis=29, exclusive cigarette=182
asked as society disapproves for exclusive SLT users
* asked as work place restrictions for exclusive SLT users
§ pooled responses for concerns of poor health, future health, and information about health

Transitions of dual and poly-tobacco use in the ITC Bangladesh survey

As in Figure 14, a more aggregated view of the trajectories of the transitions of single-, dual-, and poly-tobacco use in the ITC Bangladesh Surveys is presented. From left to right in, the trajectories indicated that transitions occur primarily between dual and single product users and between single users and non-users (quitting) between waves. Furthermore, there were generally stronger flows between transitions from multiple-product use (i.e., dual and poly-sue) toward single use or non-user in all waves. Overall, the proportion of single product use did not see any drastic change. However, the proportions of dual and poly-use decreased during the survey period, and more respondents reported as non-users.

Figure 14: Trajectories of tobacco use transitions (N=3,245)



The river plots for transition trajectories of other user groups (Cig+bidis, Cig+SLT, SLT+bidis, and poly users) from wave 1 to wave 4 were presented in Appendix 6, Appendix 7, Appendix 8, and Appendix 9.

4.5 Discussion

4.5.1 Transition Patterns in Tobacco Use Among Adults in Bangladesh

In Bangladesh, cigarettes were the most popular tobacco product among adults, followed by SLT and bidis. The estimated prevalence was similar to that reported in other longitudinal studies[182]. Findings revealed profound and distinct transitional patterns across the exclusive users of each of the three products —cigarettes, bidis, and smokeless tobacco. Trends for specific tobacco product use showed varying patterns over time: exclusive cigarette and bidis use were more stable, whereas exclusive SLT users increased in the male population but decreased in the female population. Although dual and poly-tobacco use were common in Bangladesh, the prevalence declined notably among male adults over the waves. Similar trends were observed from the two rounds of the Global Adult Tobacco Survey (GATS), in 2009 and 2017[183]. Findings from the systematic review in Chapter 2 also demonstrate that dual/poly-tobacco use is common in many LMICs, and the most common combination of tobacco use in Bangladesh was cigarette and SLT[77].

River plots for the longitudinal samples of exclusive cigarette, bidi, and SLT users demonstrated that there were unique attributes of transitional patterns within each kind of tobacco product use. Exclusive cigarette users appeared to be more stable with regards to product transitions throughout all the waves, contrasting to exclusive bidi users who were more liable to transition between different products. With regard to exclusive SLT, the most frequent transitions were moving from SLT use to non-use and vice versa (Figure 10, Figure 11, and Figure 12).

According to the patterns, adult cigarette smokers in Bangladesh showed higher loyalty to the cigarette products they used and demonstrated fewer transitions to other tobacco products. A recent systematic review of the impacts of the tobacco industry's pricing tactics in the global south found evidence that strategies adopted by industries in response to tax and price changes, such as increased tax absorption and differential taxation based on price, make tobacco consumers stick with their brand choice and have more brand loyalty, as they prefer to stay with factory-made cigarettes[184] rather than decreasing/quitting tobacco use. Bangladesh's cigarette tax has been a weak instrument in raising cigarette prices at rates over and above general inflation and the high-income growth experienced in Bangladesh in the recent past.

The differential cigarette tax and price structure in Bangladesh inherently favour low-priced cigarettes and may lead cigarette smokers to switch to lower-priced brands following tax and price increases. As a consequence, most cigarette smokers are not incentivized to quit smoking[168, 185-187].

Exclusive cigarette users were much less likely to quit or transition to other products than exclusive bidi and SLT users. This illustrated the fact that cigarette smoking is most prevalent in most LMICs, including Bangladesh[182, 184], with more smokers constantly using cigarettes. However, our study showed that, when exclusive cigarette users do transition, they are more likely to take up SLTs rather than bidis, regardless of the similarities between cigarettes and bidis. That is, to become a dual cigarette-SLT user. This may be related to the fact that SLTs have a higher prevalence in Bangladesh[157], which would be an explanation of passive transition between the products. Also, this may be a result of the active rejection of bidis among cigarette users because of cultural perceptions: cigarettes were seen as a social status symbol as compared to bidis. With the increasing affordability of tobacco products[167, 168], users of more expensive products, such as cigarette users, may be tempted to try (or switch to) another tobacco product, such as the more widely accepted SLTs, and avoid using bidis.

Furthermore, we found a sizable minority of exclusive cigarette users who eventually quit tobacco transitioned to either dual-or poly-users of cigarettes and SLTs, or exclusive SLT users during the transitioning period. This might suggest that for some cigarette users, dual cigarette and SLT use might be linked to their attempts to quit smoking using alternative products such as SLTs; whereas for some users, this might lead to a continuous use of both products or switching back to cigarette use due to nicotine dependency.

In LMICs such as Bangladesh with substantial existing prevalence of cigarette smoking and SLT use, concurrent use of cigarettes and SLT seemed to be common, notably among male adults[77]. Past studies suggests that dual use could be the transition period to eventually taking up exclusive tobacco use or quitting all tobacco use[188, 189], Therefore, it is plausible that cigarette users became dual-users through their attempts to quit using alternative products, such as SLTs, which are perceived as less harmful[141, 190]. However, some findings from higher income countries suggests that a large proportion of dual users remained dual users even after

a decade[190]. Although this may be due to the contextual differences of the culture and smokers' profile, more longitudinal data on other LMICs are still needed.

On the other hand, transition patterns for exclusive bidi users seemed to be more volatile. During the study period, there were larger fluctuations between product transitions, and fewer smokers continued as sole bidi users. Most people either switch entirely to cigarettes or to become dual-user with SLTs over time. This might imply that bidi use is more transient in nature, with consumers less likely to stick with the product. This may be linked to the fact that bidis as well as SLTs were relatively cheaper compared to cigarettes[167] in Bangladesh, consequently leading to more transitions of use among exclusive bidi and SLT users than in exclusive cigarette smokers. The similarities observed with exclusive bidis and cigarette users who were more likely to transition to dual-use with SLTs might be consistent with the previous mentioned reason that SLTs have a general higher prevalence, leading to passive transition of use.

With regards to exclusive SLT users, it was generally observed that SLT users do not seem to transition to any products. There is very little substitution or transition over time. They either continue to use SLTs or they quit altogether. This may not be surprising since SLTs are qualitatively different from STs, such as cigarettes and bids. However, given the high prevalence of SLT use in Bangladesh, this might imply that SLTs tend to be in a market by themselves.

4.5.2 Correlates of Transitions Between Cigarette, Bidi, and SLT Use Among Adults in Bangladesh

The results of the common GEE models with sociodemographic variables revealed product-specific correlates of transitions between products among subgroups of users. This distinction might be attributed to the difference in the user's characteristics (i.e., age, SES, residential area) as well as the unique nature of the tobacco product consumed (i.e., smoked vs. smokeless tobacco). Aside from the variables tested, the overall effect of time was investigated using the ITC "wave" to examine whether there was a temporal trend in transitions over time. Generally, the overall effect of wave was significant across subgroups of exclusive cigarette users,

implying that there were substantial temporal trends of transitions among exclusive cigarette users from wave 1 to wave 4.

Correlations of transitions with age

The models showed that younger male cigarette users were more likely to stick with cigarettes and were less likely to switch to bidis and SLT than their older counterparts. Similar trends were reported with male bidi smokers, who are more likely to transition to cigarette users, although the confidence intervals (CIs) include the null, which is likely because of the small sample size of exclusive bidis users. The tendencies for younger male respondents to transition to or remain as cigarette users may be explained by the tobacco industry's increased promotion of tobacco products to appeal to younger smokers, making them more interested in cigarettes and experimenting with such products[191, 192]. Recent evidence showed that the tobacco industry in LMICs has continued such promotional activities using contemporary youth-oriented media, including social media, and points-of-purchase advertisements to attract younger smokers[193]. This finding, together with the positive association between younger age and cigarette use in the longitudinal models suggest that certain adolescents may view cigarettes as elements of popular culture[194] and therefore more acceptable to use[195].

Furthermore, as compared to older SLT users, younger SLT users were more likely to switch between different products, with higher odds of making any transitions and quitting. This might be linked to younger SLT users experimenting with tobacco products, resulting in tendencies to alternate between different tobacco products[196] and quitting[197]. Although the data show that younger adults are more likely to quit SLT, this is not the case for exclusive cigarette or bidi users, who are more likely to quit at an older age. Other studies including results from the previous chapter have shown similar results, indicating that smokers are more likely to quit at an older age[105, 106].

Factors linked to area of residence

Area of residence appears to be a key sociodemographic factor associated to tobacco use transition. The data implies that there is higher volatility in tobacco use in the rural regions with exclusive cigarette users. People who use cigarettes were more likely to transition to bidi use, whereas exclusive bidi users were less likely to move to cigarettes if they resided in rural regions. This suggest that bidis may be more prevalent in rural locations, which coincides with

the sample characteristics observed for the ITC Bangladesh data (Table 11). Similar transitions were noted among individuals transitioning to SLT use. Both cigarette and bidis smokers in rural locations were more likely to switch to SLT use, and rural SLT users were more volatile but less likely to quit than urban residents. It should be noted that although the aforementioned effects were observed, certain CIs included the null in models for bidis and SLT users, which is most likely due to the limited sample sizes and small number of transitions.

Nevertheless, these findings may indicate that bidis and SLT products are popular in rural areas, and rural inhabitants using bidis or SLT and find it more difficult to quit. Reasons may be linked to the fact that bidis and SLT product are relatively cheaper[167], and are more socially acceptable among women and young adults and affordable in rural areas[156], which lead to its popularity in these communities. Besides price, crucial connections between bidis and SLT use and the socio-cultural structure that influences tobacco use largely shape the context of high alternative product use in Bangladesh[198]. Ethnographic research on tobacco consumption in Bangladesh discovered products such as bidis were closely related to cultural norms and lifestyle among the economically-disadvantaged and is widely accepted as a traditional remedy to illnesses such as toothache and indigestion[159].

The findings that rural residents were more inclined to shift to cheaper products, such as bidis and SLTs, than urban residents are noteworthy and highly relevant from a policy aspect. Rural individuals tend to move from cigarettes to other products or dual use more often and may be particularly responsive to policy measures intended to reduce tobacco use. Therefore, targeted intervention is essential for smokers residing in rural or disadvantaged areas[198] to alleviate widening tobacco-related health and social inequalities.

Factors linked to SES

In terms of tobacco use transitions, the impact of housing conditions (proxy for SES) appeared to be less influential when compared to other sociodemographic characteristics. This might imply that, compared to how well-off the respondents were, characteristics such as the respondents' residential area and age were more important when it comes to tobacco use transitions in the Bangladesh context. Among exclusive cigarette and bidi smokers, those with higher SES were less prone to switching across different tobacco products but were more likely to quit (CIs included the null for models with exclusive cigarette smokers). However, the

opposite was observed among excusive SLT users, in which the more well-off users were significantly more likely to make transitions and were prone to shifting to more expensive cigarettes (CIs included the null for transitions to cigarette use).

The increasing affordability of cigarettes and bidis could help explain why well-off smokers were more able to sustain their smoking habits without down-switching to other cheaper SLT products. The up-trade to more expensive products from SLTs is most likely caused by users' preferences for what may be perceived as higher-quality products as a result of rising income[167]. In general, transition is often driven by price differences between products. Price discrepancies and affordability may play a part in these transitions. One recent study that examined the ITC Bangladesh survey on changes in the affordability of various tobacco products discovered an increase in the affordability of cigarettes and bidis between 2009 (wave 1) and 2014-2015. (wave 4)[168]. Despite a significant price increase during this time period, the tax increase was inadequate to counterbalance the effect of growing income in discouraging tobacco users from switching between products. To ensure that the affordability of heterogeneous tobacco products continues to fall should be deemed a priority. Tax increases should be comparable across all tobacco products to decrease opportunities for substitution in response to changes in relative prices.

Aside from affordability, higher SES was also related to higher odds of quitting (statistically significant for bidi users, and marginally significant for exclusive cigarette and SLT users), which highlights the inequalities in quitting smoking. Disadvantaged and dependent smokers struggle with tobacco affordability and were more prone to smoke cheaper products[199]. As a result, more disadvantaged and tobacco-dependent users require additional assistance in quitting. Evidence shows that quitting behaviours are related with higher taxes[144]. To counteract the effect of income growth and increased affordability of tobacco products, significant tax increases would reduce the industry's ability to manipulate prices, increase quitting behaviours and consequently reduce overall tobacco use and close the gap in tobacco-related inequalities in Bangladesh.

Psychosocial factors of smoking

Beyond sociodemographics, transitions of tobacco product use were also influenced by people's attitudes towards tobacco use and their intention to quit. This is consistent with

previous longitudinal studies conducted among young adult males in the United States[200] and in Norway[201]. However, this in-depth analysis could only be conducted in the longitudinal sample of exclusive cigarette users due to sample size restrictions. As expected, results indicated that those with greater quit intentions, more unfavourable beliefs towards tobacco smoking, and those who had received doctor's advice were all more likely to quit cigarettes. Comparable results were also found in previous studies using data from waves 1 and 2 of the ITC Bangladesh survey, suggesting that psychosocial factors such as previous quit attempts, visiting a doctor in the past, perceived benefit from quitting, being worried about their own health, were related to quit intentions among Bangladeshi smokers[202, 203]. Such findings were similar to those found in Western countries[204]. The current findings revealed that receiving cessation advice from a doctor increased the odds of quitting by twofold (OR = 1.98, compared to smokers who had not visited a doctor in the previous 6 months). This demonstrates that medical advice is useful in aiding smoking cessation[205]. Health care providers should be encouraged to routinely detect whether their patients smoke and offer guidance to quit.

Interestingly, among cigarette smokers, higher quit intentions were related to a lower likelihood of transitioning to bidi use. This might imply that bidi use was not related to efforts to assist cigarette smokers to quit smoking, and that cigarette smokers do not regard bidis as a less harmful product but rather as a means to switch to cheaper products[168]. This is also reflected in smokers' belief regarding tobacco use, with a negative attitude associated with a lower likelihood of transitioning to bidi or SLT use.

Policy implications

A recent study on the use of tobacco products in Bangladesh showed young adults continued to be attracted to initiate/experiment with alternative forms of tobacco, including bidis and SLTs[206] and eventually transitioned to lifelong users of tobacco. Factors contributing to ease of transitions from experimentation to established use for bidis and SLTs in Bangladesh including low prices[167, 207], targeting of tobacco products to younger adults via multiple media outlets[195], and absence of effective counter-marketing campaigns[7] to reduce youth initiation and taper down the overall tobacco use prevalence.

Findings from this chapter are also highly relevant from a policy perspective. Younger and rural area respondents may be particularly responsive to policies intended to reduce tobacco use and transitioning between products. Enforcing prevention intervention on these vulnerable groups is essential to prevent the tobacco industry's targeting of younger adults via multiple media outlets[195], and to alleviating tobacco-related health and social inequalities among rural or disadvantaged users[198]. Furthermore, increasing taxation together with an effective and unified tax policy is required to counterbalance the rising affordability of tobacco products and the relatively lower pricing in LMICs, such as Bangladesh[167].

4.5.3 Reasons for Transition and Implications for Regulations & Policies

Major reasons for transitions

Bar charts Figure 13 provide descriptive result of the reasons why subgroups of exclusive product users initiated or transitioned to other products and answers to why they quit. Although results were meta-analysed and pooled from all following waves after the first wave, some questions were only asked to particular subgroups of users, therefore numbers may not be directly comparable between each user group and thus the rankings of responses were used to identify the most likely reasons when comparing across different exclusive user groups.

The two most common causes for respondents switching to other tobacco products were: friends and family, and curiosity. This emphasizes that smoking behaviours are heavily impacted by peers and others close to the respondents' social contacts, such as friends and family[208]. Such influence was found to be more relevant in developing countries and in the Eastern Asian cultures where smoking is a means of social activity to develop social networks and as tools for networking[209]. Previous studies pointed out that curiosity of tobacco products was also highly associated with product initiation[210]. This is an especially prominent reason why SLT users in Bangladesh started using smoked products. Receptivity to tobacco industry advertising and promotions may explain the high proportions of respondents susceptible to smoking due to curiosity[145]. As noted in previous studies, this proportion tended to increase with additional exposure to tobacco marketing throughout adolescence[211]. Furthermore, the qualitative differences between smoking and SLT products may be another reason that entice SLT users to experiment with or initiate smoking products.

For exclusive SLT users, the calming effect of smoking cigarettes and bidis, and the impression that bidis were less harmful, and taste better were the other major reasons for their transition to smoking products. This might be driven by the rising bidis and cigarette markets, as well as advertising strategies that promote the misleading impression that bidis are less hazardous and more appealing (taste better) than manufactured cigarettes[212]. Tobacco Advertisement Promotion & Sponsorship (TAPS) bans of bids and smoking products should be deemed as key policy and strengthened in this respect to discourage people to consume tobacco products in the effort to reduce overall tobacco use prevalence in Bangladesh[213], especially the vulnerable young, rural, and female population.

Reasons for quitting

Regarding reason for quitting, health concerns and disapproval from friends and family were generally the greatest deterrent for the respondents to continue using tobacco products. For cigarette smokers, doctor's advice and packaging warning labels were also effective in encouraging cessation. This suggests targeting policies in both aspects may aid to contribute to the decreasing prevalence of cigarette smoking. Since The Bangladesh Tobacco Control Act was enacted in Bangladesh in 2005, pictorial health warnings were introduced to cover at least 30% of cigarette packages. The pictorial health warnings on packages were then amended to cover 50% of the package for both combustible and SLT products in 2013, one year after the wave 3 ITC Bangladesh survey was conducted. During the same period, a number of tobacco control laws were enforced, including smoke-free laws, ban on TAPS and points of sales (POSs), cessation services, and anti-tobacco messages on media etc.[7].

As for bidi users, price seems to be a driving factor for user to quit. Although being a less expensive product than manufactured cigarettes, Bangladesh has seen an increase in price in taxes of tobacco products in this period[167]. Increased taxes may have an impact on the economically disadvantaged or those living in rural regions who are less affordable, suggesting that targeted tax increase may have a significant influence on these groups. Therefore, it should be considered a priority to ensure that the affordability of all tobacco products continues to decline across different SES groups[168].

Packaging warning labels was found to be one of the least mentioned reasons for users to quit. The reason may be related to the recent introduction of pictorial health warnings to cover at

least half of the display area for all tobacco products in 2013, after the wave 3 ITC Bangladesh survey took place. Reinforcements on warning labels on bidis packages and alternative products should be enacted to curb the growing prevalence of use in Bangladesh. Although among the reasons reported for quitting, doctor's advice accounted for a significant share of the reasons why bidi and cigarette smokers quit, this was not the case with SLT users. Only 1.5% of SLT users quit because of receiving doctor's advice. To combat the high prevalence of SLT use in Bangladesh, authorities should place a greater emphasis on integrating SLT cessation within existing health systems and cessation services on treating nicotine dependence[166].

Policy implications

Given that concerns of poor health and health information may have acted as an effective trigger for tobacco users to quit, consumer education campaigns may be an effective policy to aid tobacco users in quitting. A recent study identified education and raising public awareness around anti-tobacco advocacies in Bangladesh would stand as a key opportunity in the fight against the culturally engrained acceptance for tobacco and SLT use[166].

Anti-tobacco campaigns and cessation services should also focus on the social aspect of smoking behaviours. The influence of friends and family acts as a double edge sword; tobacco users are prone to switch products due to peer influence and are also more inclined to quit because of their disapproval[208]. Amid all responses, smoking restrictions were generally not a frequently cited reason for quitting. This implies that smoke-free laws in Bangladesh may yet not be rigorous enough to prevent tobacco users from consumption. Despite the implementation of the Bangladesh Tobacco Control Act 2005, smoking continues to be a common behaviour in public places, workplaces, and on public transportation. It wasn't until 2013 that the regulations were expanded to accommodate a list of 100% smoke-free public places. However, in many LMICs such policy is often poorly implemented or enforced[214] and the social norms in the majority of homes in LMICs therefore still permit smoking indoors. Smoking restrictions in public and workplaces should be reinforced to cover all tobacco products.

Furthermore, taxation on tobacco products, especially on SLTs remains low in Bangladesh[167] although tobacco price increases is one of the most effective measures to discourage tobacco users from continuing. However, this was not reflected in the respondents' reasons for quitting.

Price increase is proven to be a strong driver to reduce tobacco use[7]. Particularly in LMICs such as Bangladesh, increase of taxation and price of all types of tobacco products is essential to ensure that the affordability of tobacco products continues to decline.

4.5.4 Dual & Poly-Tobacco Product Use Among Adults in Bangladesh

Based on the results and discussion above, it is evident that there were complex transitional patterns occurring among different types of tobacco product users in Bangladesh over time. The current study explored different transitions between specific products, but quite often there were different combinations of those. For example, people who used cigarettes or bidis quite often transition to being dual users or poly-users. These transitional patterns often lead to mixed consumption of multiple products, such as dual and poly-product use.

The trajectories suggested that transitions were generally more volatile between dual and single product use and between single and non-use (quitting) across waves. That is to say, single or dual users often experiment with a second/third product and then go back to using one or two products again. This might indicate that policies targeting on of specific tobacco product use, may contribute to the reduction of dual and poly-tobacco use among smokers in Bangladesh. This has important implications for tobacco control in Bangladesh, as it is one of the LMICs with the highest variation in tobacco product use[182].

As reported in the study results, the most common combination of tobacco use in Bangladesh was cigarettes and SLT dual use throughout all waves. These findings were similar to the results from my previous systematic review (chapter 2), in which a high prevalence of smoking and smokeless product dual uses was observed in Southeast Asian countries, including Bangladesh[77]. Furthermore, given that cigarettes and SLT are the most commonly used products in Bangladesh, the high prevalence of dual use is to be expected. However, river plots in Figure 10 and Figure 12 suggest that cigarette and SLT dual use exhibit higher tendencies to transition back to being a single product user instead of escalating to poly-users compared to other combinations of dual tobacco product use. This supports the findings that suggest the role of SLTs in experimentation or attempts to cut down on tobacco use among respondents using smoked tobacco[192, 198].

Nevertheless, transitions that leads to dual/ poly-tobacco use might make it more difficult for people to quit and may impose a greater tobacco-related disease burden on dual and poly-tobacco users regardless of the combination of products [1]. Therefore, it is important to understand the combinations and the transitional patterns of different products so authorities can develop tobacco control policies to better target those with a higher risk of transition and strengthen current regulations to encompass all tobacco products and explicitly consider dual and poly use.

However, dual or poly-use with the involvement of SLT use may be more challenging to regulate. The qualitative differences of SLT products as opposed to smoking products such as cigarettes and bids make tobacco control complicated in LMICs such as Bangladesh. For example, a single aspect of reinforcement of a smoke-free environment may not be enough to deter smokers from starting or transitioning to use of SLT products, as they might transition to SLT products to circumvent smoke-free laws. A more comprehensive and multi-faceted approach should be adopted to tackle diversified range of tobacco use that leads to dual and poly-tobacco use and to further reduce tobacco-related disease and economic burden in Bangladesh. Such approach should emphasis on including price increases through higher taxes on both smoked and smokeless products, advertising and promotional bans around POSs, consumer education campaigns to raise public anti-tobacco awareness, smoking cessation support incorporating SLT cessation within existing health systems, and enforced product regulations (i.e., enforced pictorial warnings on all tobacco products and standardised packaging for all tobacco products) on smoked and smokeless products.

4.5.5 Strengths & Limitations

To my knowledge, this is the first study using a large longitudinal sample with appropriate statistical techniques to examine the associated factors of transitions between dual and poly-tobacco use in a longitudinal sample of tobacco users in Bangladesh. Furthermore, the study's findings provide an overview of the long-term trajectory of adult tobacco dual and poly-use of smoking and smokeless products at the national level across waves, and also identifies factors associated with transitions from one product to the other over the period of seven years from 2009 to 2015 at the individual level. The findings can also be applied to LMICs in Southeast Asia that have similar customs and populations with similar smoking contexts.

As a large-scale longitudinal study, I used all available follow-up data, providing an overview of the three major products used, namely, cigarettes, bidis, and SLTs. This allowed me to examine tobacco use changes of exclusive users over seven years of time. However, some methodological limitations should be noted. Although data from all respondents was analysed, small sample sizes and number of transitions for exclusive bidi and SLT users limited the accuracy the estimates, resulting in wider CIs and larger uncertainty around the estimates from regression models. Furthermore, the definition of current tobacco use in the study is based on daily, weekly and less than weekly use of the product. This is broader than daily use since it covers both regular and occasional users, and it may lead to more accurate estimates of the typical definitions of current users over the previous 30 days[157, 162]. Moreover, given that the ITC Bangladesh survey does not have identical definitions of SLT use in all waves (in waves 1 and 2, those who used at least weekly were captured, whereas in waves 3 and 4 those who used less than weekly was also documented, however, very few responses [<10] were recorded in these two waves). Given the above limitations, a bit of caution is warranted when interpreting the results. Nevertheless, the estimates would still be useful to readers to understand the landscape of SLT use in the country, which was accounted as the most prevalent type of tobacco product used in Bangladesh (overall prevalence 20.6% in 2017) followed by cigarette and bidi use[157].

Some policy-related factors that may influence transition patterns were not measured due to data limitations. The current study did not capture other tobacco products such as waterpipes, cigars, and e-cigarettes. It is presumed that these products were less popular with a low prevalence of use, therefore they were not surveyed in Bangladesh. However, this may limit generalisation to other settings. The current analysis did not consider the level/frequency of consumption due to methodological challenges and longitudinal analysis difficulties. Therefore, questions such as whether different levels of consumption of one product would be related to its transition to the use of other products could only be answered in future studies.

Next, as all observation studies, the use of tobacco products was self-reported, hence subject to recall biases. Huge differences in tobacco use between males and females were observed, Due to sex discrepancies in tobacco use, the number of female smokers was too small for regression analysis; except for SLT use, most models only looked at male respondents. Finally,

although I have used all the available waves of the ITC Bangladesh survey, the most recent changes over the period of the last few years beyond 2015 were not reflected in this paper.

4.5.6 What the Studies Add

This study is, to my knowledge, the most extensive analysis of ST and SLT use transitions over time in Bangladesh and in the Southeast Asia region. Although Bangladesh had implemented series of regulatory policies since the first survey (Figure 7), high tobacco consumption of STs and SLTs remains a major public health challenge in Bangladesh. Findings revealed profound and distinct transitional patterns across the exclusive users of each of the three products — cigarettes, bidis, and smokeless tobacco. In addition, our longitudinal analyses showed product-specific correlates of transitions between products among subgroups of users.

The transition patterns shed light on the interplaying nature of the markets for all three products and show the significance of products perceptions such as the higher status of cigarettes vs. bidis, which may be reflected in the significantly higher transfer rate from cigarettes to SLTs than bidis. The use of multiple tobacco products and transition patterns observed in this study suggest the ability of Bangladeshi tobacco users to choose from an array of options to maintain their nicotine dependence rather than quit. Inadequacy of cessation support programs at national and local levels may have compounded this phenomenon. Thus, a more comprehensive and multi-faceted approach should be adopted to tackle the diversified range of tobacco use that leads to dual- and poly-use and to further reduce tobacco-related disease and economic burden in Bangladesh.

In a broader sense, our findings provide a starting point for a deeper understanding of the dynamic between the tobacco products in use within the context of market strategies, product perceptions, and policies influencing different product use. This larger context may help understand use patterns and transitions in other tobacco/nicotine markets, such as nations where e-cigarettes, heated tobacco, and other emerging nicotine products are entering cigarette-dominated markets.

Chapter 5. Discussion

The purpose of this chapter is to describe the key results of the thesis as a whole and to discuss the main findings in context. The findings' implications for practice and future study, taking methodological strengths and limitations into consideration, are provided here.

5.1 Main Findings

5.1.1 Findings on The Global Prevalence of Dual & Poly Tobacco Use

The systematic literature review was the first step in understanding how previous research had operationalised dual and poly-tobacco product use in the literature and assess the epidemiology of dual and poly-tobacco product use in the tobacco control literature. I systemically searched online databases for studies published up to June 30, 2020. Twenty studies with nationally representative prevalence data on current dual or poly-tobacco use in the adult population across 48 countries were identified. Results indicated that dual tobacco use was generally higher in Southeast Asia; poly-tobacco use was prevalent in Europe as well as in Southeast Asia. Relative to single tobacco product use studies, few studies have assessed dual/poly-use among nationally representative samples, and they have used variable definitions of dual and poly-tobacco use, which limits cross-country comparisons.

Findings showed that in some studies, dual-product use was pre-defined as a specific combination of the concurrent use of two products (i.e., cigarette and SLT) in order to address the studies' research questions, while in others, it was commonly defined as the simultaneous use of any two products. Poly-product use, on the other hand, was commonly characterized as consuming more than two tobacco products at the same time. These findings formed the basis of this thesis and the research questions asked throughout the PhD, with a specific focus on dual and poly-tobacco use in the higher prevalence countries and population groups within the LMICs. In the following steps of the thesis, I have adopted the more general definition of dual and poly-tobacco use in the literature for the analyses—individuals currently using two different tobacco products were deemed dual tobacco users, while poly-tobacco users were defined as concurrently using three or more tobacco products at the time of the survey.

5.1.2 Findings on The Correlates of Dual & Poly Tobacco Use

Although multiple national-wide, large-scale datasets exist for studying tobacco use, the tobacco-using population is not always available to be broken down into different user groups and be examined through the lenses of dual/poly-tobacco use. Furthermore, data on person-level sociodemographic and other product or contextual correlates of dual/poly-tobacco use are scarce. However, I investigated the Demographic and Health Survey (DHS) the major smoking population of adult male respondents within 19 LMICs with data from the WHO tobacco report [129] and the World Bank data[130] on the impact of both individual-level and country-level factors and its association with tobacco use using multilevel models.

As anticipated, prevalence of dual or poly-tobacco use were higher in Southeast Asian and African countries. The identified factors of importance related to this were older age, low academic achievement, low-income status, being divorced, living in urban areas and high frequency of media use. In the contextual level, national wealth was not associated with dual and poly-tobacco use; however, the score of MPOWER measures was inversely associated with single tobacco use but not with dual and poly-tobacco use. This may reflect the current gaps in regulatory policies between traditional cigarettes, which are mainly stricter, and emerging alternative non-cigarette products in LMICs. Key tobacco control measures should be strengthened and reinforced to cover all tobacco products to prevent the growing burden of dual and poly-tobacco use in the nations. Following this, I then explored the impact of a broader social factor—migration status and its association with dual and poly-tobacco use in the setting of 15 LMICs among male migrants with the DHS datasets. Results suggests significant association between migration status and all types of tobacco use pattern, and more prominently, poly-product use.

In light of the analyses presented here, the work presented in this thesis helps to identify the association between multi-tobacco product use and various person, product and situational/contextual factors, such as, sociodemographic variables such as SES, education, resident area, exposure to media, and integrative factors such as migration status, etc. in large multi-national cohorts of male adults in high smoking prevalence areas in the LMICs.

5.1.3 Findings on Transitions and Temporal Patterns of Dual & Poly Tobacco Use

These key findings laid the foundation for the next chapter of the thesis and drove the focus of the research towards establishing an important point: evaluating the factors related to the transitions between different tobacco products and temporal patterns of use throughout time using the International Tobacco Control Policy Evaluation Project (ITC) - Bangladesh Survey data. This chapter provides a more granular understanding of transitions between single, dual, and poly-tobacco use by examining transitions between specific products. Extensive analysis of such longitudinal data can uncover the patterns in which people adopt and quit tobacco products as they transition into and out of dual/poly-tobacco use. Relating this temporal patterns data to person-level factors might provide insights of risk factors for dual/poly-use as well as insights into how policies that target person, product factors may impact dual/poly-use. As this is important for comprehending regulations and product use characteristics to inform tobacco control policy in order to reduce overall tobacco use.

I was able to explore this topic using the ITC survey to longitudinally investigate the patterns and factors related to transitions of tobacco use with a particular focus on Bangladesh, a vibrant nation with high acceptance of tobacco consumption (high prevalence and types of tobacco products) in the country's cultural norm. The survey period spanned from 2009 to 2015, across four waves. In this chapter of the thesis, the sociodemographic and psychosocial variables related to smoking displayed various degrees of association with different transitions of product use—Cigarettes, bidis, and SLTs.

The key factor associated with transitioning away from exclusive cigarette use to other products (bidis or SLT) or patterns (quitting, dual or poly-use) was residing in rural areas in comparison to urban areas. Doctors' advice to quit, having a negative attitude towards smoking, and having higher quitting intentions all have a significant impact on transiting to quitting. For exclusive bidi users, the major factor linked to transitions was SES. Higher SES was related to transitioning to quitting but not to other transitions. In the case of exclusive SLT users, the transition to quitting was more likely among younger respondents and less likely for those in rural areas. Lastly, from responses pooled across all waves, I explored knowledge and attitudes related to the initiation, transition, and cessation of the three major products used in Bangladesh. The most prominent reasons for respondents' switching to other tobacco products were the

influence of friends and family, and curiosity. Misleading perceptions and beliefs that bidis and SLT were less harmful were the other major reasons for transitions.

5.2 Findings in Context

The work in this thesis has demonstrated that dual and poly tobacco use represents a substantial minority of global tobacco users, especially in developing nations. Estimates from GATS and the DHS surveys reviewed in chapter 2 indicated that dual and poly-tobacco use represents approximately up to 7% and 9% of the total population, respectively, in 11 different low-income countries (LICs) and lower middle-income countries (LMICs), which were generally higher than that of the higher income countries. The high prevalence of dual and poly-tobacco use among tobacco users is most likely due to shifts in the variety, marketing, and availability of non-cigarette tobacco products[47]. The findings of my investigation in chapters 3 and 4 revealed that higher risks of dual and poly-use were associated with greater media exposure, living in urban areas, and being a higher mobility migrant, all of which may have been associated with greater exposure to tobacco-product marketing for both cigarette and non-cigarette products. Longitudinal assessments of temporal pattens of tobacco use in chapter 4 among the Bangladeshi population showed product-specific correlates of transitions between products among subgroups of users. Furthermore, factors that have to do with perceptions of harms, curiosity, calming effect etc. factors that can be influenced by tobacco control policies were also reported as top reasons for transiting/switching to using other products.

From a global health and policy perspective, the prevalence of dual and poly-tobacco use is relevant since it is associated with higher nicotine exposure and dependency and a decreased likelihood of intention to quit than single product users[37, 43]. With tobacco use being the leading cause of noncommunicable diseases, the present tobacco pandemic is likely to be exacerbated by dual and poly-use, adding a significant burden to global health and perpetuating tobacco use inequality. The conceptual model of multiple tobacco product use (MTP)[35, 47] can be useful to understand person, product, and context/situation factors and their interactions and help researchers and policy makers identify specific target populations, products, or consumer characteristics linked to these phenomena. Recognizing gaps in current tobacco control policies to expand regulations to be more comprehensive and inclusive of alternative products is important to counteract the high prevalence of dual and poly-tobacco use.

5.3 Implications & Suggestions for Future Research

Drawing from the findings in the above studies from my thesis, it is clear that more research should be done to address the complex and dynamic factors impacting dual and poly-tobacco product use. In this section, I will give policy-related implications for dual and poly-tobacco use regulation, and also limitations and recommended areas for future research.

5.3.1 Definitions of Dual & Poly-Tobacco Use

One primary aim of this thesis is to systematically review definitions of dual and poly-tobacco product use in the literature. The review eventually led to 20 eligible studies published up to 2020, with nationally representative data on the adult population across 48 countries. Among the included studies, current dual tobacco was commonly determined in one of five ways as shown in Table 4. However, definitions can be narrowed down to two broader categories: either concurrent use of any two tobacco products or concurrent use of a specific combination of two tobacco products (e.g., one smoked and one smokeless product). On the other hand, poly-tobacco use was commonly defined as consuming two or more tobacco products or in some studies, three or more products. For the purpose of this thesis, I have adopted the more general definition of dual and poly-tobacco use to avoid ambiguity: concurrent use of two different tobacco products for dual use, and three or more tobacco products for poly-use.

It is apparent that the definitions of dual and poly-tobacco use differed greatly among the studies reviewed. For a more up-to-date view of the definitions used in the literature, I updated the search of published research in January 2022 using the same methodology and criteria as the systematic review for published studies on dual and poly-tobacco use from 2020 up to 2022 (Table 17). Three out of the four newly identified studies were in the US[63, 124, 215], with definitions similar to what is used in this thesis. However, one of the US studies[215] defined poly-use as consuming two or more tobacco products, which is similar to some studies previously identified[29, 31, 86, 92, 93]. The fourth study in this updated search was conducted in Myanmar with dual use defined as concurrently consuming tobacco products (smoked or smokeless) with chewing betel quid with tobacco[216].

Table 17: Recent published studies not included in the systematic review in Chapter 2.

Region, Country	Authors, Year of Publication	Survey Year/Period	Survey Name	Sample Size	Dual/Poly tobacco Use	
					Dual use	Poly use
American Region						
United States	Hirschtick J.L. et al., 2021	2014-2016	TUS-CPS, NHIS, PATH	28,070–155,067	✓	✓
	Mattingly D.T. et. al., 2021	2014-2019	TUS-CPS, NHIS	283,825	✓	✓
	Gonzalez M. et. al., 2021	2019	NHIS	5028 *		✓※
South-East Asia Region						
Myanmar	Sreeramareddy C.T. et al., 2021	2015–16	DHS	17,622	✓#	

*sample restricted to rural adults, ※ defined as consuming two or more tobacco products, # defined as tobacco use + betel quid chewing.
Abbreviations: DHS: Demographic and Health Surveys; NHIS: National Health Interview Survey; TUS-CPS: Tobacco Use Supplement-Current Population Survey; PATH: Population Assessment of Tobacco and Health

With the proliferation of novel alternative tobacco products and growing studies on multiple-product use, it is imperative that the global tobacco community reaches a consensus regarding a consistent and widely acceptable operational definition of “dual” or “poly-tobacco use”. Varied definitions impair the generalisability and comparability of estimates across studies and, in some cases, induce discrepancies in results that add difficulty in uncovering the actual situation of tobacco use within the country/population studied[104]. Therefore, to facilitate global comparisons and strengthen tobacco use regulation on the understanding of dual and poly-tobacco use, I suggest that global health authorities and large-scale national or international studies agree on a consistent working definition that is more intuitive and easier to apply in different settings. That said, definitions should be informed by the research context and represent the scope of the investigation. Future research could base the concept of dual use on the qualitative features of the product, such as the combination of smoked/combustible and smokeless products, or on the quantitative aspect as proposed in my thesis. This would simplify cross-country comparisons, which in turn enhances research and communication for a broader understanding of these phenomena.

In terms of poly-tobacco use, future studies should adopt a working definition that minimises conflation of the definition with dual use. According to the systematic review and the most

recent update search of articles, poly-tobacco use is commonly defined as consuming three or more tobacco products, or in some studies, two or more products, which includes dual use. It is my recommendation that future research on poly use adopt a separated definition for dual use, as the latter definition (i.e., consuming two or more items) may confuse readers and increase prevalence estimates when looking at both patterns jointly.

However, it is understandable that in many cases when specific dual-use combinations of tobacco product use are of interest it is common for researchers to pre-define the two products of interest according to studies' aims. Past studies showed that when using the more stringent definition of dual product use (i.e., including specific products instead of any two products), the ranges of prevalence estimates reduced with lower variability[104]. This might improve accuracy of the estimates, which is important in establishing the health impact and risks associated with the product examined; however, this would also limit the comparability of the data to that of other studies and populations and narrow the scope to be more product focused and less generalisable when making inferences to users in other settings. In this case, it is at the researcher's discretion to use definitions meaningful to the survey and to the research question.

Concisely, definitions should depend on the context of the study and the potential role of the product. For example, studies on addiction may be better to define dual use as using one smoked product along with a smokeless one rather than any use of two products. On the other hand, studies on smoking cessation may be interested in the health impact of different kinds of product combinations, even if they are two smoking products of any kind. Taking the above considerations into account, dual and poly-tobacco use could be used as an umbrella term to define combinations of use by either quality or quantity of the used product to facilitate comparability and communication in international surveys and large-scale studies or be grouped into specific combinations of use to investigate health impact and target regulation policies on certain products. Either method of categorisation has its strengths and limitations in reporting prevalence estimates but has its unique role in providing implications to public health researchers and policymakers.

The extent of smoking/tobacco use frequency (number of days smoked per month) and amount (number of products smoked/used per day) of the respondents as a function of dual/poly-

product use is something I did not take into account in my thesis. I was only able to establish the definition of dual and poly-use as a function of the quantity of tobacco products currently used by the respondent, as I was not able to incorporate frequency data in the analyses of the DHS and the ITC-Bangladesh datasets. In my thesis, I considered daily, or occasional tobacco use in the past 30 days (past month) as "current" tobacco use. According to large-scale international surveys such as the GATS and GYTS, this threshold of current use is widely accepted as it includes both regular and occasional users and may lead to more comparable estimates across international studies.

However, frequency of use could be an important element to consider in future studies to establish epidemiological evidence between multiple-product use and a range of health-related outcomes such as nicotine dependence, quitting intentions, attitude and beliefs about tobacco[76]. Borland et al. proposed a classification system for current (at least monthly) dual-product use as a function of both the type and the frequency of tobacco-product use[217]. This resulted in an eight-level typology system characterising four patterns of concurrent use and four exclusive uses of cigarette smoking and vaping based on use frequency of each product (daily, non-daily, no current use) — predominant smokers, dual daily users, predominant vapers, concurrent non-daily users, exclusive daily or non-daily smoker, and exclusive daily or non-daily vaper (Appendix 10). This classification system could be extended to include other types of tobacco/nicotine products while taking into account frequency of use.

Lastly, I did not include the use of emerging novel tobacco and nicotine products such as heated tobacco and Electronic Nicotine Delivery Systems (ENDS) such as e-cigarettes in my thesis for several reasons. These were not assessed in the ITC-Bangladesh survey and many DHS surveys, presumably due to very low prevalence. Although these questionnaires did not include all tobacco products in all countries, it is presumable that only popular products were assessed in each country. However, this may need to be considered in future surveys. As for the systematic review, I excluded studies reporting concurrent use of non-tobacco substances (e.g. drugs, marijuana) as well as ENDS, given that they contain nicotine and not necessarily tobacco, and are not regarded as a tobacco product in many countries other than the United States (US), and thus not included in tobacco product regulation[20]. Nevertheless, in recent years, ENDS continue to grow the industry's customer base, including through attracting younger users. Thus, concurrent use of ENDS with other tobacco-products has become of particular interest

in the field of tobacco regulatory science. Whether ENDS should be included within the definitions of dual/poly tobacco product use should be reflective of the policy context within each country's own legal and regulatory frameworks around tobacco and other nicotine-containing products.

5.3.2 Improve Surveillance Capacity on Global Tobacco Use

During the course of my thesis, there has been an increasing challenge to identify nationally representative data bases to answer research questions on dual and poly-tobacco use. Despite their significance on health risk research and the high prevalence of use around the globe, the inadequacy of global surveillance on tobacco product use and outcomes of dual and poly-tobacco use may reflect that they are not yet well investigated in the field.

A stark example is my systematic review of published studies, in which I identified 24 studies (20 for the systematic review in Chapter, 4 from the updated search in January 2022) that have been based on only 11 national surveys, with almost half of them in the US and the others from the rest of the world. This is a relatively small number compared to the abundant research on smoking and tobacco use across the world, especially for outside the US. Moreover, during the screening process of the review, I discovered a large number of US studies on specific combinations of dual-use within targeted subpopulations such as pregnant women and adolescent dual-use with ENDS or vaping products. The small pool of data sources may either indicate the fact that questions on dual or poly-tobacco use are not generally included in routine tobacco use surveys, or that researchers' interest in the subject has been limited and product-oriented. Hence, few international studies have analysed available data on the use of multiple tobacco products at the population-level. In any case, the message behind it is that population data on the use of multiple tobacco products among adults is insufficient.

Improving surveillance capacity of dual/poly-use in health surveys and analyses is essential to monitor trends and use patterns and is considered a cornerstone of the WHO FCTC[7] as indicated by the first letter "M" in the WHO MPOWER measures to monitor tobacco use. One important step for future studies is to collect data on all tobacco products used and include questions on dual and poly-use in all standard routine tobacco surveys. Data on product types, duration and frequency of use should also be documented so researchers have adequate

information and the flexibility to develop their own definitions of multiple-product use depending on their interests.

The global tobacco control community should also give priority to improving surveillance capacity in developing countries outside the US. In this thesis, I have highlighted the high prevalence of dual and poly-tobacco use in some LMICs. Then I demonstrated using cross-sectional and longitudinal data that the different types and numbers of tobacco products consumed as well as the dynamics of product use (i.e., transitions between products) are critical areas that deserve further study. I show that, monitoring product use in the population and over time helps to examine whether preferences and types of products consumed are related to contextual or individual social and behavioural factors. Alternately, these factors are important not only to facilitate analysis, but to inform how regulation can be reinforced to influence consumer transitions between products.

Currently, there is little data available on the prevalence of dual and poly-tobacco use or on demographic and other person, product and contextual level correlates related to dual and poly-tobacco use[47]. Collection of data on both tobacco use and its associated factors should be consistent, comparable, and comprehensive to propel international research and improve surveillance systems. Also, it is critical for global health authorities and researchers to expand research to address the above factors as well as broader social/cultural factors and their interactions to enhance monitoring of dual and poly-use in health surveys. This would enable studies to generate evidence to support effective tobacco control interventions on multiple-product use in the population and more diverse samples.

5.3.3 Reinforce Regulatory Capacity on Dual & Poly-Tobacco Use

Multiple tobacco product users, including dual and poly-users, account for a considerable proportion of global tobacco users. Growing number of studies and also results for this thesis highlight the importance of advancing tobacco regulation to prevent the growing burden of dual and poly-tobacco use globally. Based on the evidence reviewed and generated in this thesis, I argue that effective tobacco control policies should take into account dual and poly-tobacco use and its growing concern across the globe. Although the WHO FCTC and current tobacco regulatory control authorities worldwide do not specifically mention dual and poly-use, several

governing bodies such as the Family Smoking Prevention and Tobacco Control Act (TCA) in the US[218], as well as tobacco control legislation in the UK[219] and EU (European Tobacco Products Directive)[220] have suggested the need for a more concentrated and comprehensive assessment of the use of multiple tobacco products and the potential effects of regulatory actions on dual and poly-use.

In tandem with findings from this thesis, accumulating evidence has elucidated how tobacco users are influenced by an increasingly diverse tobacco-product market and distribution of non-cigarette tobacco products. This had increased their interest in, and use of, more than one tobacco products leading to the increasing prevalence of dual/poly-tobacco use in areas of the world[77]. The same is true concerning product transition/substitution, as the availability and appeal of a wide variety of products may assist smokers in avoiding bans and deterring cessation or may provide access to cheaper or alternative forms of tobacco that offer potentially less harmful exposure than cigarette smoking. Therefore, to extend regulatory action, the dynamic tobacco marketplace, as well as the underlying mechanisms involved with product transitions and the uptake of multiple products, must be addressed.

It is worth mentioning that some literature suggests that product substitution and/or dual-use may be useful in some cases (e.g., cigarette smokers using ENDS or vaping products concurrently in transitional periods that lead to cessation)[103]. Regardless, studies of the risks and benefits of tobacco use should consider the population as a whole. Any tobacco regulatory action must consider the possible risks of all tobacco products, not only to multiple product users, but also to protect non-users.

In this section, I will focus specifically on the implications from the studies in the previous chapters to improve regulatory capacity on dual and poly-tobacco use. This would be discussed in three aspects: (i) transitions of tobacco use & the MTP model; (ii) effects of regulatory policies on dual and poly-tobacco use, and (iii) areas for future research; and lastly state conclusion and suggestions for tobacco control policies.

Transitions of tobacco use & the MTP model

This thesis examined various potential product, person, context/situational as well as some broader individual-contextual factors correlated with dual and poly-tobacco use as described

in the conceptual multiple tobacco product (MTP) model[35, 47]. One focus of this thesis is not only to describe the dual and poly-tobacco use phenomenon and its effect on population health, but also to explore the impact which the likely determinants of dual and poly-tobacco use have on tobacco regulatory policy. For this purpose, I have examined using large-scale population datasets the impact of person-level factors (e.g., sociodemographic, and psychosocial variables) associated with use in different settings and populations. From the DHS studies, results showed that the likelihood of being a dual and poly-tobacco user is strongly associated with having a disadvantaged background or being a member of a vulnerable group. Specific factors associated were: older age, low academic achievement, low-income status, being divorced, living in urban areas, and being a migrant. Using the ITC-Bangladesh dataset, longitudinal transition analyses revealed several key person-level factors associated with different transitions of cigarette, bidis, and SLT use. Particular factors of interest were age, area of residence, and psychosocial factors such as attitudes toward tobacco use and the intention to quit.

Dual and poly-tobacco use may reflect the perpetuating health inequalities within these communities, especially those with economic hardship and lower socio-economic status. Price-minimising behaviours (e.g., switching to cheaper SLT products) and social stigma associated with tobacco use, such as being divorced and residing in disadvantaged areas, may be major factors influencing their tobacco product use[65]. Vulnerable populations such as migrants, also represent a group of disadvantaged minorities faced with the extra health burden of multiple product use[106]. As a result, tobacco control efforts should prioritise and target interventions that vulnerable and disadvantaged populations are more sensitive to. Strategies such as reducing barriers to receiving health care, providing cessation services, tailoring mass media campaigns, and raising the tobacco purchase age have all been shown to be effective in reducing smoking inequality and, eventually, attenuating dual and poly-tobacco use.

From another aspect, one potential way to address multiple tobacco use is to target tobacco products and related characteristics (e.g., flavouring, pricing, market availability, packaging and labelling etc.). For example, policy restricting flavours on manufactured cigarettes is proven to reduce their appeal and reinforcement and in turn, decrease experimentation/initiation and also their substitution for traditional products. Likewise, governments can set taxes on tobacco products, which in turn have an impact on their sales.

Almost all countries worldwide impose considerably higher excise taxes on manufactured cigarettes than on other tobacco products, which has potentially contributed to the increasing use of alternative tobacco products, especially in LMICs such as Bangladesh[198]. Therefore, taxation and product regulations should be strengthened across all products comprehensively to reduce opportunities for transition/substitution in response to a single policy change.

Also, from a broader societal perspective, person-product or individual-context level factors such as perception of risks, cultural norms, or migratory status also have an impact on tobacco users' consumption, resulting in dynamic transitions or complementary behaviours of use[35, 47]. In the previous chapter of the thesis, I adopted analytic approaches that take into account varying patterns and broader person-product and societal factors in correlation with multiple product use in Bangladesh. Results have identified the ways consumers are starting specific tobacco products to indulge curiosity, social affability (influence of peers and family), or substitute products for perceived less harm or smoking cessation in addition to their original products. These findings may provide additional insight for national and local governments to set policy priorities on educational campaigns, market regulations, and the banning of specific characteristics of tobacco products. These targeted measures on certain tobacco products would in turn assist in tackling product transition and multi-product use.

Effects of regulatory policies on dual and poly-tobacco use

The MTP model pointed out that regulatory actions on any single tobacco product may influence the use of other tobacco products—Pacek and colleagues proposed specifically in their conceptual framework for MTP use that any regulatory action that decreases or increases the regulatory properties of a product can affect the use of other tobacco products by altering their cross-substitution[35, 47].

For example, introducing or reinforcing tobacco product regulations that limit the characterization of flavours may decrease their attractiveness and reinforcement of use, which would potentially decrease users' transition partially or completely to the product and reduce dual and poly-use. In the same way, implementing product standards that require warning labels or limiting nicotine content on combustible products may decrease their appeal and reinforcement of use, while increasing interest in and transition to non-combustible products if regulatory gaps on these alternative products exists. Another scenario is that successful

educational campaigns or accessible cessation services may raise awareness of the perceived harm of tobacco products, reducing their appeal to current users and, in turn, lowering the chances of multiple product use and the health risks associated with it.

Evidence from chapter 4 of my thesis also discussed the potential effects of pricing/ taxation on cigarette users' transitional patterns to dual and poly-use. Exclusive cigarette users in Bangladesh were much less likely to quit or transition to other products than exclusive bidi and SLT users. The differential cigarette tax and price structure in Bangladesh inherently favour low-priced cigarettes and may lead cigarette smokers to switch to lower-priced brands following tax and price increases[168, 186]. Ineffective regulation on cigarette prices may have a negative impact on reducing cigarette consumption. As a consequence, most cigarette smokers are not incentivized to quit smoking, and therefore continue to be cigarette users, or in some cases become dual or poly-users with other products.

Results and data from my thesis provide further evidence that policy-related actions that affects the use and appeal of one tobacco product can have consequence on the use of other tobacco products. Taking the MTP model and the findings altogether, it is important that researchers and policy makers apply a comprehensive approach and take into consideration a multifaceted approach in designing and implementing tobacco control policies.

Areas for future research

This thesis adds to the growing literature on global dual and poly-tobacco use, as well as factors related to use and transitions for different populations and user groups. With the growing evidence, research interests in areas important to tobacco product regulation have become a priority. However, little work has been done to try to unpack the effectiveness and associations of tobacco regulatory policies, such as the WHO MPOWER measures in the field of multiple tobacco use.

There is still a lack of large population studies, with a scarcity of literature on the current dynamic between tobacco control regulations and how they are associated with different combinations of tobacco use outcomes. In the DHS study, I discovered the score of MPOWER measures to be inversely associated with single tobacco use but positively associated with dual and poly-tobacco use. Nevertheless, in both the DHS and the ITC-Bangladesh studies, I was

unable to break down the details of what impact individual policies have on different patterns/transitions of use.

An important implication that arises from this is that the WHO MPOWER strategy has been successful in regulating targeted products, predominately manufactured cigarettes worldwide. However, when it comes to concurrent use of non-cigarette products, a more granular approach was needed to differentiate between MPOWER components and what impact they have on different groups of multiple product users. Based on these findings and limitations, future studies should prioritise research on how these policies affect dual and poly-use and product transitions. Specifically, research should focus on, for example, the effect of increased taxation, smoking bans, product regulations, etc. of each product used in a multiple-tobacco use combination and their association with behavioural outcomes.

In summary, the impact of possible tobacco regulatory actions on dual and poly tobacco use has not been evaluated in the full spectrum and thus little is known about how governing bodies can take regulatory actions that have a positive impact on multiple-tobacco use. Additional research on the impact of regulating one or more products on the use of products among representative samples of dual and poly tobacco users should thus be a priority.

5.3.4 Conclusions & Suggestions for Tobacco Control Policies

The use of multiple tobacco products studied in this thesis showcased that tobacco users were able to choose from an array of options to either maintain their nicotine dependence, transition completely to, or in combination with other tobacco products as dual and poly-users or quit. Various person, product and context/situational factors should be taken into account in understanding the dynamics of multiple tobacco product use.

Inadequately implemented tobacco control programmes (i.e., the MPOWER package) at national and local levels may have compounded this phenomenon and widen policy-related gaps in different jurisdictions and even between products. Thus, a more comprehensive and multi-faceted approach should be adopted to tackle the diversified range of tobacco use that leads to dual and poly-use and to further reduce tobacco-related disease and economic burden globally.

In a broader sense, findings in my thesis chapters provide starting points for tobacco control researchers and policy makers to seek a deeper understanding of the dynamic between the tobacco products in use within the context of the MTP model and beyond. Wider factors such as market strategies, product perceptions, and policies influencing different product use should also be considered in future literature. This larger context may as well help understand use patterns and transitions in other tobacco/nicotine markets, such as the novel and emerging tobacco/ nicotine products. For example, nations where e-cigarettes, heated tobacco, and other emerging nicotine products are entering cigarette-dominated markets.

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Appendices

Appendix 1: Search Strategy

#1	((multi* or alternat* or other or poly* or "poly tobacco" or concurrent or dual) adj1 (tobacco or smoking or nicotine or cigarette* or combustible or smoke*)).tw
#2	("use" or "usage" or product* or consumption or uptake or dependence).tw.
#3	(prevalence or pattern* or type* or trend* or transition* or shift or trajector*).tw.
#4	("Poly Tobacco" or polytobacco).mp.
#5	#1 and #2 and #3
#6	#4 or #5
#7 FINAL	remove duplicates from #6

Ovid for MEDLINE & Embase & Global Health (adj1: Terms right next to each other in any order)

Appendix 2: Prevalence estimates of current single product use among adults by country and region

Region, Country	Survey Year	Single Product Use (%)					
		Smoking Tobacco	Cigarette	Cigar/ Cigarillo	Pipe	Hookah/ Waterpipe	Smokeless Tobacco
South East Asia							
Bangladesh[19, 31]	2009	22.9	14.5	0.4	0.4	0.7	27.1
Indonesia[30]	2012	M: 75.9; F: 2.3	—	—	—	—	M: 0.3; F:0.3
India[†][19, 31, 82, 83]	2009/10	14.0	6.4	0.6	—	0.9	29.5
Maldives[30]	2009	M:46.8; F: 4.3	—	—	—	—	M:2.9; F:4.0
Nepal[30]	2011	M:17.5; F: 10.2	—	—	—	—	M:20.1; F: 4.0
Timor-Leste[30]	2009/10	M:70.5; F:3.2	—	—	—	—	M:0.02; F:1.5
Thailand[31]		23.7	29.1	0	0.1	0	3.9
Western Pacific							
China[19, 31]	2010	28.1	29.0	0.1	0.5	0.4	0.5
Malaysia[31]	2011	—	24.1	0.2	0.2	0.6	0.7
Philippines[19, 31]	2009	28.9	28.3	0.3	0.1	0	2.0
Viet Nam[19, 31, 82]	2010	23.7	20.6	0	0.1	6.4	1.3
Eastern Mediterranean							
Egypt[19, 31, 82]	2009	19.4	16.4	0	0	3.3	2.6
African							
Nigeria[31]	2012	—	4.7	0.5	0.3	0.3	1.90
European							
Poland[19, 31]	2009	30.3	31.7	0.5	0.2	—	0.5
France[31]	2012	—	32.4	1.4	0.4	7.1	0.8
Belgium[31]	2012	—	31.6	2.0	0.6	4.7	0.9
Netherlands[31]	2012	—	28.9	2.9	1.1	5.1	0.4
Germany[31]	2012	—	30.1	0.9	0.7	5.0	1.8
Italy[31]	2012	—	26.9	1.1	0.6	2.0	1.7
Luxembourg[31]	2012	—	28.1	2.5	0.5	7.8	1.4
Denmark[31]	2012	—	27.4	0.7	3.0	8.4	3.2
Ireland[31]	2012	—	33.2	0.5	0.2	0.9	1.6
United Kingdom[31]	2012	—	33.8	0.8	0.6	3.6	1.1
Greece[31]	2012	—	46.6	0.3	0.2	2.9	0.1
Spain[31]	2012	—	38.3	0.7	0.4	2.9	0.3
Portugal[31]	2012	—	26.6	0	0.2	1.9	2.7
Finland[31]	2012	—	29.6	2.3	0.7	1.5	3.4
Sweden[31]	2012	—	12.4	0.5	0.9	2.8	17.7
Austria[31]	2012	—	35.4	0.8	0.2	8.5	4.3
Cyprus[31]	2012	—	35.4	0.8	0.2	8.5	1.2
Czech Republic[31]	2012	—	31.9	0.5	0.4	7.9	1.4
Estonia[31]	2012	—	28.3	1.1	1.0	7.6	3.6
Hungary[31]	2012	—	36.8	0.4	0.3	2.4	0.4
Latvia[31]	2012	—	39.9	1.3	1.0	11.5	0.7
Lithuania[31]	2012	—	32.0	0.5	0.6	9.0	0.6
Malta[31]	2012	—	30.4	1.0	0.9	2.8	3.5
Slovakia[31]	2012	—	23.3	0.6	0.2	4.2	2.2
Slovenia[31]	2012	—	29.9	0	0.4	2.0	1.1
Bulgaria[31]	2011	—	38.9	0	0	1.4	0.1
Ukraine[19, 31]	2010	28.9	29.6	0.7	0.2	2.1	0.3
Romania[31]	2011	—	27.2	0.7	0.2	0.4	0.3
Russian Federation[19, 31, 82]	2009	39.2	39.2	1.3	0.8	3.8	0.6
Turkey[19, 31]	2008	31.2	32.7	0.7	0.3	2.3	0
American							
Mexico[19, 31]	2009	15.9	15.9	0.3	0.1	0	0.3
Uruguay[19, 31]	2009	24.9	29.4	0.1	0.2	0.1	0
Brazil[31]	2008	—	19.4	0.1	0.3	0.1	0.4
Argentina[31]	2010	—	22.7	0.3	0.1	0	0.2
United States[86]	2018	16.5	13.7	3.9	1.0	1.0	2.4

Note:

1. Table summarises prevalence estimates weighted from various studies and surveyed years, and therefore, figures may not be directly comparable between each usage groups.

2.Table presents most recent prevalence estimates available of each country and product use.

Abbreviations: M: male; F: female. † % for bidi use in India= 9.2%; — data not available.

Appendix 3: Multilevel regression of the effect of MPOWER on two types of dual or poly-tobacco use outcomes.

	Adjusted Odds ratio (aOR) with 95% confidence interval	
	Model 1	Model 2
MPOWER[a]	1.009	1.211***
	(0.986-1.0322)	(1.202-1.219)
N	234,537	234,537
Log Likelihood	-95641.41	-88690.79
Pseudo R2	7.74%	2.54%

Note : Model 1: dual or poly-tobacco use including cigarettes; Model 2: dual or poly-tobacco use of non-cigarette products only. Both models 1 and 2 were adjusted for age, education level, marital status, residential area, occupation and household wealth using multilevel regression models for binary outcomes. Non-tobacco use as the reference category for both models.

a: MPOWER: numbers of the MPOWER measures implemented to the highest level

Appendix 4: Questions on starting/quitting tobacco use in the ITC-Bangladesh survey.

Why start using cigarettes?	friends/family smoke cigs
	media people smoke cigs
	calms when stressed
	curious about cigs
	sign of sophistication
	to occupy time
Why start using bidis?	friends/family smoke bidis
	media people smoke bidis
	calms when stressed
	bidi less harmful
	curious about bidis
	to occupy time
	look and feel of packaging
	bidis taste better
Why start using smokeless tobacco (SLT)?	friends and family use SL
	reduce stress
	curiosity
	to occupy time
	less harm than other tobacco products
	help quit tobacco
	look and feel of packaging
	like the taste
Why quit using cigarette/bidis/SLT?	concerns for health†
	concern for others
	fewer places to smoke*
	example for children
	doctor's advice
	price
	warning label
	family/ friends disapprove#

Note: † pooled responses for concerns of poor health, concerns of future health, and information about health; * asked as work place restrictions for exclusive SLT users; # asked as society disapproves for exclusive SLT users.

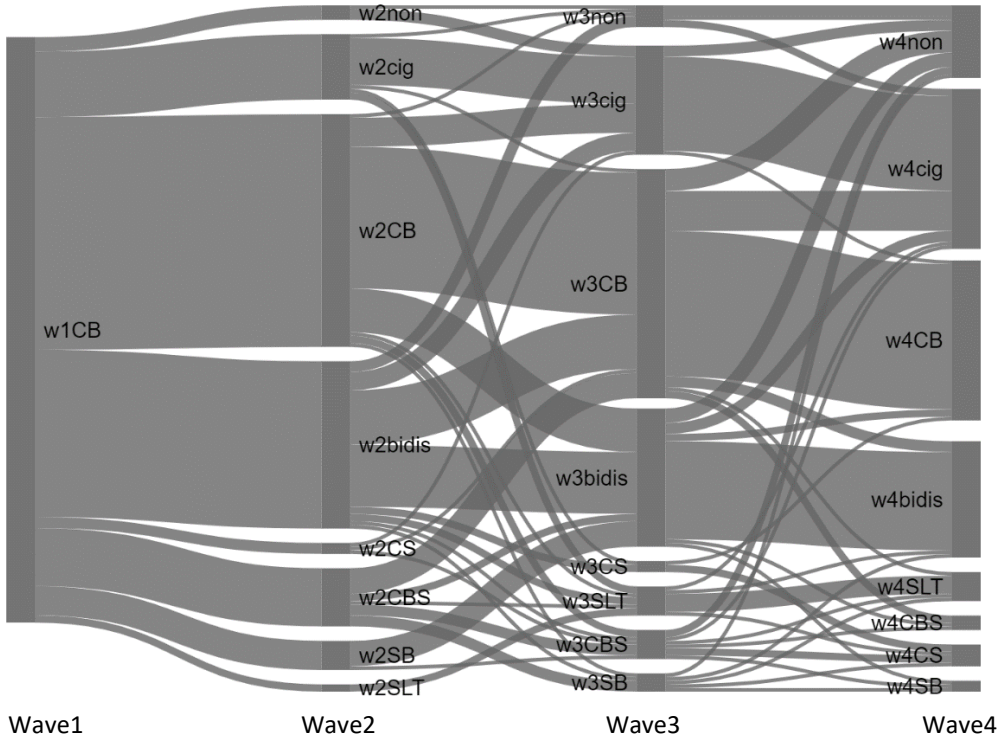
Appendix 5: Model selection and diagnostic tests of the GEE models in the ITC Bangladesh analysis.

Models	**Variables**	**QIC**	**Wald test compared to base variables**
Base	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention	809.14	Base
1	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict	807.42	P=0.28
2	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, STattitude	806.21	P<0.000*
3	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, STimpact	809.09	P=0.136
4	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict, STimpact	806.72	P=0.89
5	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict, STimpact, STattitude	804.23	P<0.000*
6	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, doctorQ	697.47	P=0.96
7	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, smokefreeQ	800.82	P=0.39
8	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, WLQ	798.75	P=0.65
9	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, doctorQ, smokefreeQ, WLQ	677.15	P=0.30
10	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict, STimpact, doctorQ	694.14	P=0.16
11	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, STattitude doctorQ	645.12	P=0.013*
12	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict, STimpact, STattitude doctorQ, smokefreeQ, WLQ	640.43	P=0.18
13	Sex, ageGrp, residence, chiIdx, edu, marry, wave, cigstatus, Qintention, cigaddict, STimpact, doctorQ, smokefreeQ, WLQ	641.63	P=0.41

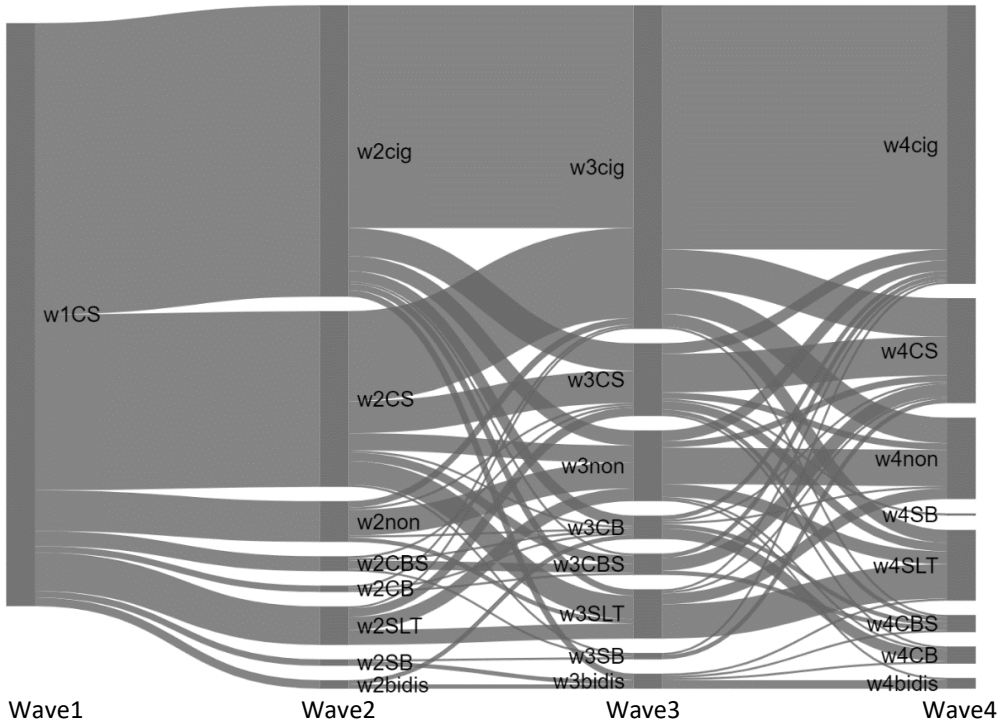
Note: According to the goodness-of-fit statistics (lower QIC value) and a significant Wald test ($p < 0.05$) against the base models, the final model selected for formal analysis is model 11.

QIC: quasi-likelihood information criteria; ageGrp: age group; residence: residence area, chiIdx: CASHPOR housing index; edu: education level; marry: marital status; cigstatus: cigarette smoking status; Qintention: quit intention; cigaddict: cigarette addiction; STimpact: impact on smoking tobacco; doctorQ: doctors' advice to quit, smokefreeQ: smoke free rules, WLQ: warning labels on package.

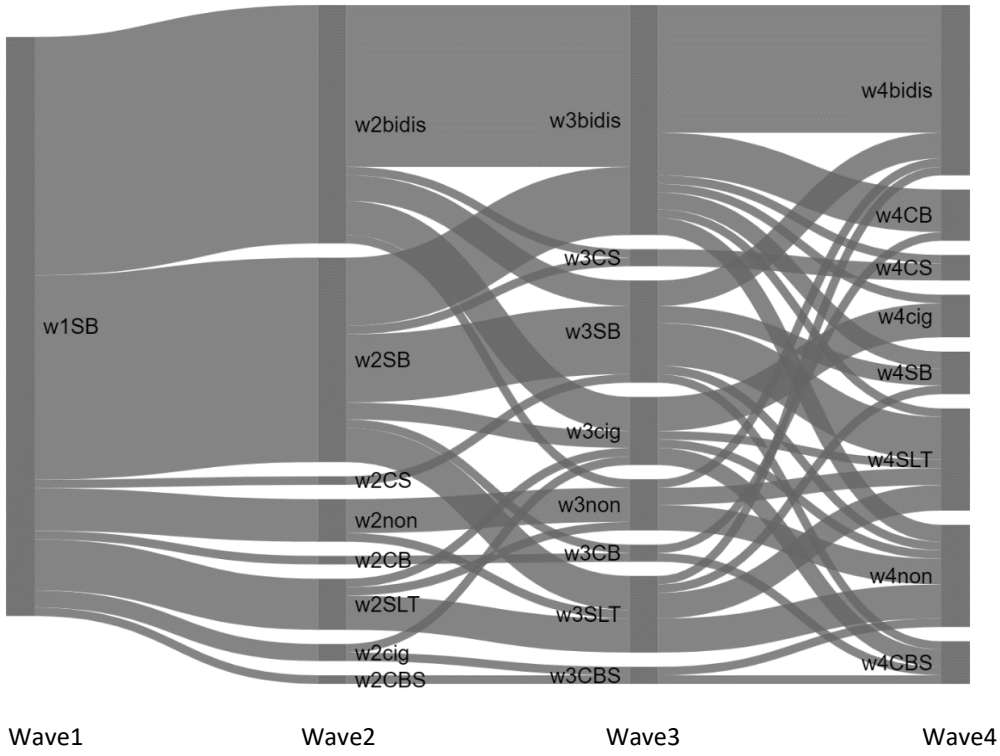
Appendix 6: Transitions of Cig+bidis users in Wave 1 (n=161) to Wave 4.



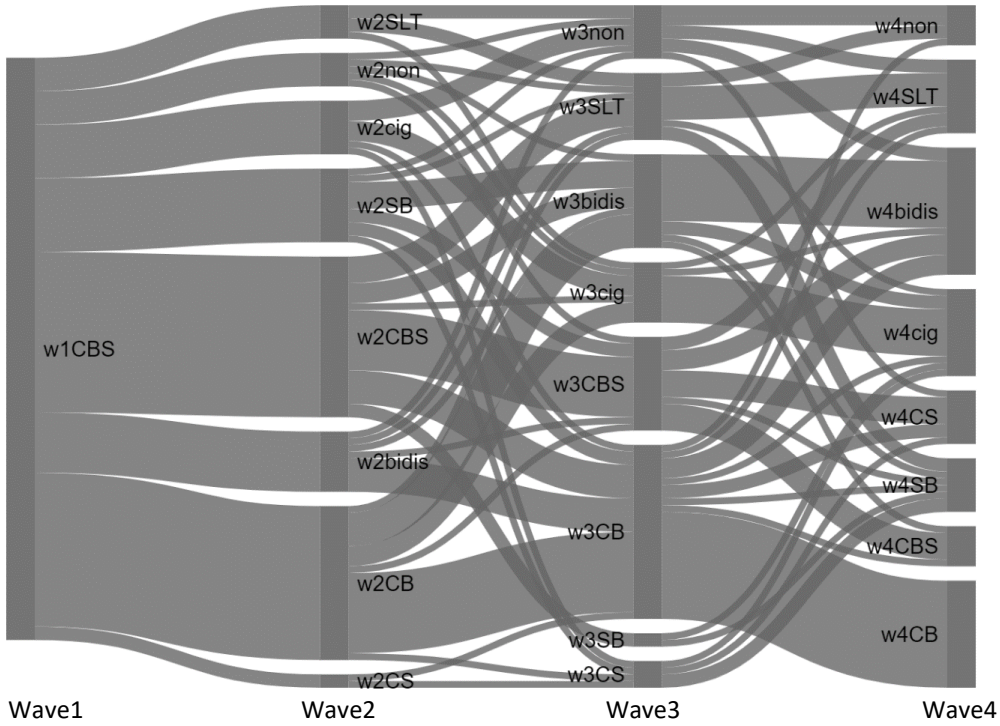
Appendix 7: Transitions of Cig+SLT users in Wave 1 (n=272) to Wave 4.



Appendix 8: Transitions of SLT+bidis users in Wave 1 (n=68) to Wave 4.



Appendix 9: Transitions of poly-users (Cig+SLT+bidis) in Wave 1 (n=87) to Wave 4.



Appendix 10: Characterisation of the 8 types of product use, adapted from Borland et al.

Vaping Status (Frequency)	Smoking Status (Frequency)		
	No current use	**Non-Daily use**	**Daily use**
No current use	No current use of either (excluded)	Exclusive non-daily smoker	Exclusive daily smoker
Non-Daily use	Exclusive non-daily vaper	Concurrent non-daily user	Predominant smoker
Daily use	Exclusive daily vaper	Predominant vaper	Dual daily user

Note: highlighted area in grey represents the 4 types of dual-product users.