EFFECTS OF THE EVOLVING GLOBAL TOBACCO PRODUCT LANDSCAPE ON SMOKERS' SWITCHING BEHAVIORS

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ABSTRACT

How effectively governments can use tobacco tax as a public health and a revenue-generating measure depends on how able smokers are to circumvent the tax by switching to other tobacco products. Recently, tobacco product switching has become more common, especially with many new tobacco product types appearing on the market. The research on these switching behaviors is scarce. This thesis provides analysis in three aspects tobacco product switching: (1) price-driven between-product substitution, (2) switching to newly-introduced tobacco products and (3) switching to products on which no domestic tax has been paid.

When the ratio of tobacco product prices changes, consumers sometimes choose to switch between products. Zambia, with a high prevalence of roll-your-own (RYO) tobacco, a less costly alternative to factory-made (FM) cigarettes, is a case in point. The study presented in the second chapter of this thesis used individual-level data obtained from the 2012 and 2014 waves of the ITC Zambia Survey to model the probability of FM and RYO cigarette smoking, as well as between-product substitution. It found that increasing the cigarette tax, with corresponding price increases, could significantly reduce cigarette use in Zambia. Furthermore, reducing between-product price differences would reduce substitution from FM to RYO.

With the proliferation of many new tobacco product types, traditional cigarettes are becoming less dominant. With the introduction of a new product to the market, between-product switching might not be influenced purely by price differences across product types, but rather driven by the increased variety of products on the market. Chapter three makes use of a natural experiment created during the rollout of a heated tobacco product, IQOS, in 2015 and 2016 in Japan to examine if trends in cigarette sales have changed with the introduction of IQOS in each region. A series of

placebo models are estimated to test if events other than IQOS introduction could have better explained trends in cigarette sales. The results show that the introduction of IQOS likely reduced cigarette sales in Japan.

Large differences in cigarette prices observed between geographical regions might incentivize some smokers from regions with higher cigarette prices to switch to cheaper cigarettes available across the border. The fourth chapter uses 2004-2017 official European Commission data and a methodology developed by Becker (1990), to analyze the association between prices and cross-border cigarette purchases in the European Union. Incentives for cross-border purchasing are measured as a function of differences in cigarette prices between bordering countries, controlling for population density near borders and for gasoline prices. The scale of cross-border cigarette purchasing in the EU is small, and not-significant through maritime borders. An upward convergence of cigarette prices across EU Member States would further reduce the cross-border purchasing problem.

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DECLARATION

I declare that this thesis is my own unaided work, both in concept and execution.

I confirm that I have been granted permission by the University of Cape Town's Doctoral Degrees Board to include the following publications in my PhD thesis, and where co-authorships are involved, my co-authors have agreed that I may include the publications:

- **Michal Stoklosa**, Fastone Goma, Nigar Nargis, Jeffrey Drope, Grieve Chelwa, Zunda Chisha, Geoffrey Fong (2018) "Price, Tax and Tobacco Product Substitution in Zambia" *Tobacco Control*. 2019;28:s45-s52

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1. INTRODUCTION

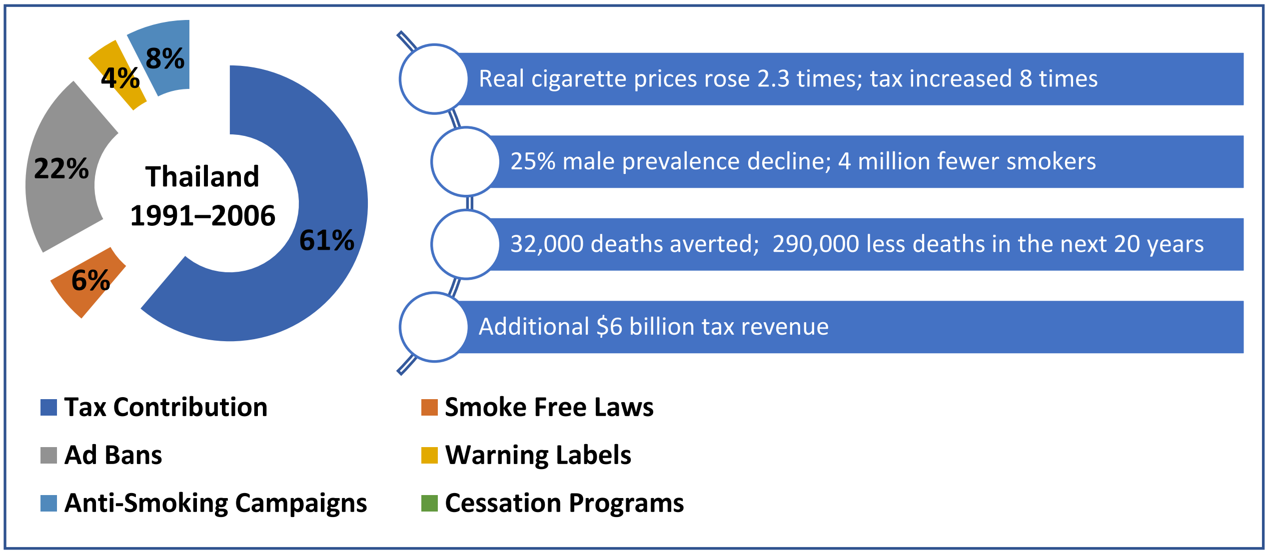
Globally, as many as 100 million people died in the 20th century due to tobacco use and, if the current tobacco use patterns persist, it is predicted that in the 21st century, tobacco will kill another 1 billion people (Drope et al. 2018). Tobacco smoking causes cancer in at least 15 body organs (American Cancer Society 2016) and more than 20% of all cancer deaths worldwide are tobacco-attributable and therefore completely preventable (Institute for Health Metrics and Evaluation 2013). It also increases the risk of cardiovascular and pulmonary diseases and exacerbates the course of other diseases, such as HIV and tuberculosis (Drope et al. 2018). Tobacco use is also a burden on countries' economic development. It is estimated that the economic cost of smoking (including health expenditures and productivity losses) totaled nearly 2 trillion dollars (purchasing power adjusted) in 2016, equivalent in magnitude to almost 2% of the world's annual gross domestic product (GDP) (Goodchild, Nargis, and d'Espaignet 2017; Drope et al. 2018). These accounts of tobacco-related costs do not include the costs associated with undernutrition and underinvestment in education, as spending on tobacco products can divert resources from essential goods and services at a household level (Chelwa and Van Walbeek 2014).

One of the fundamental tenets of economics is that when the price of a product increases, the quantity demanded falls. Therefore, to curb the health and economic burden of tobacco use, governments around the world tax tobacco products to decrease their demand. The mechanisms behind the relationship between tobacco taxes and tobacco product use are straightforward. If the tax increases are sufficient, those producing and selling tobacco products need to increase the retail price. When tobacco tax increases are small, the tobacco industry can shield its consumers from the taxes, keeping the retail price unchanged. This happened, for example, during the modest cigarette tax increases in Ukraine from January 2007 to August 2008 (Ross, Stoklosa, and

Krasovsky 2012). But, with larger tobacco tax increases, such as those in South Africa in the late 1990s and the early 2000s (Van Walbeek 2005), the industry is unable to absorb the tax and needs to pass the taxes on to consumers, which is reflected in an increase in the price of tobacco products. The impact of tobacco tax on the demand for tobacco products comes through its effect on tobacco prices. A formal review of more than sixty studies on tobacco product demand in high-income countries (HICs), conducted by the International Agency for Research on Cancer, found that most of estimates of the price elasticity of tobacco demand lie between -0.2 and -0.6, centering around -0.4 (IARC 2011). This means that in a typical HIC country a 10% increase in the price of cigarettes decreases the demand by 4%. The evidence for cigarette price responsiveness in low- and middle-income countries (LMICs) is still insufficient, but the available studies indicate that cigarette demand in these countries is at least as elastic as, and possibly even more elastic than, the demand in HICs (IARC 2011).

Tobacco tax increases that lead to higher tobacco product prices are among the most effective tobacco control measures available (World Health Organization 2015b). For example, out of the estimated 22 million tobacco-related deaths prevented by the strong tobacco control policies implemented between 2007 and 2014 globally, almost a third (7 million) were the result of increased tobacco taxes (Levy et al. 2018). In some places, the impact of tax on reduced cigarette consumption was even greater. For example, it is estimated that tobacco control policies implemented between 1991 and 2006 in Thailand had decreased smoking prevalence from 55.5% among men and 3.3% among women (predicted rates in the absence of policy change) to 41.7% among men and 2.5% among women (actual 2016 rates). Most of this decline was due to increased tobacco taxation (Figure 1.1) (Levy et al. 2008). Similarly, it is estimated that per capita cigarette consumption in South Africa in 2004 was 36% lower than it would have been in the absence of the tobacco control measures implemented from 1994 to 2004, and that this consumption decline was mostly driven by tobacco tax increases (Chelwa, van Walbeek, and Blecher 2017).

Figure 1.1. Impact of tobacco control in Thailand



Source: American Cancer Society's graph created based on data from Levy et al. 2008

In addition to enhancing public health, tobacco excise taxes typically generate a steady and predictable government income, because tobacco products have few substitutes, relatively inelastic demand, and because taxes account for only a share of the tobacco product final price (Chaloupka, Yurekli, and Fong 2012). Currently, at least 168 countries in the world levy tobacco excise taxes, with 96% of the world's population living in countries with some excise tax on tobacco products in place (World Health Organization 2015). Governments around the world collect more than US$ 328 billion in tobacco excise taxes each year (Goodchild, Perucic, and Nargis 2016). The contribution of tobacco excise tax to overall government revenue is less than that of other taxes, such as value-added tax (VAT) and personal income tax, but is not negligible. In the 28 European Union Member States, for example, cigarette excise tax revenue, on average, accounts for 3% of total receipts from taxes and social contributions (European Commission's Taxation and Customs Union 2018b; Eurostat 2019).

It recently became clear that the importance of tobacco taxation extends far beyond the public health and revenue generation spheres (Stoklosa 2017). Increasingly, economists realize that global economic progress depends not only on income maximization, but also on healthy lives and the well-being of all people. As Angus Deaton argues: *"Health is the obvious starting point for an enquiry into wellbeing. You need a life to have a good life..."* (Deaton 2013). Deaton emphasizes that to enjoy the benefits of economic growth and prosperity, one needs to stay in good health. Furthermore, health is not only a matter of individual well-being, but also an important contributor to the world's economic progress. In fact, it is estimated that about 24% of income growth in low-income and middle-income countries worldwide between 2000 and 2011 resulted from health improvements (Jamison et al. 2013). In Sub-Saharan Africa, the share of income growth resulting from health improvements during that period was even higher, at 69% (Jamison et al. 2013). As health improvements and economic growth are mutually reinforcing factors for world development, policies that are effective in improving public health, such as tobacco taxation, significantly contribute to global progress. In fact, achieving some of the key development goals related to public health, such as reaching the Millennium Development Goal of reducing tuberculosis (TB) mortality, would in some places not be possible without strong tobacco control measures, including tobacco taxation, because of the inherent comorbidity between smoking and TB (Basu et al. 2011). Some of the tobacco tax revenue could also be allocated toward growth-enhancing sectors such as education or health care, amplifying the benefits of tobacco taxes.

1.1. Existing research and models

Tobacco markets have been a focus of economic deliberation for centuries, even before the relationship between tobacco smoking and adverse health consequences was established. As a non-necessity good, tobacco has been considered an *"extremely proper subject of taxation"* (Smith 1776) and, therefore, various authorities looked at tobacco products as a source of government revenue. For example, in North America, tobacco was taxed first by the British, then by the independent United States (US) republic in the early 1790s, and subsequently by the US federal government, in part to finance the Civil War (Youths, Lynch, and Bonnie 1994).

It was not until the mid-20th century that advances in econometrics and computing allowed economists to use empirical methods to analyze the determinants of demand for a variety of products, including tobacco (U.S. National Cancer Institute and World Health Organization 2016). These early studies used aggregate data and focused on a small number of developed economies. For example, in an article published in the *Journal of the Royal Statistical Society* in 1945, Stone used annual time series data from the 1920s and 1930s to estimate price and income elasticities for many goods including spirits, soap, telegrams, and tobacco (Stone 1945). The price elasticities of tobacco demand estimated by Stone were -0.24 in the United States and -0.53 in the United Kingdom (Stone 1945).

In the 1950s and 1960s, mounting evidence about the adverse consequences for health of tobacco use (Public Health Service 1964) precipitated a large number of economic studies that investigated determinants of tobacco product demand. The early studies examined the effects of prices, as well as other factors such as advertising, income, and tastes and preferences, on the demand for tobacco products using macro-level aggregate data on cigarette consumption (U.S. National Cancer

Institute and World Health Organization 2016). In the 1990s, studies begun to use data from household- and individual-level surveys (Chaloupka et al. 2000). During the 1990s, and especially after 2000, evidence from low- and middle-income countries also began to accumulate (U.S. National Cancer Institute and World Health Organization 2016). The increase in the number of economic analyses of tobacco demand was facilitated by further advancements in econometric methodology and in computer technology, and by better data.

Since the early 2000s, a substantial body of evidence on the determinants of tobacco product demand has accumulated. A recent formal review by the U.S. National Cancer Institute (NCI) and the World Health Organization (WHO) finds overwhelming evidence confirming the role of tobacco taxation in reducing cigarette use, generating revenue, and reducing tobacco-related economic costs. This evidence, based on data from high-, middle-, and low-income countries, points not only to the effectiveness of tobacco tax policies, but also to their high cost-effectiveness (U.S. National Cancer Institute and World Health Organization 2016).

Large national and international institutions have used this evidence to create models that predict the effects of future tobacco tax increases. These models are used by those organizations to inform policy change. For example, the World Health Organization's work on designing, implementing and monitoring effective tobacco tax systems is supported by the Tobacco Tax Simulation (TaXSiM) model, an analytical tool directed at evaluating the impact of a change in the structure and level of excise taxes on cigarette use, smoking prevalence and government revenue (World Health Organization 2019). This model is widely used by other organizations, such as the World Bank (Marquez 2018). The WHO Framework Convention on Tobacco Control (FCTC) Knowledge Hub on Tobacco Taxation based at the University of Cape Town uses a different model, but one based on similar logic and principles as the TaXSiM model (World Bank 2018a).

Similarly, the economic model developed jointly by the Campaign for Tobacco-Free Kids (TFK), the American Cancer Society Cancer Action Network (ACS CAN), and Tobacconomics (a program of the University of Illinois at Chicago) to predict the impact of tobacco tax increases on state revenues, public health benefits, and health care cost savings in the United States is also based on existing evidence on the demand for tobacco (ACS Cancer Action Network 2019).

1.2. Smokers' switching behaviours undermine the effectiveness of tobacco tax

The ability of governments to use tobacco tax as a measure to improve public health and generate revenue is moderated by smokers' ability to avoid or evade the tax. Instead of reducing their consumption, quitting, or paying the full tax amount, some smokers may circumvent the tax by switching to other tobacco products. There are many product types available in the global tobacco market, including machine-made cigarettes, cigars and cigarillos, pipe tobacco, manufactured tobacco used for hand-rolled cigarettes, and water pipe tobacco, as well as smokeless tobacco such as snuff and snus. There is also a variety of tobacco products that are being used only locally, such kretek cigarettes, made with a blend of tobacco and cloves and smoked in Indonesia, or locally-grown tobacco used for rolling cigarettes in Zambia. Finally, there is a range of recently-introduced novel tobacco products such as Electronic Nicotine Delivery Systems (ENDS) and heated tobacco products (HTPs). ENDS are electronic devices aerosolizing a liquid containing varying amounts of nicotine, while HTPs heat a processed tobacco leaf substance to a high temperature, slightly short of combustion.

Significant differences between the prices of different tobacco products can create opportunities for product substitution. If the price increase of one good results in an increase in demand for another good, that is, if the cross-price elasticity is positive, then the two goods are classified as substitutes. In such cases, when the price of a tobacco product goes up, instead of reducing their tobacco consumption, some tobacco users switch to other, less expensive products. Studies have shown that when the price ratio of tobacco products changes, consumers sometimes choose to switch from the relatively more expensive to the relatively less expensive product (IARC 2011). This substitution between tobacco product types almost always goes against efforts to use taxation as a health-promoting tool. For example, when the U.S. federal government increased the excise tax on roll-your-own (RYO) tobacco in 2009, it created a substantial price difference between RYO tobacco and pipe tobacco. Within one year, RYO tobacco sales dropped by 61%, while pipe tobacco sales increased by 233% (Campaign for Tobacco-Free Kids 2015).

Existing tax systems often promote between-product substitution, mostly unintentionally. Out of 71 countries where information was gathered on taxes for the most commonly-used smoked or smokeless tobacco products in 2016, at least one of those other products was taxed at a lower rate than cigarettes in 51 (72%) of those countries (World Health Organization 2017). The differences in price, in part resulting from differential tax burdens, encourage smokers to switch to the less expensive product.

Another factor that has affected smokers' ability to avoid high tobacco product taxes recently is the introduction and expansion of novel tobacco products such ENDS and HTPs. Some current smokers have switched to these new products. Moreover, never-users, including those who would not otherwise use any tobacco products at all, might start using tobacco or tobacco-derived products through such products.. In that case, the smokers switching between different tobacco products might not be reacting simply to price differences across different product types, but also to the growth in the variety of products that are available to tobacco users and potential users, some of which may be less harmful or more appealing than traditional combustible tobacco products.

The market power of cigarettes is being decreased by the introduction of these new products, especially since the new products are heavily marketed by the manufacturers.

Finally, the third way for smokers to avoid or evade tobacco taxes is by switching to tobacco products on which domestic tax has not been paid. This type of switching behavior often occurs when prices of the same product substantially differ across geographical regions. In such case, tobacco users can choose to switch to tobacco products purchased from other regions where cigarette prices are lower. These products can be purchased by the users themselves (cross-border shopping), or by bootleggers, who then resell the products to the users. This substitution, again, weakens the effectiveness of the tax and undermines its public health objectives because smokers who substitute to cheaper cigarettes from other jurisdictions may be less likely to quit or cut down on their tobacco consumption. Such substitution also undermines the effects of other tobacco control regulations. For example, cigarettes from a neighboring country may not comply with stronger package warning requirements in the smoker's home country.

It is estimated that illicit cigarettes account for about 12% of the cigarette market globally (Joossens et al. 2010). According to the most recent data from the World Customs Organization, only about 2% of those illicit cigarettes are counterfeits (i.e. 0.24% of the total cigarette market), meaning that an overwhelming majority of illicit cigarettes were produced by legitimate or semi-legitimate tobacco companies (Gilmore, Gallagher, and Rowell 2018). At a country level, there is often a lack of credible estimates of the scope of the illicit cigarette trade problem (Ross 2015) and much of the existing evidence comes from the tobacco industry (Gallagher et al. 2019). The tobacco industry uses the threat of an increase in the illicit cigarette trade to argue against tobacco tax hikes (Schwartz and Zhang 2016) and many other life-saving tobacco control policies, such as standardized packaging (Evans-Reeves, Hatchard, and Gilmore 2015) and bans on menthol cigarettes (Stoklosa 2018c).

1.3. Research gaps

Policymakers' ability to introduce evidence-based policies aimed at reducing tobacco product use through tax-induced price increases depends on evidence from credible economic research. However, there are still large gaps in the research, particularly around smokers' switching behaviors. This lack of research hinders evidence-based policymaking.

In fact, the lack of research on smokers' switching behaviours is one of the largest research gaps identified by the influential NCI-WHO monograph on the economics of tobacco control. Most of the existing research examines the impacts of tobacco taxes on cigarette use only and *"few studies have assessed the price elasticity of demand for tobacco products other than cigarettes, and even fewer have estimated cross-price elasticities"* (U.S. National Cancer Institute and World Health Organization 2016). In part as a result of their recent introduction and popularity, research on the relationships between novel tobacco products and the use of traditional, combustible tobacco products is particularly scarce. Research on the determinants of the illicit cigarette trade, including on the role cigarette taxes and prices play in shaping the illegal market, is growing but is still relatively limited. The NCI-WHO monograph notes that: *"A better understanding of the determinants of illicit trade—including the supply of illicit tobacco products—is needed in order to maximize the effectiveness of interventions to limit illicit trade."* (U.S. National Cancer Institute and World Health Organization 2016).

Secondly, even with the limited research on smokers' switching behaviors, the modelling of those behaviors is insufficient. The models currently in use, although very precise in predicting cigarette sales, largely ignore smokers' switching behaviors. Both the WHO TaXSiM model and the ACS CAN/TFK model focus on cigarettes only and are not programmed to account for switching between tobacco product types, including switching to novel tobacco products such as e-cigarettes or HTPs. Furthermore, modelling of smokers' switching to non-domestic-tax-paid cigarettes needs more attention globally: while the ACS CAN/TFK model allows for the modelling of cross-border purchasing, the WHO TaXSiM model does not.

This lack of focus on smokers' switching behaviors made sense historically, when cigarettes were by far the most used tobacco product globally. According to Euromonitor International, a market research company, cigarette sales accounted for 92% of the market in 2012 (Euromonitor International 2019). This dominance of one product is reflected in the tobacco-related mortality and morbidity patterns. It is estimated that out of the 7.1 million deaths caused by tobacco use in 2016, 6.3 million were attributable to cigarette smoking, followed at a distance by secondhand smoke (884,000 deaths) (Drope et al. 2018).

While machine-made cigarettes dominated the tobacco market until the mid-2010s, their relative importance has recently begun to decline, with cigarettes' share of the total tobacco market falling from 92% in 2012 to 88% in 2018 (Euromonitor International 2019). Two main factors contributed to this decline. First, traditional non-cigarette tobacco products – such as RYO – that previously occupied only a small portion of the market, are slowly gaining importance. For example, the sales volume of smoking tobacco, which includes pipe tobacco and tobacco for RYO cigarettes, increased from 198 million to 206 million tonnes between 2012 and 2016 (5% increase) (Euromonitor International 2019).

More recently, many novel electronic tobacco product types have appeared on the market. Global market value of these products increased on average by 52% annually from 2010 to 2018 and amounted to 25 billion USD in 2018. While this is small in comparison to the cigarette market, estimated at 839 billion USD (Euromonitor International 2019), it has grown very sharply in a short period of time, and growth has been mostly concentrated in a limited number of markets.

The shifts in the tobacco market will almost certainly continue in years to come. Euromonitor predicts that by 2022, cigarettes will account for 85% of the global tobacco market, a figure still high, but already substantially lower than the cigarette-share figure of 92% in 2012 (Euromonitor International 2019). The tobacco industry predicts even more remarkable shifts. For example, Philip Morris International, one of the world’s largest cigarette manufacturers, predicts in its most recent report to investors that novel tobacco products will account for over 30% of the company’s sales volume and over 38% of the company’s total net revenues globally by 2025 (Philip Morris International 2018a). This suggests that future tobacco market shifts away from traditional cigarettes are inevitable.

1.4. Thesis outline

This thesis addresses several key gaps in the literature by exploring the complexities surrounding differences in prices of tobacco products and the effects of the differences on the consumption of such products. It examines how price differentials can be affected by implementing and enforcing tobacco taxes in order to advance public health.

Chapter two examines how the demand for tobacco products is affected by within-country variation in tobacco product prices. This chapter focuses on Zambia, a country with substantial differences in price between factory-made and RYO cigarettes. The analysis and results from this chapter extend current knowledge about the role that differential prices play in between-product substitution. Because many, perhaps even most, countries have multiple categories of tobacco products, this knowledge can inform policymakers seeking to reduce the demand for all tobacco products by designing tax policies intended to decrease between-product price differentials.

In chapter three, I examine the impact of the introduction of a heated tobacco product, IQOS, on trends in cigarette sales in Japan. Unlike the Zambian situation discussed in the second chapter, where the switching behavior occurs in a well-developed market and is driven mainly by between-product price differences, the third chapter examines product-switching behaviors in circumstances in which it is not possible to estimate cross-price elasticities because of the lack of a fully-developed market and of price variation.

Finally, chapter four focuses on tax and price differentials between different tax jurisdictions (EU countries), and the effects those differentials have on tobacco tax avoidance and evasion through cross-border purchasing. Specifically, the chapter uses 2004-2017 European Commission data and a methodology developed by Becker (1990) to analyze the association between prices and cross-border cigarette purchases in the EU. Incentives for cross-border purchasing are measured as a function of differences in cigarette prices between bordering countries, controlling for population density near borders and for differences in gasoline prices between countries. As the threat of a rising illicit cigarette trade is one of the main arguments that the tobacco industry uses against cigarette tax increases, this chapter contributes to the scarce, non-industry-funded, evidence for the associations between tobacco tax increases and the consumption of non-domestic-tax-paid cigarettes.

A review by the U.S. National Cancer Institute and the World Health Organization identified the three aspects addressed in the three chapters of this thesis – namely the between-product cross-price effects, the patterns of novel tobacco product use, and the determinants of illicit cigarette trade – as areas for which evidence is scarce, and additional research is still needed (U.S. National Cancer Institute and World Health Organization 2016). The aim of this thesis is to enhance knowledge on the economics of tobacco control and provide much-needed evidence that can inform future tobacco control policies.

2. CHAPTER TWO: BETWEEN-PRODUCT PRICE DIFFERENTIALS[1]

2.1. Introduction

The limited economic research – mostly from high-income countries – on the cross-price effects in tobacco product use suggests that tobacco products are generally substitutes for one another (IARC 2011). This substitution effect has significant consequences for the effectiveness of tobacco control policies around the world. Whenever a new tobacco control policy is implemented, instead of quitting or cutting back, some smokers, given the opportunity, will choose to switch to other tobacco products. Typically, there is significant variation in the level of taxes applied to different tobacco products within each country. Different tax rates apply to different tobacco products, making some product types less expensive than others. For example, in the European Union – the region with the highest cigarette taxes in the world – the taxes on roll-your-own (RYO) cigarettes are significantly lower than on factory-made (FM) cigarettes. For the excise tax floor on RYO tobacco to be equivalent to the excise tax floor on FM cigarettes in 2015 (90 € per 1000 sticks), the RYO floor should be more than twice as high as the applicable tax floor (128.5 € per kilogram for the RYO tax to be equivalent to FM tax, as opposed to the actual RYO tax of 54 € per kilogram) (Lopez and Stoklosa 2018b). The tax gap means that FM cigarettes were significantly more expensive than RYO cigarettes. In 2015, the median cigarette price among EU member states was 4.30 EUR (4.56 USD) per 20 sticks, while the median RYO price was 3.31 EUR (3.51 USD) per 20 sticks (Lopez and Stoklosa 2018a). Similarly, in Indonesia – a country with one of the highest rates of male cigarette consumption in the world – hand-rolled kretek cigarettes have tax

[1] This chapter is an updated version of manuscript previously published in the *Tobacco Control* journal (Stoklosa, Goma, et al. 2019). I would like to thank my co-authors Fastone Goma, Nigar Nargis, Jeffrey Drope, Grieve Chelwa, Zunda Chisha, and Geoffrey Fong as well as the three anonymous referees, for their valuable comments and inputs to this study.

advantages over FM cigarettes, which results in significant price differences between those products (Nargis et al. 2017). The variability in tax rates can reflect many factors, including interest groups' influence, a desire to protect local farmers and/or manufacturers, and a desire to make the tax less regressive on the poor (Chaloupka, Yurekli, and Fong 2012). The variability in tobacco product taxes results in significant differences in prices across different tobacco products. When two products are substitutes, an increase in the price of one product increases the demand for the other product. Therefore, part of the reduction in consumption of one tobacco product in response to an increase in tax on that product will be offset by increases in consumption of other tobacco products, if the prices of those other products do not change. The exact magnitudes of these substitution effects are still understudied.

The research presented in this chapter aims to explain this relationship. Using individual-level data obtained from the 2012 and 2014 waves of the International Tobacco Control Policy Evaluation Project survey in Zambia (ITC Project 2015), I model the probability of FM and RYO cigarette smoking in the country. The findings can be used by policymakers worldwide seeking to reduce tobacco product use through tax-induced price increases and to advance public health by designing tax policies that decrease between-product price differentials.

This chapter reviews the available global evidence on substitution between tobacco products. It then introduces background information on tobacco production and use in Zambia, with a focus on tobacco product prices and taxes. Finally, it discusses the data and methods used for the study of between-product substitution in Zambia, presents the results of the study, and debates the implications of the findings for efforts to control tobacco use both in Zambia and globally.

2.1.1. *Existing evidence on substitution between tobacco products*

From an economic perspective, two products are substitutes if a price increase in one leads to an increase in the demand for the other. In that sense, tobacco products are generally shown to be substitutes. A thorough literature review, conducted in 2011 by the International Agency for Research on Cancer (IARC), showed that higher cigarette prices and taxes typically encourage some substitution to bidis, cigars, loose tobacco, pipe tobacco, roll-your-own tobacco, and smokeless tobacco products (IARC 2011). A more recent review, however, shows that the relationships in switching between tobacco products might be more nuanced and might depend on country-specific tobacco use behaviors (Jawad et al. 2018). For example, while cigarettes and smokeless tobacco products are shown to be substitutes in Bangladesh (Nargis, Hussain, and Fong 2014), they are not found to be substitutes in India (Kostova and Dave 2015). This lack of substitution in India might result from the fact that smokeless tobacco use is more socially acceptable and is subject to fewer tobacco control regulations than regular cigarettes, leading to many Indian smokeless tobacco users never considering cigarettes as an alternative source of nicotine (Bandi 2019).

Additionally, since the IARC review, a new body of evidence has emerged showing substitution between cigarettes and Electronic Nicotine Delivery Systems (ENDS). The early studies have shown that cigarette users move towards ENDS (Huang, Tauras, and Chaloupka 2014; Stoklosa, Drope, and Chaloupka 2016). For early studies, the analysis of movements from ENDS to cigarettes was difficult, because the ENDS market was tiny compared to the cigarette market. Any shift from ENDS to cigarettes could not be detected in modelling the demand for regular cigarettes. However, as the ENDS market accounts for an ever larger share of the total tobacco product market over time, the most recent studies have observed that the substitution is not only from cigarettes to

ENDS but also from ENDS to cigarettes (Zheng et al. 2017; Pesko and Warman 2017). The issue of substitution between cigarettes and ENDS is discussed in more detail in the next chapter of this thesis.

Only one study from Sub-Saharan Africa has investigated the impact of product prices on substitution among tobacco products (Van Walbeek 2005).That study used data from Income Expenditure Surveys in South Africa and found substitution between cigarettes and other tobacco products in response to relative price changes, but the magnitude of these effects was not calculated.

2.1.2. Background on tobacco production and use in Zambia

Smoking prevalence in Zambia is on a slow decline. The World Health Organization (WHO) estimates that the prevalence of current tobacco smoking among persons aged 15 years and over declined from 14.6% in 2010 to 13.8% in 2015 and, if the current trends persist, it is set to decline to 12.9% in 2025 (World Health Organization 2015a). However, owing to Zambia's population growth (an annual rate of 3%), the number of tobacco users in Zambia is still on the rise (World Bank 2018b). Therefore, despite the falling rates of smoking prevalence, the number of current smokers in Zambia is set to increase from 1.2 million in 2015 to 1.5 million in 2025 (World Health Organization 2015a). The most recent survey of smoking prevalence in Zambia was the International Tobacco Control Policy Evaluation Project Survey (ITC Project 2015), which found that 10.7% of adults (22.7% of men and 0.7% of women) aged 15–49 smoked cigarettes in Zambia in 2014 (Table 2.1).

Table 2.1. Prevalence of tobacco use among adults aged 15-49 in Zambia from the ITC Project Zambia Survey, 2014

	Both sexes	Males	Females
Any tobacco use	13.20%	23.60%	3.30%
1. Smokeless tobacco use	2.38%	0.94%	2.61%
2. Cigarette use	10.69%	22.66%	0.66%
Only or primarily FM cigarette use	6.31%	-	-
Only or primarily RYO cigarette use	4.17%	-	-
Dual use	0.21%	-	-

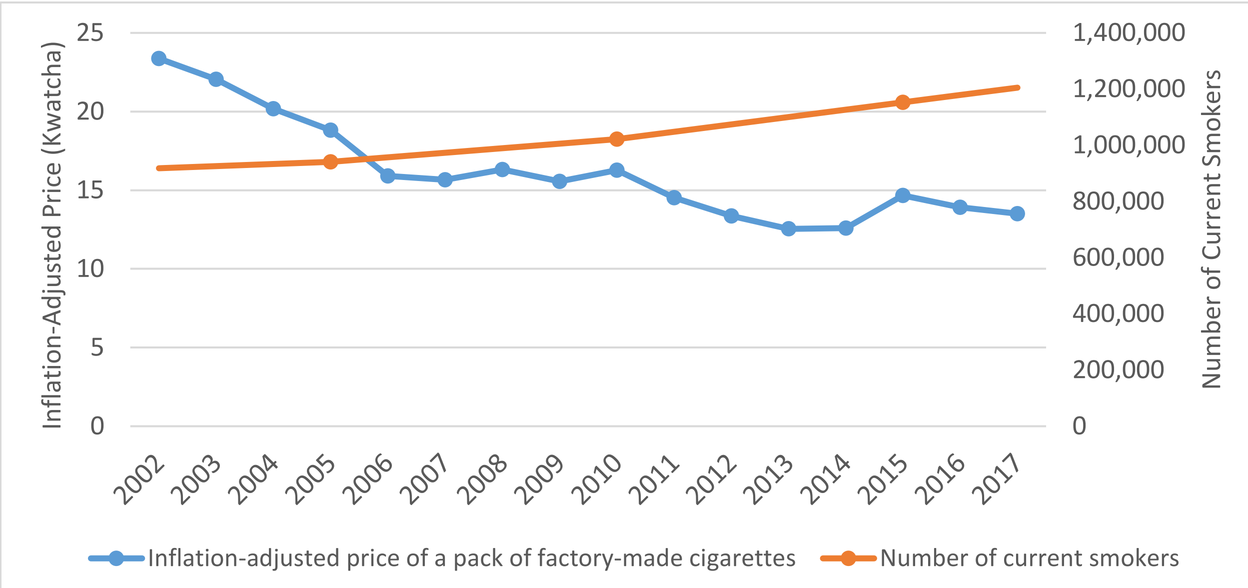
Source: ITC Project Zambia Survey, 2014

Apart from the growing population, another reason for the continuing rise in the number of tobacco users in Zambia is likely the low price of cigarettes. As reported by the Economist Intelligence Unit, a market research company that tracks prices of products and services in 133 cities worldwide, the price of a pack of cigarettes in Zambia increased in nominal terms from 3.9 ZMW (0.88 USD) in 2002 to 13.5 ZMW (1.30 USD) in 2017 (Economist Intelligence Unit 2019). But, when expressed in inflation-adjusted (constant 2016) prices, the price of cigarettes fell from 19.8 ZMW in 2002 to 13.5 ZMW in 2017 (Figure 2.1). Compared to the prices of all goods and services in the economy, cigarettes are becoming less expensive over time in Zambia.

In addition, cigarette prices have not kept pace with rising disposable incomes in Zambia (Chelwa 2012). Over the last decade, the Zambian economy grew at an annual average rate of 6% (World Bank 2018b). The combination of falling real cigarette prices and a rapidly growing economy have made cigarettes more affordable over time. With 12.9% of per-capita gross domestic product needed to purchase 100 packs of the most popular brand of cigarettes in 2016, cigarettes in Zambia were more affordable than in the average African country (13.5%) (World Health Organization

2017). Survey data also point to the high affordability of cigarettes in Zambia; only 27% of male smokers and quitters from the ITC Project Zambia Survey reported that the price of cigarettes led them to think about quitting. This was the third lowest percentage among the 20 countries surveyed by the ITC Project (ITC Project 2015).

Figure 2.1. Inflation-adjusted cigarette prices and the number of current smokers from 2002 to 2017 in Zambia



Note: 2017 is the base year for inflation adjustment. Price of factory-made cigarettes (local brand; pack of 20; mid-priced store) from the Economist Intelligence Unit; inflation from the International Monetary Fund; number of current smokers from the World Health Organization.

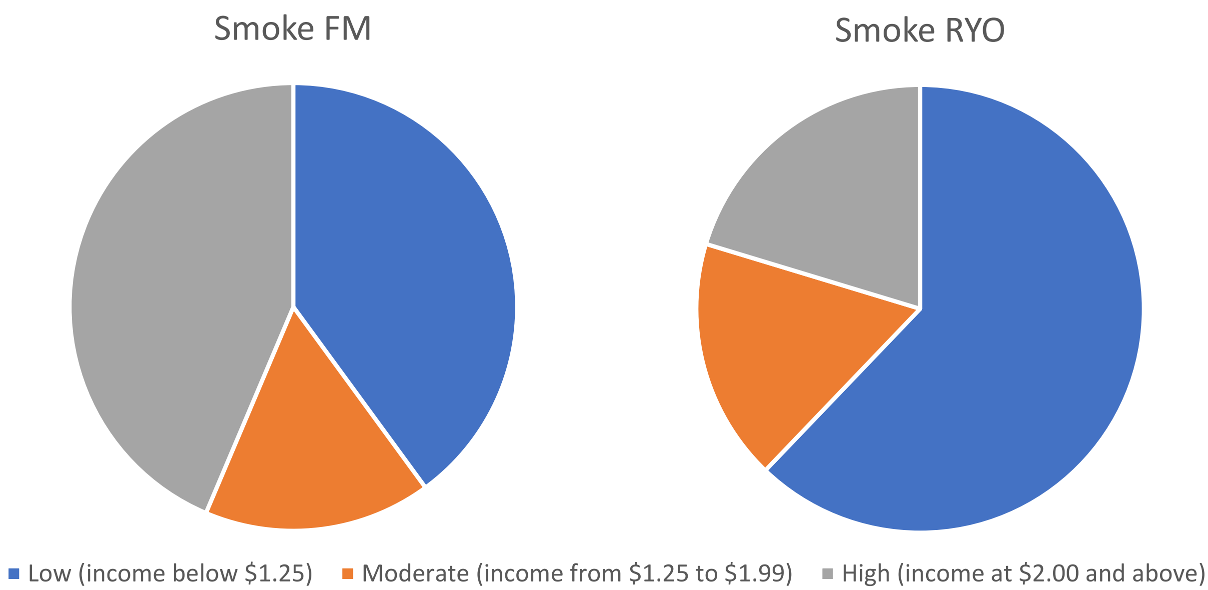
One factor that has great influence on cigarette prices is the excise tax on tobacco products. Despite high, often double-digit, inflation and rapid income growth, tobacco taxes have rarely increased in Zambia. Until 2017, the country’s cigarette excise tax was an ad valorem tax, with a specific tax floor. The ad valorem excise tax rate was introduced in 2007 and set at 145% of the Cost, Insurance and Freight (CIF) value for imported cigarettes or the Producer Price value for domestically produced cigarettes (Chelwa 2012). The specific tax floor was increased from 90 ZMW (8.72 USD) to 200 ZMW (19.37 USD) per 1000 sticks in 2016 (Zambia Revenue Authority 2016). In

2017, the ad valorem component of the tax was removed, and the tax based on a specific rate (Parliament of Zambia 2017). The specific rate was increased to 240 ZMW (23.26 USD) per 1000 sticks (Parliament of Zambia 2017), but this represents a mere adjustment for inflation back to the tax levels in 2007 when the tax floor was introduced. In 2016, tax comprised only 37% of the retail price of cigarettes of the most popular brand, compared to an average of 56% globally (World Health Organization 2017). Of the 188 countries for which the WHO publishes tax burden data, only 61 countries had a lower tax, as a percentage of cigarette price, than Zambia (World Health Organization 2017).

Aside from low tobacco taxes, another factor that heavily influences the use of cigarettes in Zambia is the availability of roll-your-own (RYO) tobacco. In 2014, 39% of Zambian smokers smoked only or primarily RYO cigarettes (ITC Project 2015). The primary reason that the smokers gave for smoking RYO cigarettes was the lower prices of those products; 88% of smokers who smoked RYO said that they do so because of the price. The other reasons given for RYO cigarette use were taste (33%) and the perception that RYO cigarettes were less harmful (10%) (ITC Project 2015). Unlike the FM cigarettes, RYO cigarettes are predominantly smoked by lower-income groups (Figure 2.2).

The fact that the low price of RYO tobacco compared to FM cigarettes is reported by almost all RYO users is striking, given that the tax rates on RYO tobacco and on FM cigarettes are comparable. In 2017, the ad valorem excise tax rate for RYO was the same as the rate for FM cigarettes (145% of CIF). The specific tax floor was at 240 ZMW per kilogram (Parliament of Zambia 2017), which would pair the RYO and FM taxes at the conversion rate of 1 gram of tobacco per cigarette. The fact that the price of a RYO cigarette reported by smokers in Zambia was often lower than the specific tax floor of 0.24 ZMW per stick (Table 2.4), suggests that much of the RYO tobacco is likely never taxed.

Figure 2.2 Type of cigarette smoked by income group (USD per person per day)



Note: N=2009; Source: ITC Zambia Survey Wave 2

This is plausible, given that that much of the RYO tobacco comes straight from the Zambian tobacco farms (ITC Project 2015) to the informal marketplace, where the government, in most circumstances, has little ability to enforce taxes. Tobacco used for RYO cigarettes comes from two sources. The first source is manufactured tobacco called “Balani”, which is grown commercially in Zambia and often sold in plastic packaging. The second and more common source of RYO tobacco is small-scale farmers. These farmers grow tobacco in a traditional way, usually along river banks, with no fertilizers and pesticides, using local seeds. The farmers pack their products in a traditional way. This kind of RYO tobacco is usually sold by the farmer directly for consumption. The small scale of the production makes it extremely difficult to tax the product (Personal communication with Dr. Fastone Goma). The availability of the Zambian-grown RYO tobacco which is not tax-compliant, in the market increases smoking in the country and keeps money from the Zambian treasury.

Consequently, with cheap RYO tobacco widely and readily available in the market, many smokers switch from FM to RYO tobacco. The patterns are confirmed by data on the tobacco market in Zambia provided by Euromonitor International (2017). Euromonitor International is a market research company that conducts comprehensive market research on consumer products, commercial industries, demographic trends, and consumer lifestyles globally. Although the company does not track the tobacco product market in Zambia directly, it provides estimates on the size of that market. According to the Euromonitor estimates, the market for FM cigarettes in Zambia declined by 6% on a volume basis from 1.4 billion sticks in 2012 to 1.3 billion sticks in 2017 (Table 2.2). At the same time, the market for smoking tobacco, which includes legally-sold RYO and pipe tobacco, remained stable at between 76 and 78 tonnes from 2012 to 2015, but increased to 89 tonnes in 2017. The market for other tobacco products (cigars and cigarillos) remained stable and was only a small portion of the total tobacco market, contributing 0.6 million units from 2012 and 2017.

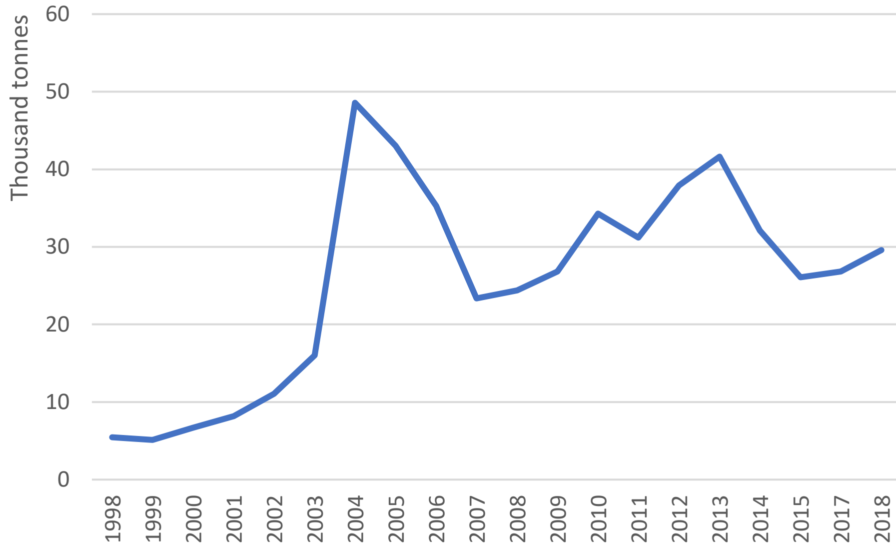
Table 2.2. Modelled retail volume of tobacco market in Zambia

Category	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Cigarettes (million sticks)	1,414.7	1,411.6	1,361.0	1,337.4	1,319.3	1,332.8
Smoking Tobacco (tonnes)	0.6	0.6	0.6	0.6	0.6	0.6
Cigars and Cigarillos (million units)	77.9	78.4	78.3	76.1	64.9	88.8

Source: Euromonitor International

The lack of comprehensive tobacco control legislation in Zambia, despite the country being a Party to the WHO FCTC since 2008, is probably related to the fact that many policymakers and other key stakeholders continue to believe that tobacco is a major contributor to the Zambian economy (Lencucha et al. 2016). As in many other middle-income countries, the majority of the 17 million people living in Zambia still depend on farming for a major part of their livelihood (World Bank 2018b). Of all employed Zambians, 53% worked in the agriculture sector in 2017 (World Bank 2018b). Tobacco is a major agricultural crop in Zambia. The amount of land dedicated to tobacco farming increased by over 350% from 1993 to 2013 (Labonté et al. 2018). There are approximately 54,000 Zambians living in tobacco farming households (Labonté et al. 2018). In terms of export value, tobacco is the third largest crop after maize and cotton (Goma et al. 2017). The vast majority of Zambian tobacco was exported to other countries such as Zimbabwe, Malawi, and South Africa (Drope 2011). The export volume increased significantly in the late 1990s and early 2000s (United Nations 2018). Recently, however, local farmers faced regional competition from other low-cost producers, including Zimbabwe (Labonté et al. 2019). Consequently, the export of raw tobacco fell from 50 thousand tonnes in 2004 to less than 30 thousand tonnes three years later and has remained relatively stable at 30 thousand tonnes since then (Figure 2.3) (United Nations 2018). Also recently, two cigarette manufacturing facilities opened in Zambia (Labonté et al. 2019). The opening of the new cigarette manufacturing plants may heighten the perceived economic importance of tobacco to the national economy as well as to several key local ones (Labonté et al. 2019).

Figure 2.3 Volume of tobacco exported from Zambia



Source: UN Comtrade

Put in perspective, however, tobacco's contribution to the Zambian economy is not large. In the first place, agriculture in Zambia makes up a relatively small portion of the value added to the economy. The combination of agriculture, forestry, and fishing contributed only 7% of the country's Gross Domestic Product (GDP) in 2017 (World Bank 2018). Contrary to the common belief held by the government (Labonté 2004), many smallholder tobacco farmers across Zambia are losing money, with their costs outweighing their revenues (Drope 2011; Makoka et al. 2018). Although tobacco is portrayed by the industry and many government officials as a major export crop (Labonté et al. 2018), the crop's contribution to the economy is modest. In 2017, the total value of tobacco exported from Zambia was 88.5 million USD, 1% of the total export value from the country (United Nations 2018). Tobacco product manufacturing is even more marginal in Zambia, with the number of people employed in leaf processing and trading estimated at less than 5000 (Labonté et al. 2018).

There is also a large health and economic burden associated with tobacco use in Zambia. Estimates show that the number of tobacco-related deaths in Zambia increased from 3000 per year (43 per 100,000) in 1990 to 8000 per year (46 per 100,000) in 2015 (Institute for Health Metrics and Evaluation 2016). Tobacco smoking is not only directly associated with numerous diseases, including lung cancer and cardiovascular disease, but also significantly worsens trajectories of other major health challenges such as tuberculosis and HIV infections. For example, tobacco smoking is connected to 8% of tuberculosis deaths in Zambia (Institute for Health Metrics and Evaluation 2016). Therefore, the societal costs of smoking include health care expenditures to treat tobacco-related diseases and productivity losses from morbidity and premature mortality. Other costs are associated with undernutrition and underinvestment in education in the tobacco-using households, as spending on tobacco products has been shown to divert resources from essential goods and services in Zambia (Chelwa and Van Walbeek 2014). There is also evidence suggesting that the crowding out of food purchases by tobacco purchases is more severe for poorer households (Chelwa and Van Walbeek 2014).

2.2. Method

2.2.1. Data Source

Longitudinal data from two waves of the ITC Zambia Survey were used in this study. The surveys were conducted from September to December 2012 (Wave 1), and from August to October 2014 (Wave 2). The ITC Zambia Survey is a nationally representative, face-to-face survey conducted on a longitudinal cohort sample of approximately 1,500 tobacco users and 600 non-users in each wave. This means that the respondents who took part in Wave 1 were contacted in Wave 2 to respond to a follow-up survey. For respondents that could not be reached, the sample was replenished to maintain similar numbers of tobacco users and non-users. The retention rate for smokers was 61%, with respondents lost to attrition after Wave 1 being replenished from the same sampling frame at Wave 2 (ITC Project 2015).

The sample of tobacco users and non-users for the ITC Zambia survey was selected through a multi-stage clustered sampling design. Specifically, a total of 150 clusters were allocated to all Zambian provinces, with the number of clusters allocated to each province being proportional to the population of that province. In each cluster, approximately 10 tobacco users and 4 non-users of tobacco were interviewed. Table 2.3 presents the demographic characteristics of the participants in the ITC Zambia survey. Additional methodological details for the survey can be found on the ITC Project website (ITC Project 2017).

Because this study focuses on the impact of prices on cigarette use, survey responses for which the price of cigarettes could not be assigned were excluded from the study. As a result, the analysis was conducted on a sample of 2575 individuals (both smokers and non-smokers), of whom 1165 appeared in both waves, yielding 3740 observations.

Table 2.3. Demographic characteristics of the ITC Zambia Wave 1 and 2 Survey respondents

	Wave 1 (N=2,071)		Wave 2 (N=2,009)	
	N	%	N	%
Gender				
Male	1,491	72.0	1,438	71.6
Female	580	28.0	571	28.4
Age Group				
15-17	53	2.6	43	2.1
18-24	308	14.9	257	12.8
25-39	820	39.6	778	38.7
40-54	468	22.6	506	25.2
55+	422	20.4	425	21.5
Household Income				
Low	1,084	52.3	878	43.7
Moderate	278	13.4	222	11.1
High	421	20.3	712	35.4
Non-response	288	13.9	197	9.8
Education Level				
Low (illiterate/< primary)	295	14.2	293	14.6
Moderate (some/completed primary)	1,039	50.2	997	49.6
High (secondary or higher)	720	34.8	712	35.4
Non-response	17	0.8	7	0.4
Marital Status				
Married	1,335	65.2	1341	66.8
Divorced or separated	137	6.7	142	7.1
Widowed	146	7.1	162	8.1
Single	427	20.9	362	18.0
Non-response	1	0.1	2	0.1
Residence in Lusaka				
Yes	359	17.3	355	17.7
No	1,712	82.7	1,654	82.3

Source: ITC Zambia National Report (ITC Project 2015)

2.2.2. Measures

To estimate the impact of cigarette prices on cigarette use in Zambia, the analysis involves modeling the probability of the discrete choice of whether an individual currently smokes. Because cigarette smoking is associated with significant health risks for even light smokers (1-4 cigarettes per day) (Bjartveit and Tverdal 2005), in this study I focus on smoking status and not smoking intensity, as this is a clinically more meaningful measure.

The primary explanatory variables in this analysis are the prices of FM and RYO cigarettes, as reported by the survey respondents. It is possible to derive self-reported cigarette prices from the ITC Zambia Survey in two ways. First, respondents reported the cost of their last cigarette or RYO tobacco purchase. Based on that self-reported cost and on the reported number of cigarettes or the amount of RYO tobacco purchased in their last purchase, I calculate the price per stick that they paid.

The amount of loose tobacco for RYO cigarettes was reported either in grams or in various other quantities and container sizes (e.g. "4 tablespoons"). For responses that were not in grams, but where the amount of tobacco purchased was still identifiable, I converted the reported amount of tobacco into grams (Aqua-Calc 2017). Prices per gram of RYO cigarettes were then converted to price per RYO stick, using the conversion of 0.92 grams per stick from the US Master Settlement Agreement (United States Government Accountability Office 2012).

While the first price measure was based on the sum of money spent during the last tobacco purchase, the second method derives the cigarette price from the reported sum of money spent on cigarettes in the last 30 days and the number of cigarettes smoked each day. These data also are used to generate the price per stick. The method assumes that, on average, cigarettes purchased in the last 30 days were also consumed in that period. This should be the case in Zambia, as about half of smokers purchased loose (single) cigarettes in 2014 (ITC Project 2015), which suggests that smokers do not stockpile. The ITC survey does not collect separate data on the number of FM and RYO cigarettes smoked per day, but rather collects information on the total number of cigarettes smoked. Therefore, the spending-based price of FM and RYO could not be calculated for those who were dual users of FM and RYO (23% of smokers in the sample).

Both price measures are subject to recall bias. As some values of the last-purchase price and the spending-based price were clearly misreported, I did not use prices that were outliers for both measures (±2 standard deviations from the survey wave mean). As well as being subject to a recall bias, the spending-based price measure can also be subject to underreporting bias, as people tend to underreport the number of cigarettes they smoke per day (Liber and Warner 2018). The value of the tobacco purchased might also be underreported. Therefore, when calculating both RYO and FM prices for each individual, I first used the self-reported price from the last purchase as the more reliable price, and used the spending-based price only if the last-purchase price was not available. I accounted for the redenomination of the Zambian kwacha that occurred in 2013, when the old currency unit was divided by 1000. The prices from the first wave were also adjusted for inflation, so that all prices used in the analysis are in 2014 kwacha.

One obstacle to using self-reported prices for estimating the demand equations is that prices may be endogenous from the simultaneity of price and consumption. To address this problem, the prices of FM and RYO were (separately) averaged by geographical regions (primary sampling units, n=20) and by wave. These averaged prices were then assigned to both smokers and non-smokers in the given region and wave. This technique was used by Nargis et al. (2014)in their analysis of similar data from the ITC Bangladesh Survey. In one geographical region, no FM price was reported in either wave, while in another one, no RYO price was reported in wave two. In those instances, prices could not be assigned, and therefore those observations (n=284) were excluded from the study.

Another explanatory variable is respondents' per capita household income. The analysis uses a survey-reported categorical variable for the income status of individuals in relation to the international poverty lines of $1.25 and $2.00 per person per day (United Nations 2009). Because 12% of respondents did not report their income, I added the missing response as one of the categories. This was done to avoid dropping the responses from the model. As a result, the income variable includes four categories: income below $1.25 (reference group), income from $1.25 to $1.99, income at $2.00 and above, and income not reported. Other explanatory variables include participants' age; a dummy variable for gender; a dummy variable for residence in an urban area; a dummy variable for residence in Lusaka; a categorical variable for educational attainment; a dummy variable for occupation in a white-collar job; and a dummy variable for self-reported health status as good/excellent.

2.2.3. Analysis

The analysis includes a model for current use of any cigarettes (FM and/or RYO), separate models for smoking status for FM and RYO, as well as a model for dual cigarette use (both FM and RYO).

Random effects probit models in the following functional form were used to estimate the probability of cigarette smoking participation (Model 1), the probability of RYO and FM cigarette smoking participation (Models 2 and 3), and the probability of dual use (Model 4):

$$\text{Model 1, 2, 3 and 4: } \Pr(current\ smoker_{it} = 1 |\ Price1_{it},\ Price2_{it}, Income_{it}, \boldsymbol{X}_{it}, \alpha_i)$$
$$= \Phi(\beta_0 + \ \beta_1 Price1_{it} + \ \beta_2 Price2_{it} + \beta_3 Income_{it} + \beta_4 \boldsymbol{X}_{it} + \alpha_i)$$

In the above equation, *current smoker* is the current cigarette smoker (either FM or RYO), the current FM cigarette smoker, the current RYO cigarette smoker, and dual user of FM and RYO cigarettes in Models 1, 2, 3, and 4 respectively. *Φ(.)* is the cumulative distribution function of the standard normal distribution, while α_i is the individual specific random effect. For individual *i* at time *t*, *Price1* is the price of FM cigarettes and *Price2* is the price of RYO cigarettes. *Income* is represented as the four-category dummy variables, while ***X*** represents other socioeconomic variables, such as age, gender, urban residence, residence in Lusaka, education, occupation, and health status variables.

The use of random effects models is preferred over fixed effects models for two reasons: (a) the fixed effects models would lose observations for those respondents who appear only once in the panel (41% of observations); and (b) the fixed effects model would not allow for the identification of the effect of any variable with no within-individual variation (e.g. gender) or little within-individual variation (e.g. smoking status) over time.

Many empirical studies based on the ITC data have used generalized estimating equations (GEE) (Thompson et al. 2006). The main difference between GEE and the random-effect models is that GEE produces population-averaged coefficients (what happens to the whole population if everyone's predictor variable is increased by 1 unit) while the random effects models produce subject-specific coefficients (what happens to a single individual when the predictor is increased by 1 unit). Subject-specific coefficients are usually considered to be more accurate estimates of the underlying causal mechanism and, therefore, the random-effect models are preferred for this study over the GEE models.

It might be unrealistic to assume that the error terms between Model 2 and Model 3 are uncorrelated, since the decisions to smoke RYO and FM cigarettes are most likely linked. This issue is addressed by estimating the bivariate probability of RYO and FM cigarette smoking participation (simultaneous equations of Model 2 and Model 3) using a bivariate seemingly unrelated random effects probit (Model 5), where the error terms from the two models are allowed to be correlated:

$Model$ 5:

$$\Pr(current\ factory\text{-}made\ cigarette\ smoker_{it} = 1 \mid Price1_{it}, Price2_{it}, Income_{it}, X_{it}, \pi_i)$$
$$= \Phi(\gamma_0 + \gamma_1 Price1_{it} + \gamma_2 Price2_{it} + \gamma_3 Income_{it} + \gamma_4 X_{it} + \pi_i)$$

$$\Pr(current\ RYO\ cigarette\ smoker_{it} = 1 \mid Price1_{it}, Price2_{it}, Income_{it}, X_{it}, \vartheta_i)$$
$$= \Phi(\delta_0 + \delta_1 Price1_{it} + \delta_2 Price2_{it} + \delta_3 Income_{it} + \delta_4 X_{it} + \vartheta_i)$$

2.3. Results

Table 2.4 summarizes last-purchase and spending-based prices of FM and RYO cigarettes, as reported in the ITC Zambia Survey. In both waves, RYO prices were significantly lower than FM prices, but the difference declined over time. The average reported FM cigarette price was almost 8 times higher than the RYO cigarette price in the first wave (t=42.36, p<0.001), but only about 4 times higher in wave 2 (t=9.63 p<0.001). This price convergence occurred as a result of a large increase in RYO prices between waves (an increase by 129% in the RYO prices, t = -2.01, p=0.045), compared to only a moderate increase in inflation-adjusted FM prices (a 15% increase in the combined FM prices, t=-2.94, p=0.003). Finally, across waves and products, the spending-based price was lower than the price based on the last purchase, possibly because the smokers underestimate the amount of money they spend on those products each month.

For smokers of FM, there was a large variation in the reported price, depending on cigarette brand. In 2014, the average reported price varied from 0.35 kwacha (0.03 USD) per stick for the Pacific brand to 0.70 kwacha (0.07 USD) per stick for the Pall Mall brand. Additionally, respondents reported paying more per stick when buying single cigarette sticks (0.65 kwacha or 0.06 USD per cigarette stick), compared to cigarette packs (0.48 kwacha or 0.05 USD per stick) and cartons (0.35 kwacha or 0.03 USD per stick) in 2014. Finally, for those who reported buying cigarettes by the pack, both the spending-based price (10.2 kwacha per pack) and the price based on the last purchase (9.68 kwacha per pack) in 2014 were similar to cigarette prices reported by the Economist Intelligence Unit for Lusaka (9.00 kwacha for local-brand cigarettes and 11.00 kwacha for Marlboro cigarettes) (Economist Intelligence Unit 2019).

Table 2.4. Inflation-adjusted cigarette prices in Zambia in 2014 (kwacha per stick)

	Wave 1		**Wave 2**		**Wave 1 and 2 combined**		**Between-wave price change**	**P-value***
	mean	**n**	**mean**	**n**	**mean**	**n**	**%**	
Factory-made cigarettes								
Last-purchase price	0.54	640	0.62	571	0.58	1211	+15%	0.001
Spending-based price	0.52	434	0.46	440	0.49	874	-12%	0.054
Combined price	0.54	650	0.62	585	0.58	1235	+15%	0.003
Roll-Your-Own cigarettes								
Last-purchase price	0.13	24	0.29	110	0.26	134	+123%	0.542
Spending-based price	0.07	280	0.10	266	0.08	546	+43%	0.001
Combined price	0.07	298	0.16	308	0.12	606	+129%	0.045

*P-value for the between-wave mean-comparison test.

Women and those who reported good or excellent health were significantly less likely to smoke in each model. Higher income was associated with a lower probability of smoking any cigarette type (either FM or RYO), a lower probability of RYO smoking, and a lower probability of dual use, but was unrelated to the probability of FM smoking. Older respondents were less likely to smoke FM and more likely to smoke RYO. On the other hand, urban residence and formal education were significantly associated with a higher probability of FM smoking and a lower probability of RYO smoking. White-collar workers were also significantly less likely to smoke RYO. Finally, residents of the capital city, Lusaka, were more likely to smoke all types of cigarettes, but especially FM, than the rest of the respondents. With a lower probability of RYO smoking by more educated and wealthier individuals, it seems that RYO is regarded as an inferior product to FM cigarettes in Zambia.

Table 2.5 summarizes the results from the five models of cigarette smoking participation in Zambia. The own-price effects for FM and RYO cigarettes on the likelihood of smoking are negative in all models, except for the model of the likelihood of dual use. The own-price effects are significant for both FM and RYO cigarettes in the model of any cigarette use (Model 1), and in models of RYO use (Models 3 and 5). Additionally, the own-price effects for FM are positive and significant in the model for dual use, which suggests that cigarette price increases lead to more dual use. There is also a positive relationship between RYO price and the likelihood of FM cigarette smoking (Models 2 and 5) and between FM prices and the likelihood of RYO smoking (Models 3 and 5). The cross-price coefficient is, however, significant only for the effect of the FM cigarette price on RYO smoking, which suggests that RYO cigarettes are substitutes for FM cigarettes.

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Table 2.6 presents the own- and cross-price probability elasticities of prevalence for RYO and FM cigarettes based on these results. For FM prices, the estimated own-price elasticity of smoking prevalence (either FM or RYO cigarettes) is -0.20. For RYO prices, the estimated own-price elasticity of smoking prevalence is -0.02 or -0.03, depending on the model. The cross-price elasticities between FM prices and RYO use were 0.27 and 0.18 in Models 3 and 5, respectively.

Table 2.5. Results of probit analyses of the probability of cigarette smoking in Zambia

Variables	Random effects probit models				Bivariate seemingly unrelated random effects probit	
	All cigarette use: Model 1	Factory-made cigarettes use: Model 2	RYO cigarettes use: Model 3	Dual use: Model 4	Factory-made cigarettes use: Model 5	RYO cigarettes use: Model 5
Price of factory-made cigarettes	-1.00**	-0.17	1.01**	1.06***	-0.30	0.91*
Price of RYO cigarettes	-0.73**	0.05	-0.41**	0.13	0.07	-0.42*
Income status Below $1.25 (reference)						
$1.25 to $1.99	0.22	0.21	0.14	0.17	0.21	0.12
$2.00 and above	-0.25*	-0.02	-0.65***	-0.41***	0.01	-0.67***
Not reported	-0.35**	-0.02	-0.32**	-0.17	-0.01	-0.34*
Age	0.001	-0.03***	0.02***	-0.004*	-0.03***	0.02***
Gender Male (reference)						
Female	-4.25***	-2.94***	-3.63***	-1.78***	-2.96***	-3.68***
Urban area of residence No (reference)						
Yes	-0.01	0.95***	-2.07***	-0.78***	0.95***	-2.06***
Residence in Lusaka No (reference)						
Yes	0.89***	0.62***	-0.45**	-0.02	0.64***	-0.44**
Education Low education (ref.)						
Primary and higher	-0.14	0.91***	-0.49***	0.37***	0.95***	-0.50***
Occupation Other than white collar (reference)						
White collar	0.03	0.21	-2.10***	-0.86*	0.22	-2.08***
Self-reported health status Poor and average (reference)						
Good and excellent	-0.70***	-0.56***	-0.85***	-0.44***	-0.52***	-0.84***
Constant	6.67***	2.30***	5.59***	1.16***	2.32***	5.67***

Note: ***p<0.01; **p<0.05; *p<0.1; number of observations: 2197

Table 2.6. The estimates of own- and cross-price elasticities of prevalence for factory-made and RYO cigarettes in Zambia

	Random effects probit			Bivariate seemingly unrelated random effects probit	
	All cigarette use	Factory-made cigarette use	RYO cigarette use	Factory-made cigarette use	RYO cigarette use
Factory-made cigarette price	-0.20**	-0.05	0.27**	-0.14	0.18*
RYO cigarette price	-0.03**	0.004	-0.03**	0.01	-0.02*

Note: ***p<0.01; **p<0.05; *p<0.1. Elasticities are calculated using probabilities estimated at the mean of the covariates.

The reason why the results from the separate probit models (Models 2 and 3) vary from those of the seemingly unrelated random effects probit model (Model 5) is the bias caused by the correlation of disturbance terms between the two equations for FM and RYO in Models 2 and 3, which is represented in the system of equations in Model 5. While the observation-specific disturbances (error terms) are uncorrelated in Model 5 (r=-0.05; 95% CI -0.23 to 0.14), there is a significant correlation between individual-specific disturbance terms (π_i and ϑ_i) (r=0.29; 95% CI 0.18 to 0.40), suggesting that, as expected, a person's decision to smoke FM is related to their decision to smoke RYO. This implies that the system of equations approach of Model 5 was appropriate, and thus that the estimates arising from that approach are superior to those arising from the non-systems approach.

2.3.1. Robustness check

In this study, the prices of FM and RYO were averaged by geographical regions to address a potential problem of prices being endogenous. Such an approach, however, assumes that much of the observed variation in prices takes place between geographical regions (primary sampling units), as opposed to within those regions. Therefore, in the robustness check, I performed an alternative analysis allowing prices to vary between individuals, rather than between regions. Specifically, I first regressed prices of FM and RYO on geographical regions and waves as well as household characteristics (income status, residence in an urban area, residence in the capital city of Lusaka) and form of tobacco purchased (single stick cigarettes, pack of cigarettes, carton of cigarettes, or hand-rolled tobacco). The models' fitted values were then predicted for both smokers and nonsmokers and used as explanatory variables in models of smoking status.

The results from the models that used fitted values of cigarette prices are presented in Table 2.7, while Table 2.8 presents elasticities calculated using those models. All cross-price effects are positive and significant in those models. The substitution effect from FM to RYO cigarette use in the event of increase in FM cigarette prices is stronger than the substitution from RYO to FM. Additionally, in those models, the own-price effects are also significant for FM use.

Table 2.7. Results of probit analyses predicting the probability of cigarette smoking in Zambia using fitted values of cigarette prices

Variables	Random effects probit models				Bivariate seemingly unrelated random effects probit	
	All cigarette use: Model 1	Factory-made cigarettes use: Model 2	RYO cigarettes use: Model 3	Dual use: Model 4	Factory-made cigarettes use: Model 5	RYO cigarettes use: Model 5
Price of factory-made cigarettes	-1.65***	-1.40***	3.98***	2.00***	-1.54***	3.66***
Price of RYO cigarettes	-0.80***	0.81***	-0.41	0.38	0.86***	-0.34
Income status Below $1.25 (reference)						
$1.25 to $1.99	0.18	0.16	-0.04	0.09	0.17	-0.0001
$2.00 and above	0.17	0.16	-0.65***	-0.42***	0.20	-0.59***
Not reported	-0.16	0.16	-0.52***	-0.24*	0.18	-0.47**
Age	0.01**	-0.04***	0.04***	-0.002	-0.04***	0.04***
Gender Male (ref.)						
Female	-0.24	-0.12	-0.48	-0.50**	-0.13	-0.36
Urban area of residence No (ref.)						
Yes	-0.22*	1.54***	-2.04***	-0.77***	1.60***	-1.98***
Residence in Lusaka No (ref.)						
Yes	0.56***	0.98***	-0.79***	-0.15	0.90***	-0.75***
Education Low education (ref.)						
Primary and higher	0.03	1.11***	-1.12***	0.49***	1.13***	-0.99***
Occupation Other than white collar (ref.)						
White collar	0.33	(omitted)	-1.51**	-0.69	(omitted)	-1.48**
Self-reported health status Poor and average (ref.)						
Good and excellent	0.40***	0.15*	-0.45***	-0.19**	0.12	-0.43***
Constant	2.67***	-0.21	1.12**	-0.65*	-0.07	1.02**

Note: ***p<0.01; **p<0.05; *p<0.1; number of observations: 2197

Table 2.8. The estimates of own- and cross-price elasticities of prevalence for factory-made and RYO cigarettes in Zambia from models that use fitted values of cigarette prices

	Random effects probit			Bivariate seemingly unrelated random effects probit	
	All cigarette use	Factory-made cigarette use	RYO cigarette use	Factory-made cigarette use	RYO cigarette use
Factory-made cigarette price	-0.19***	-0.47***	2.05***	-0.50***	2.88***
RYO cigarette price	-0.02***	0.06***	-0.04	0.06***	-0.06

Note: ***p<0.01; **p<0.05; *p<0.1. Elasticities are calculated using probabilities estimated at the mean of the covariates.

There are other areas of concern with this study. The first relates to the data set used in the estimation. The data set is a two-wave panel with a 39% attrition rate. This implies that, in the estimating sample, most individuals appear only once in the data. It is possible that attrition is correlated with smoking behavior. If that is the case, the replenishment sample might be different from the individuals who left the sample.

To address this possibility, I checked that the differences in smoking behavior between those who left the sample after the first wave and those who joined in the second wave were not significant (p-value for Pearson χ^2 test: 0.808), that is, that the replacement sample was similar in terms of smoking behavior to the individuals who left the sample. I also ran the models on the balanced sample only. The model of all cigarette use yielded price elasticity estimates that were similar to those obtained in the full-sample models: -0.28 for FM and -0.02 for RYO. Price effects were not significant in the models with the balanced sample. Results of probit analyses predicting the probability of cigarette smoking in Zambia on the balanced sample are presented in Table 2.9. These results suggest that the high survey attrition rate was not a problem in this analysis.

One other issue of concern is the large number of observations with a missing value for the income variable. Because 12% of respondents did not report their income, the missing response was one of the categories in the original models. As a robustness check, I used multiple imputation to estimate the missing income categories. The variable was multiply-imputed using the ordered logistic regression. The imputation method assumed that the missing data were missing at random. To impute variable, I utilized all covariates from the multivariable models. In another analysis, I removed observations with missing income information. Including the imputed income in the models and removing missing income observations did not change the results materially (see Table 2.9).

Another issue that warranted a robustness check in this study is the RYO cigarette-equivalence conversion rate. The relative price of RYO is dependent on the weight of a stick. I used the US Master Settlement Agreement for a conversion rate, but the question remains whether the habits of rolling a cigarette in Zambia are comparable to the US. As a robustness check, I also used an alternative conversion of 0.7 grams per stick (Silvano Gallus et al. 2014), but this did not change the results materially (see Table 2.9).

Lastly, the decision not to use survey weights in the model estimation may present challenges. A thorough academic discussion of this issue is provided by Solon, Haider and Wooldridge in their 2013 working paper published by the National Bureau of Economic Research (Solon, Haider, and Wooldridge 2013). In a nutshell, for descriptive analysis, the use of the weights is advisable and, most often, necessary. The weighting issue is more nuanced when estimating causal effects, such as in the analysis presented in this chapter. The purpose of weighting is often to reduce the heteroscedasticity so as to improve the precision of estimates. Another reason for applying weights is to correct for endogenous sampling, which can result from the purposeful overrepresentation of some populations in the sample. There are instances in which the weighted models will yield less precise estimates. When the weighted and unweighted models yield similar results, it is generally indicative that the model specification is satisfactory (Solon, Haider, and Wooldridge 2013).

For the analysis presented in this chapter, both heteroscedasticity of the error terms and endogenous sampling might be an issue. The sampling could particularly be a problem, since the ITC Survey purposefully oversamples smokers. Unfortunately, the longitudinal weights in the ITC survey are available only for the balanced sample, which means that 39% of observations would be lost if the longitudinal weights were used. To address the potential issue of the sample weights not being used in the study, the Huber-White covariance estimator was first used to obtain robust standard errors. The estimates obtained were almost identical to those from the original models, suggesting that heteroscedasticity was not an issue in those models (see Table 2.9). Secondly, as suggested by Solon et al. (2013), I estimated the weighted models and compared the estimates of the weighted and unweighted models. However, since the use of the longitudinal weights would drop nearly 40% of my observations, I pooled all observations in one large cross-section sample and used simple probit models with cross-section ITC weights. The results of that estimation are presented in Table 2.9. The new results have, as expected, the same signs as previously, and all estimates that were significant in the original models are still significant in the weighted model, except for the FM cigarette price elasticity in the model for ‘all cigarette use’, which has the expected sign, but is no longer significant. Although the coefficient estimates in the weighted models are slightly different than those in the original models, the results are still within the same magnitude as the estimates from the original model. This, again, suggests that the absence of weighting in the original model was not a serious issue.

Table 2.9. The estimates of own- and cross-price elasticities of prevalence for factory-made and RYO cigarettes in Zambia: original vs. robustness check models

	Random effects probit		
	All cigarette use	**Factory-made cigarette use**	**RYO cigarette use**
Original Models			
Factory-made cigarette price	-0.20**	-0.05	0.27**
RYO cigarette price	-0.03**	0.004	-0.03**
Analyses on the balanced sample			
Factory-made cigarette price	-0.28**	-0.04	-0.05
RYO cigarette price	-0.02*	0.01	-0.01
Analyses with income categories imputed using multiple imputation			
Factory-made cigarette price	-0.21***	-0.07	0.20**
RYO cigarette price	-0.03**	0.01	-0.02**
Analyses with missing income observations removed			
Factory-made cigarette price	-0.21**	-0.15	0.25**
RYO cigarette price	-0.03***	0.01	-0.02*
Analyses using an alternative conversion from grams to sticks for RYO prices			
Factory-made cigarette price	-0.19**	-0.06	0.28**
RYO cigarette price	-0.04***	0.01	-0.03**
Analyses with robust standard errors			
Factory-made cigarette price	-0.20**	-0.05	0.28**
RYO cigarette price	-0.03***	0.004	-0.03**
Analyses using weighted cross-sectional approach			
Factory-made cigarette price	-0.22	-0.15	0.46***
RYO cigarette price	-0.05***	0.01	-0.06***

Note: ***p<0.01; **p<0.05; *p<0.1

2.4. Discussion

This study finds that the higher prices for both FM and RYO cigarettes are significantly related to a reduced likelihood of smoking in Zambia. The estimated smoking prevalence elasticity for FM cigarettes is around -0.20. This means that a 10% increase in FM prices leads to a 2% relative reduction in smoking prevalence. This estimate is within the range usually observed in LMICs (between -0.10 and -0.40) (IARC 2011). The own-price elasticity of FM smoking prevalence was only significant in the models that used fitted values of cigarette prices, probably because there is more within-region than between-region variation in FM cigarette price. The significant estimated elasticity from the models that used fitted values of cigarette prices was -0.47, suggesting that a 10% increase in FM prices leads to a 4.7% decline in FM use. Effects of this magnitude make cigarette price increases the most effective policy instrument to discourage smoking (IARC 2011). Thus, in Zambia, increasing the excise tax on cigarettes to drive price increases will be an effective tool for improving public health and reducing tobacco-related costs.

As a party to the WHO FCTC (since 2008), Zambia has agreed to impose high cigarette taxes. Although the specific tax was raised from 90 to 200 kwacha per 1000 sticks in 2016 and from 200 to 240 kwacha per 1000 sticks in 2017, the inflation-adjusted cigarette price has nevertheless dropped during that time (Figure 2.1).

One of the reasons for low tobacco taxes in Zambia is that some sectors of the government have preferred to encourage tobacco production, processing, and manufacturing, highlighting a clear conflict between short-term economic goals and tobacco control commitments (Lencucha et al. 2016). Reduced tobacco use would generate enormous long-term economic gains through higher productivity and decreased health costs. Therefore, in order to significantly increase cigarette taxes, the Zambian Ministry of Health and civil society should actively engage in the formulation of new policies and demonstrate to finance officials that controlling tobacco use is in the long-term best economic interests of the country. Fortunately, there is evidence of significant public support for higher cigarette taxes in the country, even among smokers themselves. Most respondents to the 2014 ITC Zambia Survey (78%), including nearly three-quarters of smokers (74%), thought that their government should increase taxes on cigarettes (ITC Project 2015). Future tobacco tax increases in Zambia must take into account both the country's high inflation rates and rapid income growth.

Another factor that must be considered in the drafting of new tax policies is the extensive use of RYO tobacco. Although the price for RYO increased substantially between the waves of the study, possibly influenced by a spike in the price of raw tobacco on the formal market (Tobacco Board of Zambia 2019), including in the price of exported tobacco (United Nations 2018), RYO remains much cheaper than FM cigarettes. The estimated value of smoking prevalence elasticity for RYO cigarettes is between -0.02 and -0.03. This suggests that a 10% increase in RYO prices leads to a 0.2% - 0.3% relative reduction in smoking prevalence. These low elasticities might result from the very low RYO price. With RYO cigarettes being very inexpensive, marginal price changes do not lead to much change in quantities demanded, even with this product being predominantly smoked by the lowest-income group (ITC Project 2015).

Positive cross-price elasticities between FM and RYO cigarettes found in this study suggest that these two products are substitutes. When the price of one of the products goes up, some smokers switch to using the other product. In the models, this cross-price effect is particularly significant for the impact of FM prices on RYO use. Estimates from most models suggest that a 10% increase in the FM cigarette price would lead to a 2% to 3% increase in RYO cigarette use prevalence, although the estimates from the models that use fitted values of cigarette prices are much higher. The estimated value of the FM price elasticity of all-product smoking prevalence (-0.20) suggests that a 10% price increase for FM cigarettes would result in 2% reduction in smoking for all products, while the value of own-price elasticity of FM smoking prevalence (-0.47) suggests that a 10% price increase in FM cigarettes would result in 4.7% decline in FM cigarette use. This suggests that less than half of the effect of FM price increase is accounted for by smokers quitting smoking, and most of that effect is probably due to switching products. The cross-price effect for the impact of RYO prices on FM use was positive and significant in models that used fitted values of cigarette prices only (Table 2.8). That model suggests that a 10% increase in RYO price would result in a 0.6% increase in FM cigarette sales. The fact that in most models RYO tobacco is a substitute for FM cigarettes, when the price of FM cigarettes increases, but not the other way around, might again be resulting from the very low RYO prices.

This switching behavior weakens the impact of tax increases intended to improve public health. As a remedy, both the WHO and the implementation guidelines for Article 6 of the WHO Framework Convention on Tobacco Control (WHO FCTC) recommend taxing all tobacco products comparably in order to reduce the between-product price differences, thus dis-incentivizing substitution (World Health Organization 2015b; WHO FCTC 2014). Zambia, however, already applies the same excise tax rates for RYO tobacco and FM cigarettes, although the extent of tax compliance for RYO is unknown. Therefore, instead of simply equalizing the tax rates between products, the between-product price differences must be reduced by other means.

There are two potentially viable strategies to reduce the price differential between RYO and FM. First, the country could consider stronger measures to increase enforcement and enhance tax compliance on RYO. A good first step taken recently by Zambia is to extend the tax stamp system, which is currently limited to cigarettes, to other excisable products. The project is scheduled to be rolled out in May 2019 (Mwanakatwe 2018). Implementing other measures could be difficult, because much of the RYO tobacco comes straight from the fields with minimal processing, using mostly traditional methods, with local market forces determining the price. A stricter control of the tobacco supply chain is needed through measures such as those listed in the Protocol to Eliminate Illicit Trade in Tobacco Products (United Nations 2012).

Secondly, the government should strongly consider backing away from promoting tobacco growing and processing. Although the government's support for tobacco growing is intended to promote exports (Lencucha et al. 2016), it directly violates Zambia's commitment to the WHO FCTC, and it seems that this policy has had serious unintended consequences: local farmers are now also supplying tobacco for local RYO (Personal communication with Dr. Fastone Goma). Thus, by increasing the supply of RYO, tobacco farming is contributing to the very problem that the Ministry of Health and the country's commitment to the FCTC seek to address.

Focusing on the problems arising from RYO will be particularly important because of the socio-economic status of RYO users. This study finds that, unlike FM cigarettes, RYO use is associated with lower income and education, and with rural residence. Therefore, government policies aiming to decrease health inequalities in society and reduce the negative economic consequences of tobacco use experienced by the poor must incorporate approaches to reduce RYO use, including the tax/price approaches that are the focus of this chapter.

Besides substituting with RYO, FM cigarette smokers in Zambia can avoid paying higher cigarette prices by trading down to cheaper brands of FM cigarettes. A previous study based on the 2014 wave of the ITC Zambia Survey found that higher price was significantly associated with brand switching (Salloum et al. 2015). The significant variation in in prices of FM cigarettes in Zambia allows smokers the opportunity to trade down to cheaper brands.

The recent change in the excise tax structure to one that is based on high and uniform specific taxes should help to alleviate this problem, because it most likely will reduce the between-brand variation in cigarette prices (Shang et al. 2014). Under the previous tax system, which was based on an ad valorem tax with a specific floor, both economic FM cigarette brands and RYO tobacco were tax-advantaged over more expensive cigarette brands. Specifically, because the net-of-tax price of economy FM cigarettes and RYO tobacco was lower than the net-of-tax price of premium FM cigarettes, the ad valorem tax on lower-priced FM cigarettes and RYO tobacco was lower than the tax on premium FM cigarettes. Relying on a specific tax should mitigate the tax advantage held by economy FM cigarettes and RYO tobacco and close the price gap markedly. A specific tax system will, however, require frequent changes in the tax rates to adjust for inflation and income growth. Therefore, the best practice is to set the tax rates to increase automatically (World Health Organization 2010). The one advantage of the ad valorem system is that the value of the tax follows changes in cigarette prices.

This study advances understanding about methods to estimate the demand for multiple tobacco products. There is a substantial literature in which the demand for each product is estimated separately (IARC 2011). This literature assumes that the decision processes pertaining to the choosing of two tobacco products are unrelated. In this chapter, I found that the assumptions of the standard methods were violated. Error terms between equations are correlated, suggesting that decisions to smoke FM and RYO cigarettes in Zambia are linked. In addition, the longitudinal design of the ITC Zambia Survey allowed me to make stronger conclusions about the causal relationships between prices and the use of the two tobacco products. This increased methodological sophistication demonstrates the advantage of cohort studies like the ITC to facilitate less biased estimates of critically important parameters such as price elasticities and cross-price elasticities, relative to repeated cross-sectional designs.

2.4.1. Limitations

A limitation of this study is that the price measures used in the models are based on self-reported prices. While I addressed the endogeneity problem resulting from the simultaneity of price and consumption, I could not eliminate other issues with the data. First, both the last-purchase price and the spending-based price are subject to recall bias, while the spending-based price can also be subject to underreporting of the number of cigarettes smoked. It should be noted, however, that the longitudinal design allows for control of the individual-level unobservable characteristics, which should capture some of the respondents' biases.

Secondly, the two price measures represent slightly different prices: one is the last-purchase price, while the other represents the average purchase price for the last 30 days. Unfortunately, too, for some observations, the last-purchase price of RYO could not be calculated because the respondents' verbal description of the amount of RYO purchased did not allow us to convert it to grams. For those observations, I had to rely on the spending-based price. Finally, the spending-based price could not be calculated for dual users of FM and RYO, as the number of cigarettes smoked per day per cigarette type was not reported in the survey. Because each of the price measures had significant limitations, none could be used in the models independently. Combining the two measures is not ideal, because they are different. Nevertheless, the availability of two independent price measures allowed us to triangulate the results. In consequence, I was able to estimate price effects of both anticipated sign and magnitude.

Thirdly, the endogeneity of self-reported prices could pose some problems. Finally, the analysis presented in this chapter focusses on cigarettes only and might be missing substitution to some other product types. For example, while only 2% of all ITC Zambia survey respondents reported using smokeless tobacco in 2014 (ITC Project 2015), some of the current FM and RYO users might choose to switch to smokeless tobacco in the event the price of FM and RYO cigarettes increases relative to the smokeless tobacco price. Nevertheless, the results are robust, with the models on fitted values of cigarette prices yielding results that are of the same direction, and similar significance, though of a higher magnitude, compared to the models on the averaged prices.

2.4.2. Study application

The results presented in this chapter have already been used to advance tobacco control in Zambia. One of the advantages of this study is its applicability to the real issues that the Zambian government currently faces. Zambia is one of the countries where the economic and health policy issues in tobacco control are tightly linked and interrelated. Implementation of any new tobacco tax law would require coordinated efforts between many branches of the government. In particular, because of the availability of the cheap roll-your-own tobacco that comes straight from the tobacco farms, the tobacco tax reform would require coordination between the finance, trade, and agricultural branches of the government. This study links tobacco taxation and tobacco farming issues and, therefore, and serves a greater purpose by bringing those stakeholders together.

Since its publication in 2018, the study presented in this chapter has been used by a joint mission of the WHO FCTC Secretariat and the United Nations' Development Program (UNDP) in Zambia within the FCTC 2030 project. The aim of this project is to strengthen tobacco control in low- and middle-income countries in order to support governments in their efforts to accelerate the implementation of the WHO FCTC. A key focus area of the FCTC 2030 project is direct support to fifteen low- and middle-income Parties to the FCTC, which have demonstrated the motivation to advance tobacco control. Zambia is one of the fifteen focus countries. As stated at the convention's website: "This direct support is focused on the achievement of the general obligations and the time-bound measures of the Convention, strengthening tobacco taxation, implementing other articles of the WHO FCTC according to national priorities and promoting the implementation of the Convention as part of the 2030 Agenda for Sustainable Development" (World Health Organization 2018).

The mission, which included representatives from the University of Cape Town's Knowledge Hub on Tobacco Taxation, UNDP, and the American Cancer Society, met with several key Zambian stakeholders in Lusaka in June 2018. During the first day of the engagement project meetings, representatives from the international organizations met with local key actors who are part of the process of drafting the new comprehensive tobacco legislation at the "Stakeholder Engagement on Proposal for New Comprehensive Tobacco Control Legislation" meeting organized by the International Legal Consortium (ILC). The local stakeholders included a Member of Parliament as well as officials from the Ministries of Agriculture, Commerce, Trade & Industry, Finance, Labour, the office of the Attorney General, the local government, the University of Zambia and civil society. Over four days, the mission representatives from international organizations met individually with officials from the Ministry of Health, Ministry of Finance, Ministry of Agriculture, Ministry of Education, Parliamentary Committees, Lusaka City Council, and the Tobacco Board of Zambia. There was also a separate, formal presentation at the Parliament to the chairs and co-chairs of all of the relevant parliamentary committees.

A fact sheet based on the study presented in this chapter was distributed at each of the FCTC Secretariat/UNDP FCTC-2030 Project Engagement meetings. The fact sheet presented the key results of the study in a comprehensible and compelling way. It translated the findings of the econometric models of the study into tools for policy change (see Figure 2.4). The price elasticities calculated in this study were also used to predict the results of proposed future tax increases over the next decade, not only in terms of declines in cigarette use, but also in terms of predicted increase in government revenue (see Figure 2.5).

Figure 2.4. A graphic from a fact sheet used by the FCTC Secretariat/UNDP FCTC-2030 Project Engagement presenting the results of the current study

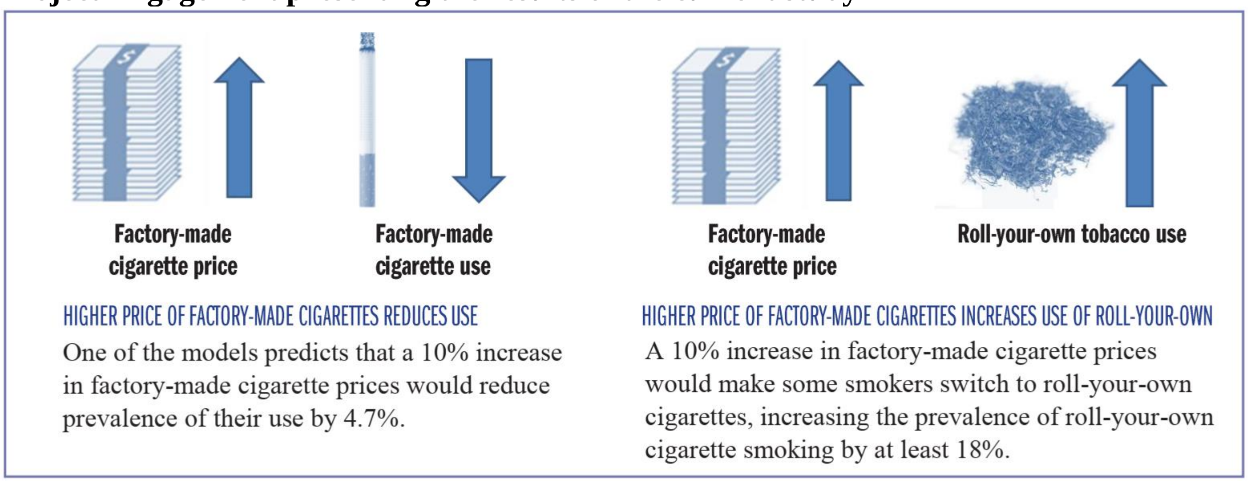
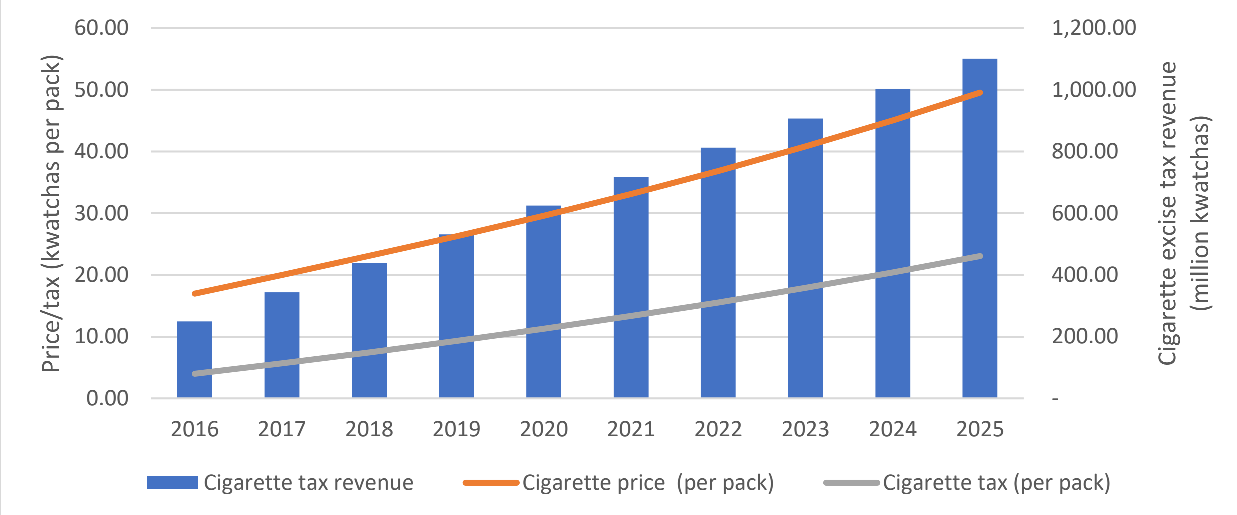


Figure 2.5. Predicted effects of tobacco tax increases in Zambia based on price elasticities estimated in the current study



As reported by members of the FCTC 2030 Project's Zambia mission team, the presentation of the results of the study was appreciated and recognized by the Zambian stakeholders. For example, the representatives from the Ministry of Finance — particularly those from the excise tax department — were genuinely interested in the models showing revenue gain from increased tobacco taxation and have invited the team back to discuss the models. The study will keep playing an influential role in the efforts of the FCTC 2030 Project in upcoming months.

2.5. Conclusions

There is little evidence pertaining to price and cross-price elasticities for tobacco products. This is the first extensive study of price and cross-price elasticities for tobacco products in Sub-Saharan Africa, and therefore significantly contributes to the limited global evidence from LMICs on the impact of tobacco product prices on between-product substitution.

I used the longitudinal design of the ITC Zambia Survey, estimating a system of equations with panel data, a method which is superior to the standard estimation techniques. The longitudinal study design enabled the determination of a temporal and causal relationship between price and the use of FM and RYO cigarettes.

The findings of this chapter indicate that FM and RYO cigarettes are substitutes in Zambia, emphasizing the need for effective policies to reduce between-product price differences. Between-product price differences undermine the effectiveness of tobacco tax policies. Further, consistent with the abundant evidence from high-income countries and a growing body of literature from LMICs, this study affirms that increasing taxes on and the price of cigarettes in Zambia can markedly reduce cigarette use. Increasing tobacco taxes, resulting in higher cigarette prices, not only improves public health and alleviates the detrimental effects of tobacco use, but also results in higher government revenue in developing economies that need the additional income.

3. CHAPTER THREE: THE EFFECT OF THE INTRODUCTION OF A NEW NICOTINE PRODUCT ON CIGARETTE SALES – EVIDENCE OF DECLINE AND REPLACEMENT[2]

3.1. Introduction

Economists' standard way of establishing between-product substitution is through product price. Therefore, in the analysis presented in the second chapter of this thesis, the factor affecting smokers' switching was the price of the product. Specifically, I showed how changes in prices of two tobacco products, cigarettes and roll-your-own tobacco, affect demand for those products and make smokers switch from one product to the other. There are, however, instances when it is impossible to determine between-product substitution using this approach, either because calculating cross-price elasticities is not feasible, or there is no well-established market for which to calculate the elasticities.

One obvious case of when calculating cross-price elasticities is not feasible is when the prices of the two goods are stable relative to inflation. With no variation in real price, over time and among the subjects, calculating cross-price elasticities is statistically not possible. In such cases, the price variable would either be treated as constant or simply dropped from a model. Whenever estimating cross-price elasticity is not feasible, product substitution cannot be determined using traditional economic means.

[2] The data used in this chapter was purchased by the American Cancer Society Inc. from Intage Inc. (Intage's Invoice number 80082575-S0101). This chapter is an updated and expanded version of a paper previously published in the *Tobacco Control* journal (Stoklosa, Cahn, et al. 2019).

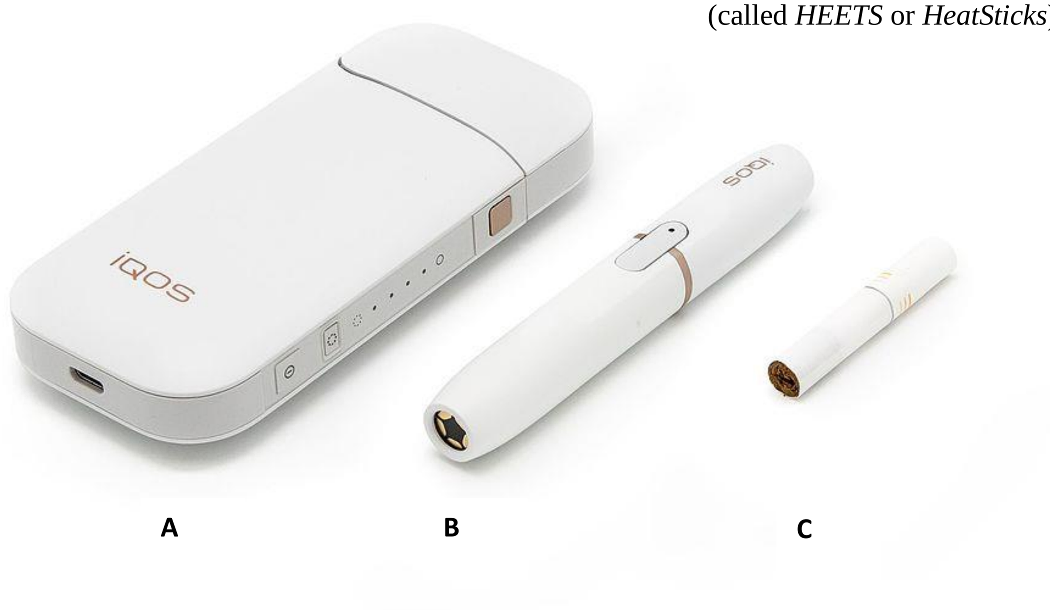
Another instance in which traditional economic methods of establishing substitution might be difficult is when goods are freshly launched on the market, i.e. when the market is still developing. In such case, prices may play only a minor role in consumers' behavior. For example, in the early stages of product market diffusion, the product is used by only a small group of consumers who are eager to try new ideas, seek for innovative products, and have relatively high incomes, allowing them to afford the risks associated with a high probability that the new, untested product will fail. In the marketing literature, those customers are referred to as innovators and early adopters (Rogers 2003). There might be also issues with supply shortages for the new product. In the absence of a fully-developed, equilibrated market, the estimated cross-price elasticities for those groups of consumers might not be reflective of the preferences of the entire population.

Issues concerning the methods that are used to determine whether two products are substitutes could apply to some products on the tobacco market. Specifically, estimating cross-price elasticities might be difficult for novel tobacco products. Recently, the introduction of different types of novel tobacco products is shifting the composition of the tobacco and nicotine market, markedly in some places. While many studies and reports observe changes in use for different tobacco product classes, rigorous studies of the exact substitution patterns between novel nicotine products and traditional tobacco products are hard to find, precisely for the reasons discussed above: the market for these products is still new and not fully equilibrated (e.g. because of the supply shortages), and there may not be enough variation in the prices of those products over the relatively short period of the products' existence on the market. Therefore, analyses of substitution between traditional, combustible tobacco products and novel tobacco products are rare. Such analyses could help policymakers comprehensively evaluate the impact of novel products at a time when there is considerable uncertainty about how to regulate such products.

Heated tobacco products (HTPs) are one of the latest in a line of products that tobacco companies market as less harmful than regular cigarettes. Unlike cigarettes, which burn tobacco leaves, HTPs heat a processed tobacco leaf substance to a high temperature, slightly short of combustion. Unlike e-cigarettes, which aerosolize a liquid containing varying amounts of nicotine (or no nicotine at all), HTPs release the nicotine directly from tobacco leaf. The products have begun to show substantial sales growth in several countries where they have been introduced. Available in at least 44 countries, as of the first quarter of 2019 (Philip Morris International 2019a), growth has been especially strong in Japan and Korea (Tabuchi et al. 2018; Kim et al. 2018). The global HTP market leader is IQOS from Philip Morris International (PMI), which, the company claims, generates a significantly lower quantity of “harmful or potentially harmful chemicals” than combustible cigarettes (Philip Morris Japan K.K. 2015). The product consists of short cigarette-like heated tobacco units (PMI’s Heatsticks) and a battery-powered device into which the Heatsticks are inserted (Figure 3.1). According to the manufacturer, one Heatstick lasts about six minutes or 14 puffs, which is comparable to smoking one regular cigarette (Philip Morris International 2019c). Like regular cigarettes, Heatsticks consist of tobacco and a filter section (Philip Morris International 2019c). Some IQOS models offer Internet connectivity, which might potentially allow the manufacturer to customise the nicotine delivery by monitoring usage patterns and adjusting the dose (Lasseter et al. 2018). PMI predicts that by 2025 their “reduced-risk” category, which could be led by HTPs, will account for over 30% of the company’s sales volume and over 38% of the company’s total net revenues globally (Philip Morris International 2018a). In New Zealand, PMI announced that it planned to switch its attention from cigarettes to IQOS and that it foresaw abandoning cigarette sales altogether (TVNZ 2019), though the credibility of these claims is uncertain, particularly because of PMI's longstanding and nearly complete reliance on combustible tobacco products as the core of its business.

Figure 3.1. The IQOS of Philip Morris International

Legend:
A – charger
B – holder
C - heated tobacco unit
(called *HEETS* or *HeatSticks*)



Source: SimonDes / Philip Morris International [This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license]. Notes: Letters A, B, and C as well as the legend were added to the original image by the author of this dissertation. Some IQOS products combine the holder and the charger.

One of the main promises made by PMI is that IQOS is intended to displace sales of regular cigarettes. In numerous statements, the company asserts that IQOS is a "unique alternative to smoking combustible cigarettes for adult smokers" (Philip Morris Japan K.K. 2015) and that the goal of the product is "to switch hundreds of millions of adult smokers to less harmful alternatives than continued smoking as quickly as possible" (Philip Morris International 2018b). It is often presumed that the introduction and growth of IQOS would lead to declines in cigarette sales, but there is, so far, little empirical evidence supporting this assumption. However, in Japan, HTP sales have grown to the point where they now constitute a substantial share of the overall tobacco and "vapor" product (e.g., e-cigarettes) market – 17.1% according to trade sources (Lavery and Kratky 2019) – outpacing the combined HTP and vapor-product sales in any other market in terms of total value by late 2018 (Euromonitor 2018).

The study presented in this chapter aims to answer the question of whether the newly-introduced IQOS product significantly affects the cigarette market in a large economy. The study attempts to determine product substitutability in circumstances when calculating cross-price elasticities is not possible. It utilizes a natural experiment in IQOS availability created during a rollout of IQOS in 2015 and 2016. PMI first introduced IQOS to twelve Japanese prefectures (a large political and geographical unit) in September 2015, ahead of their nationwide launch in April 2016. This staggered rollout created exogenous variation in the availability of IQOS across regions that can be used to assess whether IQOS introduction had a causal impact on tobacco cigarette sales. Specifically, using 2014-2018 monthly retailer panel data from Japan, the study analyses whether different dates of IQOS introduction across Japan's regions are reflected in the patterns of cigarette sales in those regions. A series of placebo models are estimated to test if events other than IQOS introduction could better explain the observed trends in cigarette sales. Unlike the study presented in the preceding chapter, this study looks at product switching behaviors regardless of the product price.

3.1.1. Tobacco use in Japan

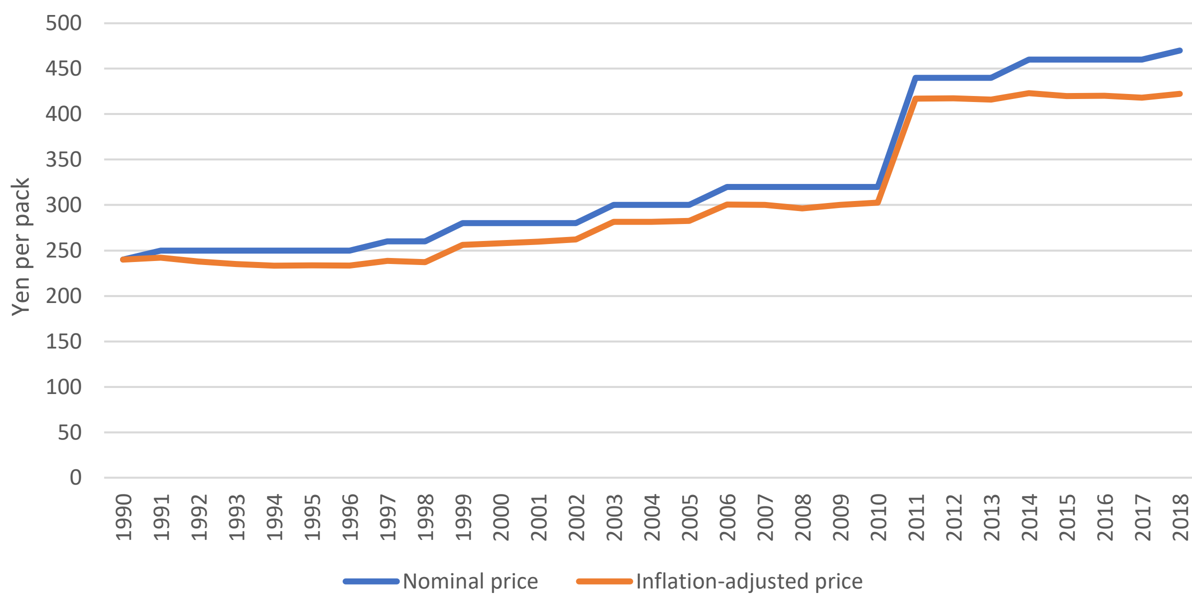
Throughout the 1980s and 1990s, Japan had one of the highest tobacco smoking rates in the world (Institute for Health Metrics and Evaluation 2017). The rate dropped substantially throughout the 2000s and 2010s, but is still above the world's average (Institute for Health Metrics and Evaluation

2017). The daily tobacco smoking rate among people aged ≥ 15 years was estimated at 16.9% (27% among men and 7.5% among women) in 2016 (World Health Organization 2018). Consequently, there are still 22 million current tobacco smokers in Japan, of which 19 million are daily tobacco smokers (World Health Organization 2018). Smoking rates are also substantially affected by socioeconomic status and place of residence. Having lower income and living in a non-urban area are both associated with significantly higher rates of smoking (Fukuda, Nakamura, and Takano 2005).

The drop in cigarette use during the early twenty-first century can only to small extent be attributed to Japan's tobacco control policies, because tobacco control laws are not strongly implemented in the country. Most existing regulations are voluntary industry self-regulation (Katanoda et al. 2014). With complete absence of national-level smoke-free policies, no tobacco advertising bans, no mass-media anti-tobacco campaigns, and only small health warnings on cigarette packs, Japan is significantly lagging behind in its implementation of tobacco control policies (World Health Organization 2017). The one relatively well-implemented tobacco control policy in Japan is its tobacco cessation policy, which makes the treatment of tobacco dependence widely available. In particular, the implementation of the 2002 Health Promotion Law was followed by the introduction of nicotine replacement therapy into the national insurance scheme, which substantially reduced costs for those seeking help with smoking cessation (Wada, Higuchi, and Smith 2016). Consequently, Japan's smoking cessation programs are now ranked among the best in the region (World Health Organization 2017).

Cigarette price is another factor that could potentially have affected smoking rates in Japan. Several studies on data from Japan show that higher cigarette prices lead to lower cigarette consumption (Luo, Abdel-Ghany, and Ogawa 2003) and lower smoking prevalence (Yuda 2013) in the country. However, over the last seven years cigarette prices in Japan have not changed very much. Figure 3.2 shows the price of Marlboro cigarettes collected from stores in Tokyo between 1990 and 2018. During the period covered by the graph, there has been only one large cigarette price hike in October 2010, when the specific cigarette excise tax was increased by 3.5 yen per cigarette, that is by 70 yen per pack (Yuda 2013). That 2010 tax hike that led to significantly higher cigarette prices resulted in a significant increase in cessation rates in the country (Tanihara and Momose 2015; Tabuchi et al. 2016). Other than that one large tax increase, there have been only a few minor tax increases (by 1 yen per cigarette). The prices are also relatively low compared to other countries. In 2016, the price of the most-sold cigarette brand in Japan (I$4.30), adjusted for purchasing-power parity, was not only much lower than the average price in a high-income country (I$7.19), but also lower than the average global cigarette price (I$4.87) (World Health Organization 2017).

Figure 3.2. Price of Marlboro cigarettes in Tokyo, Japan



Note: Price of Marlboro cigarettes (pack of 20; mid-priced store) from the Economist Intelligence Unit (Economist Intelligence Unit 2019); inflation from the International Monetary Fund (International Monetary Fund 2019).

According to the Global Burden of Disease estimates, there are still more 200 000 tobacco smoking-related deaths and more than 17 000 second-hand smoking-related deaths in Japan each year (Institute for Health Metrics and Evaluation 2018). Therefore, reducing cigarette use in Japan would yield substantial benefits in terms of the number of premature deaths averted.

3.1.2. Methodological background

A considerable amount of the economic and marketing research has been directed at studying the demand for soon-to-be-introduced or newly-introduced products. The markets researched vary from new vehicle technologies (Mau et al. 2008) to rural landscape improvements (Campbell 2007). These studies focus on understanding consumers' preferences, which should reflect their future purchasing behaviors, and are used to predict the demand for new products on the market. Such information is critical for both existing firms and for entrepreneurs, whether they plan to launch a new product, add a new product category, extend an existing product line, or introduce an existing product to a new market. The studies help firms to forecast the future stream of revenue in order to inform their business plans and design better marketing and sales strategies.

Much of this research that is focused on the impact of the introduction of a new product on the demand for existing products involves modelling the product demand using the product price as the primary independent variable. For example, a frequently-cited paper by Hausman and Leonard focusses on estimating the competitive effects of a new Kleenex Bath Tissue product introduction (Hausman and Leonard 2002). The authors estimated the price reduction for existing products as a result of the new product introduction (price effect) and used a demand system to estimate product own- and cross-price elasticities. Similarly to the analysis presented in this chapter, the paper by Hausman and Leonard used shop scanner data from before and after the new product was introduced to estimate the effect of the new product introduction on the existing product market.

However, as I demonstrate later in this chapter, the approach used by Hausman and Leonard could not be utilized in the analysis of IQOS heated tobacco product introduction in Japan because there was practically no variation in the price variable in the Japanese data. Specifically: 1) the price of the old product (regular cigarettes) did not change after IQOS introduction, 2) prices for IQOS and regular cigarettes were practically the same, 3) prices for both products did not change throughout the time of this analysis, and 4) prices of the products did not differ across the regions of Japan.

Not being able to perform the analysis using product price data to estimate products cross-price elasticities, I used instead a relatively new method in the branch of causal inference: regression kink design. The method, first devised by Nielsen, Sørensen, and Taber (2010), is nested within the larger field of regression discontinuity design (RDD) methods. It is being increasingly used to assess the impact of treatment (such as a new policy implementation) on different outcome variables. The main problem with estimating the causal effects of many treatments is the endogeneity associated with how those treatments were assigned. For example, with scholarships being awarded to only the best students, it is hard to estimate an effect of the scholarship on the students' future performance, since the well-performing students might have performed equally well, even in the absence of the scholarship. The RDD assesses whether there was a discontinuous change in the slope of the outcome of interest at the exact location of the treatment threshold (Card et al. 2016). In the student scholarship example, the RDD would compare the future performance of scholarship-receiving students who were just above the grade threshold to receive the scholarship to the future performance of students who were just below the threshold and, therefore, did not receive the scholarship. If a scholarship had no effect on the students' performance, the future performance of the two groups of students should be similar, since both groups had similar grades before the scholarship was awarded. However, if the scholarship substantially impacts the future performance of the recipients, the relationship between students' grades before the scholarship was awarded and their performance after the scholarship was awarded would be discontinuous at around the grade threshold of the scholarship.

Similarly, endogeneity problems might affect the relationship between cigarette use and novel tobacco use. Specifically, smokers who reduce their cigarette use by taking up novel tobacco products might have reduced their cigarette use had the novel tobacco products never been introduced. If a specific group of smokers were seeking to reduce their tobacco use and, therefore, took up novel tobacco products, those smokers might have reduced their cigarette use anyway, even in the absence of those products. The relationship between cigarette sales and IQOS introduction can be analysed with RDD methods. Using the regression kink design method, I conducted a series of analyses of the the relationship between the trends in cigarette sales (outcome variable) and the time of IQOS introduction (treatment variable).

3.2. Methods

3.2.1. Data

Data on cigarette and heated tobacco unit sales were obtained from Intage Inc., a market research company based in Japan. The company collects data on sales of tobacco products from participating supermarkets and convenience stores and provides tobacco market size estimates for eleven of Japan's twelve geographical regions, covering 99% of the population (Okinawa prefecture is the only region excluded from the company's retailer panel for tobacco products).

The obtained data cover the period from September 2014 to August 2018. The total number of observations in this study is 528 (11 regions x 48 months).

The Intage retailer panel data are aggregate monthly data on the number and value of items sold. While the data on cigarettes reflect sales of all cigarette brands combined, the HTP data include separate data for PMI's IQOS. These data contain detailed information on the heated tobacco units only (PMI's Heatsticks) and do not include information on the battery-powered devices (such as the PMI's IQOS holder) into which the Heatsticks are inserted.

To construct per capita cigarette sales and per capita heat sticks sales, I use information on the total population[3] by prefecture obtained from the Japan Statistical Office (e-Stat 2018). The prefecture-level data were reduced into the eleven regions in the Intage data. Because the Statistical Office provides population estimates as of the 1st of October each year, the data for the other months were imputed using linear interpolation.

3.2.2. Primary independent variable

The primary exogenous variable is derived from PMI's timeline of IQOS introduction to the Japanese market, drawn from PMI's documents (Philip Morris Japan K.K. 2015). PMI started testing the product in selected stores in the city of Nagoya in November 2014 (Tabuchi et al. 2018; Philip Morris Japan K.K. 2015). The product was then introduced to the market in two phases: the first twelve prefectures in September 2015 (treatment group), and the remaining thirty-five

[3] Total population was used, because the population data by age group by province were not available for the period of this analysis.

prefectures in April 2016 (control group) (Tabuchi et al. 2018; Philip Morris Japan K.K. 2015). Table 3.1 presents the months of IQOS introduction by prefecture.

The Intage data used in this study include regions that are generally larger than a single prefecture. Therefore, I used three approaches to assign the introduction date to each of the Intage regions. In the first approach, I weighted the prefecture-level introduction date by the prefecture's population. Specifically, in regions where most residents lived in prefectures with a September 2015 IQOS introduction, the assigned market introduction date was September 2015. Otherwise, the assigned market introduction date was April 2016. In the second approach, the regions that were not fully covered by IQOS rollout in September 2015 were assigned an April 2016 introduction date. Finally, in the third approach, I removed the regions with a partial September 2015 introduction from the analysis, leaving only the regions with a full September 2015 introduction and a full April 2016 introduction. Table 3.1 lists introduction dates by region in all three approaches.

Table 3.1. IQOS introduction by region

Prefecture	IQOS introduced in the prefecture	Share of region's total population	Region	Percentage of region's population with early (Sept-15) IQOS introduction	IQOS introduced in the region		
					Approach 1	Approach 2	Approach 3
Hiroshima	Sep-15	38%	Chugoku	38%	Apr-16	Apr-16	-
Okayama	Apr-16	26%					
Shimane	Apr-16	9%					
Tottori	Apr-16	8%					
Yamaguchi	Apr-16	19%					
Hokkaido	Sep-15	100%	Hokkaido	100%	Sep-15	Sep-15	Sep-15
Fukui	Apr-16	26%	Hokuriku	0%	Apr-16	Apr-16	Apr-16
Ishikawa	Apr-16	38%					
Toyama	Apr-16	35%					
Gumma	Apr-16	26%	Kanto	0%	Apr-16	Apr-16	Apr-16
Ibaraki	Apr-16	38%					
Tochigi	Apr-16	26%					
Yamanashi	Apr-16	11%					
Chiba	Sep-15	17%	Keihin	100%	Sep-15	Sep-15	Sep-15
Kanagawa	Sep-15	25%					
Saitama	Sep-15	20%					
Tokyo	Sep-15	38%					
Hyogo	Sep-15	27%	Kinki	82%	Sep-15	Apr-16	-
Kyoto	Sep-15	13%					
Nara	Apr-16	7%					
Osaka	Sep-15	43%					
Shiga	Apr-16	7%					
Wakayama	Apr-16	5%					
Fukuoka	Sep-15	39%	Kyushu	39%	Apr-16	Apr-16	-
Kagoshima	Apr-16	13%					
Kumamoto	Apr-16	14%					
Miyazaki	Apr-16	8%					
Nagasaki	Apr-16	11%					
Oita	Apr-16	9%					
Saga	Apr-16	6%					

<table>
<tr><th rowspan="2">Prefecture</th><th rowspan="2">IQOS introduced in the prefecture</th><th rowspan="2">Share of region’s total population</th><th rowspan="2">Region</th><th rowspan="2">Percentage of region's population with early (Sept-15) IQOS introduction</th><th colspan="3">IQOS introduced in the region</th></tr>
<tr><th>Approach 1</th><th>Approach 2</th><th>Approach 3</th></tr>
<tr><td>Ehime</td><td>Apr-16</td><td>36%</td><td rowspan="4">Shikoku</td><td rowspan="4">0%</td><td rowspan="4">Apr-16</td><td rowspan="4">Apr-16</td><td rowspan="4">Apr-16</td></tr>
<tr><td>Kagawa</td><td>Apr-16</td><td>25%</td></tr>
<tr><td>Kochi</td><td>Apr-16</td><td>19%</td></tr>
<tr><td>Tokushima</td><td>Apr-16</td><td>20%</td></tr>
<tr><td>Nagano</td><td>Apr-16</td><td>48%</td><td rowspan="2">Shinetsu</td><td rowspan="2">0%</td><td rowspan="2">Apr-16</td><td rowspan="2">Apr-16</td><td rowspan="2">Apr-16</td></tr>
<tr><td>Niigata</td><td>Apr-16</td><td>52%</td></tr>
<tr><td>Akita</td><td>Apr-16</td><td>11%</td><td rowspan="6">Tohoku</td><td rowspan="6">26%</td><td rowspan="6">Apr-16</td><td rowspan="6">Apr-16</td><td rowspan="6">-</td></tr>
<tr><td>Aomori</td><td>Apr-16</td><td>15%</td></tr>
<tr><td>Fukushima</td><td>Apr-16</td><td>21%</td></tr>
<tr><td>Iwate</td><td>Apr-16</td><td>14%</td></tr>
<tr><td>Miyagi</td><td>Sep-15</td><td>26%</td></tr>
<tr><td>Yamagata</td><td>Apr-16</td><td>12%</td></tr>
<tr><td rowspan="2">Aichi</td><td>Nov-14 - Nagoya city only</td><td rowspan="2">50%</td><td rowspan="5">Tokai</td><td rowspan="5">50%</td><td rowspan="5">Sep-15</td><td rowspan="5">Apr-16</td><td rowspan="5">-</td></tr>
<tr><td>Sep-15 – entire prefecture</td></tr>
<tr><td>Gifu</td><td>Apr-16</td><td>13%</td></tr>
<tr><td>Mie</td><td>Apr-16</td><td>12%</td></tr>
<tr><td>Shizuoka</td><td>Apr-16</td><td>25%</td></tr>
</table>

3.2.3. Statistical method

Linear trends were fitted to the per capita cigarette sales by each region using a fixed effects model. The regional fixed effects control for different initial levels of cigarette sales in the regions, which result from such factors as the social acceptability of cigarette use or the level of implementation of tobacco control regulations. If a link between IQOS and regular cigarette use exists, the event of IQOS market introduction will be reflected in the patterns of cigarette use. I used the “changing growth” time-trend model (Perron 1989) and Chow test (Chow 1960) to examine whether cigarette sales followed the same trends before and after IQOS introduction in Japan. The null hypothesis in the test is that the trend in per capita cigarette sales remained stable over time. The alternative hypothesis is that there was a structural break in the trends with the IQOS heated tobacco product introduction in each region, i.e. that the trend lines were demonstrably kinked in the months after IQOS introduction. The "changing growth" model adapted for this study has the following functional form:

$$y_{it} = \mu + \beta_1 t + (\beta_2 - \beta_1) DT_{it}^{*} + \alpha_i + e_t$$

where $DT_{it}^{*}=t-T_{Bi}$, if $t>T_{Bi}$ and 0 otherwise (Perron 1989); t refers to the time (month) and T_{Bi} refers to the time of break in region i (e.g. for regions with IQOS introduction in September 2015 the T_{Bi}=13, as September 2015 was the thirteenth month in the dataset). The α_i is the regional fixed effect. β_1 - β_2 represents the change in trend. The Chow test, in this instance, examines whether β_1 is statistically different from β_2.

Even if the Chow test finds that the trends in cigarette sales in Japan were not stable over time, this change in trends could have been caused by factors other than the introduction of the IQOS heated tobacco product. To check for that possibility, I devised a series of placebo tests to examine rigorously the likelihood that the observed relationship between IQOS introduction and cigarette sales decline could be attributed to 1) national-level factors coinciding with IQOS introduction, or 2) random chance.

First, I note that a structural break in trends in cigarette sales could have been caused by a national-level factor that affected trends in cigarette sales across all regions at once. Such a factor could include a sudden downturn in the economy, an introduction of a national-level tobacco control law, or a large-scale natural disaster, or any other exogenous shock. To test for this possibility, I estimated a set of placebo models explaining cigarette sales by a linear trend, each model with a kink for a different month of my analysis. I then compare the models' ordinary R^2 to those for the true model in which the sales trend lines are kinked in the actual months of IQOS introduction.

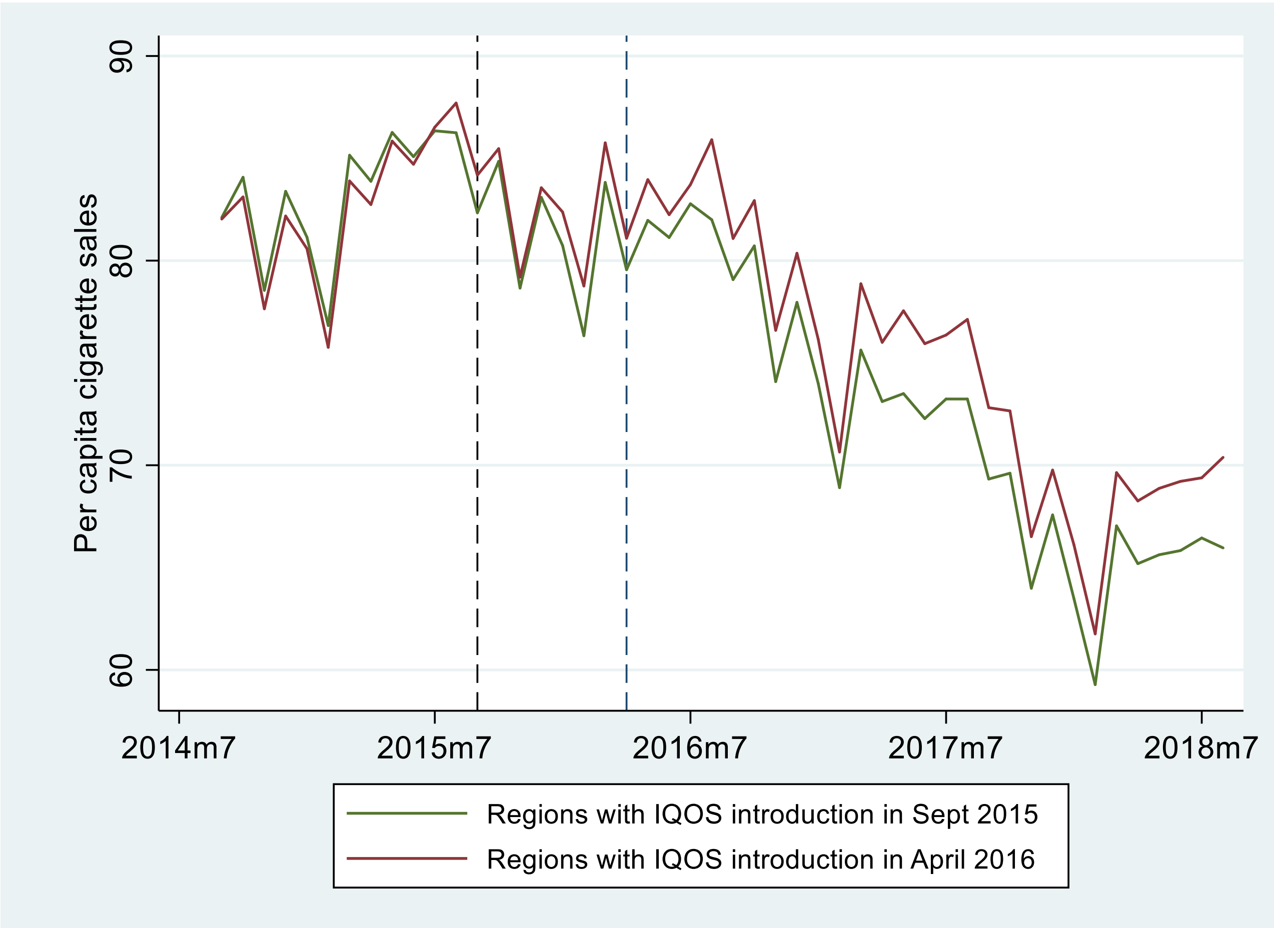
To gain confidence that the association between IQOS introduction and cigarette sales decline is not the result of chance, I also employed an exact permutation test. The set of actual observed IQOS introduction times was repeatedly redistributed so that one or more regions were assigned the IQOS introduction date that was originally associated with a different region. The time-trend model with the new combination of the introduction dates was then estimated and the R^2 recorded. This procedure was repeated for all 330 possible unique groupings of the true, original introduction dates in approach one (11!/(4!(11-4)!)=330), for all 55 possible combinations in approach two (11!/(2!(11-2)!)=55), and for all 15 possible combinations in approach three (6!/(2!(6-2)!)=15). This reassignment process allowed for the creation of a null distribution of R^2 values, each associated with a different reassignment of introduction dates. Under the null hypothesis that the timing of each region's decline in cigarette sales was unrelated to IQOS introduction, the R^2 value of the true introduction dates would represent a random draw from this null distribution. The placement of the model based on the actual dates of IQOS introduction within this distribution – i.e. the ranking of the R^2 for the introduction date model among those of the placebo permutation models – allows us to infer a p-value representing the probability that an association at least as strong as the one actually observed would have occurred due to random chance.

An introduction date model and placebo models were estimated using each of the three approaches to assign an IQOS introduction date to the regions where IQOS was only partially introduced in September of 2015.

3.3. Results

Per capita cigarette sales started to decline around the time of IQOS introduction (Figure 3.3). The patterns of cigarette use could not be affected by the pricing of the products, since IQOS and cigarette prices did not differ across regions during this period. According to the Intage data, the IQOS price remained stable at 21 yen per Heatstick across all regions and throughout the analysis. The weighted average cigarette price also remained stable at 20 yen per stick. Therefore, with no variation in the price variable, the standard, economic analysis of product substitution was not possible.

Figure 3.3. Per capita cigarette sales in regions with earlier vs. in regions with later IQOS introduction



Note: The black dashed vertical line indicates September 2015 IQOS introduction, while the blue dashed vertical line indicates April 2016 IQOS introduction.

The trend lines for per capita cigarette sales were kinked at the time of introduction of IQOS heated tobacco products in each of the eleven Japanese regions (Table 3.2 and Figure 3.4 through Figure 3.6). With high values of the Chow test statistics, the null hypothesis of the stability of the trend is rejected (F= 254.94, P<0.001 for approach one; F= 243.27, P<0.001 for approach two; F= 120.99, P<0.001 for approach three). Estimates from the test's underlying model indicate that, across all regions, per capita cigarette sales were slightly increasing before the introduction of IQOS (at a rate of 0.10 to 0.14 cigarettes per person per month on average, depending on the approach) but started to decline after the IQOS introduction (declining at a rate of 0.78-0.14=0.64 to 0.77-0.10=0.66 cigarettes per person per month, depending on the approach). Results from the models using the first, second, and third approach to define IQOS regional introduction dates are presented in Figure 3.4, Figure 3.5, and Figure 3.6, respectively.

Table 3.2 Relationship between IQOS introduction and cigarette sales in Japan: a changing growth approach

	Coefficient estimates		
	Approach 1	Approach 2	Approach 3
Time trend	0.14***	0.10***	0.10**
Change in trend	-0.78***	-0.76***	-0.77***
Constant	84.17***	84.37***	86.44***

Note: ***p<0.01; **p<0.05; *p<0.1;

Figure 3.4. Per capita cigarette sales and the model fitted values (Approach 1)

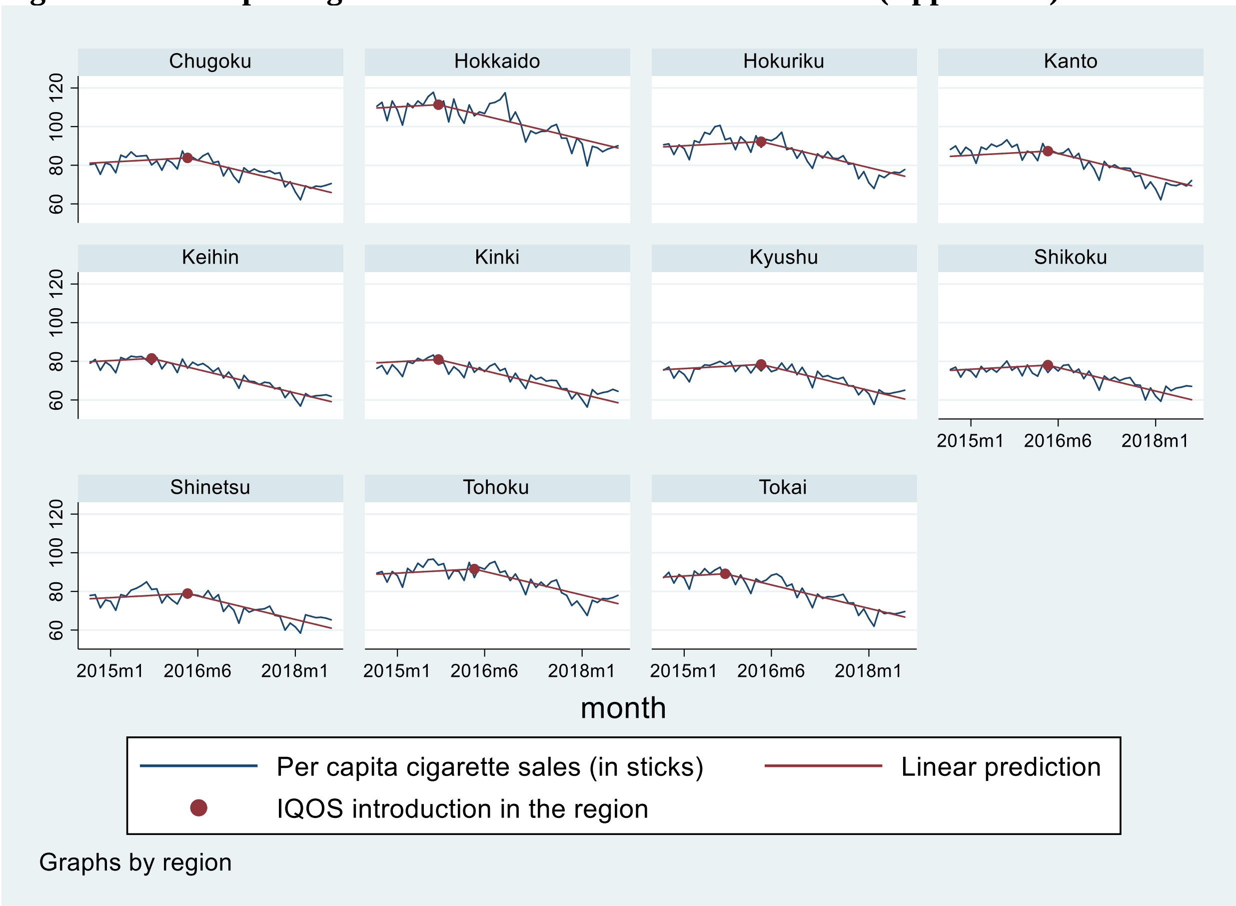


Figure 3.5. Per capita cigarette sales and the model fitted values (Approach 2)

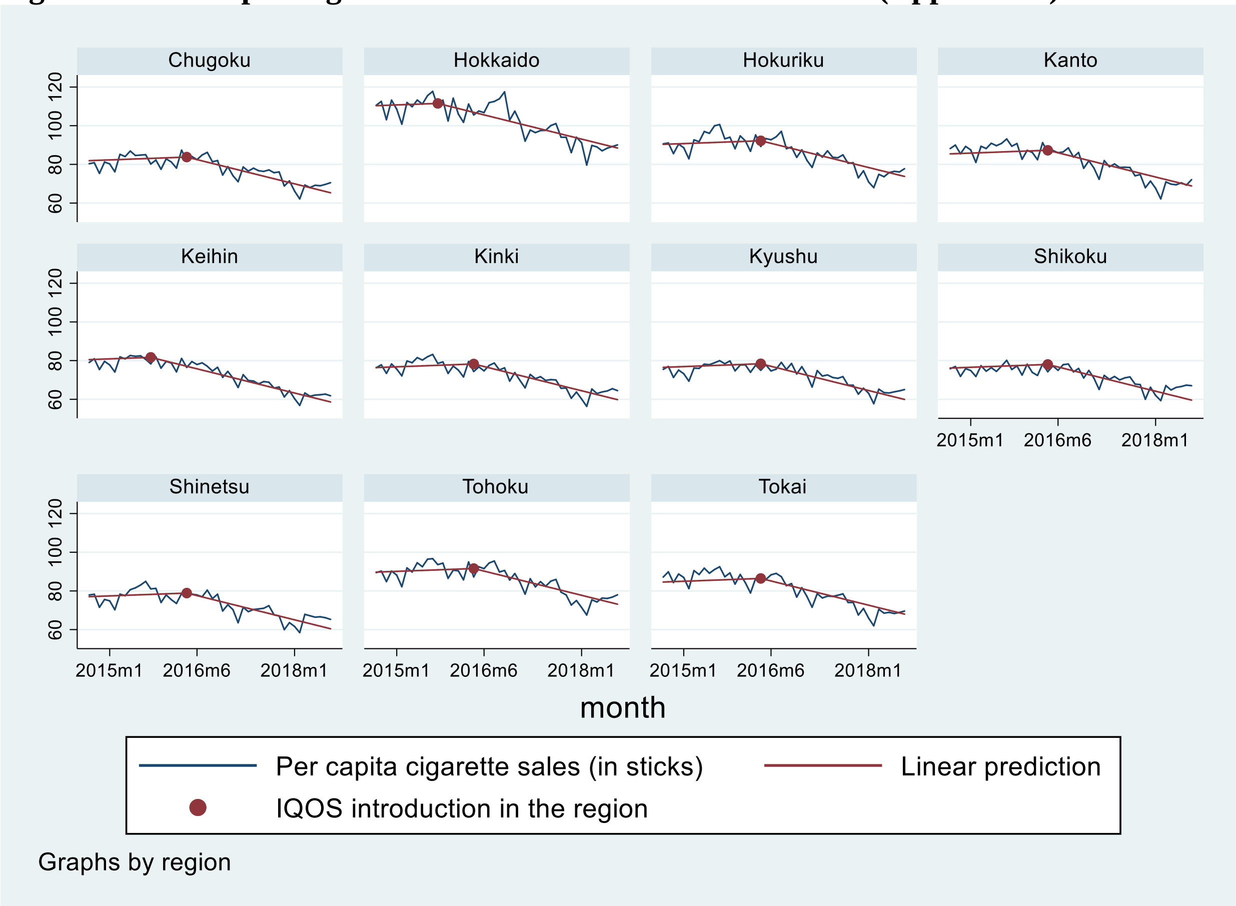
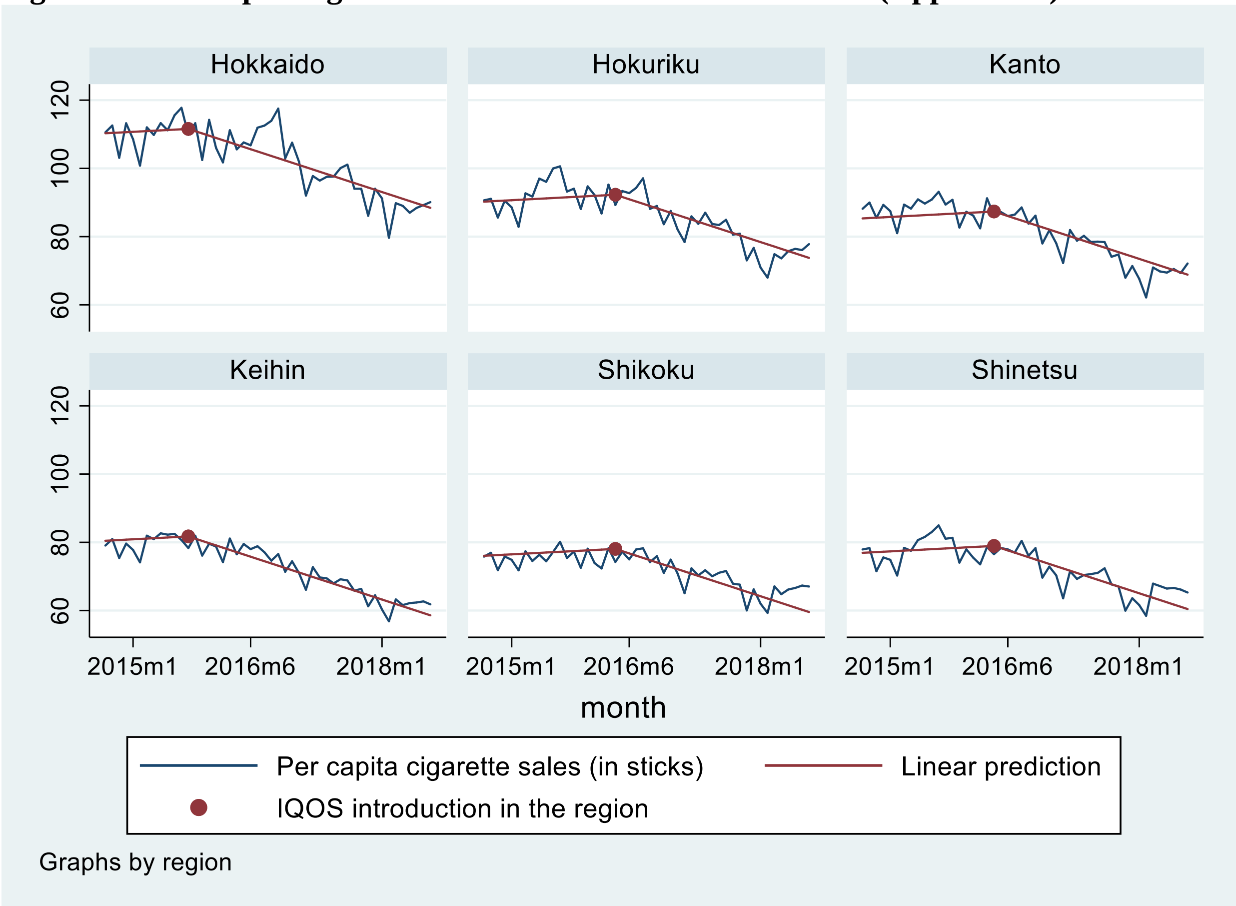


Figure 3.6. Per capita cigarette sales and the model fitted values (Approach 3)



The value of the R^2 statistic indicates that the true model with region-specific kinks at IQOS introduction fits the trends in cigarette sales in Japan better than any of the placebo models with month-specific kinks that are applied uniformly across all regions. From this result, we can conclude that regional IQOS introduction dates explain the timing of the decline in cigarette sales better than any national-level event, including the IQOS national rollout in April 2016.

The model based on the actual dates of introduction ranked in the top 98.5% (5th out of 330) of all possible placebo models with combinations of the original IQOS introduction months redistributed among regions in approach one. The model based on the actual dates of IQOS introduction also ranked in the top 92.7% (4th out of 55) of all possible placebo models in approach two, and in the top 86.7% (2nd out of 15) possible models in approach three. Table 3.3 presents the goodness of fit of the true introduction date models versus the placebo permutation models in each approach.

Table 3.3. Goodness of fit of the model using true IQOS introduction months vs. placebo models

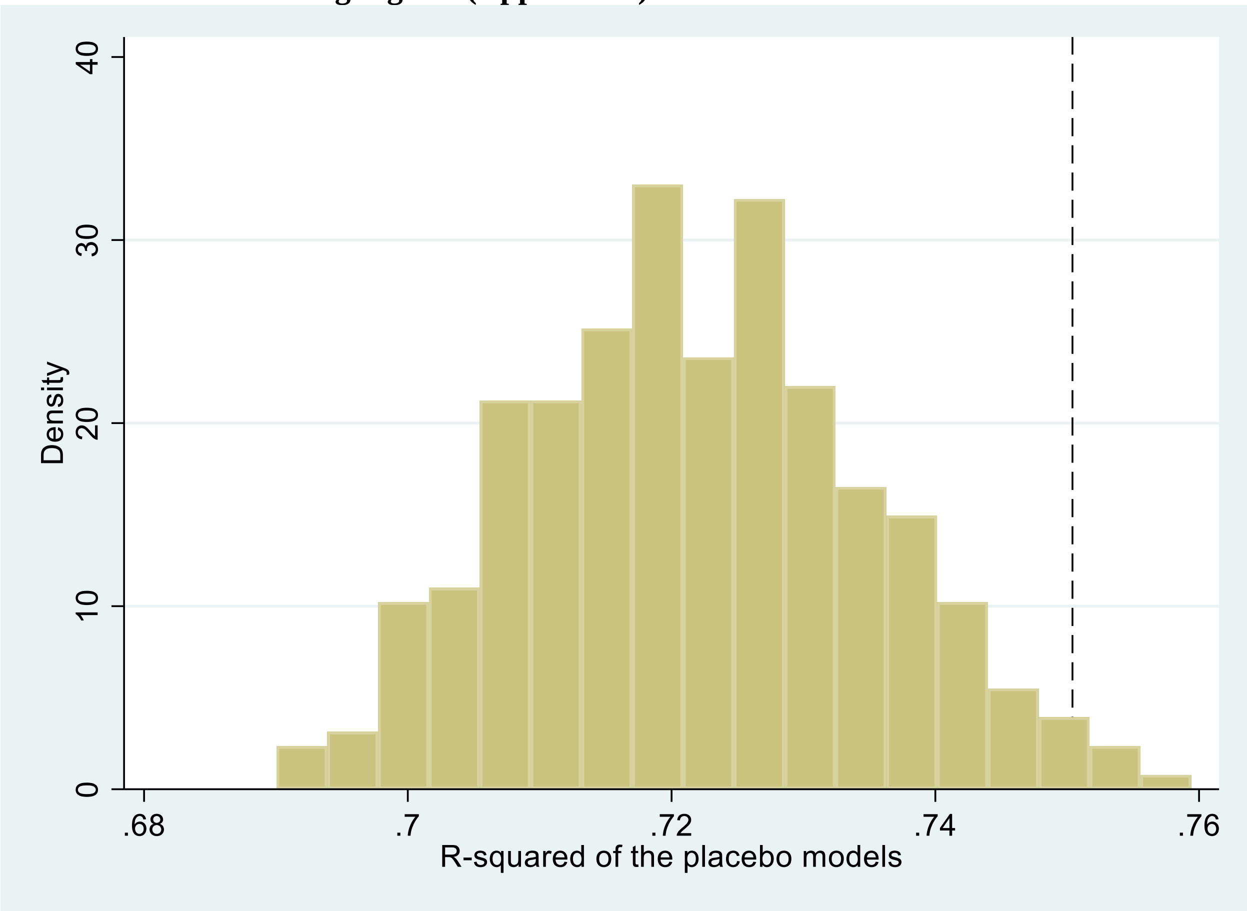
Approach	True Model R^2	Simultaneous National-Level Placebo Date Models – R^2 distribution				
		Months Tested	Mean R^2	Top 10%	Top 5%	Max
1	0.7504	47	0.6898	0.7416	0.7434	0.7456
2	0.7466	47	0.6898	0.7416	0.7434	0.7456
3	0.7452	47	0.6910	0.7391	0.7424	0.7449

Approach	True Model R^2	Exact Permutation Test: True Model and Placebo Dates – R^2 distribution						
		True Model Rank	Permutation Count	Significance Level	Mean R^2	Top 10%	Top 5%	Max
1	0.7504	5	330	1.5%	0.7219	0.7393	0.7440	0.7594
2	0.7466	4	55	7.3%	0.7290	0.7432	0.7479	0.7514
3	0.7452	2	15	13.3%	0.7230	0.7452	0.7486	0.7486

Note: For the simultaneous national-level placebo dates, n=47 (fourth-eight months in the dataset minus the first month). The larger the R^2 value the better the model fits. Ordering the models by the Akaike's and Schwarz's Bayesian information criteria (AIC and BIC) yielded the same results.

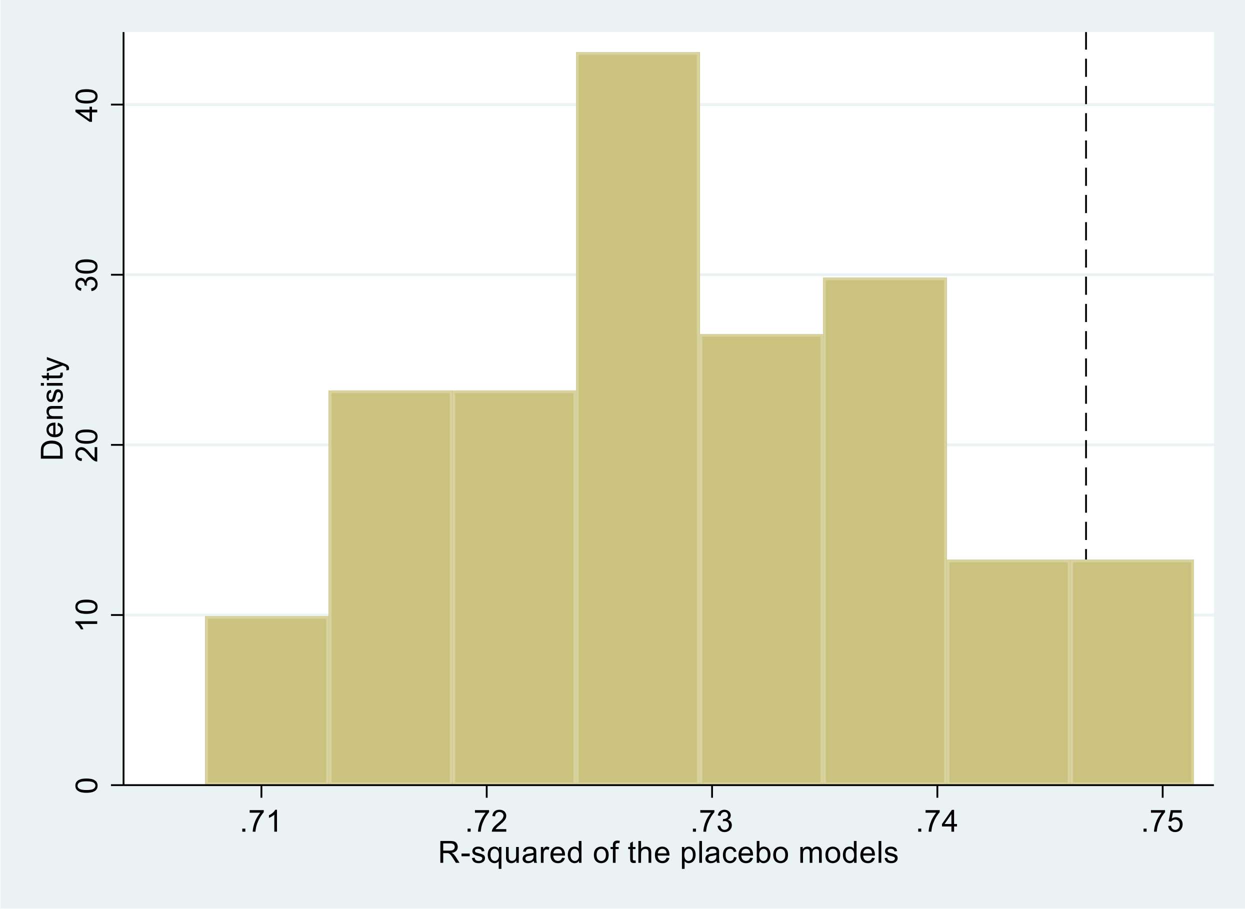
Figure 3.7 through Figure 3.9 present the histogram of the R^2 statistic for the placebo models in approaches one, two, and three, respectively, showing the placement of the test statistic for the true introduction date model amidst the null distributions. The results of this randomization test indicate that it is unlikely that the timing of the observed declines in cigarette sales are unrelated to IQOS introduction.

Figure 3.7. Distribution of R^2 values associated with all possible reassignments of IQOS introduction dates among regions (Approach 1)



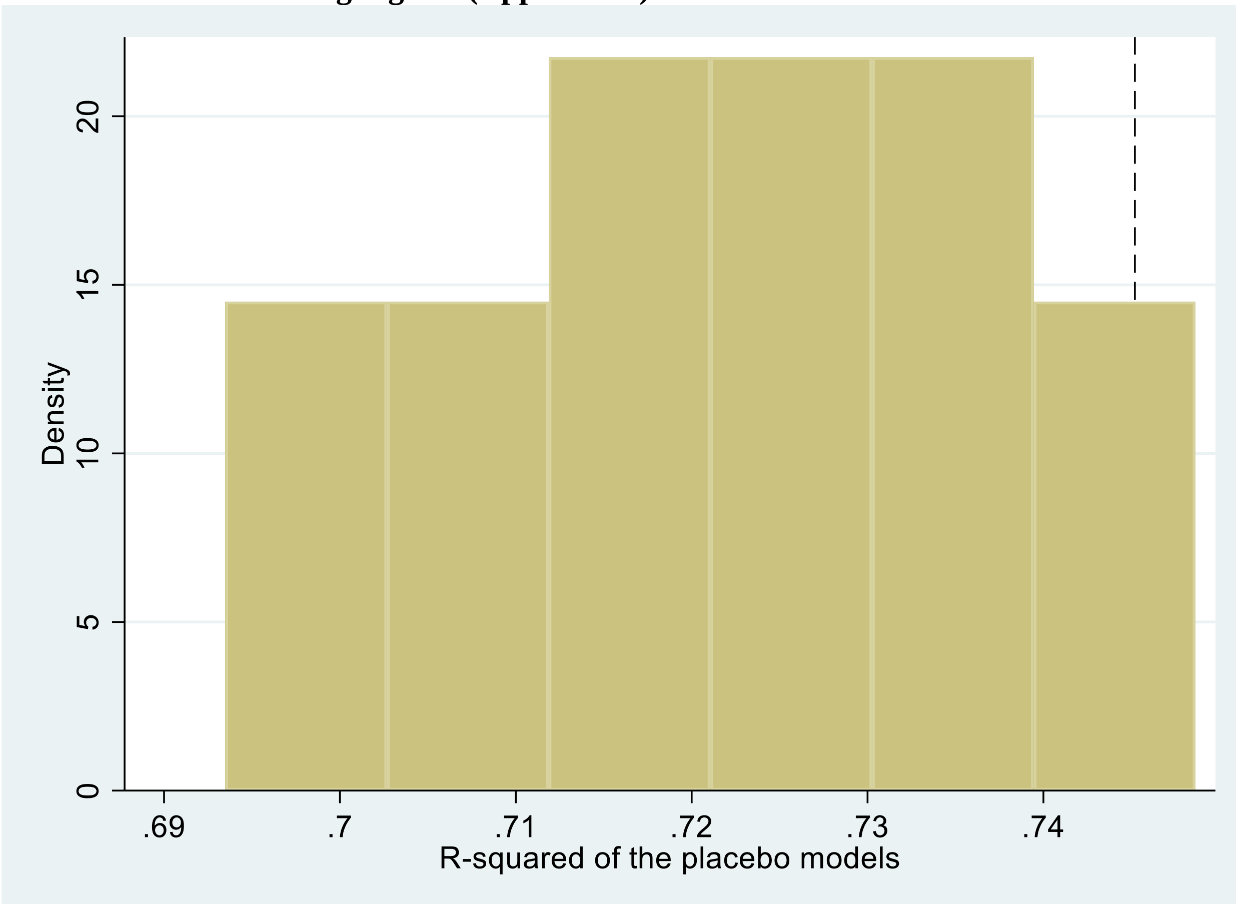
Note: The black dashed vertical line indicates r-squared of the true, original model in Approach 1

Figure 3.8. Distribution of R^2 values associated with all possible reassignments of IQOS introduction dates among regions (Approach *2*)



Note: The black dashed vertical line indicates r-squared of the true, original model in Approach 2

Figure 3.9. Distribution of R^2 values associated with all possible reassignments of IQOS introduction dates among regions (Approach *3*)



Note: The black dashed vertical line indicates r-squared of the true, original model in Approach 3

3.3.1. Robustness check

I performed several additional analyses to check the robustness of the findings presented above. Although the lack of variation in the price between the products, across the regions, and over the time period suggests that the observed changes in cigarettes sales cannot be explained by the product price, there are still other variables that economists typically use to model product demand. Economic models of product demand usually control for consumers' income. Additionally, because the data used in this analysis seems to fluctuate substantially on a monthly basis (Figure 3.3), it seems reasonable for the models to control for seasonality in the data. Therefore, in another set of models, I controlled for both income and seasonality. The Japan Statistical Office is the source for the average monthly household income and monthly inflation data (e-Stat 2018). Because the Statistical Office provides prefecture-level data, I constructed the regional monthly household income measure as the population-weighted average of the average incomes in the prefectures in each region. The income was then inflation-adjusted. Month-of-the-year dummies are included in the models to control for seasonality. However, controlling for income and seasonality in the models did not change the results significantly (Table 3.4).

Table 3.4. Goodness of fit of the model using true IQOS introduction months vs. placebo models (controlling for household income and seasonality)

Approach	True Model R^2	Simultaneous National-Level Placebo Date Models – R^2 distribution				
		Months Tested	Mean R^2	Top 10%	Top 5%	Max
1	0.9232	47	0.8730	0.9166	0.9183	0.9194
2	0.9215	47	0.8730	0.9166	0.9183	0.9194
3	0.9130	47	0.8676	0.9097	0.9114	0.9123

Approach	True Model R^2	Exact Permutation Test: True Model and Placebo Dates – R^2 distribution						
		True Model Rank	Permutation Count	Significance Level	Mean R^2	Top 10%	Top 5%	Max
1	0.9232	5	330	1.5%	0.8956	0.9125	0.9170	0.9323
2	0.9215	4	55	7.3%	0.9042	0.9190	0.9228	0.9262
3	0.9130	2	15	13.3%	0.8917	0.9130	0.9162	0.9162

Note: For the simultaneous national-level placebo dates, n=47 (fourth-eight months in the dataset minus the first month). The larger the R^2 value, the better the model fits. Ordering the models by the Akaike's and Schwarz's Bayesian information criteria (AIC and BIC) yielded the same results

The methodology used in this analysis is not commonly used in the field. The more standard approach to data from a natural experiment is a difference-in-difference model. The approach used in the analyses presented in this chapter is similar to the difference-in-difference or the two-way fixed effects methods. Like those methods, it examines whether the interaction between time and treatment/intervention is statistically significant. This is done by means of Chow's test in the current analysis. Moreover, the current method goes a step further in examining the causal effect of IQOS introduction on cigarette sales by performing a series of tests where the dates of IQOS introduction are randomly re-arranged between the geographical regions, to check whether the observed changes in trends in cigarette sales might be due to chance rather than to IQOS introduction. What distinguishes the current approach from the standard methods is that, in this analysis, both groups received the treatment (IQOS introduction), but at different times. The treatment group received it in September 2015 while the control group received it in April 2016. In standard methods, one group receives a treatment, while the other does not.

Therefore, in the second part of the robustness check, I truncated the data by removing observations from April 2016 to August 2018. This created a dataset of a standard natural experiment setting with two groups: the treatment group, which received IQOS in September 2015, and the control group, in which IQOS was not introduced. Using the two-way fixed effects model with the truncated data from Approaches 1, 2 and 3, again, did not change the results. The models still indicated that IQOS introduction in September 2015 affected trends in cigarette sales in the treatment group, compared to the control group ($p<0.001$ in Approach 1, $p=0.023$ in Approach 2, and $p=0.027$ in Approach 3). The results from that analysis are presented in Table 3.5.

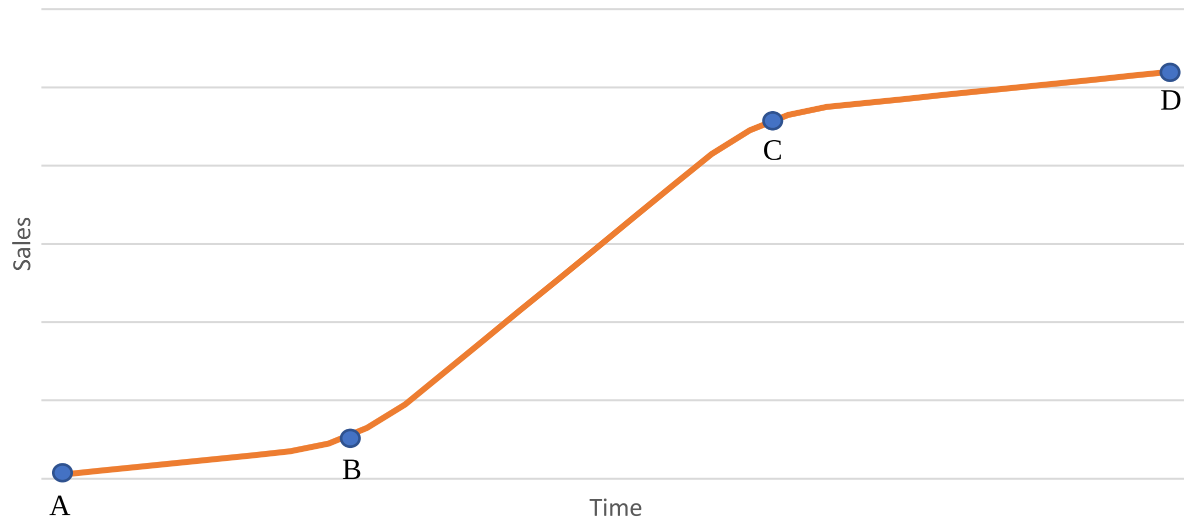
Table 3.5. Relationship between IQOS introduction and cigarette sales in Japan: a difference-in-difference approach

	Coefficient estimates		
	Approach 1	Approach 2	Approach 3
Time trend	0.17***	0.11**	0.13*
Interaction term between time and treatment group dummy	-1.00***	-0.74**	-0.80**
Constant	83.82***	84.19***	86.09***

Note: ***p<0.01; **p<0.05; *p<0.1;

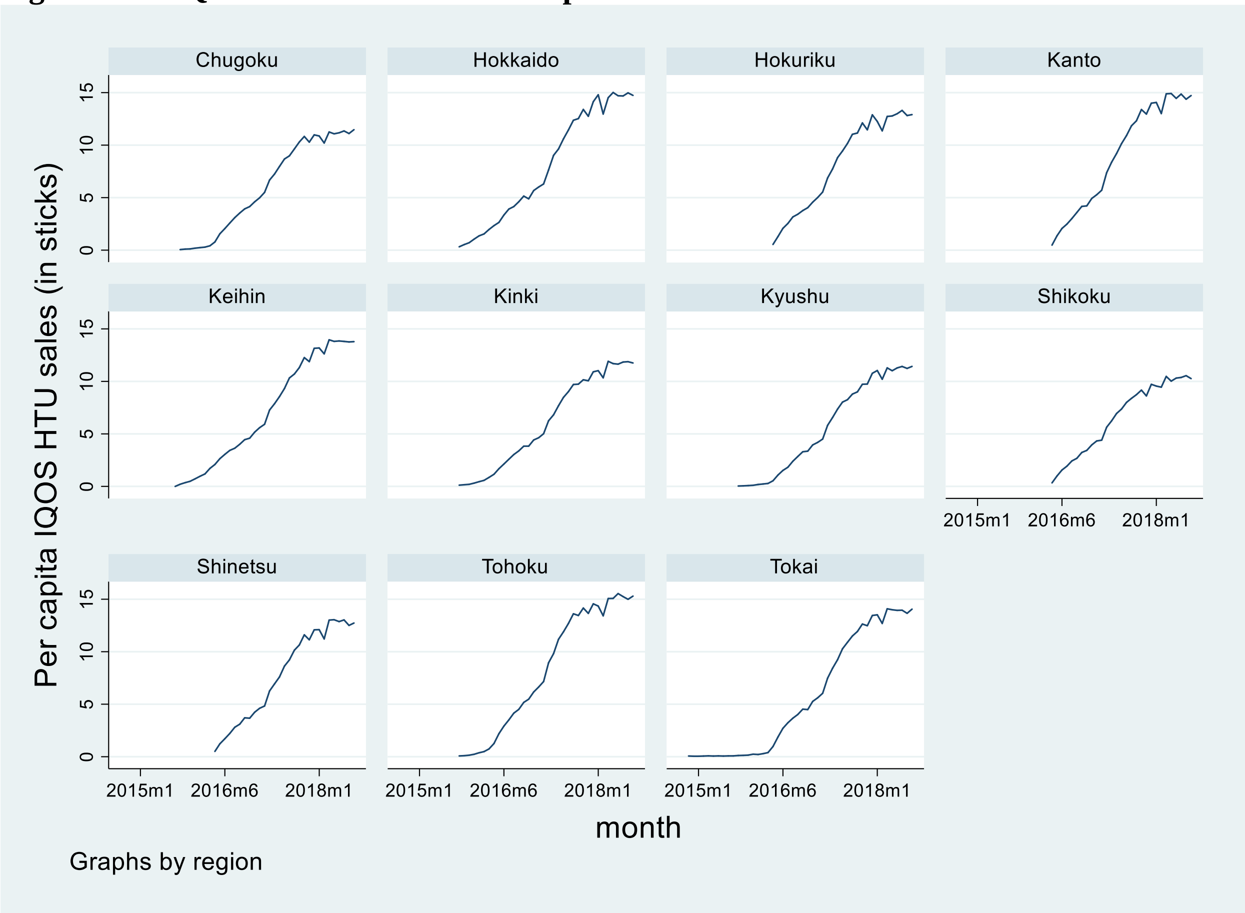
In the third part of the robustness check, I focused on the primary independent variable. The moment of product introduction might not be the best predictor of the onset of declines in cigarettes sales. As mentioned earlier, a newly-introduced product is often initially used by a small group of innovators and early adopters. It might take time for the product to be taken up by larger groups of consumers. Therefore, patterns of product diffusion are usually s-shaped, with low rate of growth in the sales just after product introduction (line segment AB in Figure 3.10), much higher growth in sales when the product is being widely adopted during the market expansion period (segment BC), and, again, a lower rate of growth at market saturation (segment CD) (Rogers 2003). In this chapter, I used point A at the new product market diffusion curve to predict the moment of the drop in sales of the old product that is being replaced by the new one. However, it might well be that point B (market expansion), and not point A (market introduction), would predict that moment better, because that is where the new product is really becoming accepted.

Figure 3.10. Typical patterns of product market diffusion



In most Japanese regions, IQOS diffusion followed the same s-shaped patterns as those observed for other products. Figure 3.11 presents those patterns by Japanese regions. It is reasonable to assume that if IQOS sales cause a reduction in tobacco cigarette sales, then cigarette sales should start sharply declining when the IQOS sales curve increases sharply (once the IQOS market begins to expand rapidly), as opposed to when the product is introduced. Therefore, in a separate set of models, I determined the time of IQOS market expansion and used that time to predict the drops in cigarette sales.

Figure 3.11. IQOS market diffusion in Japan



In the additional models, the month of IQOS expansion is determined by establishing an appropriate market volume threshold – the minimum level of sales volume that reliably and consistently predicts immediate and rapid diffusion of IQOS in a given region. Specifically, the IQOS expansion date in each region is defined by reaching a set threshold of heat sticks sold, which I set at one heat stick per capita per month in this case. The threshold of one heat stick per capita was chosen arbitrarily, since I could not find an industry document providing a definition of market expansion for either IQOS or cigarettes. This alternative method yields IQOS expansion dates that are different from the IQOS introduction dates used earlier in the chapter.

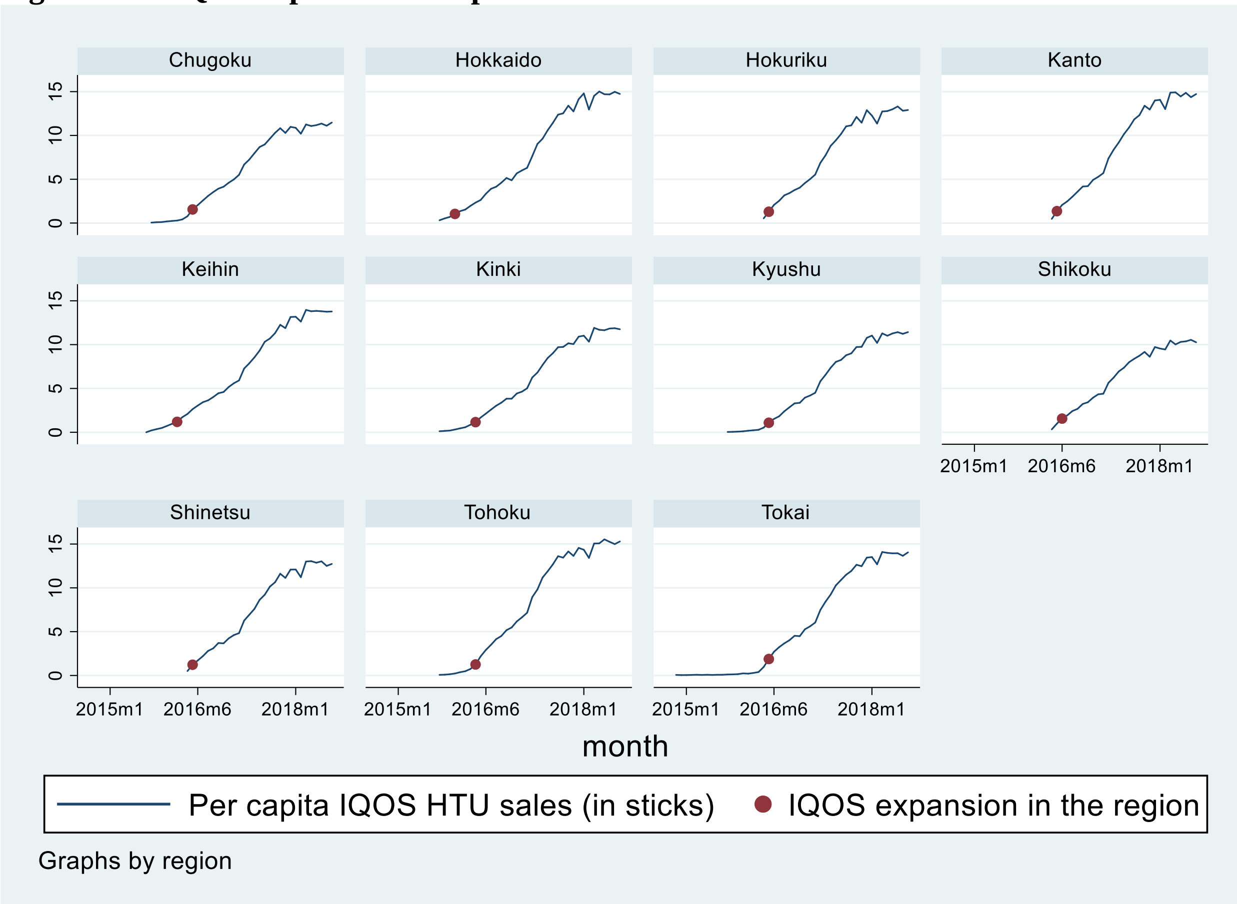
The regional IQOS expansion dates, as defined for the purpose of this robustness check, are presented in Table 3.6 and Figure 3.12. As expected, IQOS expansion dates fall around the time when the IQOS sales curve begins to climb. The variation in the expansion date across the regions is substantial – the date of IQOS expansion varies from December 2015 in Hokkaido to June 2016 in Shikoku.

Table 3.6. IQOS introduction and expansion by region

Region	**IQOS introduction date (Approach 1)**	**IQOS expansion date**
Chugoku	Apr-16	May-16
Hokkaido	Sept-15	Dec-15
Hokuriku	Apr-16	May-16
Kanto	Apr-16	May-16
Keihin	Sept-15	Feb-16
Kinki	Sept-15	Apr-16
Kyushu	Apr-16	May-16
Shikoku	Apr-16	June-16
Shinetsu	Apr-16	May-16
Tohoku	Apr-16	Apr-16
Tokai	Sept-15	May-16

Note: IQOS expansion is defined as the first month the IQOS sales reached one heat stick per person per month.

Figure 3.12. IQOS expansion in Japan



The "changing growth" time-trend model (Perron 1989) and the Chow test (Chow 1960) were, again, used to perform this robustness check. This time, they were used to check whether cigarette sales followed the same trends before and after IQOS expansion in Japan. Again, the null hypothesis in the test is that the trend in per capita cigarette sales remained stable over time. The results of those models were similar to the results on IQOS introduction, presented earlier in this chapter. The high value of the Chow test statistic indicates that the null hypothesis of the stability of the trend should be rejected (F= 251.90, P<0.001). This means that the trend lines for per capita cigarette sales were kinked at the time of expansion of IQOS heated tobacco products in each of the eleven Japanese regions. Estimates from the test's underlying model indicate that, across all regions, per capita cigarette sales were slightly increasing before the introduction of IQOS (at a rate of 0.07 cigarettes per person per month on average) but started to decline after the IQOS expansion (declining at a rate of 0.69 cigarettes per person per month).

The comparison of the original model, explaining the trends in cigarette sales by IQOS expansion, to the set of placebo models was, again, favorable to the true introduction date model. IQOS introduction, which varied across regions, better predicted the timing of cigarette sales decline than any one month in all regions (a national-level exogenous shock). Table 3.7 presents the goodness of fit of the true introduction date model compared to all possible simultaneous national-level placebo date models.

Checking if cigarette sales declined with IQOS expansion and not by chance is more complicated. Unlike the analysis based on IQOS introduction, where there were only two groups of IQOS introduction dates (September 2015 and April 2016), there are five groups of dates of IQOS expansion to consider (one region with assigned an expansion date in December 2015, one in February 2016, two in April 2016, six in May 2016, and one in June 2016). Therefore, while in the analysis based on the IQOS introduction dates there were at most 330 possible combinations of introduction dates, in this analysis based on expansion dates there are 27 720 possible combinations of the expansion date (11x10x(9!/(2!(9-2)!))x(7!/(6!(7-6)!))x1=27720).

This number of possible permutations is impractically large. While it was relatively easy to program the statistical software so that all possible 330 permutations are included in the analysis presented earlier in this chapter, it would take much more time to program the almost twenty-eight thousand models required for the exact permutation test in this case. Fortunately, the statistics literature proposes a solution for instances when performing an exact permutation test becomes impractical. Statisticians note that the p-value of the exact premutation test can be approximated by using only a random sample from all permutations (Marozzi 2004). Therefore, the statistical approach employed to check whether cigarette sales declined with IQOS expansion and not as a result of chance were as follows: first, as in the analysis presented earlier in the chapter, the exact set of months of IQOS expansion were repeatedly redistributed so that one or more regions were assigned an IQOS expansion date that was associated with a different region. Secondly, unlike the analysis based on the IQOS introduction dates, where the time-trend model was estimated on all possible combinations of IQOS introduction dates, in this case the models were estimated only on a sub-set of all possible combinations of IQOS expansion dates. The statistical literature suggests that a sample of 5000 permutations is sufficient to approximate the result of the exact permutation test (Marozzi 2004). Using this approach, instead of programming all possible 27 720 permutations, which would be time-consuming, I programmed the software to randomly select one combination of IQOS introduction dates at a time and, if that exact combination was not previously chosen, to estimate the model and store the R^2 value.

The model based on the actual dates of expansion ranked in the top 98% (100th out of 5001) of a sample of all possible placebo models with combinations of the original IQOS expansion months redistributed among regions. Table 3.7 presents the goodness of fit of the true model versus the placebo permutation models, while Figure 3.13 presents the histogram of the R^2 statistic for the placebo models, showing the placement of the test statistic for the true model in the null distribution. The results of the randomization test once more indicate that it is unlikely that the timing of the observed declines in cigarette sales is unrelated to the appearance of IQOS on the Japanese market.

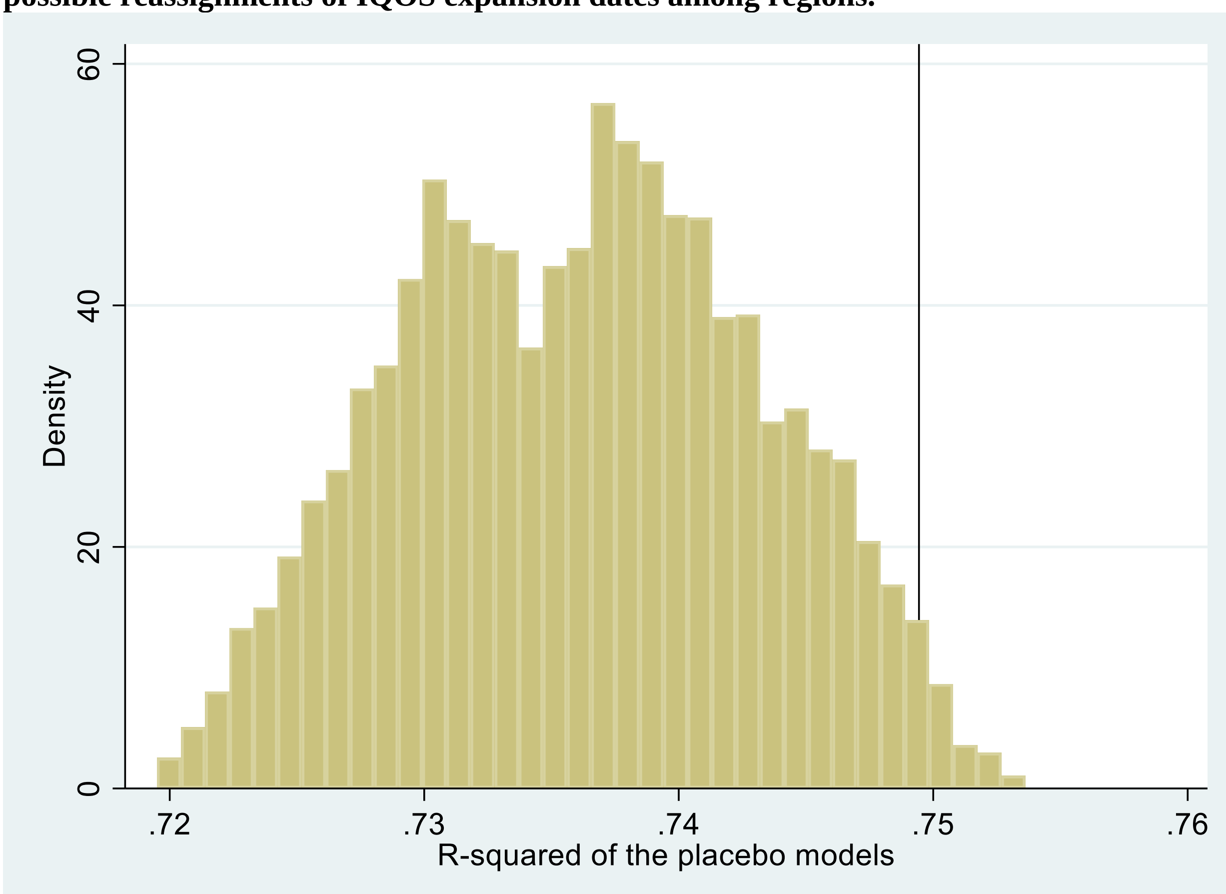
Table 3.7. Goodness of fit of the model using true IQOS expansion months vs. placebo models

True Model R^2	Simultaneous National-Level Placebo Date Models – R^2 distribution				
	Months Tested	Mean R^2	Top 10%	Top 5%	Max
0.7494	47	0.6898	0.7416	0.7434	0.7456

True Model R^2	Permutation Test: True Model and Placebo Dates – R^2 distribution						
	True Model Rank	Permutation Count	Significance Level	Mean R^2	Top 10%	Top 5%	Max
0.7494	100	5001	2.0%	0.7361	0.7457	0.7476	0.7536

Note: For the simultaneous national-level placebo dates, n=47 (fourth-eight months in the dataset minus the first month). For the permutation test, n=5001 (the original model plus a sample of five thousand models with placebo dates). The larger the R^2 value the better the model fits. Ordering the models by the Akaike's and Schwarz's Bayesian information criteria (AIC and BIC) yielded the same results.

Figure 3.13. Distribution of R-squared values associated with a sample of five thousand possible reassignments of IQOS expansion dates among regions.



Note: The black vertical line indicates R-squared of the true, original model

The fourth part of the robustness check also focused on the primary independent variable. In the analyses presented in this chapter so far, the trends in cigarettes sales were being explained by a single event: IQOS introduction or IQOS expansion. Another issue that requires closer examination is how cigarette and heat stick sales volumes are related. Are the cigarettes being replaced by heat sticks at a one-to-one ratio? Are the regions with higher growth in IQOS heat stick sales also experiencing larger drops in sales of regular, combustible cigarette?

To answer these questions, I devised a test similar to the one presented above. Regional, monthly per capita cigarette sales were regressed on IQOS heat stick sales using a fixed-effects model. The model was specified as follows:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_i + \varepsilon_{it}$$

where β_0 is an intercept, α_i is a set of fixed regional constants, and ε_{it} is the error term. The dependent variable in this model (y_{it}) is per capita cigarette sales volume in a given region (i) in a given month (t). The independent variable is the per capita Heatsticks sales (x_{it}) and α_i is a set of fixed regional constants. If a link between IQOS and regular cigarette use exists, IQOS sales will be reflected in the patterns of cigarette use. To establish more confidently that the association between IQOS and cigarette sales is not due to chance, I employed a permutation test in which the set of actual observed IQOS per capita sales was repeatedly redistributed so that one or more regions were assigned the IQOS sales originally associated with a different region. The model with the new combination of the IQOS sales was then estimated and the R^2 recorded. Since there are 39 916 800 (or 11 factorial) possible rearrangements of the original IQOS sales among the eleven regions, performing an exact permutation test is, again, impractical. Therefore, following the statistical literature (Marozzi 2004), the procedure was repeated on a sample of five thousand possible rearrangements of the original IQOS per capita sales.

Table 3.8. Relationship between cigarette and IQOS sales in Japan, fixed-effects regression

	Coefficient estimates	Standard Error
IQOS sales (Heatsticks per capita)	-1.20***	0.03
Constant	85.72***	0.23

Note: N=528, R^2=0.7327,*** p<0.001

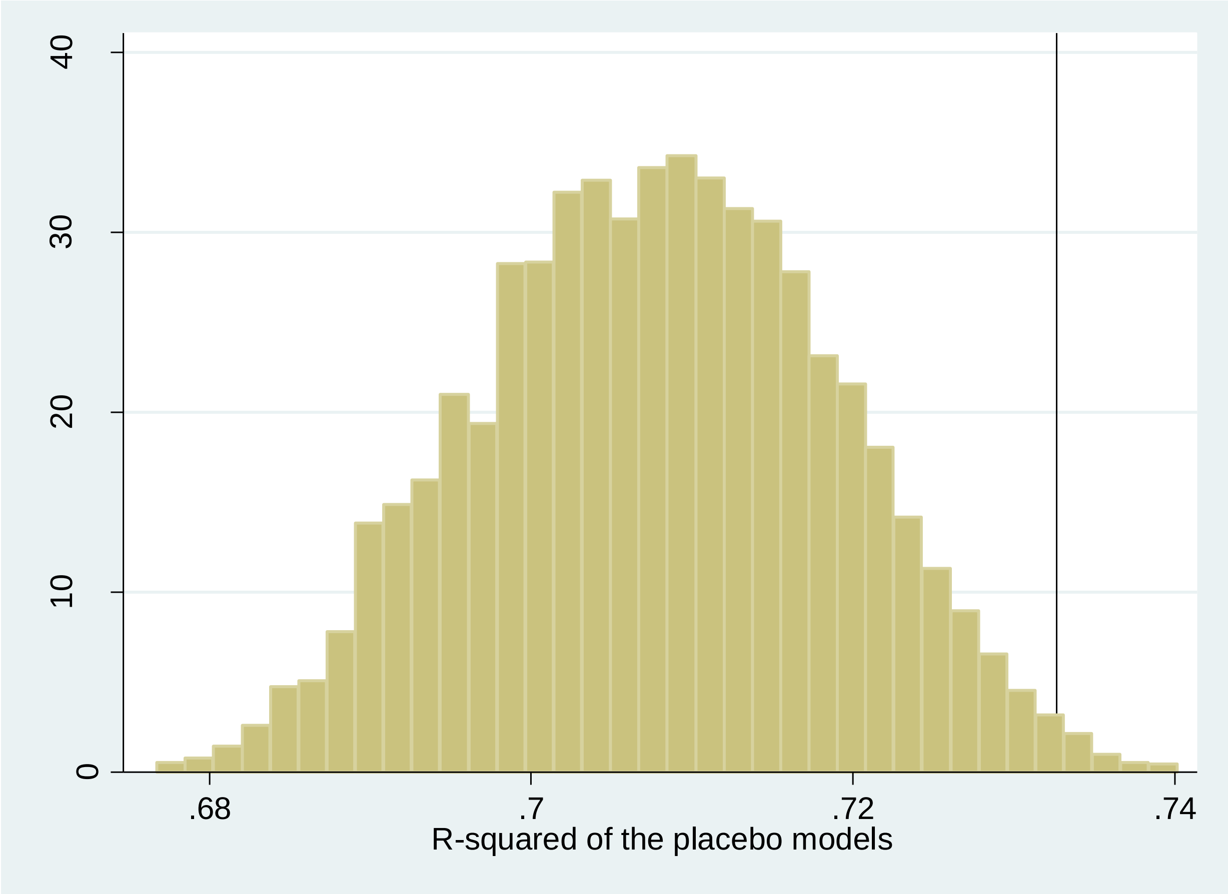
Estimates from the test's underlying model indicate that, across all regions, per capita cigarette sales declined by 1.2 cigarette sticks per person (95% CIs [-1.26, -1.13]) with each IQOS sales increase of one Heatstick per person (Table 3.8). This suggests that cigarettes were being replaced by IQOS heat sticks on the Japanese market. The model based on the actual IQOS sales ranked in the top 99% (46th out of 5001) of a sample of all possible placebo models with combinations of the original regional IQOS per capita sales redistributed among regions. Table 3.9 presents the goodness of fit of the true model against the placebo permutation models, while Figure 3.14 presents the histogram of the R^2 statistic for the placebo models, showing the placement of the test statistic for the true model in the null distribution. The results of this randomization test, yet again, indicate that it is very unlikely that cigarette sales were not causally related to IQOS sales.

Table 3.9. Goodness of fit of the model using true IQOS per capita sales vs. placebo models

True Model R^2	**Permutation Test: True Model and Placebo Sales – R^2 distribution**						
	True Model Rank	**Permutation Count**	**Significance Level**	**Mean R^2**	**Top 10%**	**Top 5%**	**Max**
0.7327	46	5001	0.9%	0.7078	0.7222	0.7260	0.7402

Note: For the permutation test, n=5001 (the original model plus a sample of five thousand models with placebo sales). The larger the R^2 value the better the model fits. Ordering the models by the Akaike's and Schwarz's Bayesian information criteria (AIC and BIC) yielded the same results.

Figure 3.14. Distribution of R-squared values associated with a sample of five thousand possible reassignments of IQOS sales among regions.



Note: The black vertical line indicates r-squared of the true, original model

3.4. Discussion

The results of this study show that it is very likely that the introduction of IQOS reduced per capita cigarette sales in Japan. It is difficult to come up with alternative explanations that can account for why the true month of IQOS introduction predicts when cigarette sales began to decline in each region better than nearly all possible placebo permutations that redistribute IQOS introduction months across regions. Since IQOS introduction, which varied across regions, better predicted the timing of cigarette sales decline than any one month across all regions, one can conclude that it is not likely that a national-level exogenous shock was the true cause of the observed decline in cigarette sales. In particular, there was no national-level tobacco control legislation implemented near the time of IQOS introduction. Japan adopted its first national smoke-free legislation in mid-2018, which is being implemented in phases through April 2020 (Associated Press 2018). Patterns of cigarette use could not be affected by pricing of the products either. Prices of IQOS and cigarettes were very similar (21 yen per Heatstick vs. 20 yen per cigarette stick) and stable across regions throughout the analysis, making the standard demand analysis inexecutable. Because there was little variation in the price variable, it was not possible to use standard economic methods of establishing product substitutability to estimate cross-price elasticities of product demand, such as those presented in chapter two. Additionally, attempts to control for monthly household income and seasonality did not change the models' results. Cigarette sales trends might have also been affected by the rollout of products competing with IQOS, such as British American Tobacco's Glo and Japan Tobacco's Ploom Tech, but those products were launched nationally much later than IQOS – in late 2017 and in 2018, respectively (British American Tobacco 2019; Japan Tobacco International 2019) – and their use did not expand nearly as quickly as the use of IQOS (Tabuchi et al. 2018). Since most existing regulations have been voluntary self-regulation by the industry itself (Katanoda et al. 2014), their implementation locally could, theoretically, coincide with IQOS introduction. Alternatively, PMI could have chosen to introduce IQOS in prefectures that they anticipated would have a rapid decline in cigarette sales even without IQOS. However, these alternative scenarios are not likely. In the past, the tobacco industry has selected test markets for new product rollouts that are representative of the total market (Tobin 1986; RJ Reynolds 1989; Roper 1994). It is therefore far more likely that PMI chose places in Japan for the early-stage IQOS introduction so that they could anticipate what would happen in a national rollout. By doing so, they created the natural experiment which was used for this study.

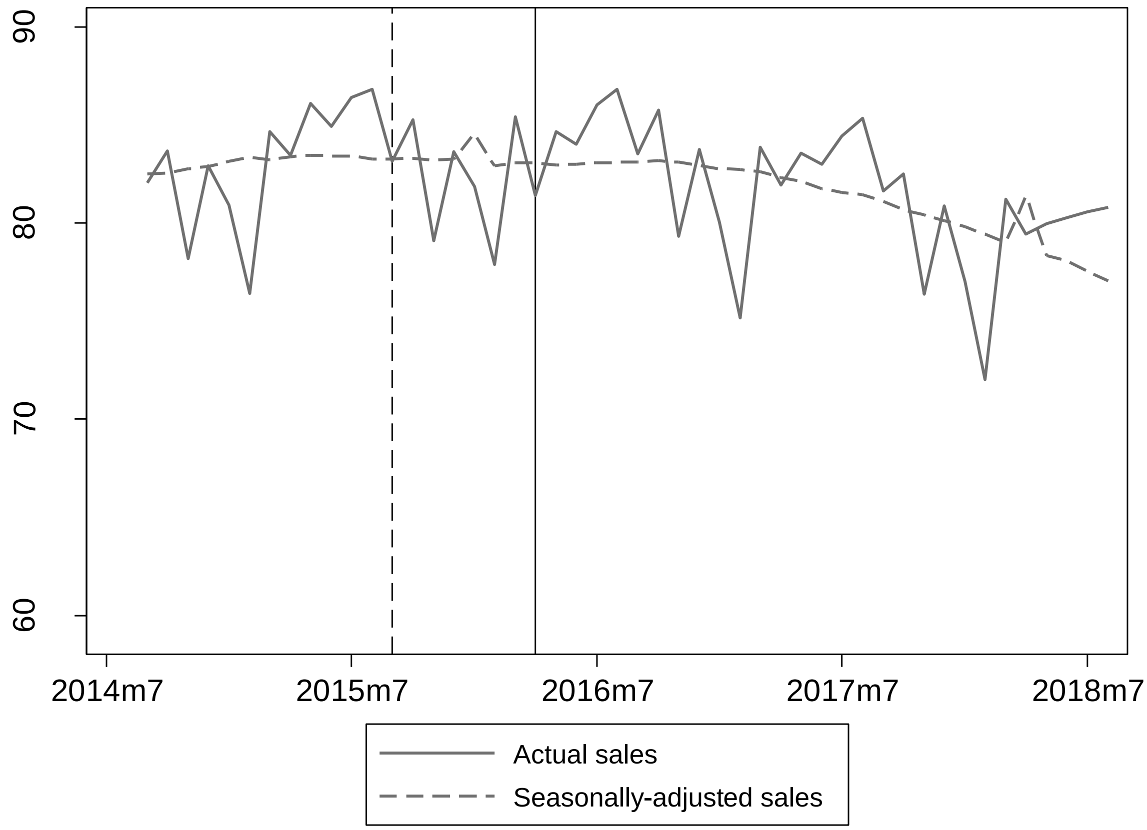
The impact of the replacement of IQOS for tobacco cigarette in Japan on population health is highly dependent on factors that cannot be determined from sales data alone. Every cigarette consumed has a causal impact on disease, but a reduction in sales, driven by reduced prevalence, which is caused by reduced smoking initiation or increased smoking cessation would have far more clinical meaning than one driven by a prolonged reduction in smoking intensity among dual users (e.g., using both cigarettes and IQOS). Also, using PMI's product equivalence rate of one heat stick per cigarette (Philip Morris International 2019c), it appears that the combined sales of IQOS and tobacco cigarettes were relatively stable in Japan during this period, especially until mid-2017 (Figure 3.15). However, it is unknown whether the availability of HTPs will lead to more or to less total tobacco product use over time. Perhaps most importantly, it is not currently possible to reach confident conclusions about the level of direct harm users will experience from IQOS use, and how this compares to the harms of smoking. Therefore, unless smokers are successfully using IQOS as a short-term cessation device, there may be uncertain and potentially substantial risks associated with prolonged use of IQOS.

Regardless of whether the product will have a negative or positive impact on population health in the long-run, it seems that it is already beneficial for PMI. According to the company, IQOS retail value amounted to over 10 billion USD in 2018 (Philip Morris International 2019b), contributing substantially to PMI sales totals, which have been otherwise undermined by drops in cigarette sales. In many countries, the product obtained preferential tax rates (Liber 2018) and does not have to adhere to the same strict tobacco control regulations as cigarettes. For example, as of 2019, all cigarette packs sold in France are standardized and bear a large pictorial health warnings, while the packs of IQOS heatsticks are still being sold in appealing packages with only a small text warnings. This special status gives a lot of market advantage to the new product.

It may not be possible to generalize from patterns of IQOS use and smoking in Japan to other countries or products. Higher rates of adoption of charcoal filter cigarettes in previous decades may be evidence of a greater priority being placed on perceived reductions in harm by Japanese smokers (Assunta and Chapman 2008). The unique characteristics of the Japanese regulatory environment may also play a role, including a highly-restrictive approach to non-tobacco vapor products such as e-cigarettes (Kennedy et al. 2017), perhaps increasing the likelihood that HTPs substitute for higher-exposure tobacco cigarettes as opposed to lower-exposure ENDS, such as e-cigarettes. In particular, it is uncertain if the findings of this study can be used to predict the effects of an IQOS launch in the United States. PMI filed an application with the US Food and Drug Administration (FDA) to commercialize the product in the United States (U.S. Food and Drug Administration 2019a), which was recently approved (U.S. Food and Drug Administration 2019b). It is reasonable to expect that in the US, unlike Japan, PMI will price IQOS at lower levels than cigarettes, given its global pricing strategy: a recent international analysis of IQOS prices showed that among 26 countries with IQOS price data, in 24 countries (92%) PMI priced IQOS products at lower levels than regular cigarettes, with the Eastern European countries of Latvia and Ukraine being the only two countries where IQOS costs more than the equivalent in traditional cigarettes (Liber 2018). Apart from the ability to price the product at lower levels than cigarettes, PMI also has substantial market power in the United States. Philip Morris USA controlled more than half of the US cigarette market in 2017 (Altria 2019). In addition, while Philip Morris's Marlboro brand is the number one cigarette brand in all 50 US states (Altria 2019), Marlboro is also a brand that PMI uses on its IQOS products globally. It stands to reason that PMI will use the vast market power of its US sister company for a vigorous IQOS expansion.

There are several limitations to the methodological approach employed in this chapter. First, the measure of product use is not perfect. Sales might not reflect product use exactly, with some of the purchased product never being used or being used at a later period, and some of the product purchased in one region being used in another region. Secondly, the data used in this analysis capture cigarette sales in Intage-participating stores only. Cigarette sales captured by Intage (109 billion sticks sold in 2017) account for 72% of the total cigarette market in Japan from Euromonitor International (151 billion cigarettes sold in 2017) (Euromonitor International 2019), suggesting the Intage market coverage data are considerable but not complete. Fortunately, the trends in cigarette sales from Intage are consistent with those from Euromonitor. Like the Intage data, Euromonitor data indicate that cigarette sales were relatively stable before IQOS introduction in Japan (1.8% average annual decline from 2011 to 2015), but significantly declined during and after IQOS introduction (9.5% average annual decline from 2015 to 2018) (Euromonitor International 2019). Lastly, specific unknown peculiarities of the methods Intage used to estimate regional market sizes, based on data from a sample of stores, the details of which are not available for this study, might affect the results. Nevertheless, despite these challenges, the models produce results that are significant and robust.

Figure 3.15. Combined per capita cigarette and IQOS heat stick sales in Japan



Note: Trends seasonally-adjusted using US Census Bureau's X-13ARIMA-SEATS model. The dashed vertical line indicates September 2015 IQOS introduction, while the solid vertical line indicates April 2016 IQOS introduction.

3.4.1. Conclusions

The example of IQOS in Japan demonstrates a circumstance in which cigarette consumption has probably been reduced through the introduction of an alternative non-combustible tobacco product. That the introduction of a novel tobacco product significantly changes the marketplace for tobacco products is important information for policymakers and public health proponents as they consider how to alter existing tobacco control policies to accommodate these new products. The mechanisms that drove the changes in Japan deserve more attention from scholars in order to identify what lessons in policy formation ought to be transferred to other jurisdictions. The net population health impact, however, cannot be assessed without resolving several uncertainties related to the direct harms of IQOS and patterns of both smoking and IQOS use.

The study presented in this chapter also adds to the growing literature on causal inference. Although the methodology borrows from the regression discontinuity literature, the use of this method in the time-series analysis is novel. Using a natural experiment setup created during the rollout of IQOS on the Japanese market, I tested whether different dates of IQOS introduction across Japan's regions are reflected in the patterns of cigarette sales in those regions. I found that IQOS introduction, which varied across regions, better predicted the timing of cigarette sales decline than any one month across all regions (a national-level exogenous shock), and also than nearly all possible rearrangements of the true IQOS introduction months among the regions (exact permutation tests). Those findings allow, with reasonable confidence, the inference that the relationship between cigarette sales and IQOS introduction in Japan is causal.

4. CHAPTER FOUR: PRICE DIFFERENTIALS BETWEEN GEOGRAPHICAL REGIONS[4]

4.1. Introduction

As an alternative to substituting from cigarettes to other tobacco products, some cigarette smokers are switching to cigarettes from other jurisdictions. In this case, instead of substituting their product for another product, they substitute it for the same product, but purchased elsewhere. The existence of between-region price differences incentivizes some smokers from regions with higher cigarette prices to switch to cheaper cigarettes available across the border (e.g., of a state, province or country). This substitution is a threat to public health, because smokers who substitute to cheaper cigarettes from other jurisdictions are less likely to quit smoking or cut down on their tobacco consumption.

Tobacco companies have made the possibility of such product substitution their staple argument against any new tobacco control regulations. Policymakers around the world are warned that a massive illicit cigarette trade will follow not only any tobacco tax increase, but also package regulations, display bans, and virtually any other new tobacco control measure (Drope et al. 2018). Numerous academic studies have shown that such claims are largely overstated. For example, in South Africa, the tobacco industry created the impression that illicit cigarette trade was rapidly growing, when, even according to the industry's own estimates, this was not the case (Van Walbeek and Shai 2014). Nevertheless, there is a general lack of peer-reviewed research on the

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[4] This chapter is an updated version of manuscript previously published in the *Tobacco Control* journal (Stoklosa 2018b). I would like to thank the three anonymous referees for their valuable comments and inputs to this study.

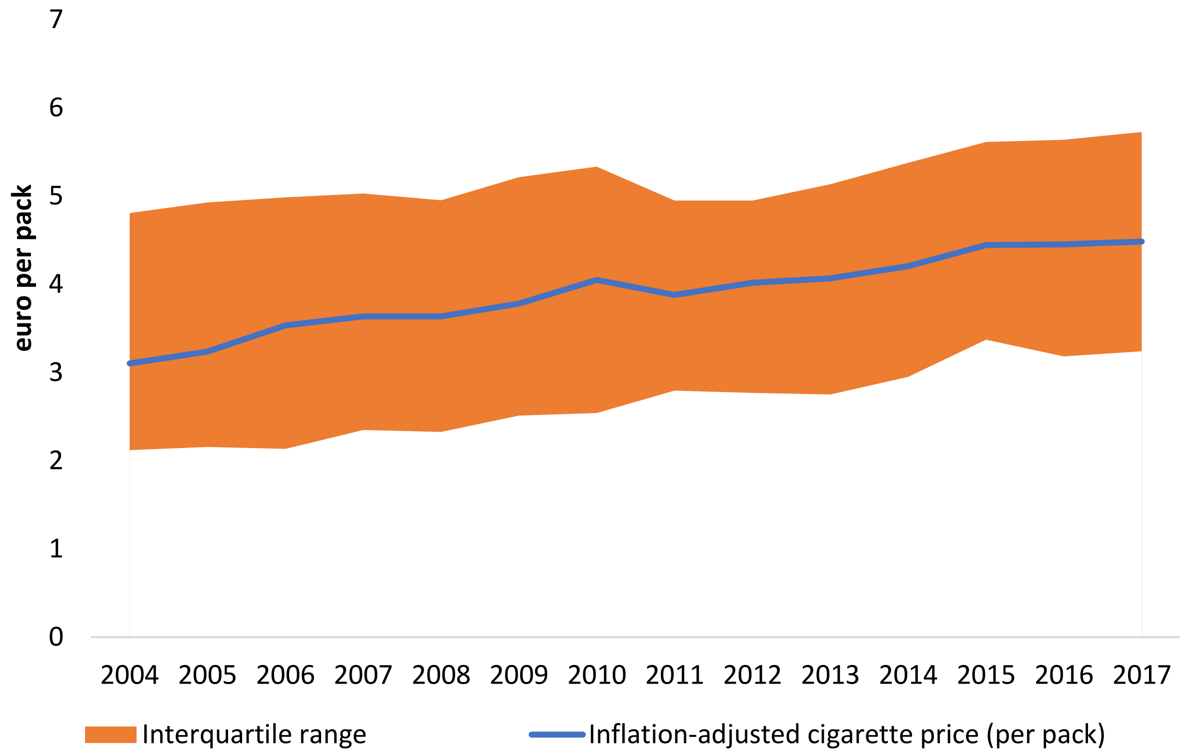
magnitude of the substitution toward undutied cigarettes (Van Walbeek et al. 2013; Gallagher et al. 2019).

Given the general lack of credible evidence on the effect of between-region cigarette price differentials on the magnitude of cross-border tobacco product substitution, this chapter will explore whether the differences in cigarette prices between neighboring countries are associated with cross-border cigarette purchasing. The study is conducted using data from the European Union (EU). The EU Tax Directives are a set of regulations intended to harmonize cigarette prices between Member States to prevent such cross-border purchases and to ensure the proper functioning of the internal market of the union (Blecher, Ross, and Stoklosa 2014), but the evidence suggests that so far there has been mixed success in achieving price harmony (Lopez and Stoklosa 2018a). The analysis in this chapter will, therefore, not only help to assess the scale of cross-border tobacco product substitution, but will also evaluate the effectiveness of the Tax Directives.

4.2. Background

The European Union's (EU) Tobacco Tax Directive (The Council of the European Union 2011), through its minimum tax requirements, is the major driving force behind cigarette tax increases in the region (Blecher, Ross, and Stoklosa 2014; Bouw 2017). Those tax increases have resulted not only in significant drops in smoking prevalence in Europe (Gallus et al. 2006), but also serve to safeguard Member States' budgetary revenue (Stener Pedersen et al. 2014). Nevertheless, substantial differences in cigarette prices between Member States still exist (Lopez and Stoklosa 2018a). Although inflation-adjusted cigarette prices have been steadily increasing, variation in cigarette prices across EU member states persist (see Figure 4.1). Despite tax harmonization efforts in the EU, cigarette prices in the countries from Eastern and South-Eastern Europe, which joined the EU relatively recently, have not yet reached the levels of the cigarette prices in the rest of the Union. In addition, as in the case of Zambia described in chapter two, significant differences between cigarette and roll-your-own prices still exist in most EU Member States. In 2015, twenty roll-your-own cigarettes cost, on average, almost one euro less than a pack of cigarettes (Lopez and Stoklosa 2018a).

Figure 4.1. Evolution of cigarette prices in the EU, 2004-2017



Source: Author's own graph based on data gathered from the European Commission (European Commission's Taxation and Customs Union 2018b) for a manuscript previously published in *Tobacco Control* (Lopez and Stoklosa 2018a).

The Directive specifies that the overall excise rate on cigarettes must be (a) at least EUR 90 per 1000 cigarettes and (b) at least 60% of the weighted average retail selling price in the Member States that apply an excise duty of less than EUR 115 per 1000 cigarettes (The Council of the

European Union 2011). The minimum tax rates applicable under the Directive have not been revised since 2010 (The Council of the European Union 2010). However, a revision of the minimum rates is being considered as of December 2018 (European Commission's Taxation and Customs Union 2018c), making the analysis of the impact of cigarette prices on tax avoidance and evasion timely and germane.

Tobacco tax avoidance refers to legal activities undertaken in order to pay less tobacco tax, or none at all, and includes cross-border purchasing of tobacco products within the legal limits for smokers' own consumption (Joossens and Raw 2012). Tobacco tax evasion, on the other hand, refers to illegal activities and includes trade in illicitly manufactured and/or smuggled (transported across borders illegally) tobacco products (Joossens and Raw 2012). Cross-border purchasing falls into the tax evasion category whenever it occurs above the legal limits (smuggling), or when the products purchased across the border within the legal limits are for resale and not for personal consumption. This chapter focuses on all cross-border purchasing of cigarettes in lower-tax jurisdictions by individuals from higher-tax jurisdictions, contributing both to tax avoidance and tax evasion.

Much of the cross-border cigarette purchasing directly undermines all three primary objectives of the Tobacco Tax Directives: 1) to ensure the proper functioning of the internal market, 2) to maintain a high level of health protection by using higher excise taxes to drive up tobacco product prices and, therefore, lower consumption, and 3) to generate fiscal revenue for Member States (Bouw 2017). Moreover, the tax harmonization mechanisms might be the only way to curb cross-border cigarette purchasing. Since the limits on the number of cigarette packs that can be legally transported across EU borders for personal use are high (40 packs) (European Commission's Taxation and Customs Union 2018a), such purchases are most often legal. Therefore, no measures designed to curb illicit cigarette trade, such as law enforcement or the measures listed in the Protocol to Eliminate Illicit Trade in Tobacco Products (United Nations 2012), would apply to cross-border purchases that occur within the legal limits for smokers' own consumption.

There is some evidence that indicates that cross-border cigarette purchasing is affected by between-country differences in cigarette prices, with lower cigarette prices in a neighboring jurisdiction (Nagelhout et al. 2014; Baltagi and Levin 1986; 1992) and larger price difference between jurisdictions (Agaku et al. 2016; Becker, Grossman, and Murphy 1990; Chaloupka and Saffer 1992; Yurekli and Zhang 2000; Merriman, Yurekli, and Chaloupka 2000) being significantly associated with more cross-border cigarette purchasing. Proximity provides an opportunity for legal cross-border purchases and facilitates illegal activities such as re-selling legally purchased cross-border cigarettes, while between-country price difference is an incentive for such activities. Efforts to harmonize cigarette prices across the region should decrease cross-border purchasing, but there is a dearth of studies quantifying both the magnitude and the nature of this effect.

An increasing number of studies that measure tobacco tax avoidance and evasion, and are independent from the tobacco industry, are being published (Ross 2015; Gallagher et al. 2019). In the EU, such studies involve analyzing the gap between survey-reported cigarette consumption and tax-paid sales (HM Revenue & Customs 2017), examining packs presented by smokers (Joossens et al. 2014; Guindon et al. 2014), and collecting packs discarded as litter (Stoklosa and Ross 2014). These studies, however, do not distinguish between large-scale illicit trade and cross-border purchasing. Only a few studies use European data to focus on cross-border purchasing specifically. A 2013 study analyzes survey data from five EU countries and finds that cross-border purchasing might be more frequent in regions bordering countries with lower cigarette prices, but that the overall magnitude of the problem is not large (Nagelhout et al. 2014). A more recent study uses survey data for smokers in 27 Member States to study the impact of price differences on cross-border cigarette purchasing in the EU (Agaku et al. 2016). The study finds that, although the effects of between-country price differences on cross-border cigarette purchasing are significant, only 4% of all EU smokers purchased most of their products through cross-border transitions. However, both studies use survey-reported data, which might be affected by the fact that tax avoidance activities are often underreported. Moreover, because these studies asked about cross-border purchasing by smokers themselves, they do not capture instances when the cigarettes were bought abroad by other individuals, such as a smoker's family member or a friend. Finally, both studies use a single cross-section of data and, therefore, a causal relationship cannot be established.

This study aims to shed light on the effects of cigarette price differences between EU Member States on cross-border cigarette purchases. Additional evidence on this relationship is needed to guide tobacco tax policies in Europe. This study verifies findings by Agaku and colleagues, but uses methods that are free from potential reporting bias attached to the analysis of survey data.

4.3. Data and Methods

The method employed in the current study involves analyzing aggregate data on cigarette prices and tax-paid sales using panel techniques. This method was developed by Becker et al. (1990), and was applied in other studies on US data (Chaloupka and Saffer 1992; Yurekli and Zhang 2000) and, in a slightly modified version, on 1989-95 data from several European countries (Merriman, Yurekli, and Chaloupka 2000). It is based on the notion that if cross-border price differences affect cigarette purchasing from neighboring regions, those purchases should be reflected in higher tax-paid sales in the country with lower cigarette prices where the purchases took place (exporting country) and in lower tax-paid sales in the country with higher cigarette prices (importing country).

Since this study focuses on EU Member States only, the analysis starts in 2004, when ten new Members joined the EU. For the same reason, data for Bulgaria and Romania from before 2007 and for Croatia from before 2013 were dropped. The analysis covers the period up to 2017, the last year for which data on the number of cigarettes released for consumption were available at the time of the analysis (August 2018). Therefore, the total number of observations in this study is 377 (28x14 – 9 (Croatia) – 2x3 (Romania and Bulgaria)).

4.3.1. Data Sources

This study uses longitudinal, 2004-2017 data for 28 EU Member States. The data were obtained from various sources. The number of cigarettes released for consumption and cigarette price data for the EU Member States are from the European Commission (European Commission's Taxation and Customs Union 2018b). The European Commission is also the source for data on the border population (defined as the number of people living within 25 kilometers from the border) of the EU countries and their neighbors (Müller 2018), as well as for data on gasoline prices (European Commission 2018). Although the study focuses on cigarette sales in the EU Members States only, it takes into account cigarette prices in bordering non-EU countries. Cigarette prices for those EU-neighboring countries are from Euromonitor (Euromonitor International 2019). Per capita Gross Domestic Product (GDP), inflation, and population data are from the World Bank (World Bank 2018b). Scores for non-price tobacco control measures (smoke-free air laws, help available to quit tobacco use, warnings about the dangers of tobacco, and bans on tobacco advertising, promotion and sponsorship) are from the World Health Organization (World Health Organization 2017). A full dataset used in this study is now published at The Tobacco Atlas web page (Stoklosa 2018a).

4.3.2. Dependent variable

The dependent variable is per capita cigarette sales measured by the number of cigarettes released for consumption. This reflects the number of cigarettes that were released from bonded warehouses to be sold in each Member State each year. Releases for consumption can be artificially high in certain years due to stockpiling, i.e. when large quantities of cigarettes are released to the market prior to tax increases to avoid the new, higher taxes. However, a clear majority of Member States (19 out of 28 in 2014) apply anti-stockpiling measures, which aim to limit the ability of economic operators to take advantage of the lower excise rates before a planned tax change (Stener Pedersen et al. 2014). These measures include caps on tax stamps (e.g. companies cannot purchase significantly more stamps than in previous years in the same time of the year), caps on release for consumption (e.g. the number of cigarettes that can be released for consumption during the yearend is limited), and sell-by date (e.g. excise stamps applied on cigarette packs in a given year in Poland are valid only until the end of February of the next year (Senate of the Republic of Poland 2009)). The countries that did not have anti-stockpiling measures in 2014 were Austria, the Czech Republic Finland, Germany, Greece, Ireland, Italy, Sweden, and Spain (Stener Pedersen et al. 2014). Moreover, for 253 out of the 377 observations in the sample, the tax rate changed in the following year (European Commission's Taxation and Customs Union 2018b). Therefore, with the anti-stockpiling measures in place and the frequent tax increases, the number of cigarettes released for consumption should closely reflect the tax-paid sales in the EU Member countries. For countries without anti-stockpiling measures in place, I assume that the carry-over stock in one year is similar to the carry-over stock the next year. The sales for each year are divided by the countries' estimated adult population (15+) to obtain a per capita measure.

4.3.3. Primary independent variables

The primary independent variables are the population-weighted between-country differences in cigarette prices. Those variables are constructed following the methods developed by Becker et al. (1990). The import incentive variable for cross-border cigarette purchasing is defined as follows:

$$Imports_{it} = \Sigma_j K_{ij}(Price_{it} - Price_{jt})$$

where K_{ij} is the fraction of the population of the higher-price, importing, country *i* living in the border regions neighboring the lower-price country *j* ($K_{ij}=Border\_POP_{ij}/POP_i$). Weight *K* is included in the formula to reflect the fact that the greater the proportion of the population living near the border with the lower-price country, the more likely cross-border cigarette purchases from that country are. The sum is taken over all lower-price neighboring countries. The export incentive variable is defined as follows:

$$Exports_{it} = \Sigma_j K_{ji}(Price_{jt} - Price_{it})(POP_j/POP_i)$$

where K_{ji} is, again, the fraction of the population of the higher-price country *j* living in the border regions neighboring the lower-price, exporting country *i*. POP_j and POP_i represent the total populations of the high-price and low-price countries, respectively. The sum is taken over all higher-price neighboring countries.

The relative-population weight is included in the formula for the exports incentives to reflect the fact that exporting cigarettes to a larger neighbor is more likely to affect per capita sales in the lower-price country, than exporting to a smaller neighbor is, simply because more cigarettes are expected to be exported to a larger neighbor than to a smaller neighbor. In a concrete example, assume that Spain is an exporting country. Then, according to this model, two factors will affect Spain exporting to France and to Portugal. First, it is affected by the number of French and Portuguese people living near the Spanish borders (captured by the K_{ji}). Secondly, it is affected by how large France and Portugal are compared to Spain (captured by the relative-population ratio). The inference is that there is much greater potential to export to France than to Portugal, simply because the population of France is more than 6 times larger than that of Portugal.

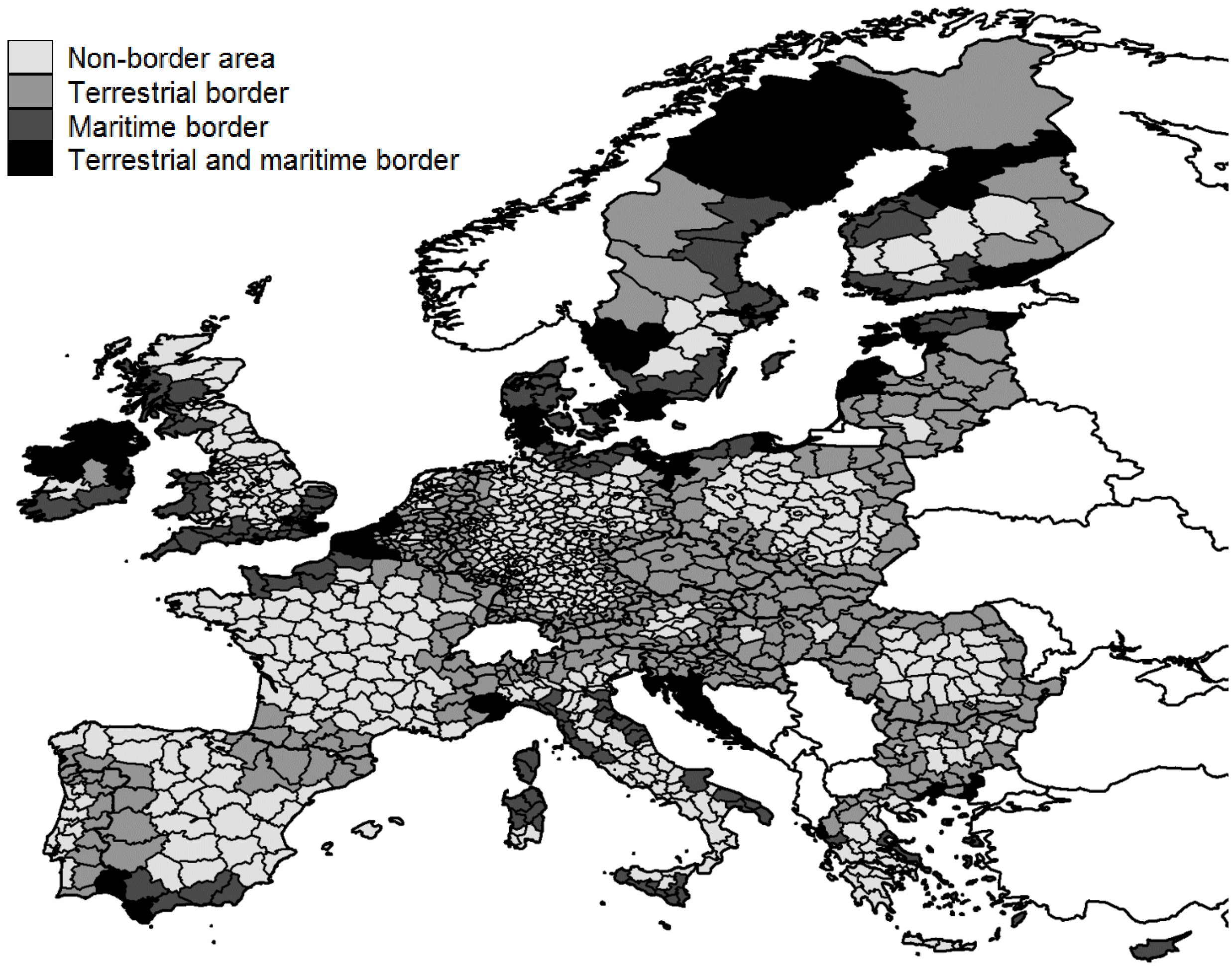
Cigarette prices used in this study are the Weighted Average Prices (WAP) expressed in euros. Before 2010, the EU Member States did not report WAP to the European Commission, reporting the Most Popular Price Category (MPPC) instead. However, the difference between MPPC and WAP is very small (4% on average among those countries which continued reporting both WAP and MPPC) (Lopez and Stoklosa 2018a). Therefore, MPPC was used as a proxy for WAP for EU Member States for the years before 2010. For non-EU countries, WAP was calculated using the formula from the 2010 EU Tax Directive (The Council of the European Union 2010), that is, by dividing total cigarette value by the total quantity of cigarettes reported by Euromonitor (Euromonitor International 2019).

The dataset of the EU border regions, obtained from the European Commission, consisted of 973 level-3 geographical regions from the Nomenclature of Territorial Units for Statistics classification (NUTS3 regions) (Eurostat 2018b). The dataset covers both regions along terrestrial borders and those along maritime borders. Maritime borders are defined as coastlines located at less than 150 km from overseas coastlines (see Figure 4.2). For example, parts of France and the UK share a maritime border, because their coastlines are less than 150 km apart. Spain and the UK do not share a maritime border, because their coastlines are more than 150 km apart. As well as the border regions in the EU Member States, the dataset includes border regions in several non-EU countries that border EU countries (Liechtenstein, Macedonia, Norway, Switzerland, and Turkey)[5]. In the dataset, there are also estimates of each region's border population in 2011, defined as the number of people living within 25 kilometers from the border.

To construct the weights for the import and export incentive variables, I first dropped overseas regions of Spain (Fuerteventura and Lanzarote) and France (Guadeloupe, Martinique, Guyane, La Réunion, and Mayotte) that were included in the dataset, but that are not relevant for the analysis, because of the lack of geographical proximity. The 2011 estimates of border populations for the remaining European regions were then added up along each border and, together with the 2011 estimates of the total countries' populations, were used to construct the weights. These computed weights and 2004-2017 cigarette prices were then used to compute the import and export incentive variables for each country and each year, according to the formulas described above. All import and export variables were adjusted for eurozone inflation.

[5] Information on the border population of many non-EU countries is missing from the database. However, this information is only needed to calculate the exports incentive variable if the non-EU country had higher price than a given EU Member State, and hence the EU country has an incentive to export. As explained later in this chapter, there were only three instances when a non-EU country (Serbia) had higher cigarette prices than an EU-country (Romania).

Figure 4.2. Border NUTS3 regions in the European Union



Note: Although regions vary in size, weights used in this study are based only on the estimated number of individuals living within 25 km from each border.
Source: Author's own map created based on European Commission data (European Commission's Taxation and Customs Union 2018b).

The dataset of the EU border regions includes estimates of border population in several EU-neighboring countries with relatively high cigarette prices (Lichtenstein, Norway, and Switzerland). This permits the computation of import and export variables covering not only internal but also external EU borders. For three cases when the border population data for a non-EU member, necessary to construct the variables, were not available (all three for exports to Serbia), it was assumed that there was no between-country price difference in those cases.

Subsequently, I constructed import and export incentive variables covering internal and external EU borders, both terrestrial and maritime. I also constructed separate variables for EU internal versus EU external borders and for terrestrial versus maritime borders. These additional variables permit analyses that are more precise and advanced than any of the previous studies employing a similar methodology (Becker, Grossman, and Murphy 1990; Chaloupka and Saffer 1992; Yurekli and Zhang 2000; Merriman, Yurekli, and Chaloupka 2000).

Another way of looking at the import and export incentives is in terms of transaction costs. With this approach, the decision to purchase cigarettes across the border is influenced by the cost of the trip. I therefore used gasoline prices as a proxy of the transaction costs of cross-border cigarette purchasing, weighting the cross-border price differences by gasoline prices rather than by border population. The methods used to construct the gasoline price-weighted incentive variables and the results from the models using those incentive variables are presented in the Robustness Check section of this chapter.

4.3.4. Covariates

Other variables in the multivariable analyses are cigarette prices, measured by WAP and MPPC, as described above, and per capita income, measured by per capita GDP. Both variables are expressed in euros and are adjusted for inflation. To control for other, non-price tobacco control measures, I use scores for smoke-free air laws, help available to quit tobacco use, warnings about the dangers of tobacco, and bans on tobacco advertising, promotion and sponsorship, all taken from the WHO Report on the Global Tobacco Epidemic (World Health Organization 2017). The WHO scores are valued from one (least implemented measure) to five (fully implemented measure).

Attempts to control for each of the non-price tobacco control measures separately created collinearity problems in the models, because governments often implement several measures together. As suggested by Saffer and Chaloupka, a way to avoid multicollinearity in such cases is to create dummy variables for combined multiple tobacco control measures (Saffer and Chaloupka 2000). Therefore, I use a dummy variable that reflects strong implementation of all four non-price tobacco control measures – i.e. the value of the WHO score for each of the measures is four or five.

The WHO scores for the four measures are available for 2008, 2010, 2012, 2014, and 2016 only. In 2008, except for the UK, each EU Member State was still lagging behind its stated intention in the implementation of at least one non-price tobacco control measure (World Health Organization 2017). Therefore, for the years 2004-2008, the dummy for non-price tobacco control measures takes the value of zero in all EU countries, except the UK. The UK dummy takes the value of zero for the years 2004-2006 and one for the years 2007-2017, because the country had already implemented comprehensive tobacco control laws in 2007 (Campaign for Tobacco-Free Kids 2018). For all countries, the missing values for 2009, 2011, 2013, 2015, and 2017 were imputed using values from the preceding year.

4.3.5. Statistical analysis

Pooled time-series data are used to estimate the impact of the between-country cigarette price differences on cigarette sales. The model was specified as follows:

$$\mathrm{y}_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 \mathrm{x}_{2it} + \beta_3 \mathrm{x}_{3it} + \beta_3 \mathrm{x}_{4it} + \alpha_i + \alpha_t + \varepsilon_{it}$$

where β_0 is an intercept, α_i is a set of fixed country constants, α_t is a set of fixed time constants, and ε_{it} is the error term. The dependent variable in this model (y_{it}) is a logarithm of per capita cigarette sales volume in a given country (i) in a given year (t). The independent variables are the logarithm of inflation-adjusted average cigarette price (x_{1it}), logarithm of inflation-adjusted per capita income (x_{2it}), dummy for strong implementation of four non-price tobacco control measures (x_{3it}), and a vector for import and export incentive variables (x_{4it}). The estimated coefficient β_1 represents price elasticity of demand for cigarettes, while β_2 represents income elasticity of demand for cigarettes. Country fixed effects are included in the models to control for unobserved, stable, characteristics of the countries, such as the social acceptability of tobacco use or the general level of tobacco control regulations. Year fixed effects are also included to capture trends over time as well as unobserved events in EU-level tobacco control, such as the implementation of the Tobacco Products Directive in 2016 (European Parliament and the Council of the European Union 2014).

The Hausman test was used to determine whether the country and time fixed effects should be included in the model. The null hypothesis in the Hausman test is that the preferred model is the random effects model versus the alternative that the fixed effects is preferred. Specifically, the test examines whether the covariance between x_{it} and α from the above equation is equal to zero. If the value of the covariance is zero, then both the random effects and the fixed effects estimators are consistent, but the random effects is preferred, as it is the more efficient estimator. Alternatively, if the value of the covariance is not zero, then the fixed effects estimator is solely consistent and, therefore, the fixed effects model is preferred. Previous work with a similar panel model setup, but on US data, found the time fixed effects not to be justified (Gallet, Hoover, and Lee 2006). However, the result of the Hausman test for this study strongly suggests using both country

(Hausman test: $\chi^2=48.49$, $p<0.001$) and year (Hausman test: $\chi^2=80.19$, $p<0.001$) fixed effects in the model.

Another model setup that was considered for this study is the mixed effects model. Mixed effects models work well with many panel data studies, because they produce fixed-effect estimates for the time-varying predictors as well as random-effect estimates for the time invariant predictors. The mixed effects method works perfectly with, for example, longitudinal survey data where there are both time-invariant predictors (e.g. gender) and time-variant predictors (e.g. income). However, in the case of the EU cigarette sales data there are no time-invariant predictors. All the explanatory variables in the models used in this study change over time. Thus, the mixed effects models were not used in this analysis.

The assumption behind the models used in this analysis is that if the between-country differences in cigarette prices led to cross-border cigarette purchases from neighboring countries with lower cigarette prices, cigarette sales in the higher-priced country would be negatively affected. In such a case, one would expect the coefficient for the import incentive variable to be significant and negative. Similarly, if the between-country differences in cigarette prices led to cross-border cigarette sales to neighboring countries with higher cigarette prices, cigarette sales in the lower-priced country would be positively affected. In such a case, one would expect the coefficient for the export incentive variable to be significant and positive. Sales, price, and income were logged, so that the estimated coefficients of the price and income variables represent price and income elasticities, respectively.

In the first model specification, the vector for import and export incentive variables (x_{4it}) includes import and export incentive variables covering internal and external EU borders, both terrestrial and maritime (Model 1). The second specification includes separate import and export variables for terrestrial and maritime borders (Model 2). In the third model specification, separate import and export variables for internal terrestrial and external terrestrial borders are included (Model 3).

4.4. Results

Table 4.1 summarizes the key variables, while Table 4.2 presents 2017 values of key variables by country. All extremely high values of per capita cigarette sales (above 4,000 cigarettes per adult annually) are for Luxemburg, a country known for serving as a source of cross-border purchased cigarettes for France (Bogdanovica et al. 2011) and Germany (Hanewinkel and Isensee 2007). Cigarette sales at above 3,500 sticks per adult annually were also found in 2004-2009 in Greece, a country with historically one of the highest cigarette consumption levels in the world (Harvard School of Public Health 2011). The lowest levels of consumption (below 600 sticks per adult per year) were found in recent years in the UK, Europe's highest performer in tobacco control (Joossens and Raw 2017). The lowest cigarette price in the database (0.67 euro per pack) was reported in Latvia in 2005, just after the country joined the EU. The EU Directive's minimum rates still did not apply in Latvia at that time owing to the transition arrangement that the country negotiated before joining the EU (Blecher, Ross, and Stoklosa 2014). The highest cigarette prices, more than 10 euros per pack, were recently recorded in Ireland and the UK. Seventeen countries never achieved strong implementation of all non-price tobacco control measures, while eleven Member States strongly implemented those measures at some point between 2007 and 2017.

The highest value of the import incentive variable was for Malta in 2004, due to the price difference between Malta and Italy. Although the price difference was relatively small (1.08 euro per pack), the fact that the entire population of Malta lives in a border region with Italy drove the value of the incentive variable up. The country with the second largest values for the import incentive variables was Finland, caused by the country's high price difference with its EU neighbor, Estonia. The two countries share a maritime border. Estonia has had much cheaper cigarettes than Finland throughout the analysis, with the maximum price difference amounting to 3.15 euro per pack in 2004.

The values of export incentive variables are generally larger than the values of import incentive variables, mainly due to the presence of the relative population weight in the export incentive variable. The largest value of the export incentive variables was for Estonia, as a result of the above-mentioned price difference with Finland. The country with the second largest value of export incentive variables is Luxemburg. Even though the price difference between Luxemburg and its neighbors was not as large as the price difference between Latvia and Finland, the value of the export incentive variable was driven up by the relative population weight. As Luxemburg is a small, low-priced country neighboring two large, higher-price countries (France and Germany), there is a high potential for Luxemburg to serve as a source of cross-border purchased cigarettes for its neighbors.

Both the largest and the smallest absolute price differences between neighboring counties were for Finland. In 2012, cigarettes in Finland cost up to 7.88 euros per pack less than in its non-EU neighbor, Norway. In 2017, on the other hand, Finland's cigarettes were up to 4.85 euros per pack more expensive than in its non-EU neighbor, Russia. In both cases, however, the values of the import and export incentive variables for Finland were not extreme, because very few people live close to the borders between Finland and Norway and between Finland and Russia. In fact, regions around the border between Finland and Norway are one of the least densely populated regions in

Europe, which makes cross-border cigarette purchasing by shoppers coming from Norway to Finland very rare.

Incentives for imports across maritime borders are significantly greater than those for terrestrial borders ($t=-3.17$, $p<0.01$), while the export incentive variables do not differ according to whether the border is terrestrial or maritime ($t=-1.17$, $p=0.24$) (Table 4.1). Focusing on terrestrial borders only, incentives for EU countries to import from other EU countries (through internal borders) do not differ from incentives to import from non-EU countries (through external borders) ($t=-0.34$, $p=0.73$). However, the incentives for EU countries to export within the EU (across internal borders) are significantly greater than the incentives for EU countries to export to non-EU countries (across external borders) ($t=6.40$, $p<0.01$).

Table 4.1. Summary Statistics of Key Variables

Variables	**Mean**	**SD**	**Min**	**Max**
Per adult cigarette sales (sticks)	1887	1805	526	17122
Cigarette price per pack (euros)	4.13	1.85	0.67	10.12
Per capita income (GDP-measured, euros)	27699	17622	5040	92380
Dummy for strong implementation of four non-price tobacco control measures	0.13	0.34	0	1
Import incentive (1) *internal and external terrestrial and maritime borders*	0.23	0.28	0.00	1.38
Export incentive (1) *internal and external terrestrial and maritime borders*	0.54	0.98	0.00	5.09
Import incentive (2a) *internal and external terrestrial borders*	0.09	0.09	0.00	0.51
Export incentive (2a) *internal and external terrestrial borders*	0.24	0.66	0.00	4.41
Import incentive (2b) *internal and external maritime borders*	0.14	0.28	0.00	1.37
Export incentive (2b) *internal and external maritime borders*	0.30	0.79	0.00	5.09
Import incentive (3a) *internal terrestrial borders*	0.04	0.07	0.00	0.45
Export incentive (3a) *internal terrestrial borders*	0.23	0.66	0.00	4.41
Import incentive (3b) *external terrestrial borders*	0.05	0.07	0.00	0.31
Export incentive (3b) *external terrestrial borders*	0.01	0.04	0.00	0.29

Number of observations: 377

Table 4.2. Key variable values in 2017

Country	Cigarette price per pack (euros)	EU Member	Per adult cigarette sales (sticks)	Dummy for strong implementation of four non-price tobacco control measures	Import incentive 1	Export incentive 1
Austria	4.76	Yes	1636	0	0.259	0.412
Belgium	5.88	Yes	1013	0	0.030	1.451
Bulgaria	2.57	Yes	2258	1	0.058	0.157
Croatia	3.19	Yes	1741	0	0.242	0.753
Cyprus	4.28	Yes	1313	0	0.840	0.000
Czechia	3.31	Yes	2318	0	0.023	0.439
Denmark	5.40	Yes	1273	0	0.016	1.217
Estonia	3.55	Yes	1525	0	0.166	4.312
Finland	6.70	Yes	908	0	1.240	0.005
France	6.81	Yes	805	0	0.150	0.424
Germany	5.64	Yes	1055	0	0.106	0.137
Greece	4.10	Yes	1302	1	0.213	0.067
Hungary	3.59	Yes	845	1	0.181	0.057
Ireland	10.07	Yes	953	1	0.672	0.000
Italy	4.76	Yes	1324	0	0.180	0.070
Latvia	3.20	Yes	1156	1	0.207	0.033
Lithuania	3.18	Yes	1208	0	0.288	0.002
Luxembourg	4.60	Yes	5700	0	0.000	3.109
Malta	5.25	Yes	1252	1	0.494	0.000
Netherlands	6.19	Yes	693	0	0.167	0.165
Poland	3.20	Yes	1286	0	0.064	0.061
Portugal	4.47	Yes	1219	1	0.000	0.005
Romania	3.46	Yes	1416	1	0.347	0.005
Slovakia	3.23	Yes	1544	0	0.071	0.145
Slovenia	3.51	Yes	2084	0	0.097	0.798
Spain	4.52	Yes	1126	1	0.179	0.031
Sweden	6.03	Yes	650	0	0.240	0.090
United Kingdom	8.83	Yes	526	1	0.633	0.049
Albania	1.13	No	-	-	-	-
Belarus	0.64	No	-	-	-	-

Country	Cigarette price per pack (euros)	EU Member	Per adult cigarette sales (sticks)	Dummy for strong implementation of four non-price tobacco control measures	Import incentive 1	Export incentive 1
Bosnia and Herzegovina	2.26	No	-	-	-	-
Liechtenstein	10.17	No	-	-	-	-
Montenegro	1.7	No	-	-	-	-
Morocco	2.28	No	-	-	-	-
Norway	11.61	No	-	-	-	-
Republic of Moldova	1.04	No	-	-	-	-
Russian Federation	1.85	No	-	-	-	-
Serbia	1.94	No	-	-	-	-
Switzerland	8.11	No	-	-	-	-
Syrian Arab Republic	0.74	No	-	-	-	-
The former Yugoslav Republic of Macedonia	1.28	No	-	-	-	-
Tunisia	1.41	No	-	-	-	-
Turkey	2.56	No	-	-	-	-
Ukraine	0.77	No	-	-	-	-

Results from the models capturing the effects of between-country price difference on cross-border cigarette purchases are presented in Table 4.3. Cigarette price significantly affects cigarette sales in the EU. Estimated price elasticity varies, depending on the model specification, from -0.47 to -0.35. Estimated income elasticity is positive and significant in all models (from 0.66 to 0.70). The estimated effects of non-price tobacco control policies all have the expected negative sign and reach significance at the 0.05 level in Model 1 and at the 0.10 level in Models 2 and 3. The coefficients for both import and export incentive variables have the expected sign in all models (negative for import incentive and positive for export incentive), except for the export incentive across maritime borders (2b) in Model 2. In Model 1, the overall effect of price differences on cross-border purchasing is not significant. When the effects of between-country price differences are estimated separately for maritime and terrestrial borders, the import and export incentive variables are significant for terrestrial borders (joint test: F=9.25, p<0.01), but not for maritime borders (joint test: F=0.25, p=0.78). After the effects of those incentives are further disentangled into separate effects for EU internal terrestrial borders and EU external terrestrial borders, the incentives for EU countries to trade within the EU (across internal borders) are jointly significant (joint test: F=8.19, p<0.01), while incentives for EU countries to trade with non-EU countries (across external borders) are not (joint test: F=1.56, p=0.21). When the model is estimated only for countries with external EU borders (n=251), the incentive variables for external borders are still not significant (F<0.01, p=0.99).

Table 4.3. Cigarette sales in Europe: fixed-effects models

Variables	**Border type included in the incentive variable**				**Model 1**	**Model 2**	**Model 3**
	Terrestrial	Maritime	Internal	External			
Price elasticity					-0.47***	-0.38***	-0.35***
Income elasticity					0.70***	0.66***	0.67***
Dummy for strong implementation of four non-price tobacco control measures					-0.07**	-0.06*	-0.06*
Import incentive (1)	✓	✓	✓	✓	-0.04		
Export incentive (1)	✓	✓	✓	✓	0.03		
Import incentive (2a)	✓		✓	✓		-0.42**	
Export incentive (2a)	✓		✓	✓		0.27***	
Import incentive (2b)		✓	✓	✓		-0.003	
Export incentive (2b)		✓	✓	✓		-0.03	
Import incentive (3a)	✓		✓				-0.38*
Export incentive (3a)	✓		✓				0.27***
Import incentive (3b)	✓			✓			-0.59
Export incentive (3b)	✓			✓			0.55
Constant					1.10	1.38	1.26

Number of observations: 377; *p<0.1; **p<0.05; ***p<0.01

4.4.1. Robustness check

One concern with the study presented in this chapter is with the parameter of border population that this study uses as a weight of cross-border price differences. Because there are no estimates of the border population for years other than 2011, the method assumes that the proportion of the population living near the borders of the EU Member States did not significantly change throughout the period of this analysis. However, this assumption may not be plausible. Each year, the EU receives many immigrants from non-EU countries, and many EU citizens relocate to other Member States. For example, in 2016, 2.3 million EU citizens relocated to a another Member State and 2 million non-EU citizens immigrants arrived in the EU from a non-EU country (Eurostat 2018a). This statistic also does not account for EU citizens who relocated within their country., It might therefore not be reasonable to believe that all border populations remained relatively unchanged in recent years.

As a robustness check, as well as weighting the cross-border price differences by the 2011 border population, I ran the analysis weighting the price differences by yearly gasoline prices. This approach assumes that cross-border cigarette purchasing behaviors are influenced by the transaction costs, measured by the gasoline cost, rather than by the number of people living near the border.

The gasoline price data are from the European Commission (European Commission 2018). They reflect the price of the Euro-super 95 gasoline (taxes included) as of the first week of June each year. Since the gasoline prices were available for the EU countries only, the models weighting the cross-border price differences by the gasoline price are for the EU internal borders only. In those models, the import incentive variable for cross-border cigarette purchasing is defined as follows:

$$Imports_i = \Sigma_j G_{it}(Price_{it} - Price_{jt})$$

where G_{it} is the proportion of the EU average gasoline price in year t to the gasoline price in the importing (Model 4 and 5) or exporting (Model 6 and 7) country that year ($G_{it}=Average\_gasoline\_price_t/Gasoline\_price_{it}$). Weight G is included in the formula to reflect the fact that the higher the gasoline price, the higher the transaction costs, the less likely it is that cross-border cigarette purchases from that country will occur. The export incentive variable is defined as follows:

$$Exports_{it} = \Sigma_j G_{it}(Price_{jt} - Price_{it})(POP_j/POP_i)$$

where G_{it} is, as before, the proportion of the EU average gasoline price in year t to the gasoline price in the exporting (Model 4 and 5) or importing (Model 6 and 7) country that year. Models 4 and 5 assume that the gasoline is purchased in country i, while Models 6 and 7 assume that both gasoline and cigarettes are purchased in the country bordering i. The results from these models are presented in Table 4.4.

Table 4.4. Cigarette sales in Europe: fixed-effects models with gasoline price used as a cross-border price difference weight

Variables	Model 4	Model 5	Model 6	Model 7
Price elasticity	-0.48***	-0.47***	-0.47***	-0.47***
Income elasticity	0.71***	0.70***	0.70***	0.70***
Dummy for strong implementation of four non-price tobacco control measures	-0.08**	-0.07**	-0.08**	-0.07**
Import incentive *Internal borders and gasoline price from the importing country*	-0.001			
Export incentive *Internal borders and gasoline price from the exporting country*	0.002***			
Import incentive *Internal terrestrial borders and gasoline price from the importing country*		-0.01		
Export incentive *Internal terrestrial borders and gasoline price from the exporting country*		0.002***		
Import incentive *Internal borders and gasoline price from the exporting country*			-0.004	
Export incentive *Internal borders and gasoline price from the importing country*			0.002***	
Import incentive *Internal terrestrial borders and gasoline price from the exporting country*				-0.01
Export incentive *Internal terrestrial borders and gasoline price from the importing country*				0.002***
Constant	0.96	1.08	1.06	1.15

Number of observations: 377; *p<0.1; **p<0.05; ***p<0.01

Weighting the cross-border price differences by yearly gasoline prices instead of weighing it by the 2011 border population did not change the results substantially. The estimated price elasticity, the income elasticity, and the coefficient for the dummy for strong implementation of four non-price tobacco control measures are almost identical in the models weighted by gasoline prices to those weighted by border population. As well, the estimated impact of reducing incentives from cross-border purchasing down to zero on sales in an exporting country is also very similar in the models weighted by gasoline prices and in the models weighted by border population. Weighting by the minimum gasoline price between the two countries did not change the results either. This suggests that the results presented in this chapter are robust to the type of weight used for the cross-border price difference: it is the price difference that affects the cross-border cigarette purchases, irrespective of whether population or gasoline prices are used as weights.

Luxembourg seems to be an outlier in this study. With extremely high per capita cigarette sales and export incentives (Table 4.2), the country stands out from the rest of the EU. As estimated by the consultants KPMG, as much as 81% of cigarettes legally sold in Luxembourg in 2016 were not consumed in the country, but were rather purchased in Luxembourg to be smoked in other countries (KPMG 2017). No other EU country had cigarette outflows constituting so large a portion of the market as Luxembourg. Although the KPMG estimates have to be used with caution, because they might represent the interests of the tobacco industry (Gilmore et al. 2014), they indicate that the cross-border purchasing in Luxembourg is an anomaly in Europe. Therefore, in another robustness check, I removed Luxembourg from the dataset to check how my estimates would behave without this country.

Removing Luxembourg from the models did not change the estimates of the price and income elasticities significantly. These results are presented in Table 4.5. Cigarette price still significantly affects cigarette sales in the EU. Estimated price elasticity varies, depending on the model specification (from -0.50 to -0.41). Estimated income elasticity (from 0.68 to 0.72) and the effects of non-price tobacco control policies (from -0.07 to -0.08) are also significant. The import incentive variables are not significant in the first model specification, but are significant in the other two model specifications and have a similar magnitude to those estimated in the full-sample models. One major difference between the estimates from these models and the estimates from the full sample presented earlier in this chapter is that the export incentive variable is not significant in any of the models. This suggests that Luxembourg was largely a cigarette-exporting country.

Table 4.5. Cigarette sales in Europe: fixed-effects models with Luxembourg removed

Variables	**Border type included in the incentive variable**				**Model 8**	**Model 9**	**Model 10**
	Terrestrial	Maritime	Internal	External			
Price elasticity					-0.50***	-0.41***	-0.42***
Income elasticity					0.72***	0.68***	0.68***
Dummy for strong implementation of four non-price tobacco control measures					-0.08**	-0.07**	-0.07**
Import incentive (1)	✓	✓	✓	✓	-0.05		
Export incentive (1)	✓	✓	✓	✓	-0.02		
Import incentive (2a)	✓		✓	✓		-0.48**	
Export incentive (2a)	✓		✓	✓		0.01	
Import incentive (2b)		✓	✓	✓		-0.002	
Export incentive (2b)		✓	✓	✓		-0.02	
Import incentive (3a)	✓		✓				-0.50**
Export incentive (3a)	✓		✓				-0.08
Import incentive (3b)	✓			✓			-0.30
Export incentive (3b)	✓			✓			0.30
Constant					0.93	1.20	1.29

Number of observations: 377; *p<0.1; **p<0.05; ***p<0.01

4.5. Discussion

This study shows that in an average EU Member State only a small portion of cigarette sales can be explained by cross-border purchasing, which includes both individual smokers cross-border shopping, as well as larger scale bootlegging of purchases in lower-tax jurisdictions for resale in higher-tax jurisdictions. Taking the value of the estimated coefficient for imports across EU internal terrestrial borders (coef: -0.38 from Model 3), the value of that coefficient indicates that, in a theoretical scenario, when incentives for cross-border imports fall from their mean level (i.e. 0.04) to zero, *ceteris paribus*, local sales would increase by about 1.5% (0.38*0.04). At the same time, reducing incentives for cross-border exports through EU internal terrestrial borders down to zero, *ceteris paribus*, would reduce sales by about 6% (0.27*0.23). These results were similar (from 4% to 6%) in the models where the EU cross-border price differences were weighted by gasoline prices instead of by border population. The mean value of the export incentive variable varied from 22 in Model 7 to 29 in Model 4. Therefore, when the value of the estimated coefficient for exports across EU internal borders is taken (coef: 0.002 in Models 4 to 7), the value of that coefficient indicates that, in a theoretical scenario, when incentives for cross-border exports fall from its mean level to zero, *ceteris paribus*, sales in the exporting countries would fall by between 4% (0.002*22) and 6% (0.002*29). In reality, reducing the between-country price differences would require an adjustment in domestic price as well. Therefore, the equilibrium for tax-paid sales if there are no cross-border price differences is harder to predict. The equilibrium would be different, depending whether it was achieved through an upward adjustment of cigarette prices across Member States, a downward adjustment of cigarette prices, or an adjustment to the mean price. However, some useful inferences can still be made based on the value and ratio of these effects. The small magnitude of the two effects suggests that little of the variation in tax-paid sales can be explained by cross-border purchasing incentives. This is consistent with studies by Nagelhout et al. (2014) and Agaku et al. (2016), which both find that in most EU countries only a small portion of all smokers reported frequent cross-border cigarette purchasing.

The fact that the effects of the incentive variables are higher for exports (0.27*0.23) than for imports (0.38*0.04) suggests that cross-border cigarette purchasing has a greater effect on sales in the exporting country than in the importing country. A similar conclusion can be made from the fact that, in different model specifications, the export incentive variables are more often significant than the import incentive variables. This could mean that some of the cigarettes purchased across the border are smoked in addition to domestic duty-paid cigarettes, as opposed to being substitutes for domestic cigarettes. This implies that overall cigarette consumption would be lower, were it not for the availability of lower-priced cigarettes from across the border. Thus, increasing cigarette taxes to reduce between-country price differences would curb tobacco use in two ways: first, through the effects of price increases on cigarette consumption alone and, secondly, through reduced cross-border purchasing.

The significance of the export incentive variable depends on one country only, i.e. Luxembourg. The base elasticities for price and income are not much affected in the models with Luxembourg removed, but the export incentive variable is. This, again, suggests that price differences do not really have a strong effect on cross-border purchasing.

Another finding of this study is that patterns in cross-border cigarette purchasing differ by border type. Even though incentives to purchase cigarettes from across maritime borders were higher than incentives for terrestrial borders (Table 1: 2a vs. 2b), between-country price differences were not significantly associated with purchases across maritime borders. This is an expected finding and suggests that a large area of water poses a barrier for cross-border purchasing in terms of both cost and time. Perhaps more interestingly, between-country difference in cigarette prices did not affect cigarette purchasing across EU external, terrestrial borders. This is likely because of stricter restrictions associated with crossing EU external borders, both in terms of required travel documents and in the number of cigarette packs that can be legally transported across those borders. This finding suggests that further increases in EU cigarette prices, which increase the price differences with non-EU neighbors, are not expected to impact cross-border purchases from outside of the EU significantly. Thus, the larger price differences with non-EU countries should not distort the functioning of the EU internal market.

The findings of this study consistently indicate that cigarette prices affect cigarette sales. Even when the effects of cross-border purchases are controlled for, higher prices are effective in reducing cigarette demand. Estimated price elasticity varies from -0.47 to -0.35, depending on the model specification. This suggests that a 10% increase in cigarette prices reduces cigarette sales by 3.5% to 4.7%. These findings are consistent with other studies from the EU (S Gallus et al. 2006; Nguyen, Rosenqvist, and Pekurinen 2012) and with abundant evidence from other high-income countries (IARC 2011). The estimated income elasticity, ranging from 0.66 to 0.70, is also within the expected range (IARC 2011). These findings confirm that higher tobacco taxes that lead to higher cigarette prices in the EU will significantly reduce demand for cigarettes in the EU, improving public health and reducing tobacco-related costs. Because higher income is associated with higher cigarette sales, future tax increases need to account for the effects of growing income, to make cigarettes less affordable over time (Blecher, Ross, and Leon 2013).

According to Model 1, non-price tobacco control measures affected cigarette sales in the EU. If a country does well on all four non-price variables, it can expect to decrease cigarette consumption by 7-8%.

This study also contributes to research on new methods for estimating tobacco tax avoidance and evasion. This is the first study of cross-border purchasing across the entire European Union conducted using the econometric modelling of cigarette demand. Secondly, unlike previous studies based on the Eurobarometer and the ITC Project surveys, which captured cross-border purchases by the smokers themselves, this study captures all forms of cross-border purchases. Thirdly, creating separate import and export incentive variables by border type (internal versus external borders and terrestrial versus maritime borders) was novel. It allowed a distinction to be made between the effects of between-country price differences on cross-border cigarette purchasing within the EU and the effect on cross-border trading with neighbouring non-EU countries.

The fact that findings from this study are consistent with findings from studies based on survey data (Nagelhout et al. 2014; Agaku et al. 2016) suggests that surveys of smokers on their cross-border purchasing are not affected by underreporting bias. Methods relying on official data of tax-paid sales and prices, such as the methods employed in this study, and methods relying on surveys of smokers, might both be adequate for measuring the impact of between-country price differences on cross-border purchases. These two methods can be used independently, depending on the availability of data. Finally, the longitudinal setup of this study permits stronger conclusions about the causal relationships between cigarette price differences and cross-border cigarette purchases.

4.5.1. Limitations

Even though the EU provides excellent data on the quantity and prices of cigarettes purchased in its Member States, the size of the sample constructed on these data is still relatively small. As a result, there may be imprecise estimates and lack of significance for some of the variables. Secondly, although the number of cigarettes released for consumption should closely reflect the tax-paid sales in the EU Member countries, it is not an exact measure of sales, especially in countries without anti-stockpiling rules in place. Thirdly, the fact that the EU switched from reporting MPPC to reporting WAP affected the quality of the price measure used in this study. However, this switch should be picked up by the models' year fixed effects. Fourthly, the fact that the price data used for the neighboring non-EU countries came from an unofficial commercial source (Euromonitor) could be problematic. It is likely that the data collected by the European Commission are of better quality than the price measure for some non-EU countries, such as Syria, for which Euromonitor provides only modeled estimates. This might have affected the estimate of cross-border purchasing between EU and non-EU countries. Fifthly, the estimates of border populations for years other than 2011 were not available. Therefore, any change in border population throughout the period of this analysis might have affected the accuracy of the incentive variables. However, weighting the cross-border price differences by yearly gasoline prices instead of by the 2011 border population did not change the results substantively, which suggests that the results are robust to the type of weight used for the cross-border price difference. Sixthly, there is no EU-wide, longitudinal, database for annual data on non-price tobacco control measures, such as smoking bans or advertising bans. Consequently, values for these other tobacco measures were imputed for every other year from 2008 to 2017. Seventhly, while some non-Schengen EU countries, namely Bulgaria, Croatia, Ireland, Romania, and the UK, still have some border control, borders between countries that belong to the Schengen block are virtually non-existent. This might result in an uneven enforcement of the limits on the number of cigarette packs that can be legally transported across EU borders, which could affect the findings. Eighthly, the models use the weighted average prices, which do not capture the variability in cigarette prices within each country. In reality, the cross-border purchasing might be driven more by the differences between prices of the cheapest cigarette brands rather than by the differences in the average prices. However, no good yearly data on the price of the least expensive brand exists to test this hypothesis. Finally, the study presented in this chapter focuses on substitution to cigarettes from across the border only. Due to the lack of European Commission data on prices of tobacco products other than cigarettes, the problem of the substitution to other tobacco products was not addressed in this chapter. However, despite the shortcomings, the model produces results that are robust, with the estimated effects having the expected signs.

4.5.2. Study application

In late 2017, the European Commission Directorate-General for Taxation and Customs Union (DG TAXUD) commissioned a study on the structure and rates of excise duty applied to manufactured tobacco. The aim of that study was to contribute to the Commission's evaluation report and to a possible impact assessment on the review of Directive 2011/64/EU. The study also analyzed and reported on the market developments of new products such as e-cigarettes and heated tobacco products. The study has been commissioned to a consortium led by Economisti Associati Srl., a research group based in Bologna, Italy, and was scheduled to be carried out from January to November 2018. The study involved, among other things, interviews with competent authorities in the EU member states, economic operators, industry and producers' associations, non-state actors and other relevant stakeholders. The results of the study described in this chapter were shared with Economisti Associati and they will become a part of the report for the European Commission and, therefore, will serve to inform the policymaking process in Europe.

4.6. Conclusions

This study finds that differences in cigarette prices across the EU Member States significantly affect cigarette purchasing across internal, terrestrial, EU borders. No such effect was found for cigarette purchasing across maritime borders or for cross-border cigarette trading with countries from outside the EU. These findings underscore the need for further efforts to harmonize taxation within the EU, particularly through increasing minimum tobacco tax rates, as is required in the Tobacco Tax Directive, which will also have a positive public health effect. Increases in minimum tobacco tax rates, resulting in higher cigarette prices and in the convergence of those prices across the Member States, would improve public health by contributing to decreases in cigarette consumption and ensuring proper functioning of the internal EU cigarette market by removing some market imperfections through reduced cross-border cigarette purchasing.

5. CONCLUSION

This thesis provides analysis of three aspects of tobacco product switching: (1) price-driven, between-product substitution, (2) switching to newly-introduced tobacco products, and (3) switching to products on which domestic tax has not been paid. All three switching behaviors undermine the effectiveness of tobacco taxation. In the first instance, when many smokers are switching between products after a tobacco tax increase, instead of quitting or cutting back on their use, the public health effect of the tax is undermined. In addition, by switching to other tobacco products, smokers avoid or evade tobacco taxes, which decreases governments' tax revenue streams. The ability to account for and predict such switching behaviors is critical in the design of more effective tax systems and in implementing other evidence-based policies aimed at reducing cigarette use.

In 2016, the US National Cancer Institute and the World Health Organization concluded that research studies on cross-price effects on the use of tobacco products in any country are scarce, and practically non-existent for low- and middle-income countries (U.S. National Cancer Institute and World Health Organization 2016). The few existing studies generally show that when the ratio of tobacco product prices changes, consumers sometimes choose to switch between products. This suggests that governments should aim for tax parity across products when substitution of similarly harmful products, such as between FM and RYO cigarettes, is likely. All combustible tobacco products are very harmful because the preponderance of carcinogens and toxins are generated by the combustion. Aware of smokers' switching behaviors, the World Health Organization (WHO) notes that taxing all tobacco products comparably reduces incentives for substitution; the need for comparable taxation on all tobacco products is increasingly clear (World Health Organization

2015b). This approach to reducing between-product price differentials through tobacco taxation is also recommended in the Article 6 guidelines of the WHO FCTC (WHO FCTC 2014).

This issue of between-product switching, the role the product prices play in the switching behavior, and the implications for policymakers who want to design tobacco tax systems aimed at reducing tobacco use are examined in the second chapter of this thesis. The analyses presented in the chapter utilize individual-level data obtained from the 2012 and 2014 waves of the International Tobacco Control (ITC) Zambia Survey. In Zambia, the number of cigarette users is growing, and the lack of strong tax policies is likely to be an important cause. When adjusted for inflation, levels of tobacco tax in Zambia have not changed since 2007. Moreover, roll-your-own (RYO) tobacco, a less-costly alternative to factory-made (FM) cigarettes, is widely used and easily accessible throughout the country. The study models the probability of FM and RYO cigarette smoking, as well as between-product substitution, using two estimation methods: a standard estimation method involving separate random effects probit models and a method involving a system of equations (incorporating a bivariate seemingly unrelated random effects probit) to estimate price elasticities of FM and RYO cigarettes and their cross-price elasticities. The longitudinal design of the ITC Zambia Survey permits strong inferences about causal relationships between price and the use of FM and RYO cigarettes, while the use of a system of equations allows for more precise analyses of the impact of price on the use of FM and RYO cigarettes and of the degree of their substitutability.

This study argues that tax-led price increases could significantly reduce cigarette use in Zambia. Furthermore, reducing between-product price differences would reduce substitution from FM cigarettes to RYO. Since RYO use is associated with lower socio-economic status, efforts to decrease RYO use, including through tax/price approaches and cessation assistance, would decrease health inequalities in Zambian society and mitigate the negative economic consequences of tobacco use experienced by the poor. The findings from this study can be used by policymakers seeking to reduce tobacco product use through tax-induced price increases and to advance public health by designing tax policies intended to decrease the between-product price differentials.

Global tobacco markets are undergoing large shifts: with the proliferation of many new tobacco products, such as e-cigarettes and HTPs, traditional cigarettes are losing market share. In such cases, the between-product switching might not be driven simply by price differences across different product types, but rather by the increased variety of product types on the market and/or the different characteristics of these products. The 2014-2016 introduction of a heated tobacco product, IQOS, in Japan is a case in point. Philip Morris International, one of the largest transnational cigarette manufacturers, has heavily invested in its new product, IQOS, marketing it aggressively as a less harmful alternative to cigarette smoking. However, the company’s assertions that the product replaces cigarettes have never been independently tested.

The objective of the study presented in the third chapter of this thesis is to determine whether the introduction of IQOS affected cigarette sales in a large economy. The study makes use of a natural experiment created during the rollout of IQOS in 2015 and 2016 in Japan. Monthly retailer panel data on cigarette sales in eleven Japanese regions from 2014 to 2018 are linked with IQOS introduction dates in those regions. A Chow test is used to determine whether trends in cigarette sales have changed with IQOS introduction in each region. A series of placebo models are estimated to test if events other than IQOS introduction could have better explained trends in cigarette sales in Japan. The analysis is conducted using three alternative ways to define the date of IQOS regional introduction for regions with partial initial coverage.

The study found that per capita cigarette sales substantially declined at the time of the introduction of IQOS heated tobacco products in each of eleven Japanese regions. Trends in cigarette sales are explained substantially better when the regions are assigned their IQOS introduction months, than when any one month is applied to all regions (a national-level exogenous shock), and compared to all possible permutations of the true IQOS introduction months among the regions. These results show that the introduction of IQOS likely reduced cigarette sales in Japan, while combined product volumes remained broadly unchanged. The net population health impact, however, cannot be assessed without resolving several key uncertainties related to the direct harms of IQOS and the patterns of both smoking and IQOS use.

Large differences in cigarette prices between geographical regions might also lead to tobacco product substitution similar to that described in the second chapter of this thesis. The existence of between-region price differences might incentivize some smokers from regions with higher cigarette prices to switch to cheaper cigarettes available across the border in another tax jurisdiction (e.g., a state, province or country). This substitution undermines the effects of tobacco tax policies, because instead of quitting or cutting back smoking, some smokers switch to less expensive undutied cigarettes. Moreover, the threat of illicit trade in tobacco products is being used by the tobacco industry as an argument against implementation of new tobacco control measures. Yet evidence on determinants of this kind of switching behavior and in particular the role tobacco=product prices play in driving this behavior, is limited. Policymakers need such analyses to inform the development of new tobacco tax policy.

Accordingly, the chapter analyses the association between prices and cross-border cigarette purchases in the EU, using potentially richer data. Previous studies of cross-border cigarette purchases in the region relied on survey-reported data—e.g., Eurobarometer and the ITC Project surveys—and therefore their results might be affected by underreporting of tax avoidance in the surveys. This analysis aims to shed light on the effects of cigarette price differences between EU Member States on cross-border cigarette purchases using a method that is free from potential reporting bias. Previous studies captured cross-border purchases by smokers themselves, whereas this study captures all forms of cross-border purchases. The study uses 2004-2017 official European Commission data and Becker's seminal methodology to disentangle the effects of higher cigarette prices on cigarette demand in the EU. Incentives for cross-border purchasing are measured as a function of differences in cigarette prices between bordering countries, controlling for population density near borders. Separate incentive variables are calculated for EU internal versus EU external borders and for terrestrial versus maritime borders. Tax-paid cigarette sales are modelled as a function of cigarette price, per capita income, non-price measures, and incentive variables using fixed-effects models.

The study finds that an upward convergence of cigarette prices across EU Member States would reduce cross-border cigarette purchasing and improve public health by contributing to a decline in cigarette consumption. Between-country price differences are not significantly associated with purchases across maritime borders and across borders with non-EU neighbors. In an average EU country, however, only about 1.5% of tax-paid sales are lost due to cross-border purchasing from neighboring countries with lower cigarette prices.

This is the first study of cross-border purchasing across the entire European Union using an econometric modelling of cigarette demand. Including separate import and export incentive variables by border type in the model (internal vs. external borders and terrestrial vs. maritime borders) is a new strategy and helps identify, for the benefit of policymakers and enforcement officials, the types of border (i.e. maritime or terrestrial) that are most likely to be crossed for cigarette purchasing. The study validates survey-based methods that examine cross-border purchasing. The finding that the estimates from this study are similar to those from the surveys is important, because currently much of the surveillance of cross-border cigarette purchases relies on surveys of smokers. The longitudinal setup of this study permits strong inferences about the causal relationships between cigarette price differences and cross-border cigarette purchases.

5.1. Policy implications

The findings from the studies presented in this dissertation reveal a number of important policy implications. The second chapter demonstrates that WHO FCTC guidelines pertaining to the unification of tax rates between different combustible tobacco product types might not be sufficient to reduce between-product substitution. Even though the tax rates on FM and RYO cigarettes in Zambia were equal, RYO tobacco was still substantially cheaper than FM cigarettes, most likely as a result of poor tax compliance for locally-farmed and informally-sold tobacco. Therefore, governments that consider unifying taxes across tobacco product types should also consider other measures to ensure tax compliance. These can include better monitoring of the tobacco supply chain or higher fines for retailers or farmers who sell products outside the official tobacco supply chain.

Under some circumstances, if one subscribes to the concept of harm reduction, price differentials incentivizing such substitution may be desired, when high-risk tobacco products are substituted to significantly lower-risks products. For example, the government of Sweden has historically kept taxes for snus (a form of lower-harm, smokeless tobacco) at lower levels than taxes for cigarettes, deliberately creating the price difference between these products to incentivize cigarette smokers to switch to snus (Sweanor, Alcabes, and Drucker 2007). This was an intentional decision by policymakers, because the use of Swedish snus is associated with a lower risk of cancers and cardiovascular diseases than cigarette smoking (Rodu and Cole 2009). Swedish men, in particular, have switched to snus, and tobacco-related deaths for men have dropped markedly compared to those of neighboring countries and of Swedish women (Ramström and Wikmans 2014).

The third chapter found that new electronic tobacco products can substitute for the old combustible products when the new product enters the market. In this particular case, the health risks of the new products, especially of HTPs, are still largely unknown. However, if these new products are found to be substantially less harmful to use than combustible cigarettes, reducing price differences to disincentivize switching between different tobacco products might no longer be optimal from a public health perspective. In such cases, if quitting tobacco products altogether is not a realistic goal, incentivizing a current smoker to switch to using the less harmful product could reduce that smoker's risk of developing cancer, cardiovascular disease, or other diseases caused by smoking tobacco.

It is necessary to understand the ways in which the harm associated with the use of these new products can be reduced in order to form policies to regulate that use. Wisely managed, government policies could use the introduction of less-harmful products to reduce overall tobacco-related harm and advance public health. For example, taxes on less-harmful new products could be used to raise prices so as to deter initiation by never users (particularly youth). At the same time, taxes on combustible products could be raised substantially higher than taxes on the lower-harm products in order to give current smokers an incentive to switch from combustible products to less-harmful ones, particularly those smokers who have had difficulty quitting using other means or who would like to continue using nicotine products.

The study presented in the fourth chapter of this thesis also has important policy implications. The study shows that European policymakers should not heed the tobacco industry's alarmist narrative of rising tax avoidance and evasion. The scope of cross-border cigarette purchasing in the EU is not large and an upward harmonization of cigarette prices across EU Member States would help to further reduce the scope of the problem. The study did not find that differences in cigarette prices between EU member countries and neighbouring non-EU countries had a significant impact on cross-border purchasing. This suggests that factors other than price are likely to determine the scale of the illicit cigarette trade from those countries. Most importantly, the study indicates that further tax increases in the EU, reducing variation in cigarette prices across the EU, would not only lead to reduced cross-border purchasing, but also to a decrease overall cigarette consumption. This would improve the health of EU residents and contribute to the Union's economic progress through lower healthcare costs and the higher productivity of a healthier population. Because the study finds higher income to be associated with higher cigarette sales, future tax increases need to account for the effects of growing income, to make cigarettes less affordable over time.

5.2. Further research

The research presented in this thesis is a starting point for further research in several key areas:

- The findings from the second chapter show that tobacco taxes need to be accompanied by strong measures to assure tobacco tax compliance. Little guidance in this matter is available for countries, particularly those with limited enforcement resources. In this case, it is clear that more research should be conducted to find viable policy options for increased tax compliance in lower-capacity tobacco farming countries, such as Zambia, where the likelihood of tobacco being sold in the informal sector is strong.

- These findings also indicate that the most-commonly used techniques to estimate between-product substitution are not perfect. Estimating demand equations for each product separately assumes that the error terms between the two models are uncorrelated. This is probably an unrealistic assumption because the decisions to smoke one product or to smoke another are almost certainly linked. Further research should address this issue by estimating the equations simultaneously, such as by using the seemingly unrelated regression (SUR) technique, where the error terms from the two models are allowed to be correlated.

- The research presented in the third chapter examined whether the event of IQOS introduction affected trends in cigarette sales. With so few cases analyzed to date, additional research on the issue of the exact rates of product substitution is needed.

- Additionally, throughout the period of analysis presented, product prices were practically the same for IQOS and regular cigarettes, and both stayed unchanged over time. It is important to seek other data with variability in prices to examine the role that the relative prices of the two products played in IQOS and cigarette use.

- There are aspects of the cigarettes-to-IQOS replacement that cannot be determined from sales data alone. A reduction in sales that is driven by reduced smoking initiation or by increased smoking cessation would potentially have far more clinical meaning than one driven by a prolonged reduction in smoking intensity among dual users (e.g., using both cigarettes and IQOS) because the harm from smoking is not linear (i.e., smoking only a few cigarettes per day generates as large a proportion of the harm as smoking 10 or more cigarettes). These relationships can only be examined using individual surveys of cigarette and IQOS users. Therefore, future research should examine individual-level tobacco product use.

- Findings from the fourth chapter indicate that regional tobacco tax harmonization efforts can be effective not only in reducing tobacco consumption, but also in reducing cross-border purchasing of tobacco products. Yet, other than in the EU, there has been little success in regional tobacco tax harmonization efforts. Future research should focus on the feasibility of using the EU experience to implement similar tax harmonization efforts in other regions of the world.

- Lastly, the effects of smokers switching behaviors are not incorporated in, and therefore cannot be predicted by, most existing economic models used by large organizations, because these models typically focus on cigarettes only. Findings from all three studies presented in this thesis demonstrate significant effects of those switching behaviors. Therefore, researchers should work to incorporate smoker's switching behaviors into existing models that are being used to inform tobacco tax policy change better.

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