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How tobacco excise increases affect smoking behaviours in Australia

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How tobacco excise increases affect smoking behaviours in Australia

David Whytcross

Abstract

Australia has been at the global forefront in using higher cigarette taxes to curb smoking behaviours. This paper aims to utilise Australia's precipitous increase in cigarette taxes (via its tobacco excise) to examine how it is affecting smoking behaviours across the population. Data from the *Household, Income and Labour Dynamics in Australia* (HILDA) Survey are used to estimate individuals' behavioural changes in response to rising cigarette taxes, with the analysis extended to detail household income quintiles and discrete age groups. In general, it is difficult to separate the effect of rising cigarette taxes with growth in anti-smoking sentiment, but it is evident that higher cigarette taxes work to reduce smoking behaviours, and that it affects different groups in different ways. Notably, financially constrained people in the lowest-income households are much more likely to quit smoking or reduce their smoking intensity in response to higher cigarette taxes than those in higher-income households, while younger people are becoming less inclined to start smoking and subsequently become addicted.

Keywords: Cigarettes, Tax, Demand Elasticity, Addiction, Household Surveys, HILDA

JEL classification: C23, D12, D62, H21, I12, I18

Smoking is a public health issue of great importance with respect to policy responses, both globally and domestically in Australia. The use of higher taxes on cigarettes has been a cornerstone of a suite of measures used to curb smoking rates. To this end, Australia has undertaken a rapid above-indexation escalation of the tobacco excise on manufactured cigarettes since April 2010. The highly substantial jump in the tobacco excise has created an interesting natural experiment, as it provides the requisite variability in cigarette taxes to try to measure just how effective tax increases can be to curb smoking – both in general and for different sub-groups of the population that may have heterogeneous demand responses.

To explore the issue, this research paper will combine time series tax data with the wealth of panel data available from the *Household, Income and Labour Dynamics in Australia (HILDA) Survey*. The HILDA Survey is an annual ongoing longitudinal survey that commenced in 2001 and is intended to be representative of the Australian population. HILDA Survey respondents are asked questions regarding their smoking behaviours, including whether they smoke and, if so, how many cigarettes they smoke each week and how much they spend on cigarettes. These responses, among others, can be combined with the broad range of demographic and other data for each respondent to help achieve a sense of how the tobacco excise affects the population.

The estimations in this research paper use fixed effects techniques with the HILDA Survey data so that the results reflect changes to individuals' behaviour over time as the tobacco excise is increased, rather than changes to the sample composition. The research will estimate the effect of tobacco excise increases on smoking participation (whether someone is a smoker or not), the cessation rate (propensity to quit smoking), the initiation rate (propensity to start smoking), and smoking intensity (if an individual is a smoker, the quantity of cigarettes they smoke). While the intent is to isolate the effect of tobacco excise increases on smoking behaviours, it is noted that there may be confounding variables that affect smoking behaviours. The estimations are subsequently partitioned on the basis of income quintiles and age groups to illuminate potentially heterogeneous demand responses to higher taxes. There may also be alternative demand responses that the HILDA Survey data is unable to capture detail for, such as downgrading to cheaper cigarettes.

The estimation results indicate that tobacco excise increases are contributing to lower smoking participation and lower smoking intensity, and that these effects are continuing even as the tobacco excise continues to rise. However, the effect of increasing the tobacco excise can be difficult to decouple from the passage of time, as there is collinearity with growing anti-smoking sentiment and reduced likelihood of smoking as people grow older. Where the effect of tobacco excise increases is most noticeable is for lower-income households, which are more tax-elastic in terms of smoking participation and smoking intensity, although despite declining smoking behaviours they are still often considerably worse off than higher-income households as a result of the higher taxes.

This research contributes to the literature through the use of HILDA Survey data to explore smoking behaviours at a population and demographic level. While there has been considerable use of panel data to measure changes in smoking behaviour, including in Australia, the literature review for this paper only found use of the HILDA Survey for this purpose by Buddelmeyer and Wilkins (2011), with a study that only covered 2001–2003. This research uses the full time series of the HILDA Survey where possible, so it includes all of the years containing the largest tobacco excise increases.

The paper is structured in the following manner. *Section I* provides the institutional background behind Australia's tobacco excise increases and other anti-smoking measures. *Section II* outlines an extensive literature review into a broad range of smoking and tax research. *Section III* details the types of data being used to perform the research. *Section IV* outlines the identification strategy for measuring changes to smoking participation and smoking intensity (among other more detailed estimations), while *Section V* outlines the estimation results and *Section VI* provides a discussion surrounding the results. *Section VII* explains some limitations to the research, including the presence of confounding variables and challenges with HILDA Survey data. Finally, *Section VIII* concludes the paper and briefly notes some potential opportunities for future research and policy responses.

I. Institutional background

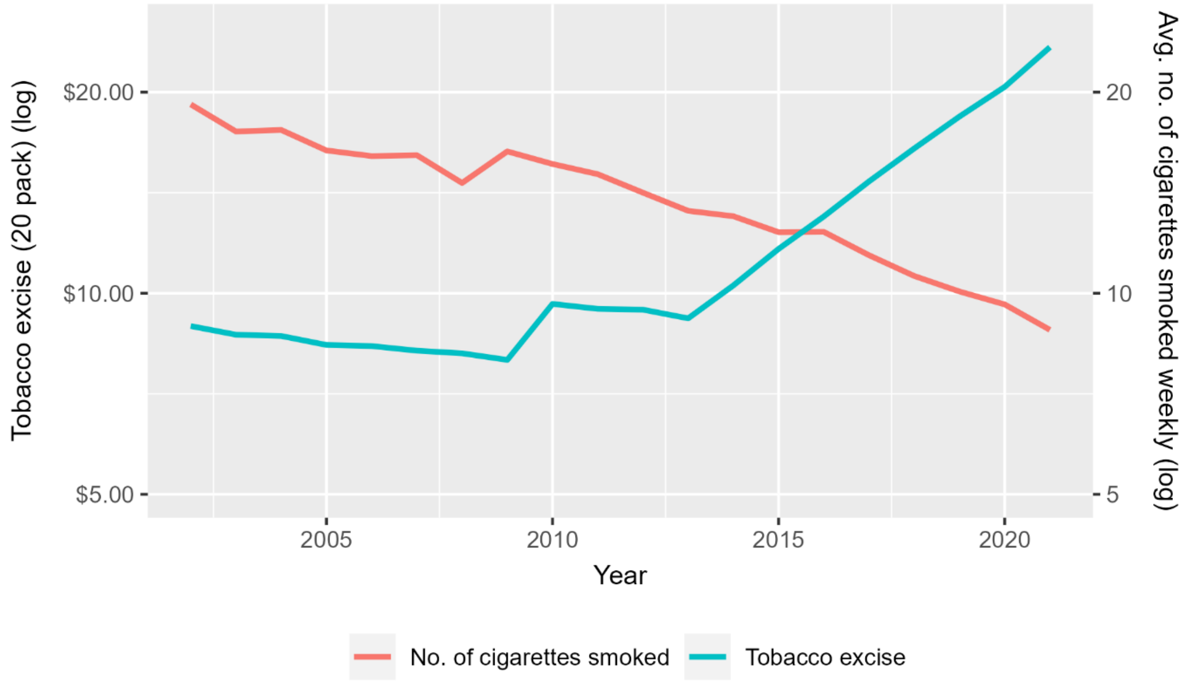
Australia has long been a global leader in implementing anti-smoking policies. These have included tobacco excise increases and a range of other measures, which Wilkinson et al. (2019, p. e618) summarises as including "mass-media campaigns, smoke-free environments, access to cessation aids, regulation of marketing, pictorial health warnings, and world-first standardisation of tobacco product package design".[1] These policy measures have occurred at the federal and state levels of government. The Federal Government is responsible for the tobacco excise (political support for which has largely been bipartisan), access to cessation aids (through the inclusion of nicotine replacement therapy products in the Pharmaceutical Benefits Scheme) and package design laws. State governments are primarily responsible for marketing regulation outside of package design (such as point-of-sale display bans) and the creation of smoke-free environments.[2]

While all of the anti-smoking measures are likely to have curbed smoking behaviours, the rapid rise in the tobacco excise since April 2010 may be the most effective measure. Figure 1 compares the 'per stick' tobacco excise on manufactured cigarettes throughout the HILDA Survey time period (indexed to average weekly ordinary time earnings (AWOTE) in 2023 Australian dollars) with the average number of cigarettes smoked per week by the entire population (non-smokers are included, being counted as smoking zero cigarettes each week). Both variables use a log scale, so percentage changes are presented equally throughout. It demonstrates that one or both of smoking participation and smoking intensity have continued to fall as the tobacco excise has risen in real terms.

[1] The "world-first standardisation of tobacco product package design" refers to plain packaging laws instituted under the *Tobacco Plain Packaging Act 2011*, which took effect on 1 December 2012.

[2] For example, within the duration of the HILDA Survey, the following list represents a selection of measures the Victorian Government has instituted: banning smoking in restaurants in July 2001; banning point-of-sale cigarette advertising in January 2002; banning smoking in pubs and clubs in July 2007; banning smoking in cars with children in January 2010; banning point-of-sale display of cigarettes in January 2011; and banning smoking in commercial outdoor dining areas in August 2017.

Figure 1: Australia's tobacco excise rate vs average cigarettes smoked weekly



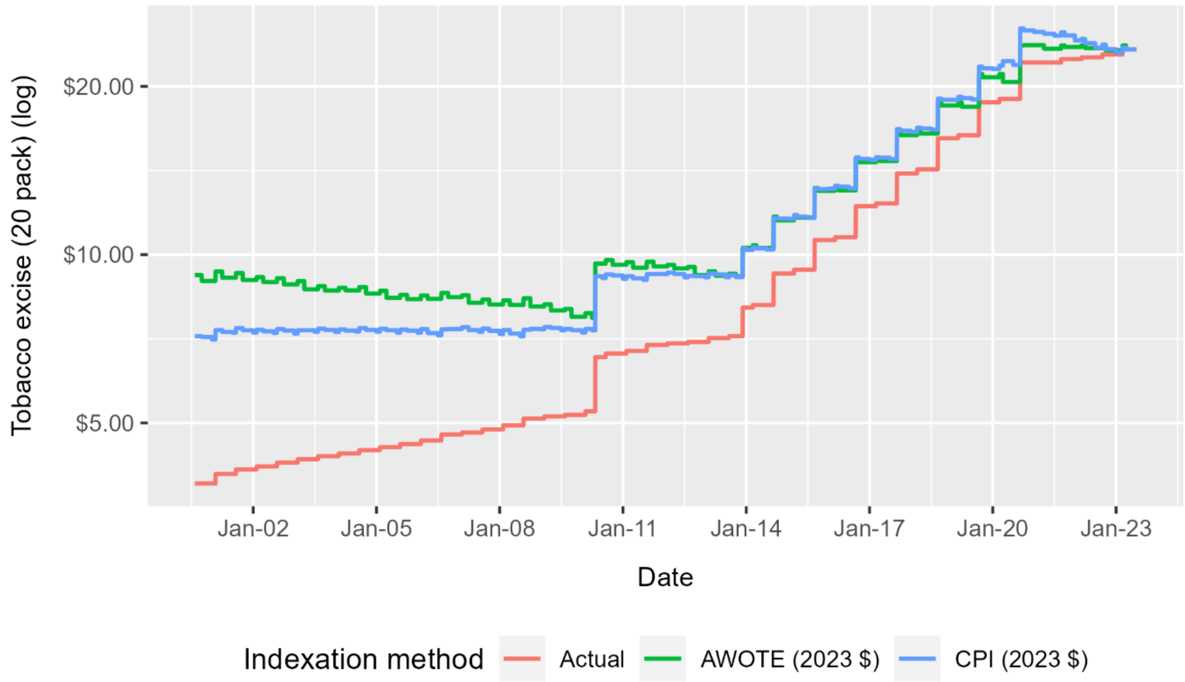
Note: Tobacco excise reflects value on 30 June each year, indexed to AWOTE (in 2023 dollars); average cigarettes smoked is based on the annual cross-sectional weighted values of HILDA respondents.

While the tobacco excise is indexed biannually, Figure 1 demonstrates that it became more affordable during the 2000s. During this period, the tobacco excise underwent biannual indexation based on the Consumer Price Index (CPI), which was outpaced by wage growth (as measured by AWOTE), so the tobacco excise became more affordable relative to wages. In addition, there were no above-indexation increases. The above-indexation increases commenced with a 25 per cent hike in April 2010, which was imposed with minimal notice. This was followed by eight pre-announced 12.5 per cent hikes beginning in December 2013 and occurring annually every September thereafter until September 2020.[3] There are further increases to the tobacco excise in the pipeline that are not included in Figure 1. The 2023-24 Budget legislated three further above-indexation tobacco excise increases of 5 per cent each – the first increase occurred in September 2023, with the remaining two increases to occur in September 2024 and September 2025.

The period outlined in Figure 1 also included a change in the indexation method from CPI to AWOTE in March 2014 so that indexation would keep up with relative affordability for the population, while biannual indexation now occurs every March and September rather than February and August to align with AWOTE data availability. Figure 2 demonstrates the timeline of how these changes have occurred, displaying how the tobacco excise has risen nominally and with respect to indexation by CPI (i.e., how the tobacco excise compares with general price levels) and AWOTE (i.e., the relative affordability of the tobacco excise).

[3] There were initially four tobacco excise increases announced, with the second round of four increases (from September 2017 through September 2020) announced in May 2017.

Figure 2: Australia's tobacco excise under different indexation methods



The tobacco excise referred to in Figure 2 is the 'per stick' rate on manufactured cigarettes, which simply means that each manufactured cigarette (e.g., a single cigarette that could be purchased as part of a pack of cigarettes) has that rate of excise imposed. A substitute for manufactured cigarettes is loose-leaf tobacco (LLT, also known as roll-your-own tobacco), for which the excise is based on a per kilogram rate that is equivalised against the excise on manufactured cigarettes. It should be noted that the excise for LLT has not only been subject to the same above-indexation increases as manufactured cigarettes, but has progressively had its equivalisation weight reduced, leading to even higher percentage increases to its specific excise.[4] While this research paper focuses on the 'per stick' rate for manufactured cigarettes, this is important context as it is making an obvious substitute product for manufactured cigarettes considerably less affordable.

II. Literature review

There is a wealth of literature available regarding smoking behaviours and tobacco regulation, including the use of taxes to curb smoking. This section intends to provide extensive coverage of the various literature, which generally falls under three themes: the *economic theory* informing research on smoking behaviours and regulation; the *research techniques* used to examine these issues; and

[4] To calculate the LLT excise, the 'per stick' excise is divided by the equivalisation weight (roughly the estimated weight of a manufactured cigarette in grams) to find a per-gram rate, which is multiplied by 1000 to find the per kilogram rate. The equivalisation weight was progressively reduced from 0.8 grams to 0.7 grams in four 0.025-gram increments from September 2017 through September 2020, and a further progressive reduction from 0.7 grams to 0.6 grams is scheduled to occur. For example, the LLT excise as of 30 June 2023 was $1,663.36 per kilogram with an equivalisation weight of 0.7 grams, which is 14.3 per cent higher than if an equivalisation weight of 0.8 grams was kept ($1,455.44 per kilogram).

the *common limitations* faced in conducting such research. This review will also consider how previous research can inform the content of this research paper.

Economic theory

Rationale for higher cigarette taxes

DeCicca et al. (2022, p. 891) explain that the "economic rationale for regulating tobacco typically is based on two main objectives: 1) reducing externalities and internalities associated with tobacco consumption, and 2) raising revenue." The concepts of externalities and internalities are most important as they refer to the negative health consequences imposed by smokers on others and themselves. Negative externalities are costs imposed on others, and can be generated in the form of second-hand smoke, increased public healthcare costs, reduced labour productivity (e.g., due to absenteeism or potential inability to work), greater mortality at earlier ages, and even reduced birth weight for infants of pregnant smokers (DeCicca et al., 2022). Conversely, internalities are costs smokers impose on themselves, and are generally manifested as long-term health costs due to present-biased short-term decisions to smoke, which can result in a reduction in lifetime utility (DeCicca et al., 2022; Gruber & Köszegi, 2001).

General demand elasticity and addiction

Wilkinson et al. (2019) describe how tobacco tax increases can support smokers quitting, disincentivise non-smokers from taking up the habit, and reduce the amount of cigarettes consumed by continuing smokers. However, the extent to which this occurs and results in cigarette taxes acting to reduce externalities and internalities – rather than simply raising revenue – is tied to the price elasticity of demand (Gallet & List, 2003) and the extent of pass-through of taxes to retail prices. In the event of a tax increase, inelastic demand means the reduction in consumption is low and more revenue is raised due to higher taxes collected per cigarette, whereas elastic demand means consumption is reduced considerably, with smokers generating lesser internalities and externalities. The literature indicates that demand for cigarettes is relatively inelastic (Crespi et al., 2021; DeCicca et al., 2022; Field et al., 2006; Nesson, 2017), and that this contributes to relatively high pass-through of taxes to retail prices (DeCicca et al., 2022).

The relative inelasticity of demand for cigarettes is typically attributed to the addictive nature of cigarettes and the habit formation of smokers, although the literature regarding these concepts is varied. Some research into addiction assumes a reasonable level of control over addictive behaviours. For instance, there is some evidence of 'rational addiction', where in the event of a future cigarette tax increase, smokers assess the current and future costs of current cigarette consumption – rather than just current costs – and make lifetime welfare-maximising decisions (Gruber & Köszegi, 2001). The ability to act rationally extends to people who continue to smoke, as they reduce their smoking intensity as taxes rise despite their addiction, potentially due to larger shares of their income being taken up by cigarette purchases (Caulkins & Nicosia, 2010). The smoking intensity outcomes resulting from an increased tobacco excise in Australia will be explored in the research in this paper.

The majority of literature is generally less positive about the control that addicts have regarding their consumption of cigarettes and other addictive products. In extending the research to non-smoking addiction, Acuff et al. (2023) define the 'reinforcer pathology' model as where an addict excessively overvalues the immediate rewards of a drug-specific reinforcement (e.g., withdrawal relief) compared with the longer-term health costs of smoking, which are delayed and less certain. The overvaluation of very short-term benefits associated with addictive products aligns with research by Field et al. (2006) that indicates that smokers are typically found to be more impulsive than non-smokers and that smokers will place greater delayed reward discounting on cigarettes than on money. O'Donoghue and Rabin (2015) argue that caution should be exercised regarding time-preference experiments, however, as the value of greater certainty of current payoffs and the potential for additional transaction costs in the future may bias towards preferencing immediate payoffs.

A further consideration in the addiction literature is Buckell et al. (2021) outlining the concept of 'experience-conditioned choice' models, whereby current consumption of tobacco products is conditioned upon users by their previous consumption of tobacco products. The intuition with these models relates to how long-term smoking is associated with addiction and 'habit formation' – the barriers to quitting smoking include the physical addiction and the psychological habits for smoking that have formed over time. Renke and Sinne (2020) provide greater consideration to habit formation, explaining that reducing consumption can be more difficult for those with less self-control who have formed habits for welfare-reducing consumption as they are subject to greater withdrawal costs associated with breaking the habit.

Heterogeneity of demand elasticity

The general theory for demand elasticity for cigarettes can be summarised as when taxes increase, cigarette consumption declines, but cigarette expenditure still increases (Field et al., 2006). This means demand is inelastic as consumption falls by less than taxes (or prices) increase. However, demand elasticity is not uniform, but rather can be heterogeneous depending on how taxes change and the groups affected by tax changes.

With regard to how taxes change, Renke and Sinne (2020) explain that demand elasticity for addictive products is lower when taxes are increasing as opposed to decreasing. If taxes increase and an individual wants to respond by reducing consumption, their addiction and/or habit formation means they can incur withdrawal costs associated with breaking or curbing the habit, which can limit the extent to which they are willing or able to reduce consumption. In contrast, when taxes decrease there is not the same limiting factor preventing an increase in consumption, leading to more elastic demand.

Demand heterogeneity across different groups within the population is notable in the literature and is going to be examined in this paper (with respect to income and age). People of lower income tend to be more responsive to higher cigarette taxes (Goldin & Homonoff, 2013; Haavio & Kotakorpi, 2011), but are also more likely to be smokers already (DeCicca et al., 2022). Crespi et al. (2021) note that younger people tend to have more elastic demand for cigarettes, as higher cigarette taxes are effective in preventing smoking initiation and therefore future cigarette consumption, which may be a useful consideration for cigarette tax policy.

There are further unexpected cigarette demand heterogeneity concerns, such as lighter smokers being more likely to quit than heavier smokers in response to a tax increase (Adda & Cornaglia, 2013). In addition, there are apparent network effects for smoking behaviours, as people who are part of fixed friendship groups that include smokers are less able to respond to higher cigarette taxes than people who have greater ability to move between friendship groups (Badev, 2021). These matters suggest that demand responses to higher cigarette taxes can be complex at the individual level and provide a strong basis for using fixed effects techniques in this research paper.

Tax pass-through to retail prices

It was previously noted that the effectiveness of cigarette taxes depended on both demand elasticity and the extent of pass-through of taxes to retail prices. The relatively inelastic demand for cigarettes means taxes should largely be able to be passed on (DeCicca et al., 2022). Harding et al. (2012) explain that taxes do not necessarily get passed on to the full extent, but that this is likely due to the context of the United States' state-based cigarette taxes – the availability of cheaper cigarettes across nearby borders partially dampens the ability to pass through tax costs as within-state demand is more elastic (Goolsbee et al., 2010; Hanewinkel et al., 2008).

While this is less relevant for countries with nationally applied cigarette taxes, Gilmore et al. (2013) indicate that tobacco companies adjust their tax pass-through depending on the product category. In an attempt to keep incentivising people to take up or retain the habit of smoking, lower-priced cigarettes have less tax pass-through so that more affordable cigarette options remain, while higher-priced cigarettes have much higher pass-through. However, there is not necessarily any evidence that similar strategies have been undertaken in the Australian market – given the extent of tobacco excise increases over the past 15 years, it is unlikely that even ultra-low-cost cigarettes could be considered relatively affordable for low-income earners.

Optimal sin taxes

There is complexity involved in determining the 'optimal' level of cigarette taxes (and sin taxes in general), and this is an important topic given the a focus of this research paper is to assess whether continuing to raise cigarette taxes remains effective. O'Donoghue and Rabin (2006, pp. 1825-1826) explain that sin taxes are typically imposed to "raise revenue, correct externalities, or to redistribute wealth," although the cost of internalities means that optimal sin taxes may need to be even higher than rationalised under this standard framework to reduce current *and* future consumption, and consequently maximise social welfare.

This theory was informed by Gruber and Köszegi (2001) and has been expanded upon by Haavio and Kotakorpi (2011), who outline that optimal sin taxes may be even higher than the political equilibrium sin tax. The political equilibrium sin tax is already substantial for cigarettes, as the median voter is unlikely to smoke due to low smoking participation but would benefit from the redistributed tax revenue and avoidance of externalities. Despite the case for higher sin taxes to correct for internalities, Ayyagari et al. (2009) note with respect to alcohol consumption that heavier users are less likely to reduce consumption and that the benefits of reducing internalities would not be achieved, hence higher sin taxes can be significantly welfare-reducing for those particular individuals – a similar concern to the tobacco excise in Australia, which has already increased to very high levels for continuing smokers.

Regressivity of cigarette taxes

Understanding who bears the burden of higher cigarette taxes is important, particularly in instances where individuals are unable to quit smoking. DeCicca et al. (2022) explain that smokers differ from non-smokers in noticeable ways, as smokers typically have lower education and income. Considering the inelastic demand for cigarettes, it is likely that cigarette tax increases will be regressive and place a greater tax burden on people of lower income, although the regressivity of a tax increase will depend on the relative elasticity of demand for lower income groups versus higher income groups.

There is research indicating that people under financial stress are more likely to be unable to quit smoking, as they use cigarettes to alleviate stress (Haavio & Kotakorpi, 2011). Smokers with lower income are more likely to be financially stressed due to cigarette prices. As such, while higher cigarette taxes may provide enough financial incentive to break the cycle and quit, it may otherwise reinforce a cycle of financial stress and smoking dependence. The potential outcome is diminishing returns to higher cigarette taxes as the remaining smokers are those under financial stress who find it more difficult to quit.

Research techniques

Panel data

Controlled experiments into smoking behaviours would be unethical due to negative health impacts and impractical due to the long timeframes that would be involved, so most research performed regarding the effects of tobacco regulation on smoking behaviours tends to rely on natural experiments. These natural experiments usually involve panel data, as they rely on multiple observations of the same subjects to analyse changes in behaviour.

Cotti et al. (2016, p. 107) effectively surmise why techniques like fixed effects rather than OLS are useful for such research, noting that “it is difficult to attribute changes in across-wave smoker behaviour to changes within smokers,” because as “cigarette taxes increase, some smokers choose to quit smoking, leaving a different pool of smokers.” For this type of research, it is the change in behaviour within smokers, rather than across a varying selection of smokers, that is most useful to understand. It has previously been noted that Adda and Cornaglia (2013, p. 3112) provide similar insight when stating that “an OLS regression of smoking intensity on excise taxes may find a spurious positive effect due to a change in composition in the pool of smokers,” assuming the likelihood of people dynamically selecting out of smoking (i.e., quitting smoking) is related to a particular trend, which in their case was that the ‘low smoking intensity group’ was more likely to quit.

The available panel data for this research is typically sourced from detailed surveys or sales tracking (DeCicca et al., 2022). Survey panel data source examples include the HILDA Survey in Australia, which is being used for this research paper, and both the National Health and Nutrition Examination Survey (NHANES) and the National Health Interview Survey (NHIS) in the US. The most common sales tracking research uses Nielsen Homescan data, which is also based in the US. It relies on participants scanning the unique product code (UPC) of all products they have bought in order to find a nationally representative sample of American consumer purchases. There are helpful examples of survey and sales tracking data use in academic research both within Australia and overseas.

In the Australian context, Wilkinson et al. (2019) used commissioned monthly survey data from Roy Morgan Research between 2001–2017 to analyse the differential effects of the one-off tobacco excise increase of 25 per cent in April 2010 versus the first four 12.5 per cent excise increases beginning in 2013, concluding that the one-off large increase was more effective for smokers of lower socioeconomic status, while sustained increases led to more consistent smoking reduction outcomes across the population, and in all cases many people switched to LLT. Dunlop et al. (2011) exploited the Tobacco Tracking Survey of the Cancer Institute NSW being in progress when the April 2010 excise hike occurred to analyse the likelihood of people attempting to quit smoking in different demographic groups, noting that it led to a spike in quit attempts that was not sustained soon after the hike. Buddelmeyer and Wilkins (2011) used HILDA Survey data to analyse changes in smoking behaviours from 2001–2003 as several state-based tobacco regulations were implemented, concluding that these milder restrictions had negligible effects on smoking.

In the US, Cotti et al. (2016) use Nielsen Homescan data to analyse smoking behaviour changes following tobacco regulation changes. The research concluded that higher taxes reduced smoking participation and intensity, while purchases of smoking cessation products increased, and there was some heterogeneity in demand responses. Harding et al. (2012) also use the data to assess how cigarette taxes are passed through to retail prices in different states, using fixed effects based on the UPC of different cigarettes. Adda and Cornaglia (2013), on the other hand, use NHANES data to run an experiment regarding whether smokers are smoking each cigarette more intensely in response to tax increases, such that they get the same amount of cotinine (a metabolite of nicotine that is commonly used to measure nicotine exposure) out of a lower quantity of cigarettes.

Standard approaches and variables

Panel data usefulness is determined by the variables available within the data set and how they are used. The consumption of sin products like cigarettes is typically assessed in terms of its ‘extensive margin’ or ‘participation elasticity’ (i.e., smoking participation, which is whether someone smokes at all) and its ‘intensive margin’ or ‘conditional elasticity’ (i.e., smoking intensity, which is the amount or frequency of smoking among those that do smoke) (Caulkins & Nicosia, 2010; DeCicca et al., 2022; Renke & Sinne, 2020). Studies therefore often rely on data regarding whether individuals smoke and, if so, the quantity of cigarettes they smoke over a particular timeframe. This is consistent with the research that is being performed in this paper.

The use of tax or retail price data is a common issue in smoking research with respect to data availability, endogeneity concerns and the examination of policy outcomes. While retail price data would be ideal for measuring price demand elasticity, there are benefits to the use of tax data. Adda and Cornaglia (2013) note that prices may be endogenous, as they simultaneously influence and are influenced by demand changes, whereas tax changes are exogenous shocks that are better suited as independent variables. Furthermore, price elasticities tend to be relatively similar when using tax or price data (Abrevaya & Puzzello, 2012). The availability and certainty of tax data also makes it easier to use, although the lack of retail price data can be challenging if industry pricing strategies attempt to circumvent the impact of higher taxes (Wilkinson et al., 2019).

Common limitations

It can be difficult to isolate for the effect of tobacco excise increases on smoking participation and intensity due to confounding variables for the excise and alternative responses available to smokers.

Confounding variables

There is generally considered to be unobservable, perpetual growth in anti-smoking sentiment over time. This is difficult to disentangle from sustained excise increases when estimating relative contributions to declining smoking participation and intensity. It may create endogeneity issues for estimations, as anti-smoking sentiment may be relied on for political support to implement tax increases (DeCicca et al., 2022; Harding et al., 2012; Pesko & Warman, 2022). The variety of complementary tobacco regulation (noted in *Section I*) can also confound the effect of tobacco excise increases, leading to measures like those described by Wilkinson et al. (2019), including the imposition of plain packaging legislation as a dummy variable in their research.

Alternative responses to higher taxes

There is considerable research into the different ways people can respond to higher cigarette taxes beyond reducing smoking intensity or quitting entirely. Crespi et al. (2021) specifically study this issue, noting that smokers have alternative options including: downgrading to cheaper cigarette brands; substituting with cheaper alternative products (e.g., LLT cigarettes); or switching to cigarettes with higher nicotine to maintain their nicotine intake while reducing cigarette expenditure. These concerns are supported in other research, including Gibson and Kim (2019) explaining that smokers may respond to higher cigarette taxes on the quality margin rather than quantity margin by downgrading to cheaper cigarettes; Hanewinkel et al. (2008) explaining that LLT cigarettes are commonly a lower-cost, attractive substitute to manufactured cigarettes; and both Nesson (2017) and Adda and Cornaglia (2013) noting that smokers may attempt to maintain nicotine intake, either by switching to cigarettes with higher nicotine content or smoking each cigarette more intensely.

Finally, e-cigarettes present new difficulties in estimating tax effects on smoking behaviours. As DeCicca et al. (2022, p. 922) describe, there is uncertainty over whether e-cigarettes are a substitute or complement to tobacco cigarettes – i.e., it “may be a precursor to future cigarette smoking or perhaps a longer-run substitute for it.” E-cigarettes have often been successfully used as a smoking cessation device, and Pesko and Warman (2022) explain that it is primarily used as a substitute to tobacco. It is noted here as research into e-cigarettes is an emerging space and the impact on smoking estimations is unknown, and as such it will be discussed further in *Section VII* of this paper.

III. Data

This research project brings together a combination of HILDA Survey and tobacco excise data to analyse how changes to cigarette taxes affect the population.

HILDA Survey

The key source of data in this research paper is the HILDA Survey, covering 2001–2021. The HILDA Survey is a longitudinal survey that the HILDA website (The University of Melbourne, n.d.) notes covers more than 17,000 Australians each year, with the intent of being representative of Australia's population (with the exception of some recent migrants and people in remote communities). The HILDA Survey is funded by the Federal Government, and is largely administered by the *Melbourne Institute: Applied Economic and Social Research*, which is part of the University of Melbourne (Watson, 2021). It is a rich data source that is useful for this research as it combines demographic and background data with responses to questions on issues like individuals' finances, lifestyle, health and education, among others.

Individuals are denoted with a cross-wave identification number (HILDA variable name: *xwaveid*) so that they can be tracked across waves, where each wave is a different year of the survey. There are multiple components to the HILDA Survey. The 'household form', 'household questionnaire', 'continuing person questionnaire' and 'new person questionnaire' are completed in the presence of an interviewer, while the 'self-completion questionnaire' (SCQ) is as described, with written or online answers provided in a respondents' own time. The SCQ is most relevant for this research as it contains the questions related to smoking, although this means that any estimations are confined only to people who have responded to the SCQ (as the smoking status of non-respondents is unable to be assumed). This can reduce the sample size available for estimations, particularly when attempting to use a balanced panel over several years, as SCQ responses are required in each year.

The two main SCQ questions focused on in this research relate specifically to smoking and form the basis of dependent variables in estimations. The first question is 'Do you smoke cigarettes or any other tobacco products?' (*lssmoke* in Wave 1, *lssmkf* in Wave 2-21), for which there are five potential answers: 'No, I have never smoked'; 'No, I no longer smoke'; 'Yes, I smoke daily'; 'Yes, I smoke at least weekly (but not daily)'; and 'Yes, I smoke less often than weekly'. This question has been asked in each wave of the survey, although the available responses in Wave 1 only had a single 'Yes, I smoke' response. For the purposes of estimations in this research paper, responses for all years have been aligned to the Wave 1 responses, so individuals in a given wave are only being considered as lifetime non-smokers ('No, I have never smoked'), former smokers ('No, I no longer smoke'), or current smokers (any 'Yes, I smoke…' response). The second question is 'How many cigarettes do you usually smoke each week?' (*lstbcn*, available from Wave 2), which only has to be answered if an individual responds to the previous question that they are a smoker.

The HILDA Survey data also enabled the creation of household income quintiles and multiple age groups. For household income quintiles, the most appropriate data is the respective positive and negative imputed annual household income (*hifdip* and *hifdin*), which allows for a more complete dataset by imputing missing or implausible values in given waves.[5] For this research, the positive and negative columns have been combined into a single variable for imputed annual household income, then partitioned into quintiles for each wave based on the entire HILDA sample in each year. When the data is filtered to only include SCQ respondents, each quintile may not have an equal number of responses (e.g., the lowest income quintile tends to be more responsive to the SCQ than other quintiles), but it has been completed this way as household income quintiles should be based on relative position against the population rather than against the less representative sample of SCQ respondents. For age groups, individuals were partitioned into 15-year age groups, including 15-29, 30-44, 45-59, 60-74 and 75+. Individuals under 15 were not considered as they do not respond to the HILDA Survey themselves.

Tobacco excise data

The tobacco excise data was collected from the 'Historical Excise Rates' spreadsheet available on *data.gov.au* (Australian Government, 2023). The 'per stick' rate for manufactured cigarettes is the relevant excise data extracted from that spreadsheet, and this was extrapolated into a daily time series so that all days throughout the HILDA Survey period would have excise data available for estimation purposes. To convert the daily excise data into 'real' values, CPI (Australian Bureau of Statistics [ABS], 2023, June) and AWOTE (ABS, 2023, May) data were both used, as the tobacco excise has been indexed by each data set at different times during the relevant period (see Figure 2 and related discussion in *Section I* of this paper).

AWOTE was ultimately used for indexation when performing estimations. The research is assessing the affordability of excise increases, which should be based on relative incomes rather than relative prices of other goods and services. AWOTE data is collected biannually at the mid-point of the June and December quarters each year, which means it is effectively collected in mid-May and mid-November. The tobacco excise is then indexed in the following quarter (e.g., the mid-November AWOTE data informs the indexation on 1 February the following year). For this research, to index the daily tobacco excise data set, AWOTE is first converted to a daily time series where each day in a reference quarter (when the data was collected) and its immediately following quarter (when tobacco excise indexation occurs) reflect the reference quarter value (e.g., the December and March quarters are represented by the new value calculated in mid-November). The tobacco excise is subsequently indexed to these values, using the excise on 30 June 2023 as a base.

[5] Each individual in a single household will be listed as having positive or negative imputed annual household income, but not both (i.e., they could have a positive value and a zero negative value, or a negative value and a zero positive value).

IV. Identification strategy

There are several smoking behaviours that are possible to estimate using the HILDA Survey data and will be considered here. The effect of the increasing tobacco excise, which will be the primary independent variable in all cases, will be estimated with respect to dependent variables including smoking participation (i.e., the probability that someone smokes), the cessation rate (i.e., propensity to quit smoking), the initiation rate (i.e., propensity to start smoking), and smoking intensity (i.e., the quantity of cigarettes consumed by smokers). The models, particularly for smoking participation and smoking intensity, closely follow the approach of Nesson (2017).

For all estimations, fixed effects techniques will be used so that the change in behaviour 'within' individual smokers is estimated. There will be autocorrelation between individuals' observations over time (e.g., a non-smoker is more likely to be a non-smoker in the following year), so fixed effects help control for that issue while also preventing the changing composition of smokers over time causing issues, as discussed in the *Panel data* section of the literature review.

Smoking participation, cessation rate and initiation rate

For smoking participation, the cessation rate and the initiation rate, the dependent variable is a binary response, which means a probabilistic regression like a logit or probit model should be used. A conditional logit model is being used in this case, as it effectively enables fixed effects in a logistic regression. It means that we can estimate the logistic probability that an individual will be a smoker (or will cease or initiate smoking) based on the logged value of the tobacco excise, while also controlling for autocorrelation between individuals' observations in different time periods.

Fixed effects are applied for each individual (HILDA variable name: *xwaveid*), as well as for each Australian state or territory (*hhstate*). For smoking participation, individuals are considered smokers if they answer with any of the 'Yes' responses to the relevant question in the HILDA Survey (*lssmoke* or *lssmkf*) and will be given probability of $y = 1$ as a result. In these estimations, the use of unbalanced and balanced panels is compared, with balanced panels using an interrupted time series approach.

For the cessation rate, only individuals whose previous survey response was that they are a smoker were considered, and if their current response was 'No, I no longer smoke', then they are given $y = 1$ as they have quit. For the initiation rate, only individuals whose previous response was either of the 'No' responses were considered, and if their current response was any of the 'Yes' responses, then they are given $y = 1$ as they have started or restarted smoking.

The model therefore estimates the logistic probability for an individual i to decide to smoke in year t in state or territory s:

$$\Pr(y_{its} = 1) = \alpha_i + \beta \log{(excise)_{it}} + X_{its} + \mu_s + \epsilon_{its},$$

where y_{its} is the indicator variable for whether an individual currently smokes, has ceased to smoke or has initiated smoking; α_i is the unique fixed effect for each individual; $\log(excise)_{it}$ is the logged value of the tobacco excise (it is the same for all states in each year); X_{its} represents the vector of controls (i.e., household income quintiles and age groups); μ_s is the state-based fixed effect, and ϵ_{its} is an error term. The coefficient β measures the effect of the change in $\log(excise)_{it}$ on $\Pr\,(y_{its} = 1)$.

Smoking intensity

To measure smoking intensity, a linear fixed effects model has been estimated. The sample is confined only to people who smoke in any year, so it is accordingly an unbalanced sample. The logged number of cigarettes smoked weekly is the dependent variable, while the same independent variables are used as for the smoking participation model.[6] The model therefore estimates the logged weekly number of cigarettes that smoker i will smoke in year t in state or territory s:

$$Y_{its} = \alpha_i + \beta\log\,(excise)_{it} + X_{its} + \mu_s + \epsilon_{its},$$

where Y_{its} is the logged number of cigarettes smoked weekly; α_i is the unique fixed effect for each individual; $\log(excise)_{it}$ is the logged value of the tobacco excise (it is the same for all states in each year); X_{its} represents the vector of controls (i.e., household income quintiles and age groups); μ_s is the state-based fixed effect, and ϵ_{its} is an error term. The coefficient β measures the effect of the change in $\log(excise)_{it}$ on Y_{its} (as both variables are logged, it is measuring elasticity).

Further considerations

Depending on the estimation, both unbalanced and balanced panels are used, which are each necessary in different instances but can create different challenges for fixed effects. Unbalanced panels are the only option for estimating smoking intensity, cessation rate and initiation rate, as each examine groups of smokers or non-smokers, which can dynamically change from year to year. However, fixed effects will omit individuals with only one observation in unbalanced panels, while there is no ability to use the HILDA Survey's population weights. In contrast, balanced panels have population weights available and are useful to estimate smoking participation.

There is an issue with balanced panels in that if an entire multi-decade timeframe is used, the sample becomes heavily biased towards older people in later years – i.e., if the youngest person that could be included in Wave 1 was 15 years old, the youngest person in Wave 21 in a balanced panel must be 35 years old. While a balanced panel estimation has been provided in the results, the issue has been mitigated via an interrupted time series approach, whereby the sample is the same group of respondents within each discrete time period. The time periods selected are in four-year groups (or five years for the first group when Wave 1 data is available), which means they are 2002–2005 (or 2001–2005), 2005–2009, 2009–2013, 2013–2017 and 2017–2021.

For the interrupted time series, the end year for one period is the start year for the next period so that change can be measured between all years across time series (e.g., if the second period was 2006–

[6] To try to use a balanced panel, non-smokers would have to be included, and as the logarithm of zero is undefined, less-useful linear values would have to be used for the dependent variable. During this research process, these estimations were attempted with and without the use of whether someone smokes as a control variable, but the results were largely not significant, and were inappropriate to include in this paper.

2009 instead of 2005–2009, the time series would miss behaviour changes between 2005 (when the first period ends) and 2006 (when the second period would begin)). The periods in the interrupted time series can be grouped or defined as particular eras for the tobacco excise in Australia: 2001–2005 and 2005–2009 each represent similar periods when the tobacco excise became more affordable but state-based regulations became more stringent; 2009–2013 represents the period of the 25 per cent hike (in April 2010) and its aftereffects; while 2013–2017 and 2017–2021 each represent periods of sustained 12.5 per cent increases in the tobacco excise.

For the independent variable, the tobacco excise will be used rather than retail prices for several reasons considered in the literature review, most important of which is data availability.[7] The tobacco excise will be indexed according to AWOTE so that it measures relative affordability over time, with the 30 June 2023 value of the tobacco excise used as a base (i.e., it used 2023 dollars). The indexed tobacco excise is then logged so that percentage changes are considered equally across the relevant time period, as otherwise later price increases would have an outsized effect on the estimations as percentage increases reflect greater monetary values due to the lower real value of money. The use of lagged or leading excise amounts was considered and estimated, but did not generate any significant results, which is consistent with Dunlop et al. (2011) noting that smoking behaviours tend to bounce back to existing levels soon after a tax increase.

For each general estimation model, household income quintiles and age groups are used as control variables. The models will focus on each of the quintiles/groups by partitioning the data and applying the estimation to each partition, to see how the effects change across demographics. It should be noted that an individual's age (as a continuous variable) has considerable collinearity with excise increases and growth in anti-smoking sentiment, which can confound the effects of those factors. This is why age groups (with dummy variables for each 15-year age segment) were used instead.

Time fixed effects have not been used, so there are no 'two-way' fixed effects models. The annual nature of the HILDA Survey data means that each time observation is a new year, often with a much higher tobacco excise as above-indexation increases occurred annually over a large portion of the time series. Due to the relative lack of granularity in HILDA Survey data, the models are unable to separate unobservable changes over time (e.g., growing anti-smoking sentiment) from tobacco excise increases.

V. Results

Each dependent variable being used in estimations will be analysed from multiple viewpoints. The analyses each start with a general estimation, followed by how they have changed over time (through interrupted time series analysis – for smoking participation and smoking intensity only), how they

[7] For comparison purposes, it should be noted that while the nominal tobacco excise increased from $0.26220 in the March 2010 quarter to $1.16435 in the June 2023 quarter (4.44 times greater), the ABS CPI series for tobacco increased from 74.4 to 341.2 over the same period (4.59 times greater) (ABS, 2023, June), so retail prices have largely followed tobacco excise increases.

affect different income groups (by breaking it down into household income quintiles) and how they affect people of different ages (by breaking it down into age groups).

Smoking participation

Entire sample – Wave 1 to Wave 21

The four models in Table 1 and Table 2 are conditional logit models that account for fixed effects and measure the effect of the tobacco excise on the logistic probability of smoking using differing control variables. Table 1 includes an unbalanced sample, while Table 2 is a balanced sample of only individuals that responded to the SCQ in all waves, using longitudinal population weights.

Table 1: Smoking participation on tobacco excise – unbalanced sample

	Logistic probability of smoking			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.369***	-0.375***	-0.165***	-0.171***
	(0.016)	(0.016)	(0.020)	(0.020)
2nd h/h income quintile		-0.030*		-0.040***
		(0.016)		(0.016)
3rd h/h income quintile		-0.066***		-0.079***
		(0.018)		(0.018)
4th h/h income quintile		-0.087***		-0.097***
		(0.020)		(0.020)
5th h/h income quintile		-0.068***		-0.080***
		(0.023)		(0.023)
Age group: 30-44			-0.228***	-0.224***
			(0.021)	(0.021)
Age group: 45-59			-0.393***	-0.390***
			(0.031)	(0.031)
Age group: 60-74			-0.718***	-0.725***
			(0.044)	(0.044)
Age group: 75+			-1.224***	-1.235***
			(0.074)	(0.074)
Observations	287,182	287,182	287,182	287,182
R^2	0.002	0.002	0.003	0.003
Max. Possible R^2	0.588	0.588	0.588	0.588
Log Likelihood	-127,056.200	-127,044.900	-126,891.200	-126,876.900
Wald Test	545.970*** (df = 1)	568.510*** (df = 5)	865.440*** (df = 5)	893.830*** (df = 9)
LR Test	564.807*** (df = 1)	587.504*** (df = 5)	894.891*** (df = 5)	923.536*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 1 are intuitive. For a given individual, their probability of being a smoker is likely to decrease as the excise rate increases, or as they move away from being in the bottom household income quintile, or as they get older. The effect of age groups in particular dilutes the effect of the tobacco excise (see difference between model (2) and model (4)), but the excise remains significant.

Table 2: Smoking participation on tobacco excise – balanced sample

	Logistic probability of smoking			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.581***	-0.586***	-0.359***	-0.362***
	(0.001)	(0.001)	(0.001)	(0.001)
2nd h/h income quintile		-0.002		-0.010
		(0.001)		(0.001)
3rd h/h income quintile		-0.057**		-0.069***
		(0.001)		(0.001)
4th h/h income quintile		-0.062**		-0.081***
		(0.001)		(0.001)
5th h/h income quintile		-0.031		-0.061**
		(0.001)		(0.001)
Age group: 30-44			-0.259***	-0.259***
			(0.001)	(0.001)
Age group: 45-59			-0.385***	-0.388***
			(0.001)	(0.001)
Age group: 60-74			-0.664***	-0.677***
			(0.001)	(0.001)
Age group: 75+			-0.951***	-0.966***
			(0.002)	(0.002)
Observations	86,481	86,481	86,481	86,481
R^2	1.000	1.000	1.000	1.000
Max. Possible R^2	1.000	1.000	1.000	1.000
Log Likelihood	-473,670,373	-473,661,784	-473,540,615	-473,528,534
Wald Test	534.700*** (df = 1)	547.250*** (df = 5)	761.460*** (df = 5)	785.750*** (df = 9)
LR Test	1,237,312*** (df = 1)	1,254,490*** (df = 5)	1,496,829*** (df = 5)	1,520,991*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

While the results in the balanced SCQ-respondent panel in Table 2 are largely presented for completeness, they are similar to the Table 1 results in terms of signs and significance. The differences are that the tobacco excise is ascribed a stronger negative value in Table 2, while the older age groups have a slightly more subdued negative effect. The reason for this is unclear, but it could be theorised that the balanced sample only includes people who were still alive and responding in Wave 21 and therefore had not suffered premature mortality, so the balanced panel may be relatively biased towards healthier non-smokers for whom the difference in smoking probability when reaching older age groups does not have as far to decline.

Entire sample – interrupted time series (Wave 2 to Wave 21)

The interrupted time series regression in Table 3 below breaks the time period down into four-year segments (inclusive of base year and end year), with the exception of the first period (as 2001 has been excluded to allow for consistency with smoking intensity estimations, which only had available data from 2002). For each time period, the model uses the equivalent of model 4 in the above estimations, with the full set of household income quintile and age group controls.

Table 3: Smoking participation on tobacco excise – interrupted time series

	Logistic probability of smoking

	2002-2005	2005-2009	2009-2013	2013-2017	2017-2021
Tobacco excise	0.731***	0.813***	-0.305***	-0.097***	-0.243***
	(0.013)	(0.011)	(0.003)	(0.002)	(0.002)
Observations	31,366	38,507	42,143	57,417	57,145
R^2	0.248	0.387	0.289	0.205	0.317
Max. Possible R^2	1	1	1	1	1
Log Likelihood	-107,841,393	-142,433,262	-133,677,557	-127,158,634	-120,328,894
Wald Test (df = 9)	28.900***	37.510***	30.730***	34.810***	30.560***
LR Test (df = 9)	8,954.900***	18,835.120***	14,354.980***	13,149.470***	21,758.860***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in each time period in Table 3 are significant to one per cent, but the first two periods in particular are counterintuitive. The reason for this is that the tobacco excise became slightly more affordable, while smoking participation declined in general, hence there was a positive correlation between taxes and smoking. The estimation encounters difficulty untying the tobacco excise from general anti-smoking sentiment. The results in later time periods are more intuitive as the toabcco excise began to increase considerably. The strong negative effect in 2009–2013 may indicate that the one-off 25 per cent excise hike was more effective than later graduated increases, although the larger negative effect in 2017–2021 compared with 2013–2017 may suggest that as the tobacco excise kept rising, people became more likely to be pushed over their affordability threshold and give up smoking.

Household income quintiles – Wave 1 to Wave 21

Moving back to using the unbalanced panel for all waves of the dataset (as per Table 1), we can break it down into separate estimations for different subsets of the sample. The first breakdown is by different household income quintiles (outlined in Table 4), to explore how the trends vary within these different quintiles when the tobacco excise changes. Age groups and household income have been used as controls in this model (household income to control for heterogeneity within quintiles).

Table 4: Smoking participation on tobacco excise – household income quintiles

	Logistic probability of smoking (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-0.267***	-0.117**	-0.254***	-0.238***	-0.183**
	(0.043)	(0.049)	(0.056)	(0.063)	(0.073)
Observations	65,664	56,183	53,425	55,098	56,812
R^2	0.003	0.001	0.002	0.002	0.002
Max. Possible R^2	0.547	0.493	0.421	0.354	0.308
Log Likelihood	-25,932.710	-19,063.000	-14,509.910	-11,964.520	-10,393.000
Wald Test (df = 6)	187.090***	72.150***	123.480***	124.310***	107.920***
LR Test (df = 6)	193.865***	75.355***	128.520***	127.092***	110.859***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results for each household income quintile in Table 4 suggest that the lowest income households are most strongly affected by the rising tobacco excise, and with the exception of the second quintile (which has counterintuitive results in all estimations), the coefficients became progressively less pronounced as household income increases. This is an intuitive outcome – people in lower income households are more likely to reach an affordability threshold for cigarettes and be incentivised to give up (or not start) smoking, notwithstanding potential difficulties due to addiction and habit formation.

Age groups – Wave 1 to Wave 21

The next estimation of subsets within the sample is by age group. The breakdown occurs similarly to the model above, with household income quintiles used as controls in this instance.

Table 5: Smoking participation on tobacco excise – age groups

	Logistic probability of smoking (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	0.335***	-0.383***	-0.325***	-0.489***	-0.607***
	(0.042)	(0.041)	(0.039)	(0.067)	(0.213)
Observations	72,786	74,010	70,940	49,196	20,250
R^2	0.002	0.001	0.001	0.001	0.0005
Max. Possible R^2	0.536	0.597	0.565	0.357	0.127
Log Likelihood	-27,913.820	-33,578.370	-29,452.080	-10,828.720	-1,374.249
Wald Test (df = 5)	110.510***	91.440***	71.790***	68.080***	9.120
LR Test (df = 5)	110.200***	92.832***	72.818***	69.440***	9.366*
Note:	*p<0.10 **p<0.05 ***p<0.01				

While each coefficient is significant at one per cent and most have intuitive negative signs, the sign of the coefficient for the 15-29 age group in Table 5 is particularly counterintuitive. It is apparent from visualising smoking participation across different ages (see Figure 3 in *Section VI*) that individuals tend to increase their smoking habits as they grow older within the 15-29 age group. Due to the use of fixed effects, which estimates how individuals change their behaviour over time, this age-based variation has overpowered the effect of the tobacco excise increases for this estimation. The use of age to control for variation within each age group was considered, but estimations using that type of model did not provide additional clarity over the results in Table 5 above.

Cessation rate

The same approach as for smoking participation will be used for estimating smoking cessation, although it should be noted that a positive sign is related to less smoking in this case – it means that the probability of a smoker quitting is greater. The results begin from Wave 2 as this is the first year where we can compare if someone quit compared with the previous year. Interrupted time series are not analysed for the cessation rate as four-year periods are relatively short timeframes in which to assess quitting behaviour.

Entire sample – Wave 2 to Wave 21

Table 6: Smoking cessation on tobacco excise – unbalanced sample

	Logistic probability of cessation			
	(1)	(2)	(3)	(4)

Tobacco excise	0.962***	0.962***	0.597***	0.600***
	(0.054)	(0.054)	(0.068)	(0.068)
2nd h/h income quintile		-0.103*		-0.083
		(0.055)		(0.055)
3rd h/h income quintile		-0.017		-0.0002
		(0.061)		(0.061)
4th h/h income quintile		-0.009		0.008
		(0.065)		(0.066)
5th h/h income quintile		-0.053		-0.026
		(0.073)		(0.074)
Age group: 30-44			0.431***	0.428***
			(0.069)	(0.069)
Age group: 45-59			0.711***	0.707***
			(0.108)	(0.108)
Age group: 60-74			1.329***	1.322***
			(0.152)	(0.152)
Age group: 75+			2.187***	2.175***
			(0.252)	(0.252)
Observations	47,923	47,923	47,923	47,923
R^2	0.006	0.007	0.008	0.009
Max. Possible R^2	0.340	0.340	0.340	0.340
Log Likelihood	-9,810.919	-9,808.361	-9,762.376	-9,760.413
Wald Test	317.440*** (df = 1)	322.520*** (df = 5)	410.830*** (df = 5)	414.850*** (df = 9)
LR Test	310.907*** (df = 1)	316.022*** (df = 5)	407.992*** (df = 5)	411.917*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 6 are intuitive, similar to Table 1. The likelihood of an individual quitting smoking increases when the tobacco excise increases, or as they move into older age groups. The household income quintile coefficients are generally not significant, although their signs are interesting in that they are negative like in Table 1, which means the opposite effect occurs (i.e., this indicates people are less likely to quit as they are of higher household income, but they are also less likely to smoke at all according to Table 1).

Household income quintiles – Wave 2 to Wave 21

Table 7: Smoking cessation on tobacco excise – household income quintiles

	Logistic probability of cessation (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	1.048***	0.381**	0.686***	0.581***	0.462*
	(0.159)	(0.189)	(0.196)	(0.213)	(0.238)
Observations	13,151	11,397	9,489	7,847	6,039
R^2	0.010	0.003	0.008	0.005	0.006
Max. Possible R^2	0.240	0.185	0.205	0.221	0.244
Log Likelihood	-1,740.443	-1,150.532	-1,050.371	-958.815	-824.811
Wald Test	124.230*** (df = 6)	33.200*** (df = 6)	66.580*** (df = 6)	40.800*** (df = 5)	33.180*** (df = 6)
LR Test	127.327*** (df = 6)	33.445*** (df = 6)	73.407*** (df = 6)	42.224*** (df = 5)	38.043*** (df = 6)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 7 are similar to that for smoking participation, with the tobacco excise having a far greater – and highly significant – effect on the lowest income quintile. The effect progressively weakens as household income grows (with the exception of the second income quintile), although the effect for the fifth household income quintile is only significant at 10 per cent.

Age groups – Wave 2 to Wave 21

Table 8: Smoking cessation on tobacco excise – age groups

	Logistic probability of cessation (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	1.385***	0.893***	1.370***	0.915***	1.995***
	(0.159)	(0.136)	(0.152)	(0.224)	(0.668)
Observations	12,439	16,022	13,429	5,250	783
R^2	0.007	0.003	0.007	0.007	0.015
Max. Possible R^2	0.275	0.277	0.259	0.283	0.282
Log Likelihood	-1,961.029	-2,566.905	-1,965.324	-854.731	-123.555
Wald Test (df = 5)	82.850***	52.390***	94.260***	34.170***	11.460**
LR Test (df = 5)	85.115***	52.624***	96.338***	35.566***	12.127**
Note:	*p<0.10 **p<0.05 ***p<0.01				

The effect of the tobacco excise on smoking cessation across different age groups in Table 8 is consistent. The 15-29 age group has a more intuitive response for the cessation rate than it does for smoking participation, likely because rising smoking participation as individuals move through this age group is due to greater smoking initiation over time, whereas the probability of quitting would be less associated with age. The sample size for some of these estimations – particularly for older age groups – is quite low considering the number of time periods (20 years) being examined.

Initiation rate

The approach for estimating smoking initiation is identical to that for smoking cessation, except the sample only includes people who did not smoke in their immediately preceding annual response to the HILDA Survey. The approach estimates whether those non-smokers will take up smoking. Similar to smoking participation, a negative sign is correlated with less smoking behaviour, as it demonstrates a greater likelihood that an individual will not take up smoking.

Entire sample – Wave 2 to Wave 21

The four models below use the same controls as Table 1 and Table 6.

Table 9: Smoking initiation on tobacco excise – unbalanced sample

	Logistic probability of initiation			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.692***	-0.720***	-0.219***	-0.250***
	(0.052)	(0.053)	(0.066)	(0.066)
2nd h/h income quintile		-0.249***		-0.270***
		(0.056)		(0.056)

3rd h/h income quintile		-0.342***		-0.358***
		(0.061)		(0.062)
4th h/h income quintile		-0.424***		-0.440***
		(0.066)		(0.066)
5th h/h income quintile		-0.407***		-0.422***
		(0.072)		(0.072)
Age group: 30-44			-0.649***	-0.618***
			(0.073)	(0.073)
Age group: 45-59			-1.014***	-0.979***
			(0.116)	(0.117)
Age group: 60-74			-1.946***	-1.965***
			(0.170)	(0.170)
Age group: 75+			-2.882***	-2.945***
			(0.276)	(0.276)
Observations	207,000	207,000	207,000	207,000
R^2	0.001	0.001	0.002	0.002
Max. Possible R^2	0.084	0.084	0.084	0.084
Log Likelihood	-8,984.026	-8,960.262	-8,903.734	-8,878.267
Wald Test	175.190*** (df = 1)	221.750*** (df = 5)	326.380*** (df = 5)	375.750*** (df = 9)
LR Test	183.412*** (df = 1)	230.941*** (df = 5)	343.996*** (df = 5)	394.930*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 9 are similar to Table 1 and Table 6. The likelihood of an individual initiating smoking decreases when the tobacco excise increases, and as they move into older age groups. The household income quintile coefficients are negative and significant, unlike for smoking cessation, indicating that there is a notable income effect on smoking initiation (i.e., the tobacco excise is more likely to affect lower income households in their propensity to start smoking). The combined results for smoking participation, smoking cessation and smoking initiation suggest that lower income households are more likely to smoke in general, but then are also more likely to be affected by the tobacco excise in determining whether they cease or initiate smoking (although the cessation coefficients are insignificant).

Household income quintiles – Wave 2 to Wave 21

Table 10: Smoking initiation on tobacco excise – household income quintiles

	Logistic probability of initiation (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-0.479***	0.153	-0.341	-0.420**	-0.135
	(0.175)	(0.189)	(0.212)	(0.207)	(0.209)
Observations	46,714	38,271	37,441	40,619	43,955
R^2	0.001	0.001	0.001	0.001	0.001
Max. Possible R^2	0.052	0.049	0.045	0.041	0.043
Log Likelihood	-1,208.587	-955.015	-838.932	-841.946	-951.734
Wald Test (df = 6)	52.610***	18.320***	33.060***	32.380***	46.150***
LR Test (df = 6)	55.418***	21.357***	34.518***	35.290***	49.316***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 10 follow those in Table 9 – the lowest household income quintile is significantly affected by the tobacco excise, with a strong negative coefficient indicating a lower probability of starting smoking when the tobacco excise rises. The coefficients for the other household income quintiles are generally negative but not overly significant, indicating a weaker effect of a rising tobacco excise on people with household income that enables cigarettes to remain relatively affordable in spite of higher taxes.

Age groups – Wave 2 to Wave 21

Table 11: Smoking initiation on tobacco excise – age groups

	Logistic probability of initiation (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	0.625***	-0.583***	-0.545***	-0.968***	-0.428
	(0.110)	(0.147)	(0.157)	(0.277)	(0.651)
Observations	45,518	50,361	51,977	40,837	18,307
R^2	0.002	0.0005	0.0003	0.0003	0.0002
Max. Possible R^2	0.123	0.071	0.053	0.025	0.010
Log Likelihood	-2,937.880	-1,840.289	-1,409.135	-501.796	-90.611
Wald Test (df = 5)	87.480***	22.610***	16.920***	13.690**	1.950
LR Test (df = 5)	88.139***	22.887***	17.226***	14.281**	2.946
Note:	*p<0.10 **p<0.05 ***p<0.01				

The negative coefficients for most age groups in Table 11 indicate that people are generally less likely to take up smoking when the tobacco excise rises. The exception is the 15-29 age group, but this follows the results in Table 5, whereby the effect of people becoming more likely to smoke as they get older within this age group overpowers the effect of the tobacco excise, as there is collinearity between age and the tobacco excise, particularly since April 2010. The significance of the 15-29 age group coefficient can cause doubt regarding the significance of the other coefficients, as it is hard to discern whether their strong negative signs are due to the tobacco excise or due to lower likelihood of smoking initiation as people grow older.

Smoking intensity

While the smoking participation models estimated the probability that an individual would smoke, the smoking intensity models estimate the extent to which smokers consume cigarettes, using linear fixed effects (although the dependent variable of weekly cigarettes smoked is logged). These estimations use an unbalanced sample, including any observation where an individual has reported that they are a smoker and therefore smoke greater than zero cigarettes per week.

Entire sample – Wave 2 to Wave 21

Table 12: Smoking intensity on tobacco excise – unbalanced sample

	No. of cigarettes smoked weekly (log)			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.045***	-0.047***	-0.030*	-0.032**

	(0.013)	(0.013)	(0.016)	(0.016)
2nd h/h income quintile		-0.022*		-0.025**
		(0.012)		(0.012)
3rd h/h income quintile		-0.029**		-0.034**
		(0.014)		(0.014)
4th h/h income quintile		-0.042***		-0.047***
		(0.015)		(0.015)
5th h/h income quintile		-0.011		-0.018
		(0.018)		(0.018)
Age group: 30-44			0.005	0.007
			(0.017)	(0.017)
Age group: 45-59			0.014	0.015
			(0.025)	(0.025)
Age group: 60-74			-0.090**	-0.093**
			(0.036)	(0.036)
Age group: 75+			-0.116*	-0.122*
			(0.062)	(0.062)
Observations	49,753	49,753	49,753	49,753
R^2	0.001	0.001	0.002	0.002
Adjusted R^2	-0.239	-0.239	-0.239	-0.238
F Statistic	4.488*** (df = 8; 40108)	3.786*** (df = 12; 40104)	5.178*** (df = 12; 40104)	4.584*** (df = 16; 40100)
Note:	*p<0.10 **p<0.05 ***p<0.01			

These results for smoking intensity in Table 12 are relatively intuitive, similar to Table 1. For a given individual who smokes, the model estimates that the quantity of cigarettes they consume should decrease in response to an increase in the tobacco excise. While the household income quintile effects are similar to smoking participation, where higher income quintiles are associated with smoking fewer cigarettes, the effects of age groups are not overly significant.

Entire sample – interrupted time series (Wave 2 to Wave 21)

Table 13: Smoking intensity on tobacco excise – interrupted time series

	No. of cigarettes smoked weekly (log)				
	2002-2005	2005-2009	2009-2013	2013-2017	2017-2021
Tobacco excise	0.565	-2.858***	-0.044	0.048	-0.122**
	(0.347)	(0.314)	(0.084)	(0.037)	(0.049)
Observations	10,508	11,489	12,439	13,096	12,067
R^2	0.003	0.014	0.004	0.004	0.004
Adjusted R^2	-0.704	-0.559	-0.639	-0.555	-0.577
F Statistic	1.050 (df = 16; 6150)	6.557*** (df = 16; 7264)	2.010*** (df = 16; 7557)	2.310*** (df = 16; 8386)	1.819** (df = 16; 7620)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 13 are not significant, outside of 2005–2009 and 2017–2021. The coefficient for 2005–2009 is due to a pronounced increase in smoking intensity among smokers during this period that was negatively correlated with the falling AWOTE-indexed value of the tobacco excise. The coefficient for 2017–2021 is more consistent with expected demand elasticity for cigarettes, although it is only significant at the five per cent level.

Household income quintiles – Wave 2 to Wave 21

Table 14: Smoking intensity on tobacco excise – household income quintiles

	No. of cigarettes smoked weekly (log) (by household income quintiles)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-8.593***	-4.948**	-6.085**	1.714	-0.388
	(2.155)	(2.277)	(2.775)	(3.002)	(3.335)
Observations	13,270	11,987	9,922	8,216	6,358
R^2	0.006	0.007	0.008	0.005	0.001
Adjusted R^2	-0.417	-0.593	-0.732	-0.796	-0.746
F Statistic	4.509*** (df = 13; 9305)	4.020*** (df = 13; 7474)	3.357*** (df = 13; 5685)	1.714* (df = 13; 4551)	0.446 (df = 12; 3636)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results for each household income quintile outlined in Table 14 are glaring. The coefficients for the first, second and third household income quintiles are significant and strongly negative, particularly for the first quintile. This indicates that lower income is correlated with smokers reducing their smoking intensity, as the rising tobacco excise has a greater impact on their finances. The fourth and fifth household income quintiles do not have significant coefficients, indicating that if individuals in these quintiles are to maintain their smoking habit, the rising tobacco excise is not necessarily causing them to change behaviour and reduce consumption.

Age groups – Wave 2 to Wave 21

Table 15: Smoking intensity on tobacco excise – age groups

	No. of cigarettes smoked weekly (log) (by age groups)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	7.616***	-1.996	-10.657***	-21.699***	-16.557**
	(1.944)	(1.835)	(1.924)	(3.132)	(8.212)
Observations	14,815	16,118	13,246	4,902	672
R^2	0.003	0.001	0.005	0.014	0.045
Adjusted R^2	-0.480	-0.334	-0.264	-0.285	-0.383
F Statistic	2.529*** (df = 12; 9979)	1.466 (df = 12; 12061)	4.244*** (df = 12; 10427)	4.549*** (df = 12; 3759)	3.677*** (df = 6; 463)
Note:	*p<0.10 **p<0.05 ***p<0.01				

While each coefficient in Table 15 (except for the 30-44 age group) is significant at one per cent, the sign for the 15-29 age group appears counterintuitive, just as it was for smoking participation. The reasoning behind this is likely similar to that for smoking participation – as people grow older within this age group, they are likely to increase their smoking intensity if they are a smoker. The results of this estimation appear to largely reflect age profiles rather than the effect of the tobacco excise. The use of age as a control was considered, but once again estimations using that type of model did not provide additional clarity over the results in Table 15 above.

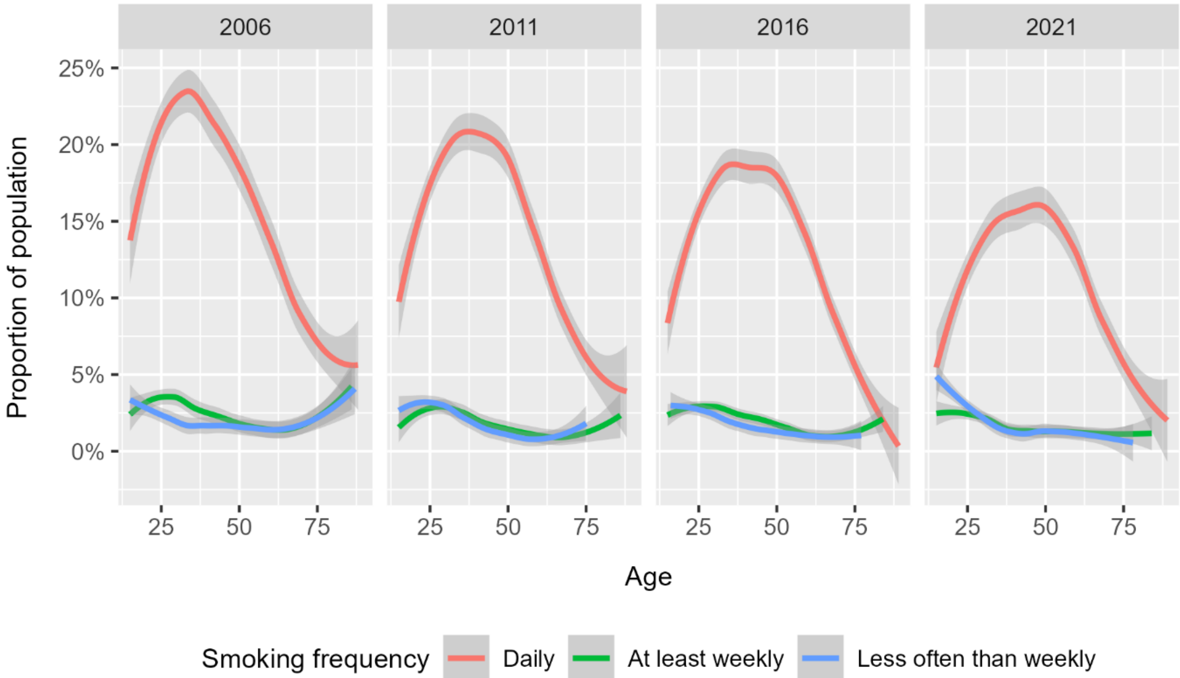
VI. Discussion

The major takeaway from the results in the general models covering the whole population is that there is ongoing growth in anti-smoking sentiment, which is difficult to decouple from the effects of tobacco excise increases. This was noticeable in the interrupted time series results from 2002–2009, where smoking participation declined at the same time as the AWOTE-indexed tobacco excise marginally declined, leading to a counterintuitive positive correlation between the two variables. The results from early parts of the HILDA Survey data may simply be consistent with DeCicca et al. (2022, p. 923) noting that small changes in cigarette taxes are less "plausible exogenous" and may not generate significant findings. The years that included above-indexation tobacco excise increases tended to have more significant trends. However, the extent to which trends between 2009–2021 are due to the tobacco excise or growing anti-smoking sentiment is difficult to discern.

Where the results can be more useful is in examining how the range of dependent variables were affected in different ways, and how population sub-groups were affected differently. For instance, the tobacco excise's impact on smoking participation seems to be much greater than the impact on smoking intensity, the latter of which is not subject to overly significant effects across the general population. This likely means that smokers do not linearly decrease their demand, but rather that smokers may reach a cost threshold that incentivises them to quit smoking altogether, provided they are able to do so. The relatively strong negative coefficient for smoking participation in the 2017–2021 time period indicates that many smokers may have been reaching that threshold in recent years.

While smoking intensity across the general population does not necessarily change significantly in response to tobacco excise changes, responses appear to be contingent on household income levels. The lower household income quintiles (particularly the first household income quintile) have significant negative coefficients for smoking intensity against the tobacco excise, whereas the fourth and fifth household income quintiles have no significant effects. These drastic differences between household income quintiles for smoking intensity, particularly when compared with the differences for smoking participation, may indicate that people from lower income households that are unwilling or unable to quit smoking are more budget-conscious and have to give greater thought to their cigarette consumption than those from higher income households with less affordability concerns. It is likely that this group forms those suffering the strongest negative welfare effects from the rising tobacco excise, as they are demonstrating conscious demand responses to the rising cost of cigarettes but are still paying high amounts of tobacco excise to maintain their addiction.

Figure 3: **Smoking participation frequency by age in four separate years**



Note: The plotted lines are smoothed averages across ages for each smoking frequency variable.

The results for age groups were less clear than for household income quintiles, which appear to be due to smoking behaviours following a clear trend with age. This is outlined in the diagrams in Figure 3, which plot the proportion of the population smoking (including three different frequencies of smoking participation) for each age of an individual in four different years.

Smoking participation has generally decreased for all ages across the years, but it is apparent that the probability that someone will smoke trends upwards as individuals grow older within the 15-29 age group. This explains the positive sign for smoking participation in this age group, while the subsequent downward trend as people get older largely explains the negative signs for those older age groups. Fixed effects techniques are difficult to apply in circumstances like this, as although the change within individuals is what should be being estimated, collinearity between age and the increasing tobacco excise makes it difficult to discern the extent to which each is affecting an individual's changing smoking behaviours, particularly when general anti-smoking sentiment is also growing.

The most important insight gathered from the age group analysis is that the rising tobacco excise is associated with a declining smoking initiation rate among the 15-29 age group. The reduced affordability of cigarettes for younger people may therefore be having an impact in preventing people from taking up smoking altogether, which should flow through to lower smoking participation at older ages as younger people do not become addicted. The extent to which this is due to the tobacco excise rather than the increased availability of e-cigarettes is uncertain, however, and will be discussed further in the following section.

VII. Limitations

There were several challenges and limitations involved in performing the estimations. These include contending with collinearity between the rising tobacco excise and other factors; a lack of variation in the tobacco excise in certain time periods; the uniformity of tobacco excise increases across the country; the lack of granularity in the HILDA Survey data with respect to alternative demand responses; and more general concerns with the HILDA Survey data.

Modelling limitations

The key difficulty with the estimations was the collinearity between the rising tobacco excise and factors such as age and the unobservable growth in anti-smoking sentiment. The strong association between age and smoking behaviours, as outlined in the previous section, means it is difficult for a fixed effects model to discern whether the change within an individual's behaviour was due to them getting older or the tobacco excise increasing. This also meant that age was difficult to use as a control variable due to endogeneity, and while age groups acted as a substitute, the effectiveness of age groups may be influenced by premature mortality in older age groups due to smoking. The collinearity between the tobacco excise and anti-smoking sentiment was also difficult to separate, particularly when combined with age effects. For example, smoking participation and smoking intensity declined in the early 2000s without major excise increases, so it appears difficult to attribute the full effect of declining smoking rates in the 2010s to excise increases.

This lack of variability in the data also presented challenges – with respect to taxes in certain periods and across different geographies. The uniformity of tax increases across Australia prevented the use of any kind of control group or a difference-in-differences approach between states and territories. Whereas many studies on smoking behaviours in the US exploit between-state variability in taxes in the context of similar cultural environments, this is not possible to achieve when studying Australia. This is consistent with issues faced by studies of smoking in European countries where regulations tend to be national, which DeCicca et al. (2022, p. 945) note has resulted in studies employing "interrupted time series or cross-country comparisons across a small number of countries," which can be "highly sensitive to bias from secular shocks." The inability to use a control group also reinforces the challenges with collinearity noted above, as that collinearity would largely be consistent across states and territories, but variation in taxes between states/territories is unable to be used to this end.

Furthermore, it would have been constructive to delve deeper into the issue of smoking intensity being far more greatly affected by the tobacco excise for lower income households, but modelling limitations prevented this from occurring. The initial intent of this research was to examine how the percentage of household income spent on cigarettes affects smoking behaviours, as it would be interesting to know if there was a threshold beyond which people became more likely to reduce smoking participation or intensity. It appeared possible to explore the issue as household income and household cigarette expenditure are included variables in the HILDA Survey data. However, there were simultaneous equations concerns with the modelling that prevented treading further down that path. For example, higher cigarette expenditure as a percentage of household income may cause people to reduce smoking participation or intensity, but it is higher smoking participation or intensity that causes the high percentage of household income to be spent on cigarettes in the first place.

Data limitations

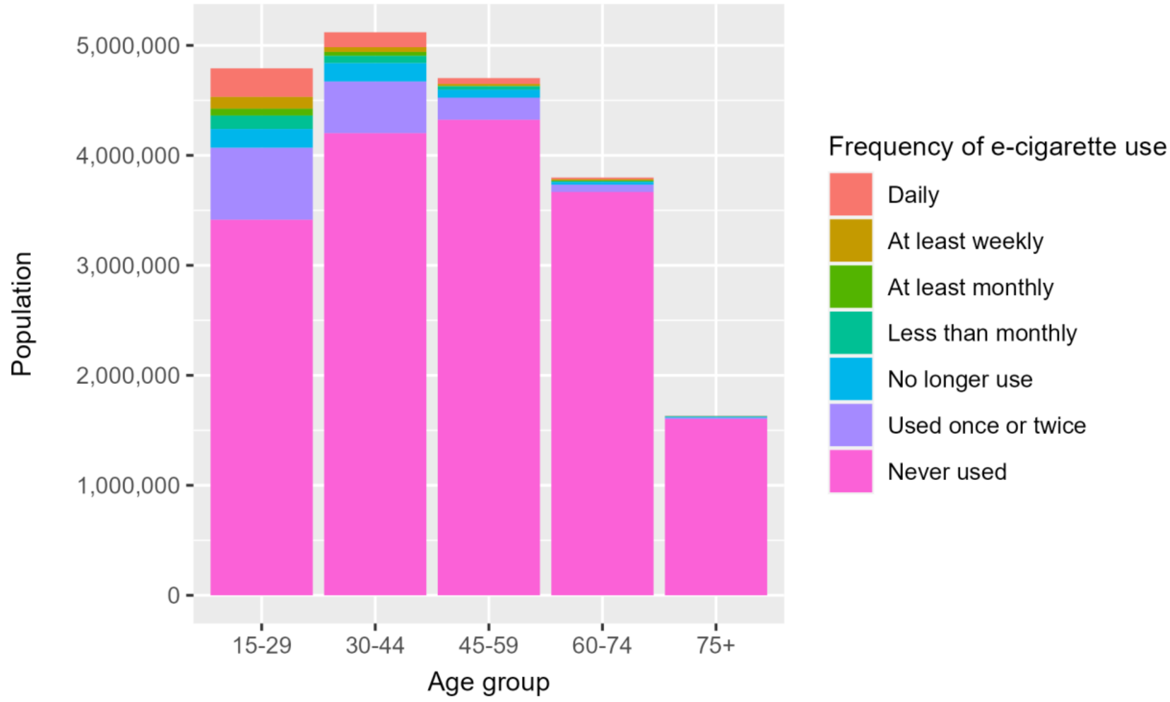
The HILDA Survey is a very rich data source, but in terms of its information on smoking behaviours, it can be a blunt instrument for population-based estimations. For instance, the willingness to purchase smoking cessation products and attempting to quit can be a strong indicator of the effect of tobacco excise increases (Cotti et al., 2016; Dunlop et al., 2011), but unsuccessful quit attempts are not evident in the data. It may be the case that as the tobacco excise continues to increase, the sample of remaining smokers are willing but less able to quit than in previous years, which may affect the estimation results.

When using HILDA Survey data, it is also difficult to determine whether people are responding to a higher tobacco excise in different ways than just reducing smoking participation or intensity. The literature review indicated that people respond to tax increases in different ways, including product substitution to cheaper cigarettes, higher nicotine cigarettes and LLT cigarettes. Higher taxes may also increase the motivation for people to purchase illegally imported black-market cigarettes. It is difficult to make these distinctions when attempting to determine the effect of tobacco excise increases using HILDA Survey data. While cigarette expenditure variables are available and can be extrapolated into a per-cigarette cost, it is particularly challenging to estimate whether people have downgraded to the cheaper substitute products outlined, as per-cigarette costs are likely to have still increased for those substitutes due to higher taxes (excluding black-market cigarettes).

The potential product substitution by individuals also extends to ‘vaping’ – the use of e-cigarettes. The HILDA Survey asked respondents about their frequency of e-cigarette use for the first time in Wave 21 (2021), which is visualised for different age groups in Figure 4 below. The understanding of how e-cigarette consumption affects smoking behaviours is limited at this stage – the literature review referred to research indicating that it is undetermined whether e-cigarettes are a substitute to tobacco cigarettes (including potential utility as a cessation device) or a complement to tobacco cigarettes (including potentially acting as a gateway to tobacco smoking). It is at least important to note, however, that younger people are much more likely to have tried e-cigarettes and frequently use e-cigarettes, which may be affecting the 15-29 and 30-44 age groups in the estimation results in this paper. The presence of harmful e-cigarettes may also reduce the welfare effect of alternative anti-smoking policies such as age-based smoking bans, which could be in the pipeline considering the lead that New Zealand and the UK have demonstrated.[8]

[8] New Zealand has passed legislation, and the UK is proposing legislation, whereby anyone born from 1 January 2009 (it is the same for both countries) would never legally be able to purchase cigarettes.

Figure 4: **Frequency of e-cigarette use by different age groups in 2021**



There are also more general concerns with the HILDA survey data containing many missing responses and being prone to measurement error. Omitting missing responses may cause selection bias if they are correlated with certain characteristics (e.g., higher-income households may be more likely to not submit responses, biasing the sample away from that group). Measurement error is understandable for any self-completed survey (e.g., there are some extreme outliers for number of cigarettes smoked). The concept of 'winsorizing' the data so that outlying values were cut back to values at a particular percentile (e.g., the 99^{th} percentile, similar to research from Renke and Sinne (2020)) was considered, but this option was not taken up – nor were the extreme outliers omitted – as they only comprised a very small portion of the dataset.

VIII. Conclusion

The research in this paper outlines some constructive findings related to the effect of tobacco excise increases on smoking behaviours in Australia. The general effects across the population are for the rising tobacco excise to decrease smoking participation (including by increasing smoking cessation and decrease smoking initiation) and to decrease smoking intensity for certain demographics. The results of estimations indicate that changes in smoking behaviours became more pronounced as the tobacco excise started to rise (i.e., from April 2010), although this research also shows that the ability to isolate the effect of the excise from other effects (like age and unobservable anti-smoking sentiment) is difficult to achieve.

Where the research was most effective was exploring the differences between household income quintiles. Cigarette taxes are generally known as being regressive, as people with lower incomes tend to bear a greater tax burden by virtue of being more likely to be smokers (DeCicca et al., 2022), which is exacerbated in Australia by huge increases to the tobacco excise. The impact on lower income households' budgets was evident, as they were more likely to quit smoking and considerably more likely to reduce smoking intensity even if they had not quit. Further research into the points at which households feel crunched by their cigarette expenditure and start attempting to quit would be helpful to explore the issue further. If a majority of people from low-income households have already passed this point, it may be the case that continued increases to the tobacco excise are more effective at raising revenue but less effective at improving welfare, and that it may be worthwhile to consider alternative anti-smoking policies in order to maximise societal welfare.

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How tobacco excise increases affect smoking behaviours in Australia

David Whytcross

Abstract

Australia has been at the global forefront in using higher cigarette taxes to curb smoking behaviours. This paper aims to utilise Australia's precipitous increase in cigarette taxes (via its tobacco excise) to examine how it is affecting smoking behaviours across the population. Data from the *Household, Income and Labour Dynamics in Australia* (HILDA) Survey are used to estimate individuals' behavioural changes in response to rising cigarette taxes, with the analysis extended to detail household income quintiles and discrete age groups. In general, it is difficult to separate the effect of rising cigarette taxes with growth in anti-smoking sentiment, but it is evident that higher cigarette taxes work to reduce smoking behaviours, and that it affects different groups in different ways. Notably, financially constrained people in the lowest-income households are much more likely to quit smoking or reduce their smoking intensity in response to higher cigarette taxes than those in higher-income households, while younger people are becoming less inclined to start smoking and subsequently become addicted.

Keywords: Cigarettes, Tax, Demand Elasticity, Addiction, Household Surveys, HILDA

JEL classification: C23, D12, D62, H21, I12, I18

Smoking is a public health issue of great importance with respect to policy responses, both globally and domestically in Australia. The use of higher taxes on cigarettes has been a cornerstone of a suite of measures used to curb smoking rates. To this end, Australia has undertaken a rapid above-indexation escalation of the tobacco excise on manufactured cigarettes since April 2010. The highly substantial jump in the tobacco excise has created an interesting natural experiment, as it provides the requisite variability in cigarette taxes to try to measure just how effective tax increases can be to curb smoking – both in general and for different sub-groups of the population that may have heterogeneous demand responses.

To explore the issue, this research paper will combine time series tax data with the wealth of panel data available from the *Household, Income and Labour Dynamics in Australia (HILDA) Survey*. The HILDA Survey is an annual ongoing longitudinal survey that commenced in 2001 and is intended to be representative of the Australian population. HILDA Survey respondents are asked questions regarding their smoking behaviours, including whether they smoke and, if so, how many cigarettes they smoke each week and how much they spend on cigarettes. These responses, among others, can be combined with the broad range of demographic and other data for each respondent to help achieve a sense of how the tobacco excise affects the population.

The estimations in this research paper use fixed effects techniques with the HILDA Survey data so that the results reflect changes to individuals' behaviour over time as the tobacco excise is increased, rather than changes to the sample composition. The research will estimate the effect of tobacco excise increases on smoking participation (whether someone is a smoker or not), the cessation rate (propensity to quit smoking), the initiation rate (propensity to start smoking), and smoking intensity (if an individual is a smoker, the quantity of cigarettes they smoke). While the intent is to isolate the effect of tobacco excise increases on smoking behaviours, it is noted that there may be confounding variables that affect smoking behaviours. The estimations are subsequently partitioned on the basis of income quintiles and age groups to illuminate potentially heterogeneous demand responses to higher taxes. There may also be alternative demand responses that the HILDA Survey data is unable to capture detail for, such as downgrading to cheaper cigarettes.

The estimation results indicate that tobacco excise increases are contributing to lower smoking participation and lower smoking intensity, and that these effects are continuing even as the tobacco excise continues to rise. However, the effect of increasing the tobacco excise can be difficult to decouple from the passage of time, as there is collinearity with growing anti-smoking sentiment and reduced likelihood of smoking as people grow older. Where the effect of tobacco excise increases is most noticeable is for lower-income households, which are more tax-elastic in terms of smoking participation and smoking intensity, although despite declining smoking behaviours they are still often considerably worse off than higher-income households as a result of the higher taxes.

This research contributes to the literature through the use of HILDA Survey data to explore smoking behaviours at a population and demographic level. While there has been considerable use of panel data to measure changes in smoking behaviour, including in Australia, the literature review for this paper only found use of the HILDA Survey for this purpose by Buddelmeyer and Wilkins (2011), with a study that only covered 2001–2003. This research uses the full time series of the HILDA Survey where possible, so it includes all of the years containing the largest tobacco excise increases.

The paper is structured in the following manner. *Section I* provides the institutional background behind Australia's tobacco excise increases and other anti-smoking measures. *Section II* outlines an extensive literature review into a broad range of smoking and tax research. *Section III* details the types of data being used to perform the research. *Section IV* outlines the identification strategy for measuring changes to smoking participation and smoking intensity (among other more detailed estimations), while *Section V* outlines the estimation results and *Section VI* provides a discussion surrounding the results. *Section VII* explains some limitations to the research, including the presence of confounding variables and challenges with HILDA Survey data. Finally, *Section VIII* concludes the paper and briefly notes some potential opportunities for future research and policy responses.

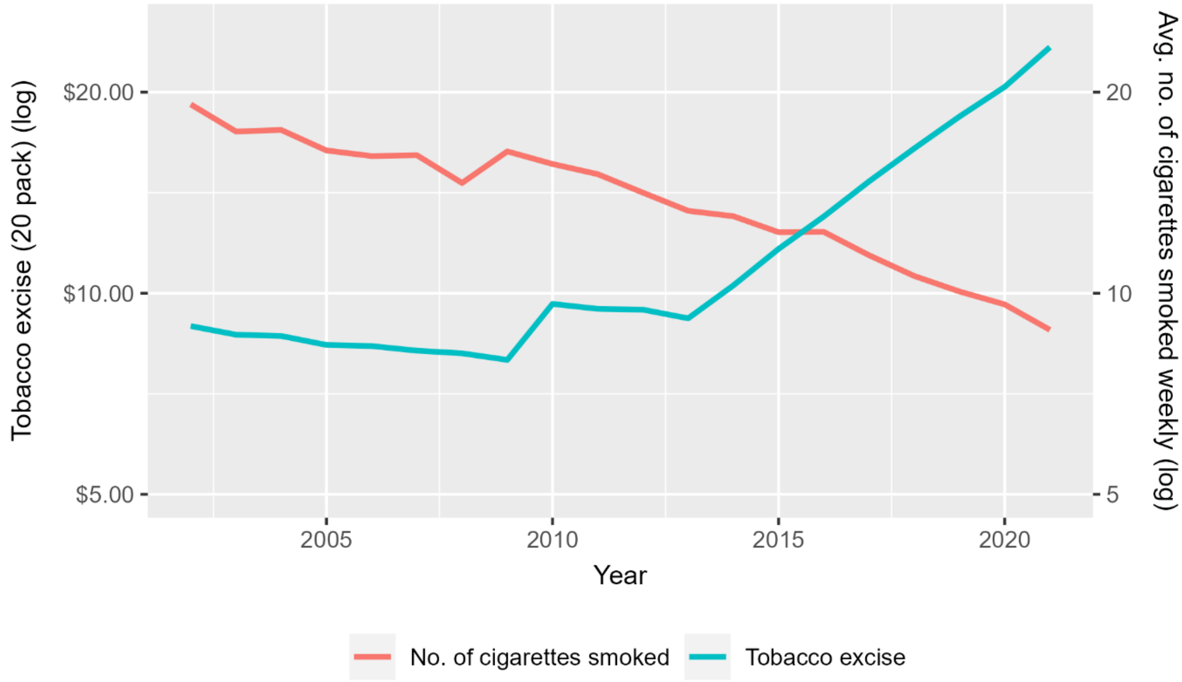
I. Institutional background

Australia has long been a global leader in implementing anti-smoking policies. These have included tobacco excise increases and a range of other measures, which Wilkinson et al. (2019, p. e618) summarises as including "mass-media campaigns, smoke-free environments, access to cessation aids, regulation of marketing, pictorial health warnings, and world-first standardisation of tobacco product package design".[1] These policy measures have occurred at the federal and state levels of government. The Federal Government is responsible for the tobacco excise (political support for which has largely been bipartisan), access to cessation aids (through the inclusion of nicotine replacement therapy products in the Pharmaceutical Benefits Scheme) and package design laws. State governments are primarily responsible for marketing regulation outside of package design (such as point-of-sale display bans) and the creation of smoke-free environments.[2]

While all of the anti-smoking measures are likely to have curbed smoking behaviours, the rapid rise in the tobacco excise since April 2010 may be the most effective measure. Figure 1 compares the 'per stick' tobacco excise on manufactured cigarettes throughout the HILDA Survey time period (indexed to average weekly ordinary time earnings (AWOTE) in 2023 Australian dollars) with the average number of cigarettes smoked per week by the entire population (non-smokers are included, being counted as smoking zero cigarettes each week). Both variables use a log scale, so percentage changes are presented equally throughout. It demonstrates that one or both of smoking participation and smoking intensity have continued to fall as the tobacco excise has risen in real terms.

[1] The "world-first standardisation of tobacco product package design" refers to plain packaging laws instituted under the *Tobacco Plain Packaging Act 2011*, which took effect on 1 December 2012.
[2] For example, within the duration of the HILDA Survey, the following list represents a selection of measures the Victorian Government has instituted: banning smoking in restaurants in July 2001; banning point-of-sale cigarette advertising in January 2002; banning smoking in pubs and clubs in July 2007; banning smoking in cars with children in January 2010; banning point-of-sale display of cigarettes in January 2011; and banning smoking in commercial outdoor dining areas in August 2017.

Figure 1: Australia's tobacco excise rate vs average cigarettes smoked weekly



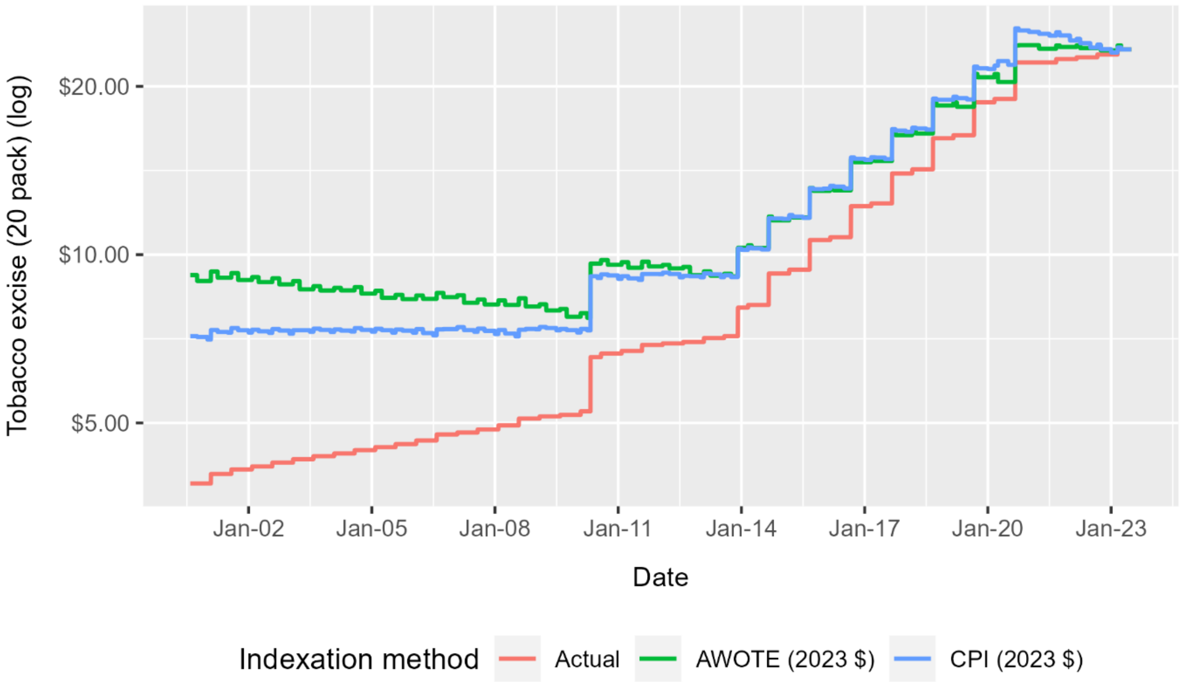
Note: Tobacco excise reflects value on 30 June each year, indexed to AWOTE (in 2023 dollars); average cigarettes smoked is based on the annual cross-sectional weighted values of HILDA respondents.

While the tobacco excise is indexed biannually, Figure 1 demonstrates that it became more affordable during the 2000s. During this period, the tobacco excise underwent biannual indexation based on the Consumer Price Index (CPI), which was outpaced by wage growth (as measured by AWOTE), so the tobacco excise became more affordable relative to wages. In addition, there were no above-indexation increases. The above-indexation increases commenced with a 25 per cent hike in April 2010, which was imposed with minimal notice. This was followed by eight pre-announced 12.5 per cent hikes beginning in December 2013 and occurring annually every September thereafter until September 2020.[3] There are further increases to the tobacco excise in the pipeline that are not included in Figure 1. The 2023-24 Budget legislated three further above-indexation tobacco excise increases of 5 per cent each – the first increase occurred in September 2023, with the remaining two increases to occur in September 2024 and September 2025.

The period outlined in Figure 1 also included a change in the indexation method from CPI to AWOTE in March 2014 so that indexation would keep up with relative affordability for the population, while biannual indexation now occurs every March and September rather than February and August to align with AWOTE data availability. Figure 2 demonstrates the timeline of how these changes have occurred, displaying how the tobacco excise has risen nominally and with respect to indexation by CPI (i.e., how the tobacco excise compares with general price levels) and AWOTE (i.e., the relative affordability of the tobacco excise).

[3] There were initially four tobacco excise increases announced, with the second round of four increases (from September 2017 through September 2020) announced in May 2017.

Figure 2: Australia's tobacco excise under different indexation methods



The tobacco excise referred to in Figure 2 is the 'per stick' rate on manufactured cigarettes, which simply means that each manufactured cigarette (e.g., a single cigarette that could be purchased as part of a pack of cigarettes) has that rate of excise imposed. A substitute for manufactured cigarettes is loose-leaf tobacco (LLT, also known as roll-your-own tobacco), for which the excise is based on a per kilogram rate that is equivalised against the excise on manufactured cigarettes. It should be noted that the excise for LLT has not only been subject to the same above-indexation increases as manufactured cigarettes, but has progressively had its equivalisation weight reduced, leading to even higher percentage increases to its specific excise.[4] While this research paper focuses on the 'per stick' rate for manufactured cigarettes, this is important context as it is making an obvious substitute product for manufactured cigarettes considerably less affordable.

II. Literature review

There is a wealth of literature available regarding smoking behaviours and tobacco regulation, including the use of taxes to curb smoking. This section intends to provide extensive coverage of the various literature, which generally falls under three themes: the *economic theory* informing research on smoking behaviours and regulation; the *research techniques* used to examine these issues; and

[4] To calculate the LLT excise, the 'per stick' excise is divided by the equivalisation weight (roughly the estimated weight of a manufactured cigarette in grams) to find a per-gram rate, which is multiplied by 1000 to find the per kilogram rate. The equivalisation weight was progressively reduced from 0.8 grams to 0.7 grams in four 0.025-gram increments from September 2017 through September 2020, and a further progressive reduction from 0.7 grams to 0.6 grams is scheduled to occur. For example, the LLT excise as of 30 June 2023 was $1,663.36 per kilogram with an equivalisation weight of 0.7 grams, which is 14.3 per cent higher than if an equivalisation weight of 0.8 grams was kept ($1,455.44 per kilogram).

the *common limitations* faced in conducting such research. This review will also consider how previous research can inform the content of this research paper.

Economic theory

Rationale for higher cigarette taxes

DeCicca et al. (2022, p. 891) explain that the "economic rationale for regulating tobacco typically is based on two main objectives: 1) reducing externalities and internalities associated with tobacco consumption, and 2) raising revenue." The concepts of externalities and internalities are most important as they refer to the negative health consequences imposed by smokers on others and themselves. Negative externalities are costs imposed on others, and can be generated in the form of second-hand smoke, increased public healthcare costs, reduced labour productivity (e.g., due to absenteeism or potential inability to work), greater mortality at earlier ages, and even reduced birth weight for infants of pregnant smokers (DeCicca et al., 2022). Conversely, internalities are costs smokers impose on themselves, and are generally manifested as long-term health costs due to present-biased short-term decisions to smoke, which can result in a reduction in lifetime utility (DeCicca et al., 2022; Gruber & Köszegi, 2001).

General demand elasticity and addiction

Wilkinson et al. (2019) describe how tobacco tax increases can support smokers quitting, disincentivise non-smokers from taking up the habit, and reduce the amount of cigarettes consumed by continuing smokers. However, the extent to which this occurs and results in cigarette taxes acting to reduce externalities and internalities – rather than simply raising revenue – is tied to the price elasticity of demand (Gallet & List, 2003) and the extent of pass-through of taxes to retail prices. In the event of a tax increase, inelastic demand means the reduction in consumption is low and more revenue is raised due to higher taxes collected per cigarette, whereas elastic demand means consumption is reduced considerably, with smokers generating lesser internalities and externalities. The literature indicates that demand for cigarettes is relatively inelastic (Crespi et al., 2021; DeCicca et al., 2022; Field et al., 2006; Nesson, 2017), and that this contributes to relatively high pass-through of taxes to retail prices (DeCicca et al., 2022).

The relative inelasticity of demand for cigarettes is typically attributed to the addictive nature of cigarettes and the habit formation of smokers, although the literature regarding these concepts is varied. Some research into addiction assumes a reasonable level of control over addictive behaviours. For instance, there is some evidence of 'rational addiction', where in the event of a future cigarette tax increase, smokers assess the current and future costs of current cigarette consumption – rather than just current costs – and make lifetime welfare-maximising decisions (Gruber & Köszegi, 2001). The ability to act rationally extends to people who continue to smoke, as they reduce their smoking intensity as taxes rise despite their addiction, potentially due to larger shares of their income being taken up by cigarette purchases (Caulkins & Nicosia, 2010). The smoking intensity outcomes resulting from an increased tobacco excise in Australia will be explored in the research in this paper.

The majority of literature is generally less positive about the control that addicts have regarding their consumption of cigarettes and other addictive products. In extending the research to non-smoking addiction, Acuff et al. (2023) define the 'reinforcer pathology' model as where an addict excessively overvalues the immediate rewards of a drug-specific reinforcement (e.g., withdrawal relief) compared with the longer-term health costs of smoking, which are delayed and less certain. The overvaluation of very short-term benefits associated with addictive products aligns with research by Field et al. (2006) that indicates that smokers are typically found to be more impulsive than non-smokers and that smokers will place greater delayed reward discounting on cigarettes than on money. O'Donoghue and Rabin (2015) argue that caution should be exercised regarding time-preference experiments, however, as the value of greater certainty of current payoffs and the potential for additional transaction costs in the future may bias towards preferencing immediate payoffs.

A further consideration in the addiction literature is Buckell et al. (2021) outlining the concept of 'experience-conditioned choice' models, whereby current consumption of tobacco products is conditioned upon users by their previous consumption of tobacco products. The intuition with these models relates to how long-term smoking is associated with addiction and 'habit formation' – the barriers to quitting smoking include the physical addiction and the psychological habits for smoking that have formed over time. Renke and Sinne (2020) provide greater consideration to habit formation, explaining that reducing consumption can be more difficult for those with less self-control who have formed habits for welfare-reducing consumption as they are subject to greater withdrawal costs associated with breaking the habit.

Heterogeneity of demand elasticity

The general theory for demand elasticity for cigarettes can be summarised as when taxes increase, cigarette consumption declines, but cigarette expenditure still increases (Field et al., 2006). This means demand is inelastic as consumption falls by less than taxes (or prices) increase. However, demand elasticity is not uniform, but rather can be heterogeneous depending on how taxes change and the groups affected by tax changes.

With regard to how taxes change, Renke and Sinne (2020) explain that demand elasticity for addictive products is lower when taxes are increasing as opposed to decreasing. If taxes increase and an individual wants to respond by reducing consumption, their addiction and/or habit formation means they can incur withdrawal costs associated with breaking or curbing the habit, which can limit the extent to which they are willing or able to reduce consumption. In contrast, when taxes decrease there is not the same limiting factor preventing an increase in consumption, leading to more elastic demand.

Demand heterogeneity across different groups within the population is notable in the literature and is going to be examined in this paper (with respect to income and age). People of lower income tend to be more responsive to higher cigarette taxes (Goldin & Homonoff, 2013; Haavio & Kotakorpi, 2011), but are also more likely to be smokers already (DeCicca et al., 2022). Crespi et al. (2021) note that younger people tend to have more elastic demand for cigarettes, as higher cigarette taxes are effective in preventing smoking initiation and therefore future cigarette consumption, which may be a useful consideration for cigarette tax policy.

There are further unexpected cigarette demand heterogeneity concerns, such as lighter smokers being more likely to quit than heavier smokers in response to a tax increase (Adda & Cornaglia, 2013). In addition, there are apparent network effects for smoking behaviours, as people who are part of fixed friendship groups that include smokers are less able to respond to higher cigarette taxes than people who have greater ability to move between friendship groups (Badev, 2021). These matters suggest that demand responses to higher cigarette taxes can be complex at the individual level and provide a strong basis for using fixed effects techniques in this research paper.

Tax pass-through to retail prices

It was previously noted that the effectiveness of cigarette taxes depended on both demand elasticity and the extent of pass-through of taxes to retail prices. The relatively inelastic demand for cigarettes means taxes should largely be able to be passed on (DeCicca et al., 2022). Harding et al. (2012) explain that taxes do not necessarily get passed on to the full extent, but that this is likely due to the context of the United States' state-based cigarette taxes – the availability of cheaper cigarettes across nearby borders partially dampens the ability to pass through tax costs as within-state demand is more elastic (Goolsbee et al., 2010; Hanewinkel et al., 2008).

While this is less relevant for countries with nationally applied cigarette taxes, Gilmore et al. (2013) indicate that tobacco companies adjust their tax pass-through depending on the product category. In an attempt to keep incentivising people to take up or retain the habit of smoking, lower-priced cigarettes have less tax pass-through so that more affordable cigarette options remain, while higher-priced cigarettes have much higher pass-through. However, there is not necessarily any evidence that similar strategies have been undertaken in the Australian market – given the extent of tobacco excise increases over the past 15 years, it is unlikely that even ultra-low-cost cigarettes could be considered relatively affordable for low-income earners.

Optimal sin taxes

There is complexity involved in determining the 'optimal' level of cigarette taxes (and sin taxes in general), and this is an important topic given the a focus of this research paper is to assess whether continuing to raise cigarette taxes remains effective. O'Donoghue and Rabin (2006, pp. 1825-1826) explain that sin taxes are typically imposed to "raise revenue, correct externalities, or to redistribute wealth," although the cost of internalities means that optimal sin taxes may need to be even higher than rationalised under this standard framework to reduce current *and* future consumption, and consequently maximise social welfare.

This theory was informed by Gruber and Köszegi (2001) and has been expanded upon by Haavio and Kotakorpi (2011), who outline that optimal sin taxes may be even higher than the political equilibrium sin tax. The political equilibrium sin tax is already substantial for cigarettes, as the median voter is unlikely to smoke due to low smoking participation but would benefit from the redistributed tax revenue and avoidance of externalities. Despite the case for higher sin taxes to correct for internalities, Ayyagari et al. (2009) note with respect to alcohol consumption that heavier users are less likely to reduce consumption and that the benefits of reducing internalities would not be achieved, hence higher sin taxes can be significantly welfare-reducing for those particular individuals – a similar concern to the tobacco excise in Australia, which has already increased to very high levels for continuing smokers.

Regressivity of cigarette taxes

Understanding who bears the burden of higher cigarette taxes is important, particularly in instances where individuals are unable to quit smoking. DeCicca et al. (2022) explain that smokers differ from non-smokers in noticeable ways, as smokers typically have lower education and income. Considering the inelastic demand for cigarettes, it is likely that cigarette tax increases will be regressive and place a greater tax burden on people of lower income, although the regressivity of a tax increase will depend on the relative elasticity of demand for lower income groups versus higher income groups.

There is research indicating that people under financial stress are more likely to be unable to quit smoking, as they use cigarettes to alleviate stress (Haavio & Kotakorpi, 2011). Smokers with lower income are more likely to be financially stressed due to cigarette prices. As such, while higher cigarette taxes may provide enough financial incentive to break the cycle and quit, it may otherwise reinforce a cycle of financial stress and smoking dependence. The potential outcome is diminishing returns to higher cigarette taxes as the remaining smokers are those under financial stress who find it more difficult to quit.

Research techniques

Panel data

Controlled experiments into smoking behaviours would be unethical due to negative health impacts and impractical due to the long timeframes that would be involved, so most research performed regarding the effects of tobacco regulation on smoking behaviours tends to rely on natural experiments. These natural experiments usually involve panel data, as they rely on multiple observations of the same subjects to analyse changes in behaviour.

Cotti et al. (2016, p. 107) effectively surmise why techniques like fixed effects rather than OLS are useful for such research, noting that “it is difficult to attribute changes in across-wave smoker behaviour to changes within smokers,” because as “cigarette taxes increase, some smokers choose to quit smoking, leaving a different pool of smokers.” For this type of research, it is the change in behaviour within smokers, rather than across a varying selection of smokers, that is most useful to understand. It has previously been noted that Adda and Cornaglia (2013, p. 3112) provide similar insight when stating that “an OLS regression of smoking intensity on excise taxes may find a spurious positive effect due to a change in composition in the pool of smokers,” assuming the likelihood of people dynamically selecting out of smoking (i.e., quitting smoking) is related to a particular trend, which in their case was that the ‘low smoking intensity group’ was more likely to quit.

The available panel data for this research is typically sourced from detailed surveys or sales tracking (DeCicca et al., 2022). Survey panel data source examples include the HILDA Survey in Australia, which is being used for this research paper, and both the National Health and Nutrition Examination Survey (NHANES) and the National Health Interview Survey (NHIS) in the US. The most common sales tracking research uses Nielsen Homescan data, which is also based in the US. It relies on participants scanning the unique product code (UPC) of all products they have bought in order to find a nationally representative sample of American consumer purchases. There are helpful examples of survey and sales tracking data use in academic research both within Australia and overseas.

In the Australian context, Wilkinson et al. (2019) used commissioned monthly survey data from Roy Morgan Research between 2001–2017 to analyse the differential effects of the one-off tobacco excise increase of 25 per cent in April 2010 versus the first four 12.5 per cent excise increases beginning in 2013, concluding that the one-off large increase was more effective for smokers of lower socioeconomic status, while sustained increases led to more consistent smoking reduction outcomes across the population, and in all cases many people switched to LLT. Dunlop et al. (2011) exploited the Tobacco Tracking Survey of the Cancer Institute NSW being in progress when the April 2010 excise hike occurred to analyse the likelihood of people attempting to quit smoking in different demographic groups, noting that it led to a spike in quit attempts that was not sustained soon after the hike. Buddelmeyer and Wilkins (2011) used HILDA Survey data to analyse changes in smoking behaviours from 2001–2003 as several state-based tobacco regulations were implemented, concluding that these milder restrictions had negligible effects on smoking.

In the US, Cotti et al. (2016) use Nielsen Homescan data to analyse smoking behaviour changes following tobacco regulation changes. The research concluded that higher taxes reduced smoking participation and intensity, while purchases of smoking cessation products increased, and there was some heterogeneity in demand responses. Harding et al. (2012) also use the data to assess how cigarette taxes are passed through to retail prices in different states, using fixed effects based on the UPC of different cigarettes. Adda and Cornaglia (2013), on the other hand, use NHANES data to run an experiment regarding whether smokers are smoking each cigarette more intensely in response to tax increases, such that they get the same amount of cotinine (a metabolite of nicotine that is commonly used to measure nicotine exposure) out of a lower quantity of cigarettes.

Standard approaches and variables

Panel data usefulness is determined by the variables available within the data set and how they are used. The consumption of sin products like cigarettes is typically assessed in terms of its ‘extensive margin’ or ‘participation elasticity’ (i.e., smoking participation, which is whether someone smokes at all) and its ‘intensive margin’ or ‘conditional elasticity’ (i.e., smoking intensity, which is the amount or frequency of smoking among those that do smoke) (Caulkins & Nicosia, 2010; DeCicca et al., 2022; Renke & Sinne, 2020). Studies therefore often rely on data regarding whether individuals smoke and, if so, the quantity of cigarettes they smoke over a particular timeframe. This is consistent with the research that is being performed in this paper.

The use of tax or retail price data is a common issue in smoking research with respect to data availability, endogeneity concerns and the examination of policy outcomes. While retail price data would be ideal for measuring price demand elasticity, there are benefits to the use of tax data. Adda and Cornaglia (2013) note that prices may be endogenous, as they simultaneously influence and are influenced by demand changes, whereas tax changes are exogenous shocks that are better suited as independent variables. Furthermore, price elasticities tend to be relatively similar when using tax or price data (Abrevaya & Puzzello, 2012). The availability and certainty of tax data also makes it easier to use, although the lack of retail price data can be challenging if industry pricing strategies attempt to circumvent the impact of higher taxes (Wilkinson et al., 2019).

Common limitations

It can be difficult to isolate for the effect of tobacco excise increases on smoking participation and intensity due to confounding variables for the excise and alternative responses available to smokers.

Confounding variables

There is generally considered to be unobservable, perpetual growth in anti-smoking sentiment over time. This is difficult to disentangle from sustained excise increases when estimating relative contributions to declining smoking participation and intensity. It may create endogeneity issues for estimations, as anti-smoking sentiment may be relied on for political support to implement tax increases (DeCicca et al., 2022; Harding et al., 2012; Pesko & Warman, 2022). The variety of complementary tobacco regulation (noted in *Section I*) can also confound the effect of tobacco excise increases, leading to measures like those described by Wilkinson et al. (2019), including the imposition of plain packaging legislation as a dummy variable in their research.

Alternative responses to higher taxes

There is considerable research into the different ways people can respond to higher cigarette taxes beyond reducing smoking intensity or quitting entirely. Crespi et al. (2021) specifically study this issue, noting that smokers have alternative options including: downgrading to cheaper cigarette brands; substituting with cheaper alternative products (e.g., LLT cigarettes); or switching to cigarettes with higher nicotine to maintain their nicotine intake while reducing cigarette expenditure. These concerns are supported in other research, including Gibson and Kim (2019) explaining that smokers may respond to higher cigarette taxes on the quality margin rather than quantity margin by downgrading to cheaper cigarettes; Hanewinkel et al. (2008) explaining that LLT cigarettes are commonly a lower-cost, attractive substitute to manufactured cigarettes; and both Nesson (2017) and Adda and Cornaglia (2013) noting that smokers may attempt to maintain nicotine intake, either by switching to cigarettes with higher nicotine content or smoking each cigarette more intensely.

Finally, e-cigarettes present new difficulties in estimating tax effects on smoking behaviours. As DeCicca et al. (2022, p. 922) describe, there is uncertainty over whether e-cigarettes are a substitute or complement to tobacco cigarettes – i.e., it “may be a precursor to future cigarette smoking or perhaps a longer-run substitute for it.” E-cigarettes have often been successfully used as a smoking cessation device, and Pesko and Warman (2022) explain that it is primarily used as a substitute to tobacco. It is noted here as research into e-cigarettes is an emerging space and the impact on smoking estimations is unknown, and as such it will be discussed further in *Section VII* of this paper.

III. Data

This research project brings together a combination of HILDA Survey and tobacco excise data to analyse how changes to cigarette taxes affect the population.

HILDA Survey

The key source of data in this research paper is the HILDA Survey, covering 2001–2021. The HILDA Survey is a longitudinal survey that the HILDA website (The University of Melbourne, n.d.) notes covers more than 17,000 Australians each year, with the intent of being representative of Australia's population (with the exception of some recent migrants and people in remote communities). The HILDA Survey is funded by the Federal Government, and is largely administered by the *Melbourne Institute: Applied Economic and Social Research*, which is part of the University of Melbourne (Watson, 2021). It is a rich data source that is useful for this research as it combines demographic and background data with responses to questions on issues like individuals' finances, lifestyle, health and education, among others.

Individuals are denoted with a cross-wave identification number (HILDA variable name: *xwaveid*) so that they can be tracked across waves, where each wave is a different year of the survey. There are multiple components to the HILDA Survey. The 'household form', 'household questionnaire', 'continuing person questionnaire' and 'new person questionnaire' are completed in the presence of an interviewer, while the 'self-completion questionnaire' (SCQ) is as described, with written or online answers provided in a respondents' own time. The SCQ is most relevant for this research as it contains the questions related to smoking, although this means that any estimations are confined only to people who have responded to the SCQ (as the smoking status of non-respondents is unable to be assumed). This can reduce the sample size available for estimations, particularly when attempting to use a balanced panel over several years, as SCQ responses are required in each year.

The two main SCQ questions focused on in this research relate specifically to smoking and form the basis of dependent variables in estimations. The first question is 'Do you smoke cigarettes or any other tobacco products?' (*lssmoke* in Wave 1, *lssmkf* in Wave 2-21), for which there are five potential answers: 'No, I have never smoked'; 'No, I no longer smoke'; 'Yes, I smoke daily'; 'Yes, I smoke at least weekly (but not daily)'; and 'Yes, I smoke less often than weekly'. This question has been asked in each wave of the survey, although the available responses in Wave 1 only had a single 'Yes, I smoke' response. For the purposes of estimations in this research paper, responses for all years have been aligned to the Wave 1 responses, so individuals in a given wave are only being considered as lifetime non-smokers ('No, I have never smoked'), former smokers ('No, I no longer smoke'), or current smokers (any 'Yes, I smoke…' response). The second question is 'How many cigarettes do you usually smoke each week?' (*lstbcn*, available from Wave 2), which only has to be answered if an individual responds to the previous question that they are a smoker.

The HILDA Survey data also enabled the creation of household income quintiles and multiple age groups. For household income quintiles, the most appropriate data is the respective positive and negative imputed annual household income (*hifdip* and *hifdin*), which allows for a more complete dataset by imputing missing or implausible values in given waves.[5] For this research, the positive and negative columns have been combined into a single variable for imputed annual household income, then partitioned into quintiles for each wave based on the entire HILDA sample in each year. When the data is filtered to only include SCQ respondents, each quintile may not have an equal number of responses (e.g., the lowest income quintile tends to be more responsive to the SCQ than other quintiles), but it has been completed this way as household income quintiles should be based on relative position against the population rather than against the less representative sample of SCQ respondents. For age groups, individuals were partitioned into 15-year age groups, including 15-29, 30-44, 45-59, 60-74 and 75+. Individuals under 15 were not considered as they do not respond to the HILDA Survey themselves.

Tobacco excise data

The tobacco excise data was collected from the 'Historical Excise Rates' spreadsheet available on *data.gov.au* (Australian Government, 2023). The 'per stick' rate for manufactured cigarettes is the relevant excise data extracted from that spreadsheet, and this was extrapolated into a daily time series so that all days throughout the HILDA Survey period would have excise data available for estimation purposes. To convert the daily excise data into 'real' values, CPI (Australian Bureau of Statistics [ABS], 2023, June) and AWOTE (ABS, 2023, May) data were both used, as the tobacco excise has been indexed by each data set at different times during the relevant period (see Figure 2 and related discussion in *Section I* of this paper).

AWOTE was ultimately used for indexation when performing estimations. The research is assessing the affordability of excise increases, which should be based on relative incomes rather than relative prices of other goods and services. AWOTE data is collected biannually at the mid-point of the June and December quarters each year, which means it is effectively collected in mid-May and mid-November. The tobacco excise is then indexed in the following quarter (e.g., the mid-November AWOTE data informs the indexation on 1 February the following year). For this research, to index the daily tobacco excise data set, AWOTE is first converted to a daily time series where each day in a reference quarter (when the data was collected) and its immediately following quarter (when tobacco excise indexation occurs) reflect the reference quarter value (e.g., the December and March quarters are represented by the new value calculated in mid-November). The tobacco excise is subsequently indexed to these values, using the excise on 30 June 2023 as a base.

[5] Each individual in a single household will be listed as having positive or negative imputed annual household income, but not both (i.e., they could have a positive value and a zero negative value, or a negative value and a zero positive value).

IV. Identification strategy

There are several smoking behaviours that are possible to estimate using the HILDA Survey data and will be considered here. The effect of the increasing tobacco excise, which will be the primary independent variable in all cases, will be estimated with respect to dependent variables including smoking participation (i.e., the probability that someone smokes), the cessation rate (i.e., propensity to quit smoking), the initiation rate (i.e., propensity to start smoking), and smoking intensity (i.e., the quantity of cigarettes consumed by smokers). The models, particularly for smoking participation and smoking intensity, closely follow the approach of Nesson (2017).

For all estimations, fixed effects techniques will be used so that the change in behaviour 'within' individual smokers is estimated. There will be autocorrelation between individuals' observations over time (e.g., a non-smoker is more likely to be a non-smoker in the following year), so fixed effects help control for that issue while also preventing the changing composition of smokers over time causing issues, as discussed in the *Panel data* section of the literature review.

Smoking participation, cessation rate and initiation rate

For smoking participation, the cessation rate and the initiation rate, the dependent variable is a binary response, which means a probabilistic regression like a logit or probit model should be used. A conditional logit model is being used in this case, as it effectively enables fixed effects in a logistic regression. It means that we can estimate the logistic probability that an individual will be a smoker (or will cease or initiate smoking) based on the logged value of the tobacco excise, while also controlling for autocorrelation between individuals' observations in different time periods.

Fixed effects are applied for each individual (HILDA variable name: *xwaveid*), as well as for each Australian state or territory (*hhstate*). For smoking participation, individuals are considered smokers if they answer with any of the 'Yes' responses to the relevant question in the HILDA Survey (*lssmoke* or *lssmkf*) and will be given probability of $y = 1$ as a result. In these estimations, the use of unbalanced and balanced panels is compared, with balanced panels using an interrupted time series approach.

For the cessation rate, only individuals whose previous survey response was that they are a smoker were considered, and if their current response was 'No, I no longer smoke', then they are given $y = 1$ as they have quit. For the initiation rate, only individuals whose previous response was either of the 'No' responses were considered, and if their current response was any of the 'Yes' responses, then they are given $y = 1$ as they have started or restarted smoking.

The model therefore estimates the logistic probability for an individual i to decide to smoke in year t in state or territory s:

$$\Pr(y_{its} = 1) = \alpha_i + \beta \log{(excise)_{it}} + X_{its} + \mu_s + \epsilon_{its},$$

where y_{its} is the indicator variable for whether an individual currently smokes, has ceased to smoke or has initiated smoking; α_i is the unique fixed effect for each individual; $\log(excise)_{it}$ is the logged value of the tobacco excise (it is the same for all states in each year); X_{its} represents the vector of controls (i.e., household income quintiles and age groups); μ_s is the state-based fixed effect, and ϵ_{its} is an error term. The coefficient β measures the effect of the change in $\log(excise)_{it}$ on $\Pr\ (y_{its} = 1)$.

Smoking intensity

To measure smoking intensity, a linear fixed effects model has been estimated. The sample is confined only to people who smoke in any year, so it is accordingly an unbalanced sample. The logged number of cigarettes smoked weekly is the dependent variable, while the same independent variables are used as for the smoking participation model.[6] The model therefore estimates the logged weekly number of cigarettes that smoker i will smoke in year t in state or territory s:

$$Y_{its} = \alpha_i + \beta \log\ (excise)_{it} + X_{its} + \mu_s + \epsilon_{its},$$

where Y_{its} is the logged number of cigarettes smoked weekly; α_i is the unique fixed effect for each individual; $\log(excise)_{it}$ is the logged value of the tobacco excise (it is the same for all states in each year); X_{its} represents the vector of controls (i.e., household income quintiles and age groups); μ_s is the state-based fixed effect, and ϵ_{its} is an error term. The coefficient β measures the effect of the change in $\log(excise)_{it}$ on Y_{its} (as both variables are logged, it is measuring elasticity).

Further considerations

Depending on the estimation, both unbalanced and balanced panels are used, which are each necessary in different instances but can create different challenges for fixed effects. Unbalanced panels are the only option for estimating smoking intensity, cessation rate and initiation rate, as each examine groups of smokers or non-smokers, which can dynamically change from year to year. However, fixed effects will omit individuals with only one observation in unbalanced panels, while there is no ability to use the HILDA Survey's population weights. In contrast, balanced panels have population weights available and are useful to estimate smoking participation.

There is an issue with balanced panels in that if an entire multi-decade timeframe is used, the sample becomes heavily biased towards older people in later years – i.e., if the youngest person that could be included in Wave 1 was 15 years old, the youngest person in Wave 21 in a balanced panel must be 35 years old. While a balanced panel estimation has been provided in the results, the issue has been mitigated via an interrupted time series approach, whereby the sample is the same group of respondents within each discrete time period. The time periods selected are in four-year groups (or five years for the first group when Wave 1 data is available), which means they are 2002–2005 (or 2001–2005), 2005–2009, 2009–2013, 2013–2017 and 2017–2021.

For the interrupted time series, the end year for one period is the start year for the next period so that change can be measured between all years across time series (e.g., if the second period was 2006–

[6] To try to use a balanced panel, non-smokers would have to be included, and as the logarithm of zero is undefined, less-useful linear values would have to be used for the dependent variable. During this research process, these estimations were attempted with and without the use of whether someone smokes as a control variable, but the results were largely not significant, and were inappropriate to include in this paper.

2009 instead of 2005–2009, the time series would miss behaviour changes between 2005 (when the first period ends) and 2006 (when the second period would begin)). The periods in the interrupted time series can be grouped or defined as particular eras for the tobacco excise in Australia: 2001–2005 and 2005–2009 each represent similar periods when the tobacco excise became more affordable but state-based regulations became more stringent; 2009–2013 represents the period of the 25 per cent hike (in April 2010) and its aftereffects; while 2013–2017 and 2017–2021 each represent periods of sustained 12.5 per cent increases in the tobacco excise.

For the independent variable, the tobacco excise will be used rather than retail prices for several reasons considered in the literature review, most important of which is data availability.[7] The tobacco excise will be indexed according to AWOTE so that it measures relative affordability over time, with the 30 June 2023 value of the tobacco excise used as a base (i.e., it used 2023 dollars). The indexed tobacco excise is then logged so that percentage changes are considered equally across the relevant time period, as otherwise later price increases would have an outsized effect on the estimations as percentage increases reflect greater monetary values due to the lower real value of money. The use of lagged or leading excise amounts was considered and estimated, but did not generate any significant results, which is consistent with Dunlop et al. (2011) noting that smoking behaviours tend to bounce back to existing levels soon after a tax increase.

For each general estimation model, household income quintiles and age groups are used as control variables. The models will focus on each of the quintiles/groups by partitioning the data and applying the estimation to each partition, to see how the effects change across demographics. It should be noted that an individual's age (as a continuous variable) has considerable collinearity with excise increases and growth in anti-smoking sentiment, which can confound the effects of those factors. This is why age groups (with dummy variables for each 15-year age segment) were used instead.

Time fixed effects have not been used, so there are no 'two-way' fixed effects models. The annual nature of the HILDA Survey data means that each time observation is a new year, often with a much higher tobacco excise as above-indexation increases occurred annually over a large portion of the time series. Due to the relative lack of granularity in HILDA Survey data, the models are unable to separate unobservable changes over time (e.g., growing anti-smoking sentiment) from tobacco excise increases.

V. Results

Each dependent variable being used in estimations will be analysed from multiple viewpoints. The analyses each start with a general estimation, followed by how they have changed over time (through interrupted time series analysis – for smoking participation and smoking intensity only), how they

[7] For comparison purposes, it should be noted that while the nominal tobacco excise increased from $0.26220 in the March 2010 quarter to $1.16435 in the June 2023 quarter (4.44 times greater), the ABS CPI series for tobacco increased from 74.4 to 341.2 over the same period (4.59 times greater) (ABS, 2023, June), so retail prices have largely followed tobacco excise increases.

affect different income groups (by breaking it down into household income quintiles) and how they affect people of different ages (by breaking it down into age groups).

Smoking participation

Entire sample – Wave 1 to Wave 21

The four models in Table 1 and Table 2 are conditional logit models that account for fixed effects and measure the effect of the tobacco excise on the logistic probability of smoking using differing control variables. Table 1 includes an unbalanced sample, while Table 2 is a balanced sample of only individuals that responded to the SCQ in all waves, using longitudinal population weights.

Table 1: Smoking participation on tobacco excise – unbalanced sample

	Logistic probability of smoking			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.369***	-0.375***	-0.165***	-0.171***
	(0.016)	(0.016)	(0.020)	(0.020)
2nd h/h income quintile		-0.030*		-0.040***
		(0.016)		(0.016)
3rd h/h income quintile		-0.066***		-0.079***
		(0.018)		(0.018)
4th h/h income quintile		-0.087***		-0.097***
		(0.020)		(0.020)
5th h/h income quintile		-0.068***		-0.080***
		(0.023)		(0.023)
Age group: 30-44			-0.228***	-0.224***
			(0.021)	(0.021)
Age group: 45-59			-0.393***	-0.390***
			(0.031)	(0.031)
Age group: 60-74			-0.718***	-0.725***
			(0.044)	(0.044)
Age group: 75+			-1.224***	-1.235***
			(0.074)	(0.074)
Observations	287,182	287,182	287,182	287,182
R^2	0.002	0.002	0.003	0.003
Max. Possible R^2	0.588	0.588	0.588	0.588
Log Likelihood	-127,056.200	-127,044.900	-126,891.200	-126,876.900
Wald Test	545.970*** (df = 1)	568.510*** (df = 5)	865.440*** (df = 5)	893.830*** (df = 9)
LR Test	564.807*** (df = 1)	587.504*** (df = 5)	894.891*** (df = 5)	923.536*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 1 are intuitive. For a given individual, their probability of being a smoker is likely to decrease as the excise rate increases, or as they move away from being in the bottom household income quintile, or as they get older. The effect of age groups in particular dilutes the effect of the tobacco excise (see difference between model (2) and model (4)), but the excise remains significant.

Table 2: Smoking participation on tobacco excise – balanced sample

	Logistic probability of smoking			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.581***	-0.586***	-0.359***	-0.362***
	(0.001)	(0.001)	(0.001)	(0.001)
2nd h/h income quintile		-0.002		-0.010
		(0.001)		(0.001)
3rd h/h income quintile		-0.057**		-0.069***
		(0.001)		(0.001)
4th h/h income quintile		-0.062**		-0.081***
		(0.001)		(0.001)
5th h/h income quintile		-0.031		-0.061**
		(0.001)		(0.001)
Age group: 30-44			-0.259***	-0.259***
			(0.001)	(0.001)
Age group: 45-59			-0.385***	-0.388***
			(0.001)	(0.001)
Age group: 60-74			-0.664***	-0.677***
			(0.001)	(0.001)
Age group: 75+			-0.951***	-0.966***
			(0.002)	(0.002)
Observations	86,481	86,481	86,481	86,481
R^2	1.000	1.000	1.000	1.000
Max. Possible R^2	1.000	1.000	1.000	1.000
Log Likelihood	-473,670,373	-473,661,784	-473,540,615	-473,528,534
Wald Test	534.700*** (df = 1)	547.250*** (df = 5)	761.460*** (df = 5)	785.750*** (df = 9)
LR Test	1,237,312*** (df = 1)	1,254,490*** (df = 5)	1,496,829*** (df = 5)	1,520,991*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

While the results in the balanced SCQ-respondent panel in Table 2 are largely presented for completeness, they are similar to the Table 1 results in terms of signs and significance. The differences are that the tobacco excise is ascribed a stronger negative value in Table 2, while the older age groups have a slightly more subdued negative effect. The reason for this is unclear, but it could be theorised that the balanced sample only includes people who were still alive and responding in Wave 21 and therefore had not suffered premature mortality, so the balanced panel may be relatively biased towards healthier non-smokers for whom the difference in smoking probability when reaching older age groups does not have as far to decline.

Entire sample – interrupted time series (Wave 2 to Wave 21)

The interrupted time series regression in Table 3 below breaks the time period down into four-year segments (inclusive of base year and end year), with the exception of the first period (as 2001 has been excluded to allow for consistency with smoking intensity estimations, which only had available data from 2002). For each time period, the model uses the equivalent of model 4 in the above estimations, with the full set of household income quintile and age group controls.

Table 3: Smoking participation on tobacco excise – interrupted time series

	Logistic probability of smoking

	2002-2005	2005-2009	2009-2013	2013-2017	2017-2021
Tobacco excise	0.731***	0.813***	-0.305***	-0.097***	-0.243***
	(0.013)	(0.011)	(0.003)	(0.002)	(0.002)
Observations	31,366	38,507	42,143	57,417	57,145
R^2	0.248	0.387	0.289	0.205	0.317
Max. Possible R^2	1	1	1	1	1
Log Likelihood	-107,841,393	-142,433,262	-133,677,557	-127,158,634	-120,328,894
Wald Test (df = 9)	28.900***	37.510***	30.730***	34.810***	30.560***
LR Test (df = 9)	8,954.900***	18,835.120***	14,354.980***	13,149.470***	21,758.860***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in each time period in Table 3 are significant to one per cent, but the first two periods in particular are counterintuitive. The reason for this is that the tobacco excise became slightly more affordable, while smoking participation declined in general, hence there was a positive correlation between taxes and smoking. The estimation encounters difficulty untying the tobacco excise from general anti-smoking sentiment. The results in later time periods are more intuitive as the toabcco excise began to increase considerably. The strong negative effect in 2009–2013 may indicate that the one-off 25 per cent excise hike was more effective than later graduated increases, although the larger negative effect in 2017–2021 compared with 2013–2017 may suggest that as the tobacco excise kept rising, people became more likely to be pushed over their affordability threshold and give up smoking.

Household income quintiles – Wave 1 to Wave 21

Moving back to using the unbalanced panel for all waves of the dataset (as per Table 1), we can break it down into separate estimations for different subsets of the sample. The first breakdown is by different household income quintiles (outlined in Table 4), to explore how the trends vary within these different quintiles when the tobacco excise changes. Age groups and household income have been used as controls in this model (household income to control for heterogeneity within quintiles).

Table 4: Smoking participation on tobacco excise – household income quintiles

	Logistic probability of smoking (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-0.267***	-0.117**	-0.254***	-0.238***	-0.183**
	(0.043)	(0.049)	(0.056)	(0.063)	(0.073)
Observations	65,664	56,183	53,425	55,098	56,812
R^2	0.003	0.001	0.002	0.002	0.002
Max. Possible R^2	0.547	0.493	0.421	0.354	0.308
Log Likelihood	-25,932.710	-19,063.000	-14,509.910	-11,964.520	-10,393.000
Wald Test (df = 6)	187.090***	72.150***	123.480***	124.310***	107.920***
LR Test (df = 6)	193.865***	75.355***	128.520***	127.092***	110.859***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results for each household income quintile in Table 4 suggest that the lowest income households are most strongly affected by the rising tobacco excise, and with the exception of the second quintile (which has counterintuitive results in all estimations), the coefficients became progressively less pronounced as household income increases. This is an intuitive outcome – people in lower income households are more likely to reach an affordability threshold for cigarettes and be incentivised to give up (or not start) smoking, notwithstanding potential difficulties due to addiction and habit formation.

Age groups – Wave 1 to Wave 21

The next estimation of subsets within the sample is by age group. The breakdown occurs similarly to the model above, with household income quintiles used as controls in this instance.

Table 5: Smoking participation on tobacco excise – age groups

	Logistic probability of smoking (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	0.335***	-0.383***	-0.325***	-0.489***	-0.607***
	(0.042)	(0.041)	(0.039)	(0.067)	(0.213)
Observations	72,786	74,010	70,940	49,196	20,250
R^2	0.002	0.001	0.001	0.001	0.0005
Max. Possible R^2	0.536	0.597	0.565	0.357	0.127
Log Likelihood	-27,913.820	-33,578.370	-29,452.080	-10,828.720	-1,374.249
Wald Test (df = 5)	110.510***	91.440***	71.790***	68.080***	9.120
LR Test (df = 5)	110.200***	92.832***	72.818***	69.440***	9.366*
Note:	*p<0.10 **p<0.05 ***p<0.01				

While each coefficient is significant at one per cent and most have intuitive negative signs, the sign of the coefficient for the 15-29 age group in Table 5 is particularly counterintuitive. It is apparent from visualising smoking participation across different ages (see Figure 3 in *Section VI*) that individuals tend to increase their smoking habits as they grow older within the 15-29 age group. Due to the use of fixed effects, which estimates how individuals change their behaviour over time, this age-based variation has overpowered the effect of the tobacco excise increases for this estimation. The use of age to control for variation within each age group was considered, but estimations using that type of model did not provide additional clarity over the results in Table 5 above.

Cessation rate

The same approach as for smoking participation will be used for estimating smoking cessation, although it should be noted that a positive sign is related to less smoking in this case – it means that the probability of a smoker quitting is greater. The results begin from Wave 2 as this is the first year where we can compare if someone quit compared with the previous year. Interrupted time series are not analysed for the cessation rate as four-year periods are relatively short timeframes in which to assess quitting behaviour.

Entire sample – Wave 2 to Wave 21

Table 6: Smoking cessation on tobacco excise – unbalanced sample

	Logistic probability of cessation			
	(1)	(2)	(3)	(4)

Tobacco excise	0.962***	0.962***	0.597***	0.600***
	(0.054)	(0.054)	(0.068)	(0.068)
2nd h/h income quintile		-0.103*		-0.083
		(0.055)		(0.055)
3rd h/h income quintile		-0.017		-0.0002
		(0.061)		(0.061)
4th h/h income quintile		-0.009		0.008
		(0.065)		(0.066)
5th h/h income quintile		-0.053		-0.026
		(0.073)		(0.074)
Age group: 30-44			0.431***	0.428***
			(0.069)	(0.069)
Age group: 45-59			0.711***	0.707***
			(0.108)	(0.108)
Age group: 60-74			1.329***	1.322***
			(0.152)	(0.152)
Age group: 75+			2.187***	2.175***
			(0.252)	(0.252)
Observations	47,923	47,923	47,923	47,923
R^2	0.006	0.007	0.008	0.009
Max. Possible R^2	0.340	0.340	0.340	0.340
Log Likelihood	-9,810.919	-9,808.361	-9,762.376	-9,760.413
Wald Test	317.440*** (df = 1)	322.520*** (df = 5)	410.830*** (df = 5)	414.850*** (df = 9)
LR Test	310.907*** (df = 1)	316.022*** (df = 5)	407.992*** (df = 5)	411.917*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 6 are intuitive, similar to Table 1. The likelihood of an individual quitting smoking increases when the tobacco excise increases, or as they move into older age groups. The household income quintile coefficients are generally not significant, although their signs are interesting in that they are negative like in Table 1, which means the opposite effect occurs (i.e., this indicates people are less likely to quit as they are of higher household income, but they are also less likely to smoke at all according to Table 1).

Household income quintiles – Wave 2 to Wave 21

Table 7: Smoking cessation on tobacco excise – household income quintiles

	Logistic probability of cessation (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	1.048***	0.381**	0.686***	0.581***	0.462*
	(0.159)	(0.189)	(0.196)	(0.213)	(0.238)
Observations	13,151	11,397	9,489	7,847	6,039
R^2	0.010	0.003	0.008	0.005	0.006
Max. Possible R^2	0.240	0.185	0.205	0.221	0.244
Log Likelihood	-1,740.443	-1,150.532	-1,050.371	-958.815	-824.811
Wald Test	124.230*** (df = 6)	33.200*** (df = 6)	66.580*** (df = 6)	40.800*** (df = 5)	33.180*** (df = 6)
LR Test	127.327*** (df = 6)	33.445*** (df = 6)	73.407*** (df = 6)	42.224*** (df = 5)	38.043*** (df = 6)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 7 are similar to that for smoking participation, with the tobacco excise having a far greater – and highly significant – effect on the lowest income quintile. The effect progressively weakens as household income grows (with the exception of the second income quintile), although the effect for the fifth household income quintile is only significant at 10 per cent.

Age groups – Wave 2 to Wave 21

Table 8: Smoking cessation on tobacco excise – age groups

	Logistic probability of cessation (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	1.385***	0.893***	1.370***	0.915***	1.995***
	(0.159)	(0.136)	(0.152)	(0.224)	(0.668)
Observations	12,439	16,022	13,429	5,250	783
R^2	0.007	0.003	0.007	0.007	0.015
Max. Possible R^2	0.275	0.277	0.259	0.283	0.282
Log Likelihood	-1,961.029	-2,566.905	-1,965.324	-854.731	-123.555
Wald Test (df = 5)	82.850***	52.390***	94.260***	34.170***	11.460**
LR Test (df = 5)	85.115***	52.624***	96.338***	35.566***	12.127**
Note:	*p<0.10 **p<0.05 ***p<0.01				

The effect of the tobacco excise on smoking cessation across different age groups in Table 8 is consistent. The 15-29 age group has a more intuitive response for the cessation rate than it does for smoking participation, likely because rising smoking participation as individuals move through this age group is due to greater smoking initiation over time, whereas the probability of quitting would be less associated with age. The sample size for some of these estimations – particularly for older age groups – is quite low considering the number of time periods (20 years) being examined.

Initiation rate

The approach for estimating smoking initiation is identical to that for smoking cessation, except the sample only includes people who did not smoke in their immediately preceding annual response to the HILDA Survey. The approach estimates whether those non-smokers will take up smoking. Similar to smoking participation, a negative sign is correlated with less smoking behaviour, as it demonstrates a greater likelihood that an individual will not take up smoking.

Entire sample – Wave 2 to Wave 21

The four models below use the same controls as Table 1 and Table 6.

Table 9: Smoking initiation on tobacco excise – unbalanced sample

	Logistic probability of initiation			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.692***	-0.720***	-0.219***	-0.250***
	(0.052)	(0.053)	(0.066)	(0.066)
2nd h/h income quintile		-0.249***		-0.270***
		(0.056)		(0.056)

3rd h/h income quintile		-0.342***		-0.358***
		(0.061)		(0.062)
4th h/h income quintile		-0.424***		-0.440***
		(0.066)		(0.066)
5th h/h income quintile		-0.407***		-0.422***
		(0.072)		(0.072)
Age group: 30-44			-0.649***	-0.618***
			(0.073)	(0.073)
Age group: 45-59			-1.014***	-0.979***
			(0.116)	(0.117)
Age group: 60-74			-1.946***	-1.965***
			(0.170)	(0.170)
Age group: 75+			-2.882***	-2.945***
			(0.276)	(0.276)
Observations	207,000	207,000	207,000	207,000
R^2	0.001	0.001	0.002	0.002
Max. Possible R^2	0.084	0.084	0.084	0.084
Log Likelihood	-8,984.026	-8,960.262	-8,903.734	-8,878.267
Wald Test	175.190*** (df = 1)	221.750*** (df = 5)	326.380*** (df = 5)	375.750*** (df = 9)
LR Test	183.412*** (df = 1)	230.941*** (df = 5)	343.996*** (df = 5)	394.930*** (df = 9)
Note:	*p<0.10 **p<0.05 ***p<0.01			

The results in Table 9 are similar to Table 1 and Table 6. The likelihood of an individual initiating smoking decreases when the tobacco excise increases, and as they move into older age groups. The household income quintile coefficients are negative and significant, unlike for smoking cessation, indicating that there is a notable income effect on smoking initiation (i.e., the tobacco excise is more likely to affect lower income households in their propensity to start smoking). The combined results for smoking participation, smoking cessation and smoking initiation suggest that lower income households are more likely to smoke in general, but then are also more likely to be affected by the tobacco excise in determining whether they cease or initiate smoking (although the cessation coefficients are insignificant).

Household income quintiles – Wave 2 to Wave 21

Table 10: Smoking initiation on tobacco excise – household income quintiles

	Logistic probability of initiation (by household income quintile)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-0.479***	0.153	-0.341	-0.420**	-0.135
	(0.175)	(0.189)	(0.212)	(0.207)	(0.209)
Observations	46,714	38,271	37,441	40,619	43,955
R^2	0.001	0.001	0.001	0.001	0.001
Max. Possible R^2	0.052	0.049	0.045	0.041	0.043
Log Likelihood	-1,208.587	-955.015	-838.932	-841.946	-951.734
Wald Test (df = 6)	52.610***	18.320***	33.060***	32.380***	46.150***
LR Test (df = 6)	55.418***	21.357***	34.518***	35.290***	49.316***
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 10 follow those in Table 9 – the lowest household income quintile is significantly affected by the tobacco excise, with a strong negative coefficient indicating a lower probability of starting smoking when the tobacco excise rises. The coefficients for the other household income quintiles are generally negative but not overly significant, indicating a weaker effect of a rising tobacco excise on people with household income that enables cigarettes to remain relatively affordable in spite of higher taxes.

Age groups – Wave 2 to Wave 21

Table 11: Smoking initiation on tobacco excise – age groups

	Logistic probability of initiation (by age group)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	0.625***	-0.583***	-0.545***	-0.968***	-0.428
	(0.110)	(0.147)	(0.157)	(0.277)	(0.651)
Observations	45,518	50,361	51,977	40,837	18,307
R^2	0.002	0.0005	0.0003	0.0003	0.0002
Max. Possible R^2	0.123	0.071	0.053	0.025	0.010
Log Likelihood	-2,937.880	-1,840.289	-1,409.135	-501.796	-90.611
Wald Test (df = 5)	87.480***	22.610***	16.920***	13.690**	1.950
LR Test (df = 5)	88.139***	22.887***	17.226***	14.281**	2.946
Note:	*p<0.10 **p<0.05 ***p<0.01				

The negative coefficients for most age groups in Table 11 indicate that people are generally less likely to take up smoking when the tobacco excise rises. The exception is the 15-29 age group, but this follows the results in Table 5, whereby the effect of people becoming more likely to smoke as they get older within this age group overpowers the effect of the tobacco excise, as there is collinearity between age and the tobacco excise, particularly since April 2010. The significance of the 15-29 age group coefficient can cause doubt regarding the significance of the other coefficients, as it is hard to discern whether their strong negative signs are due to the tobacco excise or due to lower likelihood of smoking initiation as people grow older.

Smoking intensity

While the smoking participation models estimated the probability that an individual would smoke, the smoking intensity models estimate the extent to which smokers consume cigarettes, using linear fixed effects (although the dependent variable of weekly cigarettes smoked is logged). These estimations use an unbalanced sample, including any observation where an individual has reported that they are a smoker and therefore smoke greater than zero cigarettes per week.

Entire sample – Wave 2 to Wave 21

Table 12: Smoking intensity on tobacco excise – unbalanced sample

	No. of cigarettes smoked weekly (log)			
	(1)	(2)	(3)	(4)
Tobacco excise	-0.045***	-0.047***	-0.030*	-0.032**

	(0.013)	(0.013)	(0.016)	(0.016)
2nd h/h income quintile		-0.022*		-0.025**
		(0.012)		(0.012)
3rd h/h income quintile		-0.029**		-0.034**
		(0.014)		(0.014)
4th h/h income quintile		-0.042***		-0.047***
		(0.015)		(0.015)
5th h/h income quintile		-0.011		-0.018
		(0.018)		(0.018)
Age group: 30-44			0.005	0.007
			(0.017)	(0.017)
Age group: 45-59			0.014	0.015
			(0.025)	(0.025)
Age group: 60-74			-0.090**	-0.093**
			(0.036)	(0.036)
Age group: 75+			-0.116*	-0.122*
			(0.062)	(0.062)
Observations	49,753	49,753	49,753	49,753
R^2	0.001	0.001	0.002	0.002
Adjusted R^2	-0.239	-0.239	-0.239	-0.238
F Statistic	4.488*** (df = 8; 40108)	3.786*** (df = 12; 40104)	5.178*** (df = 12; 40104)	4.584*** (df = 16; 40100)
Note:	*p<0.10 **p<0.05 ***p<0.01			

These results for smoking intensity in Table 12 are relatively intuitive, similar to Table 1. For a given individual who smokes, the model estimates that the quantity of cigarettes they consume should decrease in response to an increase in the tobacco excise. While the household income quintile effects are similar to smoking participation, where higher income quintiles are associated with smoking fewer cigarettes, the effects of age groups are not overly significant.

Entire sample – interrupted time series (Wave 2 to Wave 21)

Table 13: Smoking intensity on tobacco excise – interrupted time series

	No. of cigarettes smoked weekly (log)				
	2002-2005	2005-2009	2009-2013	2013-2017	2017-2021
Tobacco excise	0.565	-2.858***	-0.044	0.048	-0.122**
	(0.347)	(0.314)	(0.084)	(0.037)	(0.049)
Observations	10,508	11,489	12,439	13,096	12,067
R^2	0.003	0.014	0.004	0.004	0.004
Adjusted R^2	-0.704	-0.559	-0.639	-0.555	-0.577
F Statistic	1.050 (df = 16; 6150)	6.557*** (df = 16; 7264)	2.010*** (df = 16; 7557)	2.310*** (df = 16; 8386)	1.819** (df = 16; 7620)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results in Table 13 are not significant, outside of 2005–2009 and 2017–2021. The coefficient for 2005–2009 is due to a pronounced increase in smoking intensity among smokers during this period that was negatively correlated with the falling AWOTE-indexed value of the tobacco excise. The coefficient for 2017–2021 is more consistent with expected demand elasticity for cigarettes, although it is only significant at the five per cent level.

Household income quintiles – Wave 2 to Wave 21

Table 14: Smoking intensity on tobacco excise – household income quintiles

	No. of cigarettes smoked weekly (log) (by household income quintiles)				
	1st	2nd	3rd	4th	5th
Tobacco excise	-8.593***	-4.948**	-6.085**	1.714	-0.388
	(2.155)	(2.277)	(2.775)	(3.002)	(3.335)
Observations	13,270	11,987	9,922	8,216	6,358
R^2	0.006	0.007	0.008	0.005	0.001
Adjusted R^2	-0.417	-0.593	-0.732	-0.796	-0.746
F Statistic	4.509*** (df = 13; 9305)	4.020*** (df = 13; 7474)	3.357*** (df = 13; 5685)	1.714* (df = 13; 4551)	0.446 (df = 12; 3636)
Note:	*p<0.10 **p<0.05 ***p<0.01				

The results for each household income quintile outlined in Table 14 are glaring. The coefficients for the first, second and third household income quintiles are significant and strongly negative, particularly for the first quintile. This indicates that lower income is correlated with smokers reducing their smoking intensity, as the rising tobacco excise has a greater impact on their finances. The fourth and fifth household income quintiles do not have significant coefficients, indicating that if individuals in these quintiles are to maintain their smoking habit, the rising tobacco excise is not necessarily causing them to change behaviour and reduce consumption.

Age groups – Wave 2 to Wave 21

Table 15: Smoking intensity on tobacco excise – age groups

	No. of cigarettes smoked weekly (log) (by age groups)				
	15-29	30-44	45-59	60-74	75+
Tobacco excise	7.616***	-1.996	-10.657***	-21.699***	-16.557**
	(1.944)	(1.835)	(1.924)	(3.132)	(8.212)
Observations	14,815	16,118	13,246	4,902	672
R^2	0.003	0.001	0.005	0.014	0.045
Adjusted R^2	-0.480	-0.334	-0.264	-0.285	-0.383
F Statistic	2.529*** (df = 12; 9979)	1.466 (df = 12; 12061)	4.244*** (df = 12; 10427)	4.549*** (df = 12; 3759)	3.677*** (df = 6; 463)
Note:	*p<0.10 **p<0.05 ***p<0.01				

While each coefficient in Table 15 (except for the 30-44 age group) is significant at one per cent, the sign for the 15-29 age group appears counterintuitive, just as it was for smoking participation. The reasoning behind this is likely similar to that for smoking participation – as people grow older within this age group, they are likely to increase their smoking intensity if they are a smoker. The results of this estimation appear to largely reflect age profiles rather than the effect of the tobacco excise. The use of age as a control was considered, but once again estimations using that type of model did not provide additional clarity over the results in Table 15 above.

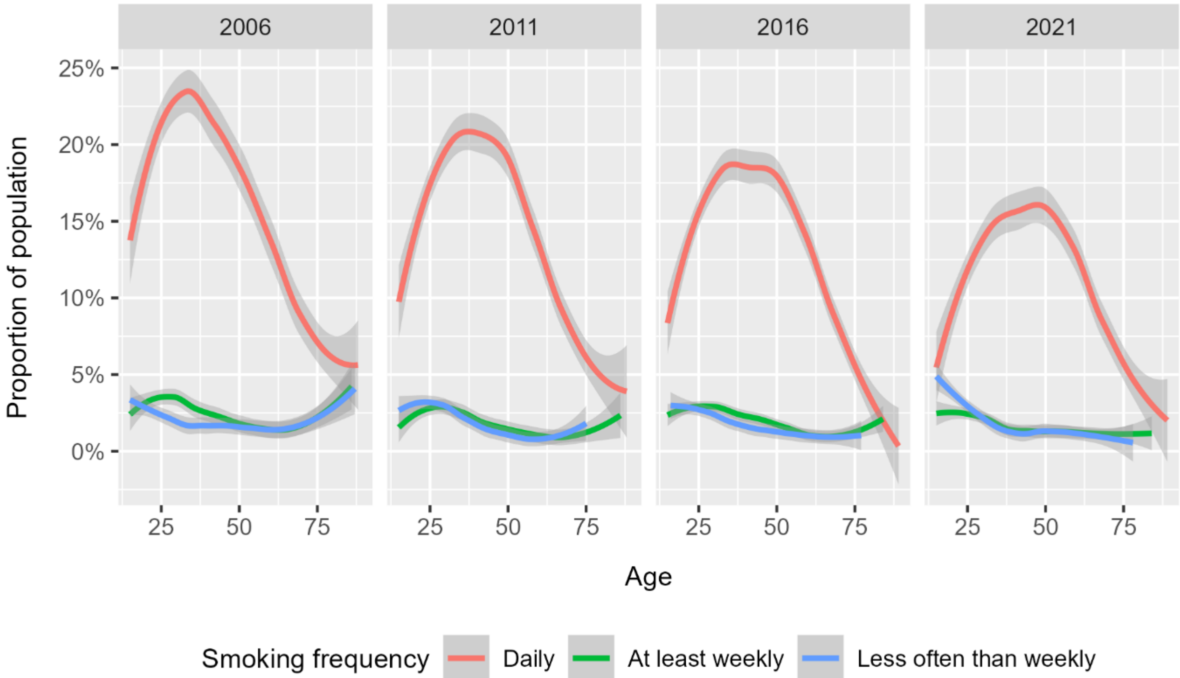
VI. Discussion

The major takeaway from the results in the general models covering the whole population is that there is ongoing growth in anti-smoking sentiment, which is difficult to decouple from the effects of tobacco excise increases. This was noticeable in the interrupted time series results from 2002–2009, where smoking participation declined at the same time as the AWOTE-indexed tobacco excise marginally declined, leading to a counterintuitive positive correlation between the two variables. The results from early parts of the HILDA Survey data may simply be consistent with DeCicca et al. (2022, p. 923) noting that small changes in cigarette taxes are less “plausible exogenous” and may not generate significant findings. The years that included above-indexation tobacco excise increases tended to have more significant trends. However, the extent to which trends between 2009–2021 are due to the tobacco excise or growing anti-smoking sentiment is difficult to discern.

Where the results can be more useful is in examining how the range of dependent variables were affected in different ways, and how population sub-groups were affected differently. For instance, the tobacco excise’s impact on smoking participation seems to be much greater than the impact on smoking intensity, the latter of which is not subject to overly significant effects across the general population. This likely means that smokers do not linearly decrease their demand, but rather that smokers may reach a cost threshold that incentivises them to quit smoking altogether, provided they are able to do so. The relatively strong negative coefficient for smoking participation in the 2017–2021 time period indicates that many smokers may have been reaching that threshold in recent years.

While smoking intensity across the general population does not necessarily change significantly in response to tobacco excise changes, responses appear to be contingent on household income levels. The lower household income quintiles (particularly the first household income quintile) have significant negative coefficients for smoking intensity against the tobacco excise, whereas the fourth and fifth household income quintiles have no significant effects. These drastic differences between household income quintiles for smoking intensity, particularly when compared with the differences for smoking participation, may indicate that people from lower income households that are unwilling or unable to quit smoking are more budget-conscious and have to give greater thought to their cigarette consumption than those from higher income households with less affordability concerns. It is likely that this group forms those suffering the strongest negative welfare effects from the rising tobacco excise, as they are demonstrating conscious demand responses to the rising cost of cigarettes but are still paying high amounts of tobacco excise to maintain their addiction.

Figure 3: Smoking participation frequency by age in four separate years



Note: The plotted lines are smoothed averages across ages for each smoking frequency variable.

The results for age groups were less clear than for household income quintiles, which appear to be due to smoking behaviours following a clear trend with age. This is outlined in the diagrams in Figure 3, which plot the proportion of the population smoking (including three different frequencies of smoking participation) for each age of an individual in four different years.

Smoking participation has generally decreased for all ages across the years, but it is apparent that the probability that someone will smoke trends upwards as individuals grow older within the 15-29 age group. This explains the positive sign for smoking participation in this age group, while the subsequent downward trend as people get older largely explains the negative signs for those older age groups. Fixed effects techniques are difficult to apply in circumstances like this, as although the change within individuals is what should be being estimated, collinearity between age and the increasing tobacco excise makes it difficult to discern the extent to which each is affecting an individual's changing smoking behaviours, particularly when general anti-smoking sentiment is also growing.

The most important insight gathered from the age group analysis is that the rising tobacco excise is associated with a declining smoking initiation rate among the 15-29 age group. The reduced affordability of cigarettes for younger people may therefore be having an impact in preventing people from taking up smoking altogether, which should flow through to lower smoking participation at older ages as younger people do not become addicted. The extent to which this is due to the tobacco excise rather than the increased availability of e-cigarettes is uncertain, however, and will be discussed further in the following section.

VII. Limitations

There were several challenges and limitations involved in performing the estimations. These include contending with collinearity between the rising tobacco excise and other factors; a lack of variation in the tobacco excise in certain time periods; the uniformity of tobacco excise increases across the country; the lack of granularity in the HILDA Survey data with respect to alternative demand responses; and more general concerns with the HILDA Survey data.

Modelling limitations

The key difficulty with the estimations was the collinearity between the rising tobacco excise and factors such as age and the unobservable growth in anti-smoking sentiment. The strong association between age and smoking behaviours, as outlined in the previous section, means it is difficult for a fixed effects model to discern whether the change within an individual's behaviour was due to them getting older or the tobacco excise increasing. This also meant that age was difficult to use as a control variable due to endogeneity, and while age groups acted as a substitute, the effectiveness of age groups may be influenced by premature mortality in older age groups due to smoking. The collinearity between the tobacco excise and anti-smoking sentiment was also difficult to separate, particularly when combined with age effects. For example, smoking participation and smoking intensity declined in the early 2000s without major excise increases, so it appears difficult to attribute the full effect of declining smoking rates in the 2010s to excise increases.

This lack of variability in the data also presented challenges – with respect to taxes in certain periods and across different geographies. The uniformity of tax increases across Australia prevented the use of any kind of control group or a difference-in-differences approach between states and territories. Whereas many studies on smoking behaviours in the US exploit between-state variability in taxes in the context of similar cultural environments, this is not possible to achieve when studying Australia. This is consistent with issues faced by studies of smoking in European countries where regulations tend to be national, which DeCicca et al. (2022, p. 945) note has resulted in studies employing "interrupted time series or cross-country comparisons across a small number of countries," which can be "highly sensitive to bias from secular shocks." The inability to use a control group also reinforces the challenges with collinearity noted above, as that collinearity would largely be consistent across states and territories, but variation in taxes between states/territories is unable to be used to this end.

Furthermore, it would have been constructive to delve deeper into the issue of smoking intensity being far more greatly affected by the tobacco excise for lower income households, but modelling limitations prevented this from occurring. The initial intent of this research was to examine how the percentage of household income spent on cigarettes affects smoking behaviours, as it would be interesting to know if there was a threshold beyond which people became more likely to reduce smoking participation or intensity. It appeared possible to explore the issue as household income and household cigarette expenditure are included variables in the HILDA Survey data. However, there were simultaneous equations concerns with the modelling that prevented treading further down that path. For example, higher cigarette expenditure as a percentage of household income may cause people to reduce smoking participation or intensity, but it is higher smoking participation or intensity that causes the high percentage of household income to be spent on cigarettes in the first place.

Data limitations

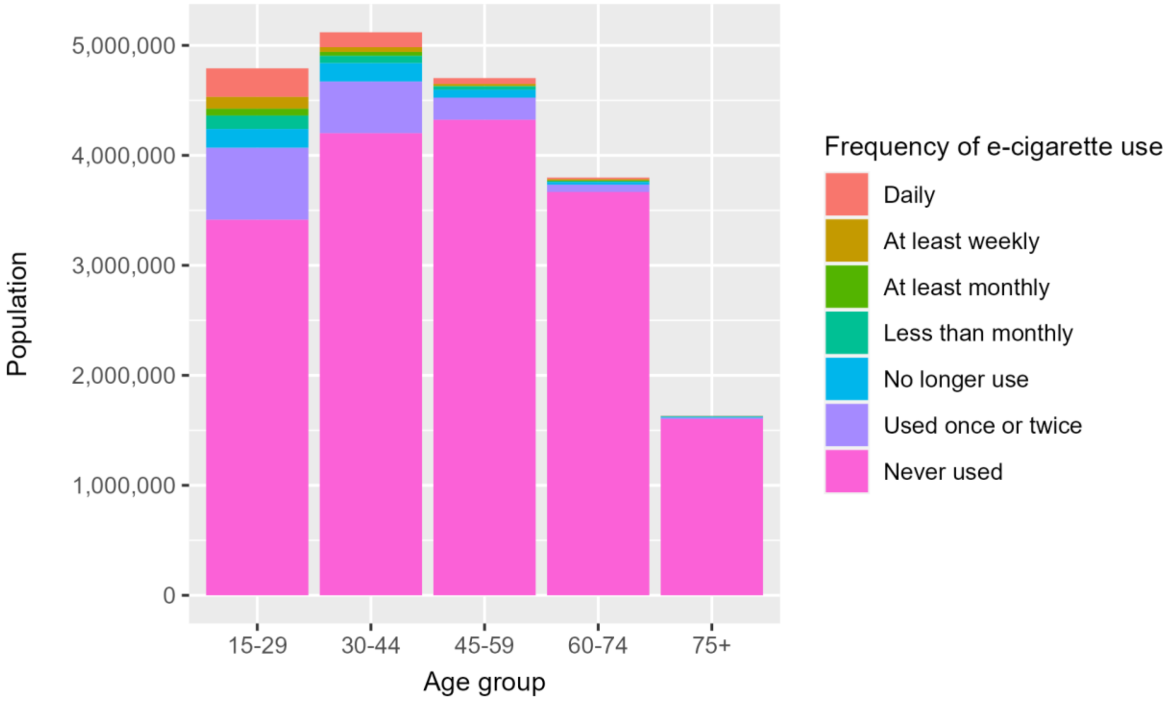
The HILDA Survey is a very rich data source, but in terms of its information on smoking behaviours, it can be a blunt instrument for population-based estimations. For instance, the willingness to purchase smoking cessation products and attempting to quit can be a strong indicator of the effect of tobacco excise increases (Cotti et al., 2016; Dunlop et al., 2011), but unsuccessful quit attempts are not evident in the data. It may be the case that as the tobacco excise continues to increase, the sample of remaining smokers are willing but less able to quit than in previous years, which may affect the estimation results.

When using HILDA Survey data, it is also difficult to determine whether people are responding to a higher tobacco excise in different ways than just reducing smoking participation or intensity. The literature review indicated that people respond to tax increases in different ways, including product substitution to cheaper cigarettes, higher nicotine cigarettes and LLT cigarettes. Higher taxes may also increase the motivation for people to purchase illegally imported black-market cigarettes. It is difficult to make these distinctions when attempting to determine the effect of tobacco excise increases using HILDA Survey data. While cigarette expenditure variables are available and can be extrapolated into a per-cigarette cost, it is particularly challenging to estimate whether people have downgraded to the cheaper substitute products outlined, as per-cigarette costs are likely to have still increased for those substitutes due to higher taxes (excluding black-market cigarettes).

The potential product substitution by individuals also extends to 'vaping' – the use of e-cigarettes. The HILDA Survey asked respondents about their frequency of e-cigarette use for the first time in Wave 21 (2021), which is visualised for different age groups in Figure 4 below. The understanding of how e-cigarette consumption affects smoking behaviours is limited at this stage – the literature review referred to research indicating that it is undetermined whether e-cigarettes are a substitute to tobacco cigarettes (including potential utility as a cessation device) or a complement to tobacco cigarettes (including potentially acting as a gateway to tobacco smoking). It is at least important to note, however, that younger people are much more likely to have tried e-cigarettes and frequently use e-cigarettes, which may be affecting the 15-29 and 30-44 age groups in the estimation results in this paper. The presence of harmful e-cigarettes may also reduce the welfare effect of alternative anti-smoking policies such as age-based smoking bans, which could be in the pipeline considering the lead that New Zealand and the UK have demonstrated.[8]

[8] New Zealand has passed legislation, and the UK is proposing legislation, whereby anyone born from 1 January 2009 (it is the same for both countries) would never legally be able to purchase cigarettes.

Figure 4: **Frequency of e-cigarette use by different age groups in 2021**



There are also more general concerns with the HILDA survey data containing many missing responses and being prone to measurement error. Omitting missing responses may cause selection bias if they are correlated with certain characteristics (e.g., higher-income households may be more likely to not submit responses, biasing the sample away from that group). Measurement error is understandable for any self-completed survey (e.g., there are some extreme outliers for number of cigarettes smoked). The concept of 'winsorizing' the data so that outlying values were cut back to values at a particular percentile (e.g., the 99^{th} percentile, similar to research from Renke and Sinne (2020)) was considered, but this option was not taken up – nor were the extreme outliers omitted – as they only comprised a very small portion of the dataset.

VIII. Conclusion

The research in this paper outlines some constructive findings related to the effect of tobacco excise increases on smoking behaviours in Australia. The general effects across the population are for the rising tobacco excise to decrease smoking participation (including by increasing smoking cessation and decrease smoking initiation) and to decrease smoking intensity for certain demographics. The results of estimations indicate that changes in smoking behaviours became more pronounced as the tobacco excise started to rise (i.e., from April 2010), although this research also shows that the ability to isolate the effect of the excise from other effects (like age and unobservable anti-smoking sentiment) is difficult to achieve.

Where the research was most effective was exploring the differences between household income quintiles. Cigarette taxes are generally known as being regressive, as people with lower incomes tend to bear a greater tax burden by virtue of being more likely to be smokers (DeCicca et al., 2022), which is exacerbated in Australia by huge increases to the tobacco excise. The impact on lower income households' budgets was evident, as they were more likely to quit smoking and considerably more likely to reduce smoking intensity even if they had not quit. Further research into the points at which households feel crunched by their cigarette expenditure and start attempting to quit would be helpful to explore the issue further. If a majority of people from low-income households have already passed this point, it may be the case that continued increases to the tobacco excise are more effective at raising revenue but less effective at improving welfare, and that it may be worthwhile to consider alternative anti-smoking policies in order to maximise societal welfare.

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