NHS Health Scotland

The validity and reliability of retail sales data for monitoring population cigarette consumption in Scotland

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All tobacco sales data are copyrighted to Nielsen.

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Summary

Introduction

Cigarette smoking is the world's leading cause of preventable poor health and premature death. In Scotland, although smoking prevalence has been broadly declining over time, wide socioeconomic inequalities exist. Smoking therefore remains a public health priority for the Scottish Government. This was clearly demonstrated by a five-year tobacco control strategy set out in 2013 which aims to make Scotland tobacco-free (prevalence of 5% or lower) by 2034.

It is important that policymaking aimed at reducing smoking prevalence is informed by valid and reliable data on smoking behaviour in the population. This is in line with the WHO Framework Convention on Tobacco Control Article 20, which highlights the need for 'national, regional and global surveillance of the magnitude, patterns, determinants and consequences of tobacco consumption and exposure to tobacco smoke'.

This report reviews the validity and reliability of using cigarette retail sales data to estimate per-adult cigarette consumption for the purpose of monitoring and evaluating tobacco control policy in Scotland.

Approach

A literature review was undertaken to describe the use of cigarette sales data and identify whether their validity and reliability had previously been assessed. Potential sources of underestimation and overestimation (i.e. bias) of per-adult smoking derived from cigarette sales data were identified and, where possible, quantified. This enabled an assessment of the extent to which the different sources of bias might impact on per-adult cigarette consumption estimates in Scotland, defined as the number of cigarettes sold per person aged 16 years and older.

Results

The literature review identified that cigarette sales data have been used widely internationally. The most common use was to evaluate tobacco control policy. Cigarette sales data were reported to be robust, but a number of limitations were also found. No studies were identified that have systematically assessed the validity and reliability of these data.

Several sources of bias that could potentially impact upon the validity and/or reliability of per-adult cigarette consumption derived from cigarette retail sales data were identified. The **Summary figure** on page 4 presents the best estimate for the size of each bias identified.

Underestimation of population cigarette consumption in Scotland using retail sales data is far more likely than overestimation. The largest bias is illicit cigarettes, which in 2013 are estimated to have accounted for an underestimation of 102 cigarettes

per adult per year, relative to the sales-based estimate of 905 cigarettes per adult (~11%). Non-inclusion of certain sales outlets in the Nielsen sampling frame and cross-border/duty-free cigarette sales are also likely to make an important contribution. Biases that are likely to cause population cigarette consumption to be overestimated are much smaller in magnitude.

Consequently, the net effect is that per-adult cigarette consumption in Scotland based on retail sales data is far more likely to underestimate actual smoking consumption. In 2013, the best estimate of the size of this underestimation was 132 cigarettes per adult per year, equivalent to 15% of the sales-based cigarette consumption estimate.

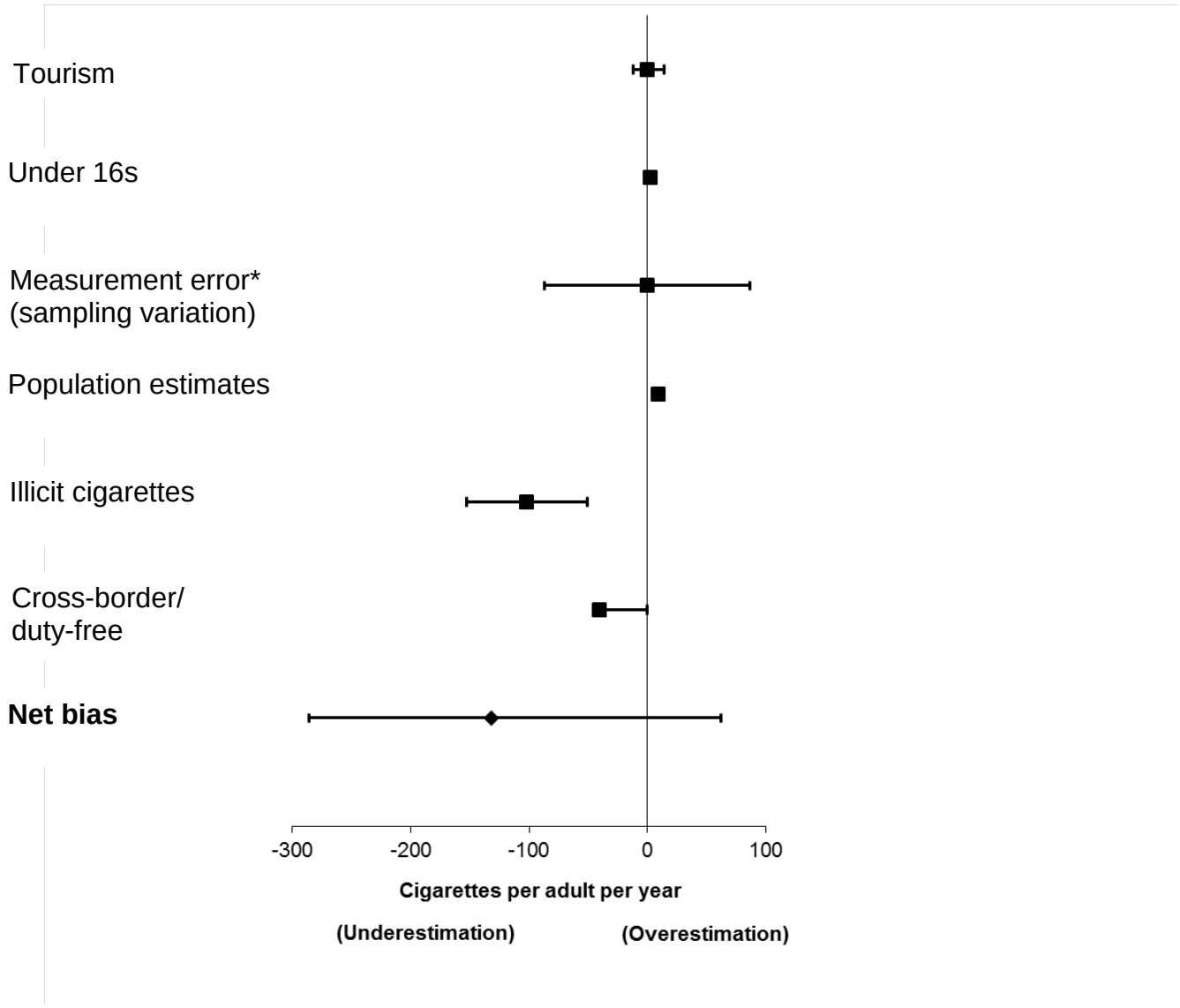
Discussion

A review of prior literature suggests that cigarette sales offer an objective data source that can overcome limitations associated with self-reported methods of measuring per-adult smoking. Such data have therefore been recommended for public health policy monitoring and evaluation.

This study has assessed the potential impact of biases that might affect the validity and reliability of using cigarette sales data to estimate population cigarette consumption in Scotland. Using a pragmatic approach to quantify biases with available data, it has been shown that actual population cigarette consumption is likely to be underestimated by 15% using retail sales data. This is largely due to the consumption of illicit cigarettes and cross-border and duty-free shopping. The uncertainty around this estimate is large (−32% to +7%) and the size of some biases has changed substantially over time.

These issues have the potential to undermine the validity and reliability of retail sales data for the purpose of estimating population cigarette consumption. However, their use should not be precluded. Retail sales data are available at weekly level, which is particularly useful for using time series analysis to evaluate population tobacco control interventions. Useful breakdowns by pack size are also possible. The data therefore offer the potential to strengthen policy evaluation when used alongside data for other smoking-related indicators and on the proviso that biases potentially affecting their robustness are carefully considered.

Summary figure: Best estimates of the size of different biases that might lead to either underestimation or overestimation of population cigarette consumption based on retail sales in Scotland.



Note: biases are represented relative to the per-adult cigarette consumption estimate in 2013 (905 cigarettes per adult). *The estimate for measurement error only includes sampling variation; however, the category also includes the non-inclusion of certain sales outlets in the data provider's sampling frame and non-response bias. These unquantifiable biases would be more likely to result in underestimation than overestimation.

1. Aim

This report aims to:

1. Review the existing knowledge base on the use of cigarette sales data as an indicator of per-adult cigarette consumption.
2. Identify if the validity and reliability of using cigarette sales data as an indicator of per-adult cigarette consumption has previously been explored.
3. Explore the potential sources of overestimation and underestimation of per-adult cigarette consumption derived from retail sales data.
4. Report on the overall validity and reliability of cigarette retail sales data as a measure of per-adult cigarette consumption in Scotland.

Note that this report explores biases potentially affecting the validity and reliability of manufactured cigarette sales; the validity and reliability of data on roll-your-own tobacco are not examined.

2. Introduction

Cigarette smoking is the world's leading cause of preventable poor health and premature death.[1-3] It is responsible for the death of five million people per year, with second-hand smoke accounting for an additional 600,000 deaths per year.[4] 12% of global deaths in those aged ≥30 years can be attributed to tobacco. Cigarette smoking is also responsible for 5% and 14% of all deaths from communicable diseases and non-communicable diseases respectively (18% of each in Europe).[5] In Scotland, the government and public health community are focused on reducing smoking prevalence and, in particular, redressing persistent inequalities in smoking. The Scottish Government have set a goal of Scotland being tobacco-free, defined as a smoking prevalence of 5% or lower among the adult population, by 2034.[6]

Accurate data with which to measure smoking in a population are vital to quantify the impact of tobacco control policies.[7-9] Methods to measure population smoking fall into two broad categories:

1. Self-reported measures from surveys which can be used to estimate smoking prevalence, patterns of smoking and cigarette consumption (i.e. number of cigarettes smoked).
2. Objective measures, such as aggregate measures of population cigarette consumption from taxation and sales data**.**

2.1. Self-reported measures

Smoking prevalence, smoking patterns and cigarette consumption can be estimated from survey data. In Scotland, this method is used to monitor smoking levels and patterns.[10,11] However, systematic biases regarding selection, response and reporting can often undermine the validity and reliability estimates drawn from self-report survey data.[12,13] For example, there is a tendency for smokers to report smoking levels in pack sizes, rounding the actual numbers of cigarettes smoked up

or down accordingly.[14-16] Smokers are also less likely to respond to surveys than non-smokers[17,18]

2.2. Cigarette sales data

Cigarette sales data can be used to estimate population cigarette consumption.[9] However, the extent to which this has been done in the past is unclear. Furthermore, the validity and reliability of using sales data for this purpose has not been exposed to the same scrutiny as self-report surveys. We therefore conducted a structured rapid literature review to explore both of these issues.

This research builds on previous research which investigated the validity and reliability of alcohol retail sales data for estimating population alcohol consumption.[13] For consistency, we have used the same definitions of validity and reliability in this report. Validity is defined as being the extent to which the data truly measure per-adult cigarette consumption. Reliability is the reproducibility or consistency in performance of the data in measuring per-adult cigarette consumption over time.

3. Literature review

3.1. Aim

The aim of the literature review was to identify the extent to which cigarette sales have been used to measure population cigarette consumption levels, and to establish whether this offers a valid and reliable approach.

3.2. Methods

The search strategy was developed in consultation with staff in the Knowledge Services team at NHS Health Scotland. The initial search was developed in Medline and adapted for other databases. A search was undertaken of four databases: Medline, Embase, Cochrane and Web of Science. The search terms used were as follows: Cigarette sale, consum*, pack*, retail*, per capita, AC Nielsen, Sales Data, Audit data, Purchase Data, EPOS, Electronic Point, Sales Figures. No geographical or language limits were applied to the search. However, only articles published post 1980 were included. The full search strategy for each database can be found in Appendix 1.

A total of 3,224 articles were identified by the search. Following deduplication and a review of titles and abstracts, 69 articles were considered to be relevant. After reviewing the full text and searching the references of relevant studies, 64 articles were included for review. Key data were extracted from the articles, including: purpose of the study; methods used to measure cigarette consumption; limitations; and whether validity and reliability were assessed. We also identified whether studies reported cigarette consumption per capita, per adult or per smoker.

3.3. Findings

The literature review identified that cigarette sales data have been used extensively in numerous countries for a number of different purposes. The most common use of sales data was for evaluation: 29 of the articles used them to evaluate government tobacco control policy or taxation changes and 16 studies used them to evaluate tobacco control programmes. Fourteen articles used sales data to measure cigarette consumption and two focused on price elasticity. Two studies examined industry pricing and methods and one study used sales data to explore the issue of cross-border purchases of tobacco. The literature review also identified a World Health Organization (WHO) global action plan for children's health and environment, which identified cigarette sales data as an indicator for children's health.

Thirty two of the articles calculated per-capita cigarette consumption (three of these also measured per-adult consumption and a further two measured per-smoker consumption). Four articles calculated per-adult cigarette consumption and three calculated per-smoker cigarette consumption. One article calculated per-household cigarette smoking. The WHO global action plan for children's health and environment recommended calculating per-adult cigarette consumption.[9]

None of the articles included in the literature review assessed the validity or reliability of cigarette sales data. However, two articles compared sales data with other methods of measuring cigarette consumption.[19,20] Both compared cigarette sales data with self-reported smoking from surveys and came to the conclusion that more than one source of data should be collected and compared when measuring cigarette consumption.

Two studies advocated for the use of cigarette sales data. Bandi *et al* [21] described cigarette sales as an 'optimal' method of measuring cigarette consumption, while the WHO[9] advised that cigarette sales data can be used to track changes in population tobacco consumption to evaluate tobacco control policies and interventions. This is consistent with WHO recommendations for monitoring population alcohol consumption levels. Specifically, the WHO state that:

> 'Reliable information on smoking habits is difficult to acquire, but data on tobacco and cigarette sales and on population numbers can be used to track changes in the level of tobacco consumption. Comparing sales after policy intervention with predicted sales derived by extrapolating data from before the policy was introduced gives an indicator of the success of the policy.'[22]

Almost all of the studies described the limitations of their findings; however, only 30 of the 64 articles described the limitations of using sales data specifically. These limitations can be grouped into the following categories:

- Sales data are limited in their ability to provide information on causality or attribution to a specific programme or policy.
- Sales data do not capture illegal cigarettes or cross-border purchases.
- Sales data are unable to ascertain changes in individual level behaviour and their accuracy can be affected by demographic changes.
- Sales data do not usually capture internet sales.

- The sampling methods used by market research companies can introduce uncertainty into the precision of the estimates.
- Not all cigarettes which are sold will be smoked.

3.4. Summary of literature review

In summary, the literature review has shown that sales data have been widely used internationally to measure cigarette consumption and track changes over time. Many studies have used these data to evaluate government tobacco policy and cigarette sales are perceived to be robust. The use of sales data was promoted in a few articles, particularly the WHO global action plan for children's health and environment; however, a number of limitations of sales data were also recognised. Importantly, the review identified no research to assess the validity and reliability of cigarette sales data. The remainder of this report will seek to fill this gap using a pragmatic approach to identify and, where possible, quantify identified biases.

4. Sources of bias in estimating per-adult cigarette consumption from sales data

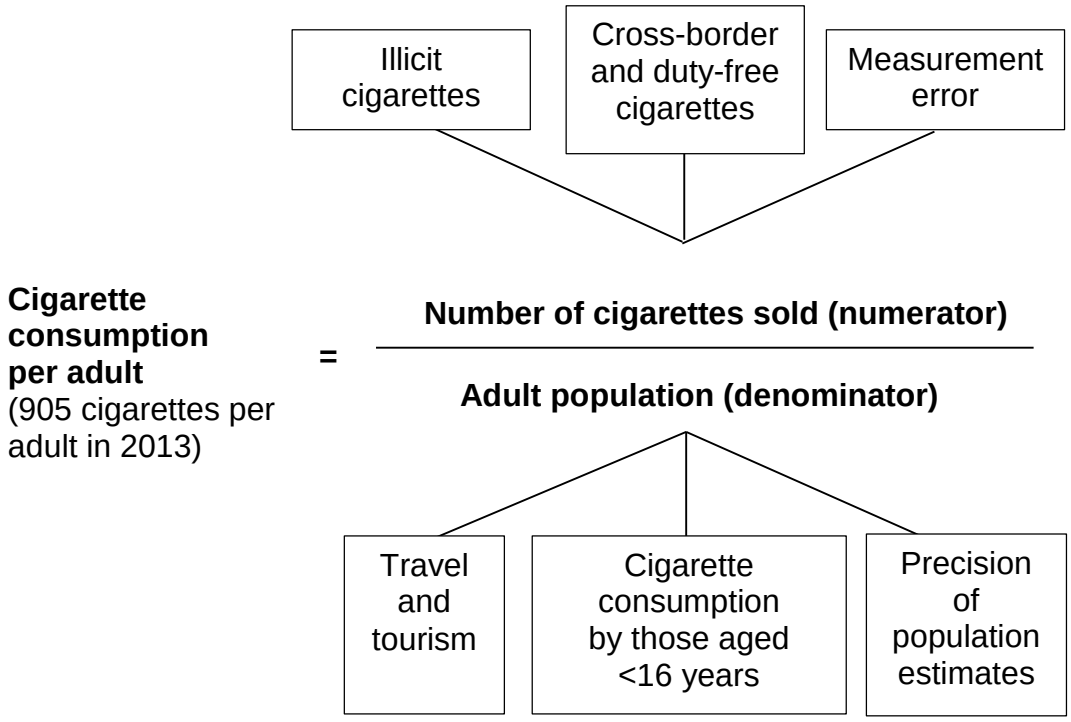
Per-adult cigarette consumption estimates in Scotland were calculated using cigarette sales data obtained from market research specialists Nielsen. These data are based on both electronic sales records from large retailers and a weighted stratified random sample of smaller retailers, and have been described in detail elsewhere.[13] Further comment on the methods used by Nielsen is also provided in Section 4.2.3.

Previous research by NHS Health Scotland identified a number of biases that may impact on the accuracy of using retail sales data to estimate population alcohol consumption levels.[13] These same biases, alongside other potential sources of bias identified from the literature review, were considered in this study. The final set of biases was reviewed by an expert steering group.

In order to express each bias as 'cigarettes per adult', biases were first categorised as affecting either the numerator or the denominator (Figure 1). For some biases – travel and tourism, and cigarette consumption by under 16s – the bias could be seen as affecting either the numerator or the denominator. Indeed, the size of the bias can be calculated based on either assumption using different approaches. This is relevant because users of sales data may choose not to express population consumption per capita or per adult, instead simply reporting the absolute consumption figures (see Chen *et al* [23]). It is crucial that, irrespective of how data are being expressed, all potential biases are considered and attempts are made to quantify their impact.

In most cases throughout this report, the calculated bias was expressed relative to the 2013 per-adult cigarette consumption estimate of 905 cigarettes per adult.

Figure 1: Biases which may impact on estimates of per-adult cigarette consumption in Scotland.



4.1. Potential biases affecting the denominator

4.1.1. Introduction

When population cigarette consumption is expressed as cigarettes sold per adult, its validity and reliability is partly dependent on the accuracy of the population denominator. For example, any overestimation or underestimation of the adult population size (those aged ≥16 years) in Scotland will translate to an underestimation or overestimation of population cigarette consumption, respectively. In addition, some cigarettes sold in Scotland will be consumed by individuals not captured in the denominator, such as tourists and those aged under 16 years old. This could cause a systematic overestimation of population cigarette consumption. In contrast, cigarettes will be consumed by Scottish residents while outside the country, thus creating a bias in the opposite direction. The likely impact of these biases is explored further below.

4.1.2. Travel and tourism

Key points

- In 2013, the net effect of tourism did not present a bias likely to impact on estimates of per-adult cigarette consumption.
- Best estimate = 0 cigarettes per adult per year.
- Range = −12 to +14 cigarettes per adult per year.

Scotland's per-adult cigarette consumption could be overestimated by failing to account for incoming visitors who consume cigarettes, thus impacting on the denominator. Conversely, cigarettes consumed by Scottish residents while outside the country will not be captured in sales data and could lead to an underestimation of Scotland's per-adult consumption. By calculating the net flow of incoming and outgoing visitors, the effect of this bias can be estimated.

In 2013, Scotland received a net gain of 338,000 visitors. On average, domestic visitors (those visiting Scotland from other parts of the UK) stayed for four nights and international visitors stayed for eight nights.[24-27] Residents of Scotland making domestic trips stayed, on average, for four nights; however, data are not available regarding the number of days residents of Scotland spent on international trips.

Assuming that Scottish residents spend an average of eight nights abroad (the same amount of time that international visitors spend in Scotland), per-adult cigarette consumption in 2013 was underestimated by 0.3 cigarettes per adult (Table 1). This could range from an overestimation of 14 cigarettes per adult to an underestimation of 12 cigarettes per adult (−1 to +1% of 2013 sales-based per-adult cigarette consumption) if it is instead assumed that Scottish residents spend an average of one or 14 nights on international visits, respectively. These calculations make a number of assumptions. First, that visitors to Scotland consume the same number of cigarettes as Scottish residents. However, smoking prevalence and cigarette consumption in Scotland is likely to be lower than in the country of origin of many visitors.[25,28,29] Second, that visitors to Scotland do not bring their own cigarettes. This is likely to depend on the price differential between the visitors' home country and Scotland, though the UK has among the highest cigarette prices in the world.[30] Finally, we assume that Scottish residents maintain the same smoking habit when visiting other places. We have no data to support this assumption. Regardless, the size of any bias resulting from tourism in Scotland is likely to be negligible, irrespective of the assumptions made.

Table 1: Effect of differing length of trips abroad by Scottish residents on per-adult cigarette consumption in Scotland, 2013.

	Assumed number of nights per trip		
	1	**8**	**14**
International trips by Scottish residents (000s)	3560	3560	3560
Total number of nights spent in international destinations by Scottish residents (000s)	3560	28,480	49,840
Net influx of nights spent in Scotland (000s)	24,425	−495	−21,855
Adjusted Scottish adult population (000s)	4484	4416	4357
Adjusted per-adult cigarette consumption (baseline = 905 cigarettes per adult in 2013)	891	905	917

Sources: Great Britain Tourism Survey,[24] Office for National Statistics,[25] Northern Ireland Statistics and Research Agency[26] and Visit Scotland.[27]

4.1.3. Cigarette consumption by individuals aged under 16 years

Key findings

- In 2013, cigarette consumption by individuals aged <16 years represented a small overestimation of per-adult cigarette consumption.
- Best estimate = 2 cigarettes per adult per year.
- Range = 0 to 2 cigarettes per adult per year.

The Scottish Schools Adolescent Lifestyle and Substance Use Survey (SALSUS) provides self-reported estimates of cigarette smoking for 13- and 15-year-olds.[31] In the 2013 survey, 2% of 13-year-olds reported being regular smokers (defined as smoking at least one cigarette on each day of the preceding week). For 15-year-olds, 9% reported being regular smokers. If it is assumed that the smoking prevalence of 14-year-olds is halfway between the frequency of 13- and 15-year-olds, and that those aged under 13 years do not smoke, the proportion of regular smokers aged under 16 years is 5%. Using these figures, cigarette smoking by those aged <16 years increases the population denominator by 9153, which leads to a small decrease in the 2013 estimate of per-adult cigarette consumption of two cigarettes per adult per year (0.2% of 2013 per-adult cigarette consumption estimate).

The SALSUS reports that there has been a sharp decline in the prevalence of smoking among 13- and 15-year-olds in recent years, which will impact on the

estimated size of this bias over time. However, when performing the same calculation using smoking prevalence estimates from the 2002 SALSUS (8% of 13-year-olds and 20% of 15-year-olds), the size of overestimation remains small (four cigarettes per adult per year, or 0.6%). Thus, cigarette consumption by those aged <16 years has only a negligible effect on the validity and reliability of using sales data to estimate per-adult cigarette consumption in Scotland.

4.1.4. Precision of adult population estimates

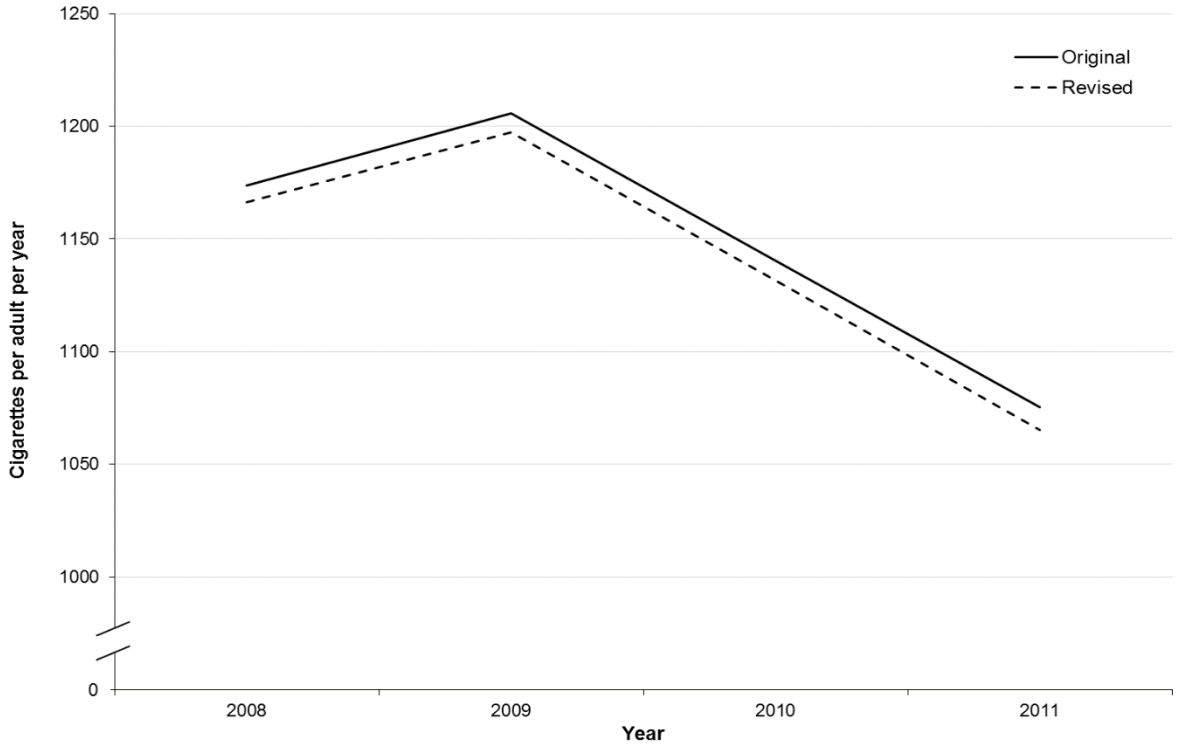
Key findings

- Inaccurate mid-year population estimates have the potential to present a small bias in per-adult cigarette consumption estimates.
- Revised population estimates between 2008 and 2011 suggest that per-adult cigarette consumption was slightly overestimated.
- Best estimate = 9 cigarettes per adult per year.
- Range = 7 to 10 cigarettes per adult per year.

The most authoritative population estimates in Scotland are obtained from a census, which takes place every 10 years. Mid-year population estimates are produced each year between censuses using data on different elements of population change in the previous 12 months, including estimates of net migration. The accuracy of the estimates is therefore limited to the quality of the data sources used to compile them. Estimates are retrospectively revised after each census, and so by comparing per-adult cigarette consumption estimates based on original and revised population estimates between the 2001 and 2011 censuses in Scotland, the size, direction and consistency of the bias this is likely to represent can be assessed.

Figure 2 shows that, in Scotland, original estimates of population sizes led to an overestimation of per-adult cigarette consumption compared with revised population estimates each year between 2008 and 2011. Average underestimation of per-adult cigarette consumption was nine cigarettes per adult. The size of overestimation increased over time with a maximum bias of 10 cigarettes per adult in 2011. The size of the bias relative to the population cigarette consumption estimates is negligible (<1% in all years). For the purposes of quantification, it is assumed that the best estimate of the bias is represented by the average between 2008 and 2011 and the range by the maximum bias observed (which could be in either direction).

Figure 2: Per-adult cigarette consumption in Scotland, calculated from original and revised mid-year population estimates.



4.2. Potential biases affecting the numerator

4.2.1. Illicit cigarette consumption

Key findings

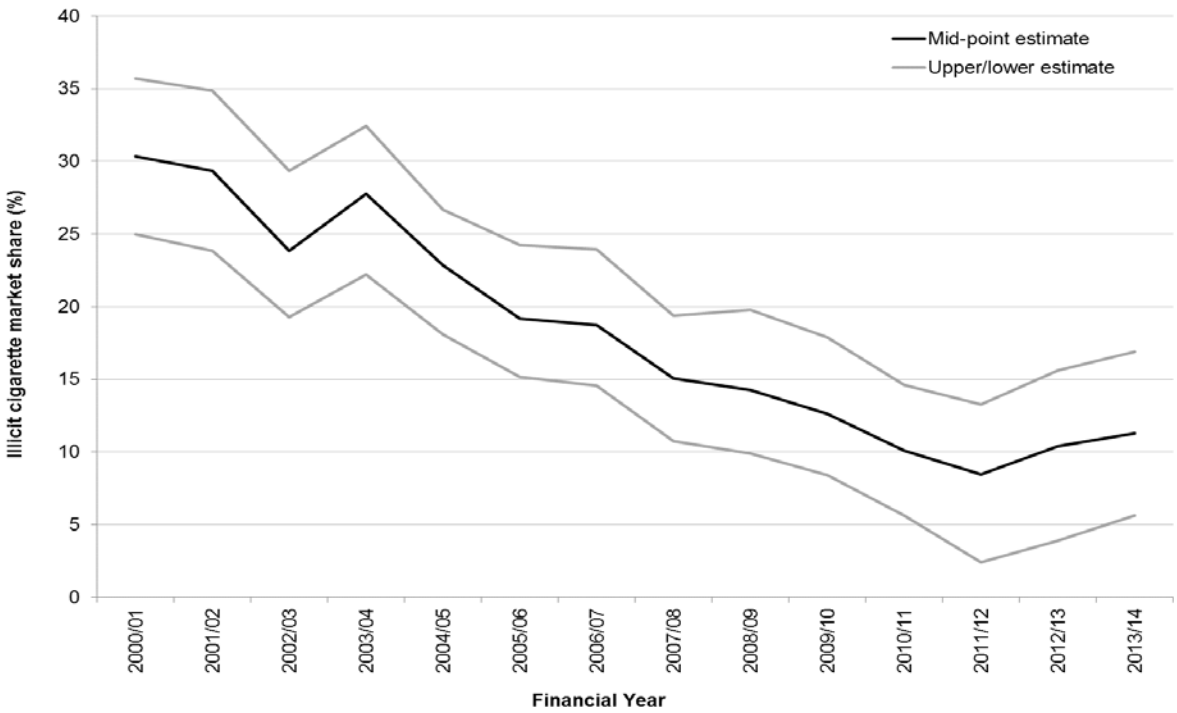
- Underestimation due to the illicit cigarette market is estimated for the UK by Her Majesty's Revenue and Customs (HMRC).
- In 2013/14, this represented an underestimation of 11% of legitimate consumption. This has decreased substantially over time.
- Best estimate = −102 cigarettes per adult per year.
- Range = −153 to −51 cigarettes per adult per year.

HMRC estimates the relative size and nature of revenue lost through 'tax gaps' in the UK.[32] Estimates of the illicit market share are calculated for different types of tax, including tobacco, and these attempt to capture tax lost through non-payment, evasion and criminal activity (e.g. smuggled tobacco, illicit tobacco production and tobacco produced legally but illegally redirected back into the UK). In 2013/14, the mid-point estimate for the illicit market share of cigarettes relative to duty paid cigarettes was 11%, with a range of 6% to 17%. Applying these UK estimates to cigarette retail sales in Scotland results in an underestimation of per-adult cigarette consumption of −102 cigarettes in 2013, ranging from −153 to −51 cigarettes. There

has been an overall downward trend in the illicit cigarette market share from the early 2000s, although it has increased slightly in recent years (Figure 3).

Illicit tobacco therefore presents a bias that has the potential to threaten both the validity and reliability of using retail sales data to estimate population cigarette consumption in Scotland. First, the bias is relatively large. Second, the bias has changed substantially over time. Finally, there is a great deal of uncertainty around the best estimate of the illicit cigarette market share.

Figure 3: Illicit market share for cigarettes, 2001/02 to 2013/14.



Source: HMRC.[32] Note: These figures are different to the headline figures in the HMRC tax gaps publication. This is because the illicit market share for cigarettes has been calculated without accounting for cross-border shopping, which we present as a separate bias in this report.

4.2.2. Cross-border and duty-free cigarettes

Key findings

- In 2013/14, cross-border and duty free cigarette purchases represented an underestimation of 4% of per-adult cigarette consumption.
- Best estimate = −41 cigarettes per adult per year.
- Range = no range estimates available.

Cross-border and duty-free is a distinct bias from travel and tourism. The former refers to cigarettes bought by visitors in a country with the intention of consuming them in their resident country. The latter refers solely to cigarettes bought by visitors to a country with the intention of consuming them in that country.

Cross-border purchases refer to cigarettes that have been produced legally in a different jurisdiction and then legally imported into the country where they are consumed. This is most common in border areas of neighbouring countries where there is a considerable difference in the price of cigarettes.[30] The number of cigarettes brought into the UK, including duty-free cigarettes bought from outside the European Union, can be estimated using data from the International Passenger Survey.[32] In 2013/14, 4% of the total volume of UK duty paid cigarettes was estimated to have been purchased outside the UK and legally imported. Assuming that cross-border shopping is of a similar magnitude in Scotland, this equates to an underestimation of −41 cigarettes per adult in 2013/14. It should be noted that this does not take into account cigarettes sold in Scotland and exported by incoming visitors. However, cigarette prices in Scotland are higher than many other EU and non-EU countries,[30] so this is unlikely to have a major impact on the magnitude or direction of this bias.

4.2.3. Measurement error due to data collection methods

Key findings

- Nielsen use outlet sampling to estimate sales through retailers who don't provide census data. This produces uncertainty around cigarette sales estimates.
- Certain retail outlets that sell cigarettes are not included in Nielsen's sampling frame and non-response of outlets is not known. The size of these biases is currently unquantifiable.
- Best estimate = 0 cigarettes per adult.
- Range = −87 to +87 cigarettes per adult per year.

This section explores the potential impact of measurement error on per-adult cigarette consumption estimates. It covers sampling variation, non-inclusion of certain sales outlets and non-response bias.

Sampling variation

The methods used by Nielsen to estimate cigarette retail sales data are very similar to those used to estimate alcohol retail sales, which have already been described in detail by Thorpe *et al.*[13] Briefly, Nielsen obtain census data on weekly cigarette sales by most large, multiple grocers ('grocery multiples'). In other words, every packet of cigarettes that is scanned at checkout will be captured. For smaller 'impulse' retailers, total cigarette sales are estimated based on a sample of outlets. The only notable difference between the methods used to estimate alcohol and cigarette sales is that there is a larger sample of smaller, independent retailers included in the 'impulse' sample used to estimate cigarette sales. The larger sample is necessary because manual audits are required in some independent outlets (which isn't the case for alcohol) to make less affluent areas more representative (Nielsen, personal communication).

Estimation of a population parameter based on a sample statistic involves a certain level of uncertainty. The variation around per-adult cigarette consumption in Scotland in 2013 is estimated as ±10%. The variation is higher than reported for alcohol sales

(±4%) because a higher proportion of cigarettes are sold through sample-based impulse retailers (~60%) than census-based grocery multiples (~40%) based on GB level data. The impact of this variation on the uncertainty around per-adult cigarette consumption estimates in Scotland in 2013 is shown in Table 2.

Table 2: 95% confidence intervals (CI) around annual estimates of per-adult cigarette consumption in Scotland, 2013.

	Cigarettes per adult per year
Best estimate	905
Lower 95% CI	817
Upper 95% CI	992

Source: Nielsen. Note: CIs have been calculated using separate standard errors for impulse retailers and grocery multiples. As cigarette sales data are only available for all retailers combined in Scotland, the relative market share of cigarette sales through each trade sector was assumed to be the same as for Great Britain (impulse = 60%; grocery multiples = 40%).

Non-inclusion of some sales outlets

Certain retail outlets that sell cigarettes are not included in Nielsen's sampling frame, including: specific internet sites; mail order; sales on military bases; certain music/entertainment festivals; duty-free sales; and sales direct to the consumer via cash-and-carry outlets.

An investigation by Action on Smoking and Health (ASH) explored the extent to which cigarettes could be bought at lower prices on the internet.[33] ASH attempted to purchase cigarettes from 12 websites claiming to deliver low-price cigarettes to the UK. It found that only three sites delivered the ordered cigarettes, one batch of which was intercepted by Customs and Excise and UK duty applied (and so included in HMRC's estimate of cigarette clearances – see Section 5.1). It was concluded that cigarettes bought on the internet, even if they are shipped in the first place, are not necessarily any cheaper than UK high street prices. As such, internet cigarette sales are unlikely to present a large bias. However, the results of the ASH study are now over a decade old and it is unclear to what extent lower-priced cigarettes are available online.

The non-inclusion of military bases and temporary events such as festivals are very unlikely to have a meaningful impact on population cigarette consumption estimates.[13] It is not possible to accurately measure cigarette sales through other outlets not included in the sampling frame, so this presents an unquantifiable source of bias.

Non-response bias

Although not quantified, non-response predominantly applies to small independent retailers and differences between the characteristics of responding and non-responding outlets are not known (Nielsen, personal communication). Non-response

bias is therefore possible within this market channel. However, it is not possible to quantify the size of the bias that non-response may present.

4.3. Net effect of biases

Best estimates for the size of each bias in Scotland in 2013 are given in Table 3, which also provides an estimated range for each bias given the available data. The largest bias is illicit cigarettes, which in 2013 are estimated to have accounted for an underestimation of 102 cigarettes per adult relative to the sales-based estimate of 905 cigarettes per adult (~11%). Non-inclusion of certain sales outlets in the Nielsen sampling frame and cross-border/duty-free cigarette sales are also likely to make an important contribution. Biases that are likely to cause population cigarette consumption to be overestimated are much smaller in magnitude. Consequently, the net effect is that per-adult cigarette consumption in Scotland is far more likely to be underestimated than overestimated, with a best estimate of 132 cigarettes per adult per year (range −286 to +62). This represents approximately 15% of the per-adult cigarette consumption estimate based on retail sales in 2013 (905 cigarettes per adult per year).

Table 3: Potential sources of bias when using retail sales data to estimate population cigarette consumption in Scotland.

	Cigarettes per adult per year			
	Best estimate	**Range**		
Measurement error* (sampling variation)	0	−87	to	87
Cross-border and duty-free shopping	−41	−41	to	0
Illicit cigarettes	−102	−153	to	−51
Precision of adult population estimates	9	7	to	10
Cigarette consumption by those aged <16 years	2	0	to	2
Tourism	0	−12	to	14
Net bias	**−132**	**−286**	**to**	**62**

Notes: Bias estimates calculated relative to the 2013 population cigarette consumption estimate (905 cigarettes per adult). These are our best estimates based on the information available, but there are many sources of uncertainty and potential error. *The estimate for measurement error only includes sampling variation; however, the category also includes the non-inclusion of certain sales outlets in the data provider's sampling frame and non-response bias. These unquantifiable biases would be more likely to result in underestimation than overestimation.

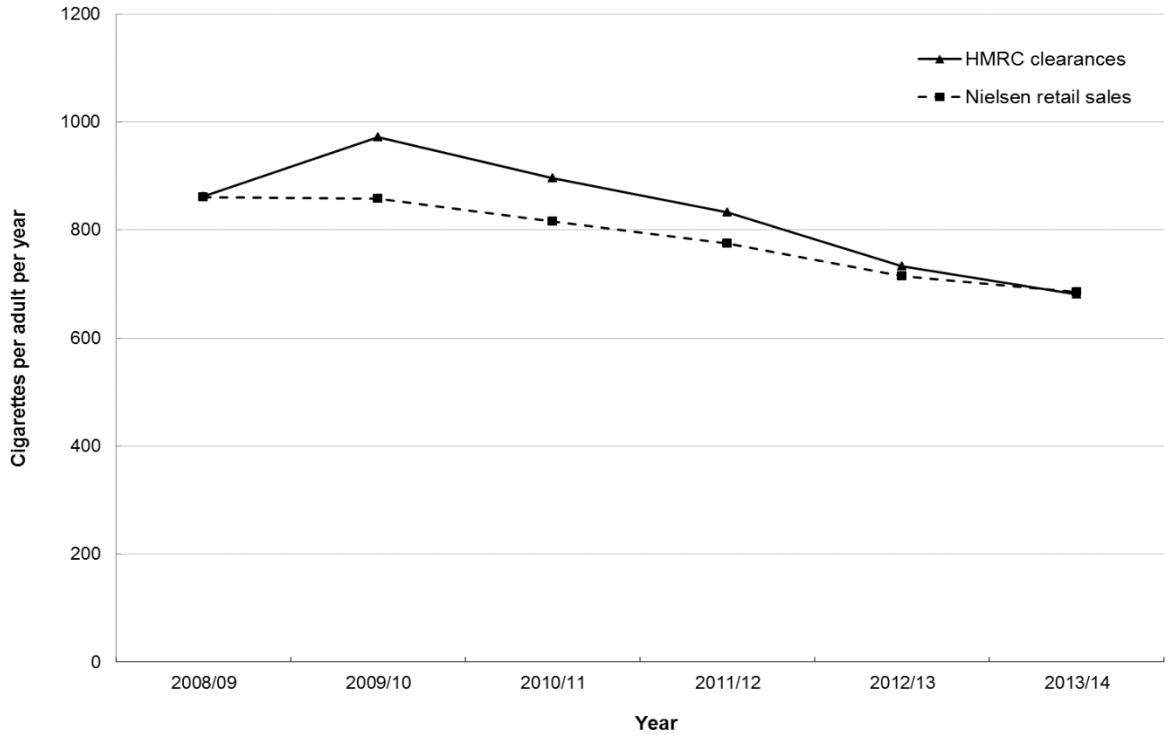
5. Comparison of cigarette consumption using different data sources

Comparing estimates of cigarette consumption based on retail sales data with other data sources enables an indirect assessment of concurrent validity. Although each data source will be subject to their own biases, similar levels and trends between different sources provides some reassurance that the data are representative and measuring what they purport to measure.[13]

5.1. Comparing cigarette retail sales and cigarette clearance data

HMRC publish data on the number of cigarettes released for sale in the UK (data are not produced for individual UK countries). These data can be considered more complete than retail sales data as they include those outlets not captured by Nielsen (see Section 4.2.3). Figure 4 shows trends in the number of cigarettes sold by UK retailers according to Nielsen compared with HMRC clearances. The level of cigarette sales based on Nielsen data were, on average, 5% lower than HMRC clearances between 2008 and 2013, which translates to an underestimate of 45 cigarettes per adult. However, there is some notable variability across the relatively short time period. For example, in 2008/09 and 2013/14 Nielsen and HMRC cigarette sales estimates were very similar, while in 2009/10 Nielsen estimates were 12% lower (underestimation of 109 cigarettes per adult). While the reasons for this variability are unclear, the consistency in the overall trend in cigarette sales estimates between sources is encouraging.

Figure 4: Estimates of cigarette sales in the UK based on HMRC tax clearance and Nielsen retail sales data, 2008/09 to 2013/14.



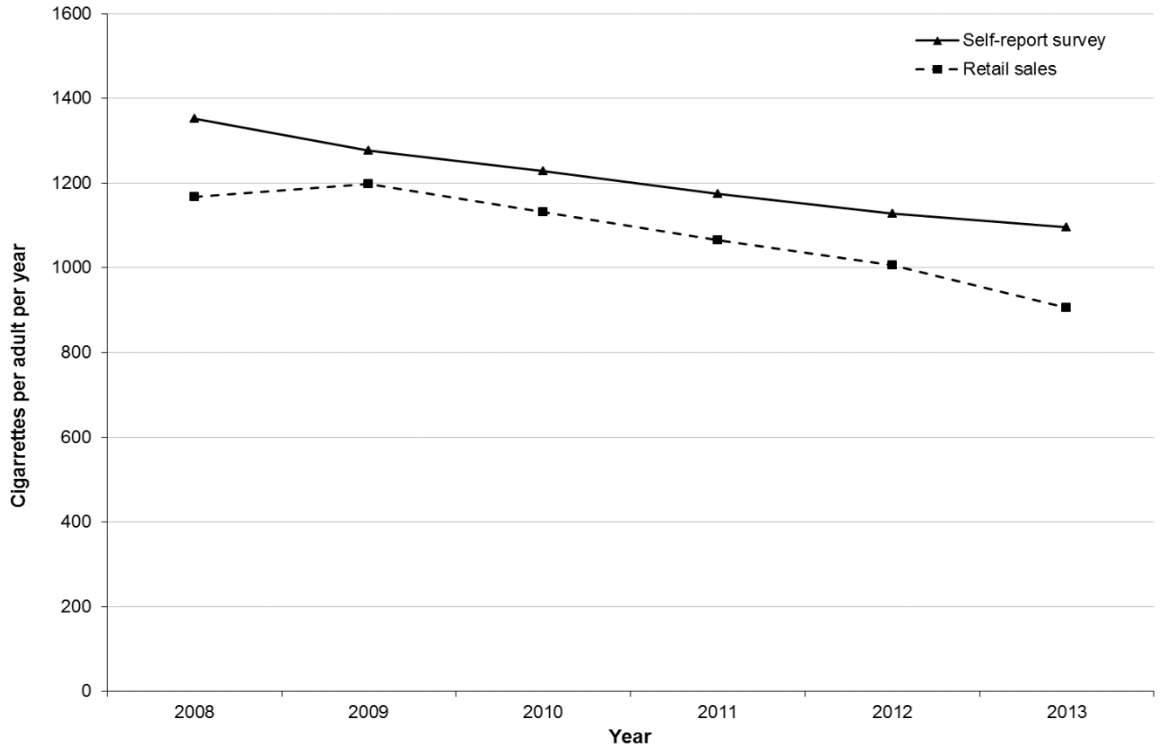
Sources: Nielsen; HMRC.[32]

5.2. Comparing cigarette retail sales and self-report survey data

Self-report survey data are generally considered to underestimate the prevalence and level of unhealthy behaviours, including smoking and alcohol consumption. It has been shown, for example, that smokers have a tendency to round down the number of cigarettes they smoke per day to the nearest ten.[14,16]

To explore the consistency between per-adult cigarette consumption based on retail sales data and survey data in Scotland, we used prevalence estimates from the Scottish Household Survey – the official source for monitoring smoking prevalence in Scotland[11] – and cigarette consumption estimates from the Scottish Health Survey (Figure 5). It can be seen that an overall downward trend in per-adult cigarette consumption is observed in both data sources. However, retail sales data produce estimates that are consistently lower than those based on self-report survey data, ranging in magnitude from 6–17% (mean = 11%). A similar pattern is evident when smoking prevalence estimates from the Scottish Health Survey are used (data not shown).

Figure 5: Estimates of per-adult cigarette consumption in Scotland based on Nielsen retail sales data and self-report survey data, 2008 to 2013.



Sources: Nielsen; Scottish Health Survey,[10] Scottish Household Survey.[11] Note: Nielsen sales data relate to manufactured cigarettes only; however, the survey question asked in the Scottish Household Survey does not distinguish between manufactured and hand-rolled cigarettes.

6. Discussion

A review of prior literature suggests that cigarette sales offer an objective data source that can overcome limitations associated with self-reported methods of measuring population cigarette consumption. Such data have therefore been recommended for public health policy monitoring and evaluation. However, biases that might impact on the validity and reliability of estimates derived from such data must be well understood before using them for this purpose. This study has assessed the potential impact of biases that might affect the validity and reliability of using cigarette sales data to estimate population cigarette consumption in Scotland.

Using a pragmatic approach to quantify biases with available data, it has been shown that actual population cigarette consumption in Scotland may be underestimated by 15% using retail sales data. This is largely due to the consumption of illicit cigarettes, cross-border purchases and duty-free shopping. The uncertainty around this estimate is large and the size of some biases has changed considerably over time. Furthermore, the total size of the smaller biases identified (cigarette consumption by those aged under 16 years and precision of population estimates) was 11 cigarettes per adult in 2013. This compares to an average year-on-year change in population consumption of 52 cigarettes per adult in Scotland over the past five years. These issues have the potential to undermine the validity and

reliability of retail sales data for the purpose of estimating population cigarette consumption.

Despite the caveats mentioned above, the use of cigarette retail sales data for monitoring and evaluating tobacco control policies should not be precluded. Retail sales data are available at a weekly level, which is particularly useful for using time series analysis to evaluate population tobacco control interventions. Breakdowns by retailer type (Great Britain only) and pack size are also possible. The data therefore offer the potential to strengthen policy evaluation when used alongside data for other smoking-related indicators. Indeed, despite some year-on-year variability, it is reassuring that the general trend in population cigarette consumption is consistent when comparing retail sales data with tax clearance and self-report survey data.

Although not a primary aim of this report, the comparison of the estimated level of per-adult cigarette consumption in Scotland between objective retail sales data and subjective self-report surveys was particularly instructive. Contrary to prior evidence on alcohol,[13] sales-based estimates were found to be lower than survey-based estimates. This may be partly explained by the fact that the survey question does not distinguish between manufactured cigarettes and hand-rolled cigarettes. It may also be because survey data are less prone to many of the biases identified in this report. For example, survey respondents are asked to report how many cigarettes they smoke in an average day, irrespective of their origin or authenticity. Interestingly, when the best estimate of the net bias is applied to cigarette retail sales in 2013, the resultant per-adult cigarette consumption remains 5% lower than the survey-based estimate. In terms of validity, this is encouraging for those using self-report survey data to estimate cigarette consumption in Scotland.

This study used the best available data to quantify the potential impact of a range of identified biases. However, the approach taken has a number of limitations. For example, there is a wide range of uncertainty around the best estimate of illicit cigarette consumption, the most influential bias identified; no data sources exist to quantify the size of other potentially important biases such as the non-exclusion of certain sales outlets from the Nielsen sampling frame; and various bias estimates are only available at UK level, meaning important differences between constituent countries may be masked. As such, it is advised that if using retail sales data to monitor population cigarette consumption, the size of biases are monitored, but are not used for the purposes of adjustment of the retail sales data. Instead, biases should be monitored to assess if there has been a step-change in the size of individual or multiple biases of sufficient magnitude to pose a significant threat to interpretation. It is also important that users of sales data have a good understanding of the methods used by data providers, which may also be subject to change. Although some methods may be considered commercially sensitive, developing good working relationships with data providers may help to improve transparency.

The focus of this report has been on cigarette sales *within* Scotland. However, the usefulness of data for monitoring and evaluation is also affected by the extent to which they can be used to compare *between* countries. Nielsen estimate the number of cigarettes sold for individual constituent countries. Nonetheless, it is likely that the relative size of each bias is similar across the UK as consistent data collection methods are used and the same cigarette sales restrictions and taxation rules apply to all three countries.

The report also omits roll-your-own tobacco. As this accounts for a growing market share,[34] it is imperative that it is considered alongside cigarettes when monitoring smoking exposure and evaluating policy. Roll-your-own tobacco sales data are available but are in a different unit of measurement to cigarette sales, thus making triangulation to a single metric problematic. Regardless, biases that might impact on the accuracy of roll-your-own tobacco, which may be of considerably different magnitude to those identified for cigarettes,[32] should be considered using the approach outlined in this report.

Conclusion

In conclusion, the validity and reliability of population cigarette consumption estimates derived from retail sales data are vulnerable to some important biases. However, retail sales data have unique strengths and therefore offer the potential to enhance policy evaluation when used alongside data for other smoking-related indicators.

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Appendix: search strategy

Database: Ovid **MEDLINE**(R) 1946 to Present with Daily Update, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <April 21, 2015>
Search Strategy:
---
1 cigarette sale*.mp. (167)
2 (sale* adj2 cigarette*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (291)
3 (cigarette* adj consum*) and sale*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (79)
4 (cigarette* and pack* and sale*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (125)
5 (retail* and cigarette* and sale*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (144)
6 (per capita and cigarette* and (sale* or consum*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (161)
7 AC Nielsen.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (6)
8 Sales Data.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (399)
9 Audit data.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (416)
10 Purchase Data.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (47)
11 EPOS.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (306)
12 Electronic Point.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (42)
13 Sales Figures.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (143)
14 7 or 8 or 9 or 10 or 11 or 12 or 13 (1339)

15 cigarette*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (53091)
16 14 and 15 (40)
17 1 or 2 or 3 or 4 or 5 or 6 or 16 (**588**)

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Database: **Embase** <1974 to 2015 April 21>
Search Strategy:
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1 cigarette sale*.mp. (179)
2 (sale* adj2 cigarette*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (311)
3 ((cigarette* adj consum*) and sale*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (85)
4 (cigarette* and pack* and sale*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (122)
5 (per capita and cigarette* and (sale* or consum*)).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (177)
6 (retail* and cigarette* and sale*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (154)
7 AC Nielsen.mp. (5)
8 Sales Data.mp. (558)
9 Audit Data.mp. (910)
10 Purchase data.mp. (57)
11 EPOS.mp. (452)
12 Electronic Point.mp. (54)
13 Sales Figures.mp. (169)
14 7 or 8 or 9 or 10 or 11 or 12 or 13 (2186)
15 cigarette*.mp. (90315)
16 14 and 15 (42)
17 1 or 2 or 3 or 4 or 5 or 6 or 16 (**643**)

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Web of Science
14 Approximately **481** (Hits)
#12 NOT #13
Timespan=All years
# 13 Approximately 480,336 TI=(electronic) or TI=(youths) or TI=(adolescent) or TI=(minors) or TI=(children) or TI=(schoolchildren) or TI=(school)
# 12 624 #9 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1

Refined by: DOCUMENT TYPES: (ARTICLE OR EDITORIAL OR REVIEW) AND [excluding] COUNTRIES/TERRITORIES: (CUBA OR BANGLADESH OR PAKISTAN OR VIETNAM OR NIGERIA OR URUGUAY OR PEOPLES R CHINA OR THAILAND OR UGANDA OR U ARAB EMIRATES OR LEBANON OR TUNISIA OR GUATEMALA OR SYRIA OR TAIWAN OR SOUTH KOREA OR SAUDI ARABIA OR ROMANIA OR INDIA OR MOROCCO OR IRAN OR INDONESIA OR SOUTH AFRICA OR GHANA OR BRAZIL OR EGYPT OR ARGENTINA)
11 706 #9 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1
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10 721 #9 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1
9 Approximately 348
#8 AND #7
8 39,589 TS=(cigarette*)
7 42,721 TS=(AC Nielsen) or TS=(sales data) or TS=(audit data) or TS=(purchase data) or TS=(EPOS) or TS=(Electronic Point) or TS=(sales figures)
6 134 TS=(retail* AND cigarette* AND sale*)
5 95 TS=(cigarette* AND pack* AND sale*)
4 80 TS=(per capita AND cigarette* AND (sale* or consum*))
3 61 TS=(cigarette* NEAR/2 consum* AND sale*)
2 182 TS=(sale* NEAR/2 cigarette*)
1 530 TS=(cigarette sale*)

Cochrane Library
#1 Enter terms for search (sale* adj2 cigarette*) 6
#2Enter terms for cigarette sale*65
#3Enter terms for (cigarette* adj consum*)79
#4Enter terms for (cigarette* and pack* and sale*)34
#5Enter terms for (retail* and cigarette* and sale*)21
#6Enter terms for (per capita and cigarette* and (sale* or consum*))13
#7Enter terms for AC Nielsen98
#8Enter terms for Sales Data261
#9Enter terms for Audit data1196
#10Enter terms for Purchase Data422
#11Enter terms for EPOS28
#12Enter terms for Electronic Point5218
#13Enter terms for Sales Figures42
#14Enter terms for (#7 or #8 or #9 or #10 or #11 or 12 or #13)209490
#15Enter terms for cigarette*4241
#16Enter terms for (#14 and #15)1504
#17Enter terms for (#1 or #2 or #3 or #4 or #5 or #6)146
#18Enter terms for (#16 or #17)**1512**

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