Studying trends in cigarette consumption per smoker in relation to trends in tar and nicotine yield of cigarettes based on national data

Author : P N Lee

Date : 12th June 2006

1. Introduction

Over the past 50 years or so, tar and nicotine yields of cigarettes have declined dramatically. One question of interest is the extent to which smokers may increase their daily cigarette consumption in an attempt to compensate for the reduction in nicotine yields of the cigarette. As discussed elsewhere[1], there are various types of data set that can be used to investigate this issue. One is based on short-term experimental brand-switching studies, a second on longer-term epidemiological follow-up studies that can relate changes in daily cigarette consumption to changes in brand yield within smoker, and a third on cross-sectional studies of the general population relating brand yield to daily cigarette consumption. A fourth, which will be used here, is to compare changes over time at national level in brand yield and in daily cigarette consumption per smoker. All the approaches have their own limitations. Those relevant to the first three approaches will not be discussed here, but some relevant to the approach used will be noted. These limitations include:

(i) The approach is ecological so does not allow linkage of changes in brand yields to changes in daily cigarette consumption within person;

(ii) National data on sales-weighted average tar and nicotine yields are not age and sex specific, so one cannot directly relate trends in yields and consumption within the same birth cohort; and

(iii) Changes over time in cigarette consumption per smoker may arise for reasons other than changes in brand yields. Such reasons include the habit becoming more popular and socially acceptable (which might explain increases in women in the early post-war period), the habit becoming less popular and less socially acceptable (which might explain decreases in recent years), and quitting occurring more commonly in light smokers than heavy smokers (which would be more relevant to men, of whom large numbers have quit in the last 30 years or so in the US and UK for example).

2 Methods

2.1 Data extraction

The second edition of International Smoking Statistics (ISS)[2] contains detailed data for 30 developed countries up to 1995 on a range of aspects of the smoking habit. The intention was to obtain, for a run of years, annual estimates for specific countries of:

- Sales weighted average tar (mg/cig) = SWAT,
- Sales weighted average nicotine (mg/cig) = SWAN,
- Cigarette consumption per adult male smoker, and
- Cigarette consumption per adult female smoker.

For only four of the 30 countries considered in ISS – Canada, Japan, United Kingdom and United States – was it possible to obtain suitable data for analysis.

Reasons for rejecting other countries were as follows:

- No tar/nicotine data at all – Bulgaria, Czechoslovakia, East Germany, Greece, Iceland, Ireland, Israel, Netherlands, Portugal, Romania, Spain, USSR, Yugoslavia.
- Tar/nicotine data only available as ranges over brand, and not as averages – Poland.
- No nicotine data at all – Australia, Denmark, Finland, Hungary, Italy, Norway, Switzerland. Having nicotine data is important as nicotine is widely believed to be the basis for compensation. For nearly all of these countries, the tar data only covered a very limited time range anyway.
- Nicotine data only very recently available – France (1992-1995), New Zealand (1994-1995).
- Consumption per smoker data only available for a short period – Belgium (1980-1985).
- Little overlap in the range of years for which tar/nicotine data and data on consumption per smoker were available.

Country	Tar/nicotine	Consumption per smoker
Austria	1960-1984[a]	1972-1995[b]
Sweden	1964-1980[c]	1963, 1985-1995[b]
West Germany	1961-1975[d], 1985	1985-1995[b,e]

[a] Nicotine data limited after 1973
[b] Only data for some years in this range
[c] No nicotine data after 1974
[d] Nicotine data only from 1966
[e] For 1995, data are for Unified Germany

For the four countries which were considered to have adequate information, the data were extracted onto a spreadsheet (SWANvsCPS trends.XLS). Points to note are as follows:

Canada Data were extracted for 1968-1995. The tar and nicotine data are for seven popular brands of Canadian cigarettes which together make up about 25% of sales. While the data are not sales-weighted and values are not available in some years for each of the seven brands, the figures provide a reasonably consistent measure of the changes over time. The cigarettes per smoker data are based on various surveys of the population for age 15+, with means of results

for multiple surveys used where applicable. For both sets of data, occasional years were missing and values estimated by interpolation or extrapolation.

Japan Data were extracted for 1969-1995. There were no missing data and the cigarettes per smoker data all came from the same series of annual surveys of the population aged 20+.

United Kingdom Data were extracted for 1950-1995. The tar and nicotine data pre 1971 come from a survey of old cigarettes, with results only expressed in periods (1921-30, 1931-50, 1951-60, 1961-65, 1966-70). The cigarettes per smoker data came mainly from two series of surveys of the population aged 16+; annual surveys for the Tobacco Advisory Council conducted from 1950-1987 and the General Household Survey conducted every other year from 1972 to 1994. More recent data, 1991-1995, came from annual Health of England Surveys. For 1989, data were estimated by interpolation.

United States Data were extracted from 1955 until 1995 for tar and nicotine and until 1992 for cigarette consumption. Cigarette consumption data were from various surveys for populations aged 17+, 18+, 19+ or 20+. Data were only available for certain years (1955, 1964-1968, 1970, 1975-1976, 1980, 1985, 1988 and 1991) and had to be estimated by interpolation (or extrapolation to 1992). Extrapolation to 1995 was considered unreliable.

The spreadsheet shows the data extracted for each year and also makes clear where and how interpolation and extrapolation was carried out and when estimates were combined from multiple surveys in a year. For further details of the derivation of the data, the reader is referred to the relevant chapters of ISS, the source tables used being indicated in the spreadsheet.

The spreadsheet also includes annual estimates of the ratio of tar to nicotine (obtained by simple division) and of overall cigarette consumption per smoker (obtained as a simple mean). Calculating a population-weighted mean was not considered necessary, given that the sex-specific data were usually only available as whole numbers and the ratio of the number of males

to the number of females in the adult population is not very different from 1 and has not changed dramatically over time.

2.2 Analysis

Let us assume that cigarette consumption per smoker (C) can be linked to brand yield (Y) by the formula:

$$C = \mu Y^{-K}$$

where μ is a constant and K is a compensation index which is assumed to be invariant over time. Thus, when there is no compensation (K=0), cigarette consumption per smoker will not depend on brand yield, and when there is complete compensation in terms of increased cigarettes per day (K=1), it will be inversely related to brand yield, so that the product of brand nicotine yield and cigarette consumption per smoker remains constant.

It is well known that considerable compensation for reduced brand yield in terms of increased intensity of smoking (e.g. higher puff volume, greater depth of inhalation) occurs, so that it is unlikely that K, when calculated based only on cigarette consumption per smoker, will approach 1, but the purpose of this document is to estimate how large K is.

Suppose that C and Y are measured at time points 1 and 2, giving

$$C_1 = \mu\, Y_1^{-K}$$

and $$C_2 = \mu\, Y_2^{-K}$$

it follows that

$$(C_2/C_1) = (Y_2/Y_1)^{-K}$$

or that

$$\log (C_2/C_1) = -K \log (Y_2/Y_1)$$

so that

$$K = \log (C_2/C_1)/\log (Y_1/Y_2)$$

Thus, if the annual increase in cigarette consumption per smoker and the annual decrease in brand yield can be estimated, these can be used to estimate the compensation index.

To estimate the annual increase in cigarette consumption per smoker, linear regression of the logarithm of cigarette consumption per smoker over time was used, with the exponential of the slope multiplied by 100 giving the estimated percentage increase per year. Similarly, linear regression was used to estimate the percentage decrease in brand yield per year. The compensation index could be estimated directly as –1 times the ratio of the two slopes.

Regressions were calculated for SWAT, SWAN, their ratio, and also for cigarette consumption per smoker, both total and sex-specific. Compensation indices were calculated based on SWAN and total cigarette consumption per smoker.

Analyses were carried out for each country based on the whole time range and also, for UK and for US, starting in 1968 to make the time ranges more comparable to the data for Canada and Japan.

To illustrate the trends graphically for SWAN and total cigarette consumption per smoker, plots over time were also produced presenting the data relative to the data for the first year considered (= 100).

Full details of the regression analyses are given in the spreadsheet and only summarized in the text below.

3. Results

Table 1 summarizes the estimated percentage changes per year for the various indices of brand yield and cigarette consumption per smoker. It is clear that in all four countries there has been a highly significant decline in brand yields, more markedly in Japan, US and UK than in Canada, and more marked for tar than for nicotine. Consistent with this, the tar/nicotine ratio has also declined, more markedly so in Canada and the UK (countries which smoke flue-cured cigarettes) than in Japan and the USA (countries which smoke blended cigarettes). The decline in the tar/nicotine ratio is not significant in Japan but is in other countries.

Any changes in cigarette consumption per smoker are proportionately much smaller than the changes in yields. This is reflected in the compensation index estimates shown in Table 2, which in four analyses (Japan, UK 1950-1995 and both USA analyses) are in the range 20 to 26.6%. (A value for the compensation index of 25%, for example, implies that a 2-fold decline in yield would be associated with an increase in cigarette consumption per smoker by a factor of 1.19.) The estimate is somewhat higher in Canada, 40.4%. Interestingly in the UK, in the analysis for 1968-1995, the index is negative, reflecting a decrease in cigarette consumption per smoker over a period when brand yields have fallen markedly.

The data for Canada and Japan show virtually no difference between men and women in the estimated annual increase in cigarette consumption per smoker. For the UK and USA, however, there is a significant difference between the sexes, with the increase greater in women than men. Indeed, in the UK there has been no increase at all in males over the whole period. Looking at the data in more detail, it can be seen that in the UK consumption in men rose from about 15 or 16 a day around 1950 to about 20 a day around 1960 where it stayed until around 1985, after which it fell back to 16 a day in 1995. In females, consumption rose steadily from about 8 a day in 1950 to about 16 around 1975 where it remained until around 1985, after which it fell back to 16 a day in 1995. The early rise in both sexes, more so in women, is also evident in the USA but there is much less evidence of a recent decline.

Figures 1 to 4 illustrate further the trends over time in SWAN and overall cigarette consumption per smoker per day, by presenting changes relative to the values in the first year (=100).

4. Comment

It is clear that any increase in cigarette consumption per day is proportionately very much less than the decline in brand yields. Given that substantial declines in brand yields will have also occurred in many other countries where detailed data is lacking, the same conclusion could doubtless be extended by noting the relatively small changes in cigarette consumption per day that have occurred in other countries not studied in detail here.

Although it seems clear that smokers do not simply compensate completely for decreased nicotine yields by correspondingly increasing the number of cigarettes they smoke, the analyses presented here should not be taken as demonstrating clearly that they compensate at all in this way. As noted above, the approach has a number of limitations, most notably the potential for confounding by other causes of change in cigarette consumption per smoker. These include the increasing tendency of women to embark on a “liberated” lifestyle, changing pressures to smoke over time as well as changes in price and availability of cigarettes. Some of the alternative approaches outlined in the discussion are more reliable ways of estimating the true relationship between changes in brand yield and changes in cigarette consumption per smoker.

TABLE 1 Percentage change per year (95% confidence interval) in various indices of brand yield and cigarette consumption per smoker per day

Country	Period	SWAT[a]	SWAN[b]	TNR[c]	Cigarette consumption per smoker		
					Total	Males	Females
Canada	1968-1995	-1.64 (-1.87 to -1.41)	-0.87 (-1.13 to -0.61)	-0.78 (-1.05 to -0.50)	0.35 (0.18 to 0.53)	0.35 (0.18 to 0.53)	0.35 (0.15 to 0.56)
Japan	1969-1995	-2.81 (-3.05 to -2.56)	-2.43 (-2.83 to -2.02)	-0.39 (-0.85 to 0.07)	0.63 (0.46 to 0.81)	0.61 (0.42 to 0.80)	0.66 (0.45 to 0.87)
UK	1950-1995	-2.67 (-2.83 to -2.52)	-1.86 (-2.04 to -1.68)	-0.83 (-0.98 to -0.68)	0.46 (0.23 to 0.69)	-0.02 (-0.23 to 0.18)	1.18 (0.89 to 1.46)
UK	1968-1995		-1.95 (-2.37 to -1.52)		-0.58 (-0.94 to -0.21)		
USA	1995-1992	-2.86 (-3.07 to -2.65)	-2.51 (-2.86 to -2.15)	-0.36 (-0.57 to -0.15)	0.68 (0.49 to 0.86)	0.49 (0.34 to 0.63)	0.92 (0.66 to 1.18)
USA	1968-1992		-1.98 (-2.37 to -1.58)		0.40 (0.04 to 0.76)		

[a] SWAT = sales-weighted annual tar (mg/cig)
[b] SWAN = sales-weighted annual nicotine (mg/cg)
[c] TNR = ratio of SWAT to SWAN
Note that for Canada the brand yields are not sales-weighted but are for 7 popular brands

TABLE 2 Compensation indices for nicotine

Country	Period	Compensation index (%)
Canada	1968-1995	40.4
Japan	1969-1995	25.7
UK	1950-1995	24.3
	1968-1995	-29.5
USA	1955-1992	26.6
	1968-1992	20.0

References

1. Lee PN, Sanders E. Does increased cigarette consumption nullify any reduction in lung cancer risk associated with low-tar filter cigarettes? *Inhal Toxicol* 2004;**16**:817-33. www.pnl.co.uk/reflist.htm [Download LEE2004R]

2. Forey B, Hamling J, Lee P, Wald N, editors. *International Smoking Statistics. A collection of historical data from 30 economically developed countries*, 2nd edition. London and Oxford: Wolfson Institute of Preventive Medicine and Oxford University Press; 2002. Errata available at www.pnlee.co.uk/ISS2.htm.

Figure 1

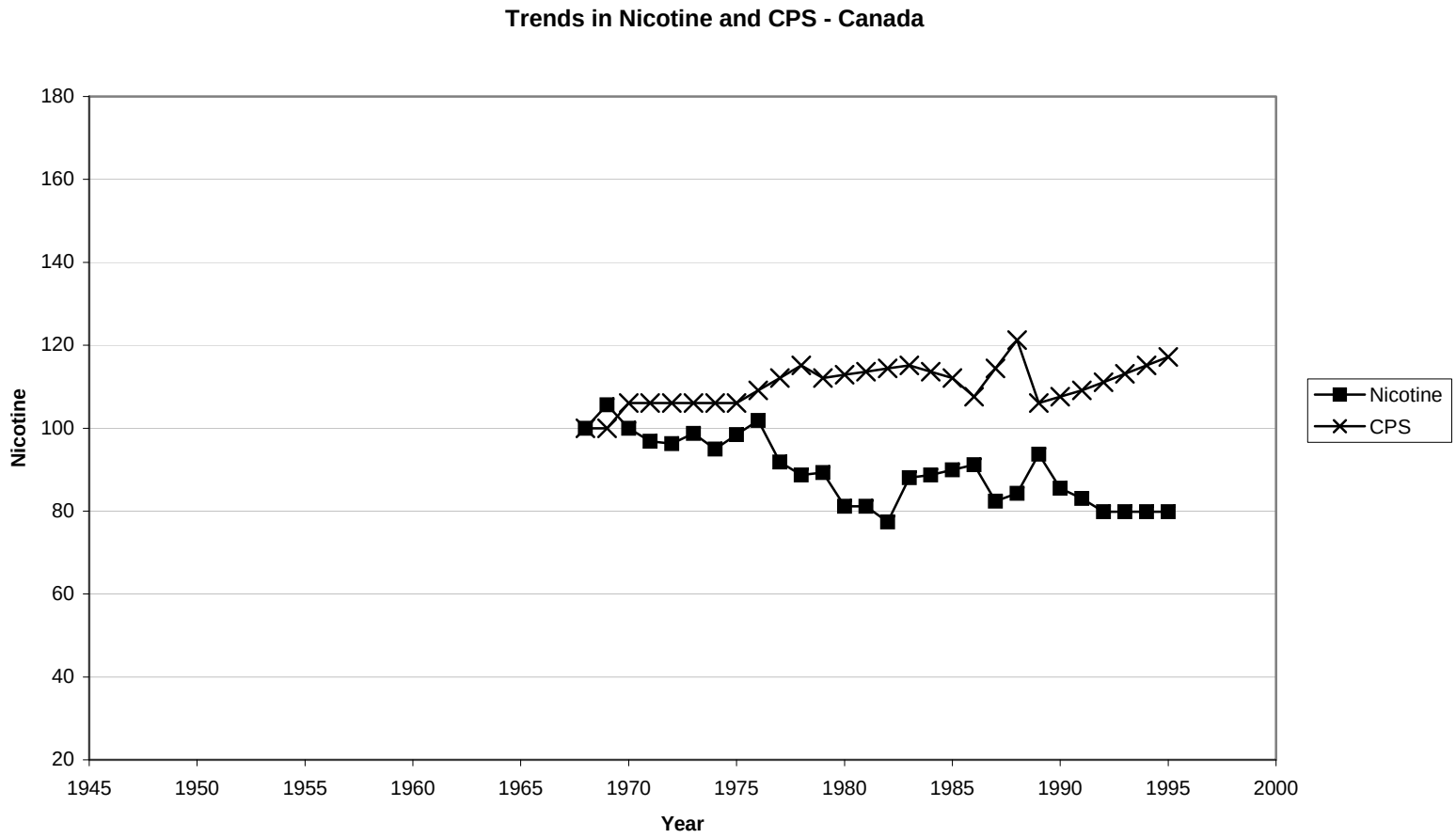

Trends in Nicotine and CPS - Canada
Nicotine
Year
180
160
140
120
100
80
60
40
20
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Nicotine
CPS

Figure 2

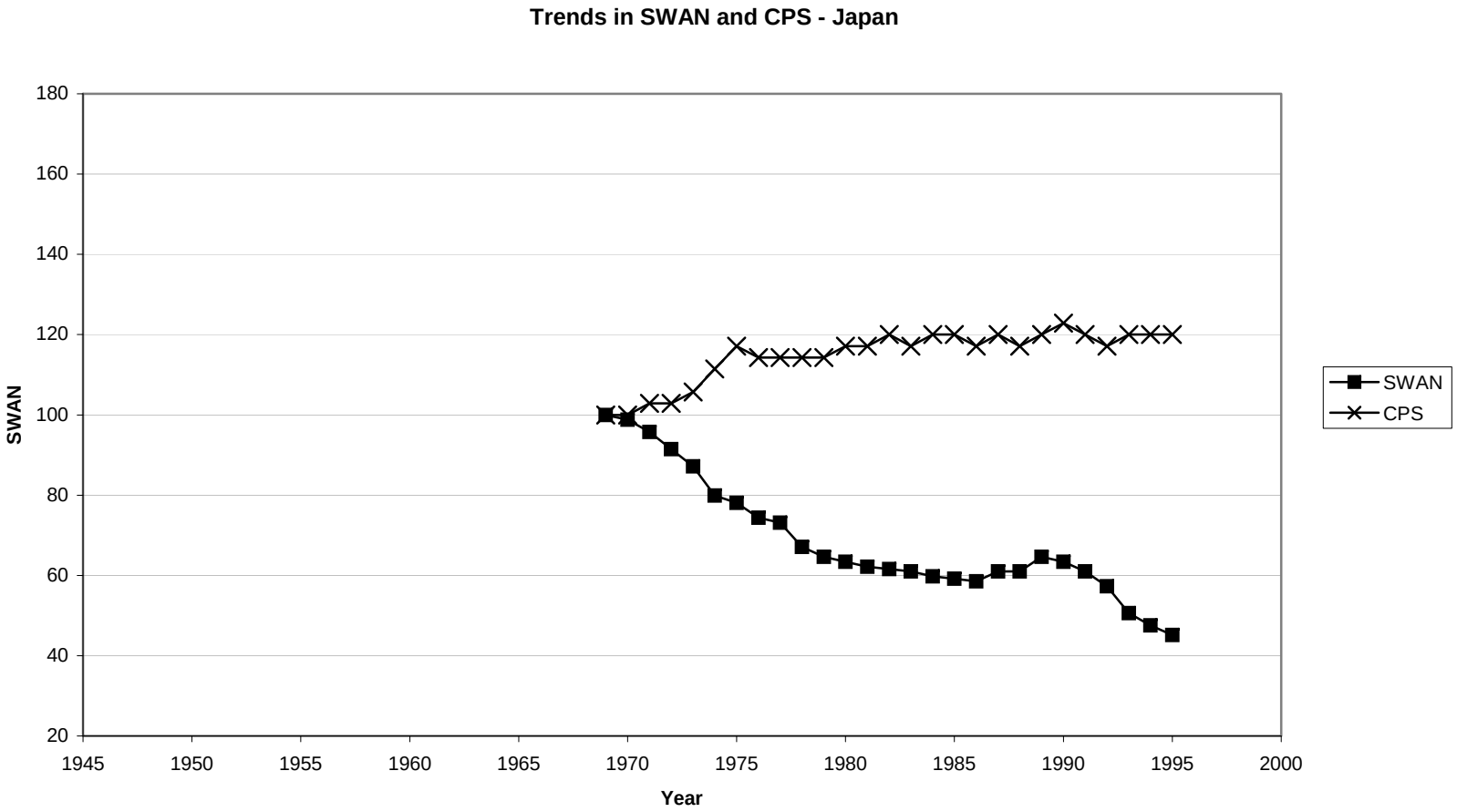

Trends in SWAN and CPS - Japan
SWAN
Year
180
160
140
120
100
80
60
40
20
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
SWAN
CPS

Figure 3

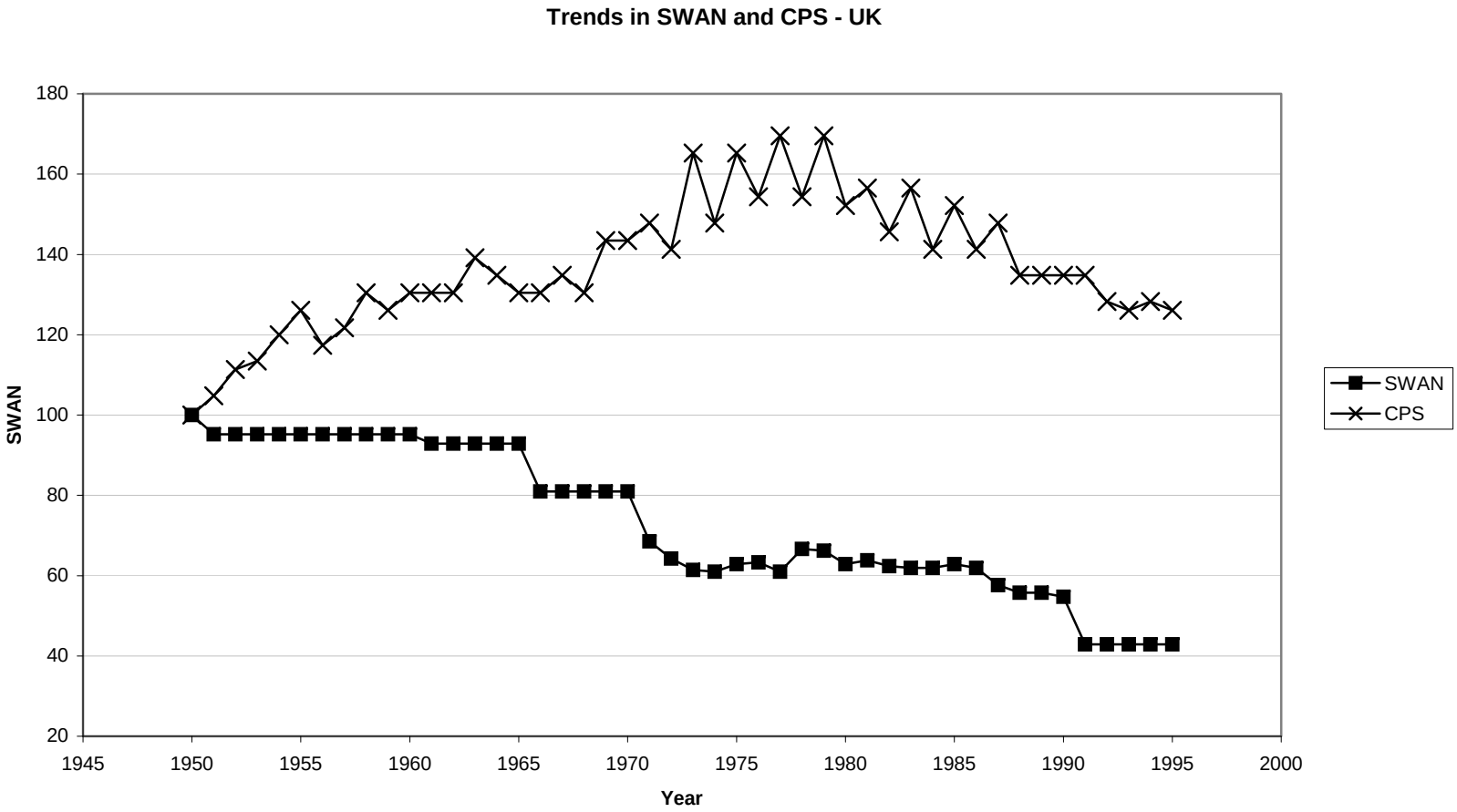
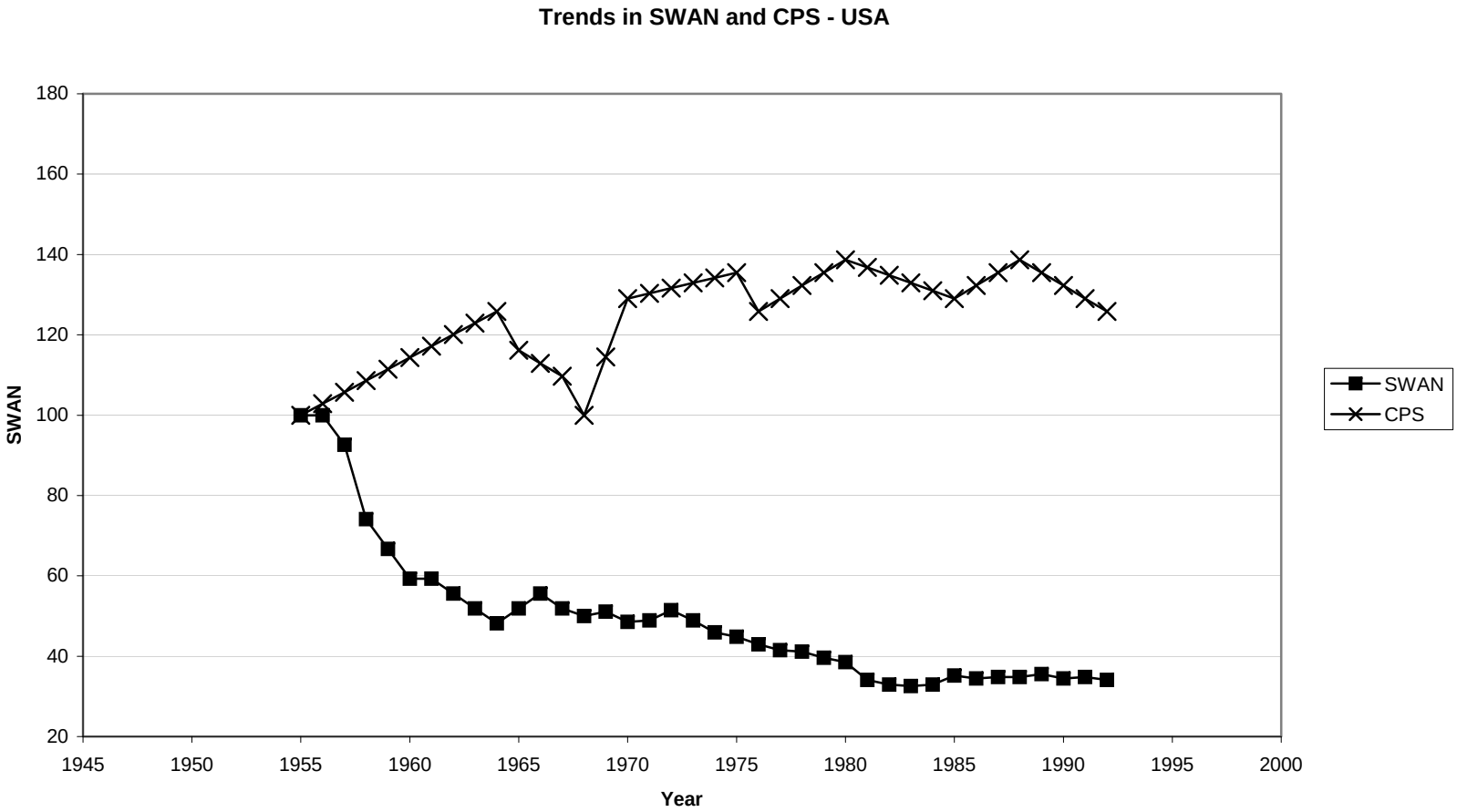

Trends in SWAN and CPS - UK
SWAN
Year
180
160
140
120
100
80
60
40
20
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
SWAN
CPS

Figure 4


Trends in SWAN and CPS - USA
SWAN
Year
180
160
140
120
100
80
60
40
20
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
SWAN
CPS