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Reconciliation of Sales and Stocks of Air Conditioners in Canada

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Executive Summary

Data on sales/shipments and stocks of air-conditioning units in Canada, collected from industry sources, do not appear to match very well with data on the stock of air conditioners that are obtained from household surveys. In particular, the sales/shipments in any year often are considerably different from the change in stocks from the preceding year to the year in question. In addition, data from different household surveys – the annual Survey of Household Spending, and the periodic Survey of Household Energy Use – also do not appear to match very well. In this paper, possible reasons for these various discrepancies are investigated. It is found that several factors contribute to the observed differences. These include variation in the scope and methodology of the different household surveys, the impact of statistical sampling on the precision of the estimates from the household surveys, and the impact of replacement of older units with newer ones on the stock of air-conditioners in use. Once these factors have been taken into consideration, many of the anomalies observed across the data sets can be reconciled.

Table of Contents

Executive Summary	i
List of Figures	iii
List of Tables	iv
1. Introduction	1
2. Overview of the Issues.....	2
2.1 The Data.....	2
2.2 Anomalies Across Data Sources.....	4
2.3 Key Questions.....	8
3 Differences in Survey Scope and Methodology.....	9
3.1 Target Populations and Survey Universe.....	9
3.1.1 Stock Data Sources.....	9
3.1.2 Shipment Data Sources.....	10
3.2. SHS and SHEU Survey Questions.....	12
3.3 SHS and SHEU Weighting Procedures.....	12
3.4 Reconciliations.....	12
3.4.1 Differences in the 1997 SHEU and the 2003 SHEU.....	13
3.4.2 SHEU Dwelling Coverage Change.....	13
3.4.3 Adjusted HRAI Value.....	15
4 Statistical Error.....	17
5 Role of Replacements.....	19
6 Conclusions.....	21

List of Figures

Figure 1: SHS Window Air-Conditioner Series	3
Figure 2: SHS Central Air-Conditioner Series	3
Figure 3: Changes in Stocks vs. Shipments for Window AC Units	5
Figure 4: Changes in Stocks vs. Shipments for Central AC Units	6
Figure 5: Ratios of Changes in Stocks to Shipments for Window and Central Units.....	6
Figure 6: SHS Changes in Stock vs. Adjusted and Non-Adjusted Shipments.....	15
Figure 7: SHS Ratios of Change in Stock to Adjusted and Non-Adjusted Shipments.....	16
Figure 8: Confidence Intervals for Window AC Stocks.....	17
Figure 9: Confidence Intervals for Central AC Stocks.....	17

List of Tables

Table 1: Stock and Shipment Data	2
Table 2: Differences Across SHS Air-Conditioning Series.....	4
Table 3: Changes in Stocks (SHS) and Shipments (CAMA, HRAI) by Year.....	5
Table 4: Changes in SHEU Stock Data from 1997 to 2003	6
Table 5: Adjusted SHEU Values for Window AC Units	12
Table 6: Percentages of SHEU Sample Population per Dwelling Type	13
Table 7: Number and Percent of Air Conditioners per Dwelling	13
Table 8: SHS Differences in Stocks vs Adjusted Shipments	15
Table 9: SHEU Differences in Stocks vs Adjusted Shipments	15
Table 10: SHS Coefficients of Variation	16
Table 11 Predicted vs. Implied Replacements of Window Units	19

1. Introduction

Stock and flow data on air-conditioning units are available from a variety of sources. Shipment/sales information are provided by the Canadian Appliance Manufacturers Association (CAMA) and the Heating, Refrigeration, Air Conditioning Institute of Canada (HRAI). Data on the stock of air-conditioning units in use in Canadian homes can be extracted from the Survey of Household Spending (SHS) and the Survey of Household Energy Use (SHEU). When comparing data from these various sources, it is found that, in some years, recorded shipments far exceed the changes in the stock of air-conditioning units in use in the residential sector. While this difference may reflect, at least in part, the purchase of replacement air conditioners, these anomalies may also be due to the exact nature of the data provided from each source and/or statistical errors inherent in the survey process.

There are three general approaches to the problem of reconciling air conditioner sales data obtained from CAMA and HRAI with household air conditioner stock data from SHS and SHEU. This first is to compare the survey universe and target populations of the four surveys. The second is to look at the magnitudes of statistical errors, especially in the household survey data, in an attempt to determine their potential contribution to the observed anomalies between shipment and sales data. The third is to try to obtain some idea of the magnitude of the replacement rate for air-conditioners, taking into account that some shipments will go towards replacement air conditioners and therefore will not appear in the change of stock numbers.

The outline of our study is as follows. Section 2 presents a summary of the available data and discusses the issues which need to be addressed in order to provide a basis for any eventual reconciliation of the data obtained from the various surveys. Section 3 provides a brief overview of areas where the survey universe and target populations of the four surveys differ, and offers some suggestions for statistical reconciliations, where possible. In Section 4, the role of the estimated relative standard error (or coefficient of variation in percent) in calculating changes in stocks of air-conditioning units is discussed. Section 5 discusses the relative importance of replacement air conditioner purchases, based on assumptions concerning the typical lifespan and growth of new purchases. Section 6 provides a summary and concluding remarks.

2. Overview of the Issues

2.1 The Data

Data on the sales/shipments of window and central air conditioners are provided by CAMA and HRAI, respectively, while data on residential sector stocks of air conditioners (both window and central) are collected in the SHS and the SHEU surveys. The CAMA, HRAI and SHS data are collected annually, while the SHEU survey is conducted on an occasional basis. In this study, we examine the data from these sources for the 1997-2004 period. The basic data are summarized in Table 1.

Table 1: Stock and Shipment Data

	1997	1998	1999	2000	2001	2002	2003	2004
Sales/Shipment Data								
Window (CAMA)	154000	139000	125000	147000	150000	191000	266000	300000
Central (HRAI)	110197	151002	185029	179603	146557	221117	230275	195014
STOCK DATA								
SHS – Canada								
Window	1396199	1453271	1540558	1423049	1512922	1647379	1814114	1791657
Central	2189850	2288468	2406405	2589592	2700977	2834598	2996301	3345162
SHS-Ten Provinces								
Window	1419309.05	1493336.5	1548363.9	1427391.3	1552418.7	1675446.1	1804473.5	1793473.5
Central	2188665.02	2298641.9	2399618.8	2604595.8	2754572.7	2840549.6	2999526.5	3353526.5
SHS Std. Tables								
Window	1401000	1475000	1541000	1418000	1533000	1671000	1813000	1793000
Central	2184000	2291000	2396000	2603000	2736000	2837000	3008000	3354000
SHEU								
Window	784513						2166278	
Central	1821176						2982025	

Note that there are three different series on air conditioner data available from SHS: (i) for Canada in total; (ii) a sum over the ten provinces; and (iii) a total value extracted from the SHS Standard Tables (Equipment). The data from these three series available from SHS are plotted in Figures 1 and 2 (for window and central units, respectively). As can be seen from these Figures, the three series track fairly closely over time. The magnitudes of the differences across series for each year are summarized in Table 2. The maximum difference refers to the largest difference across any pair of measures for each category of air-conditioning unit in each year. There are no

discernable patterns across year or type of unit. The final two columns of Table 2 present the ratio of the largest difference across series for each year to the minimum value across the three series for that year. This ratio is small in all cases. For the remainder of this study, we will focus mainly on the SHS “Canada” series in our discussions.

Figure 1: SHS Window Air-Conditioner Series

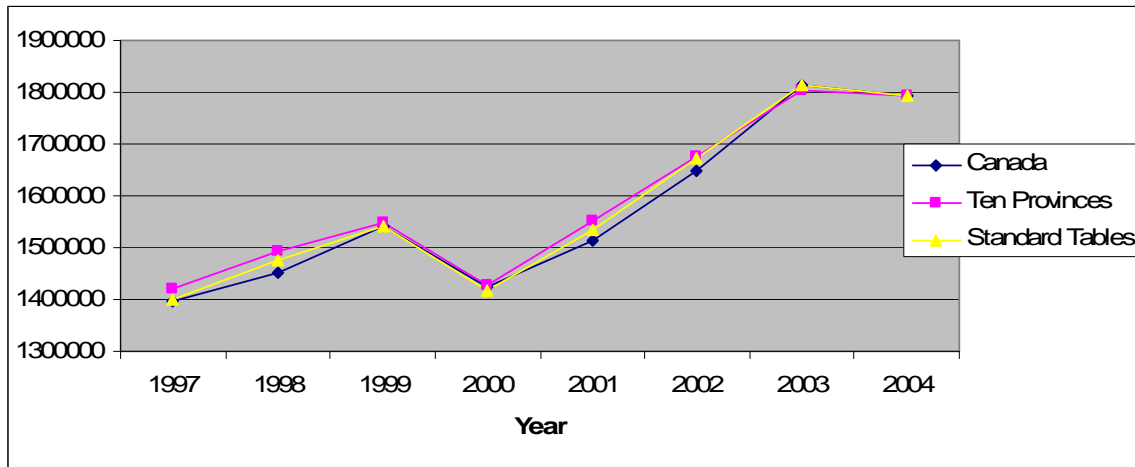


Figure 2: SHS Central Air-Conditioning Data Series

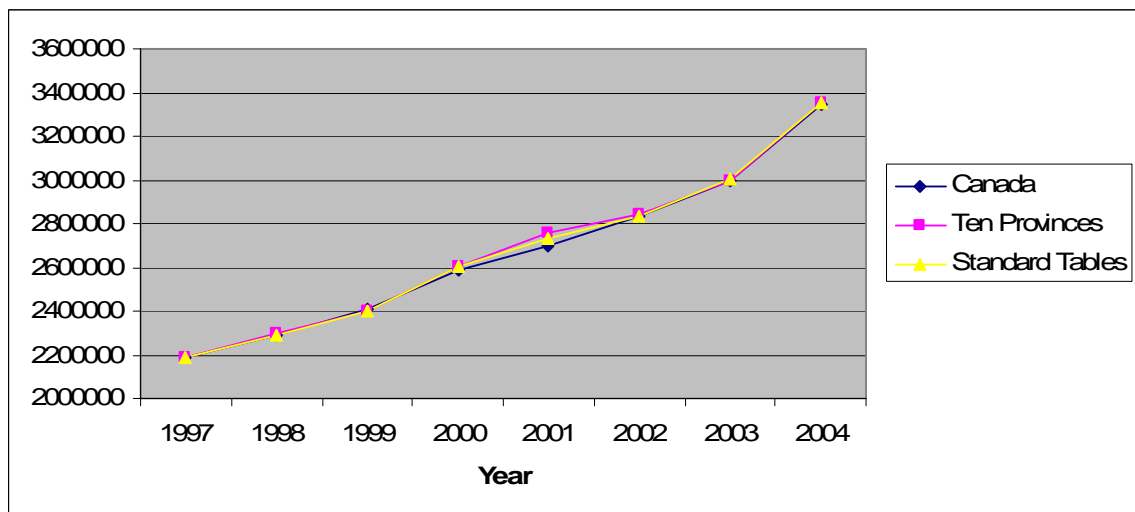


Table 2: Differences across SHS Air-Conditioning Series

	Max Difference		Max Diff / Min Value	
	Window	Central	Window	Central
1997	23110.05	5850	0.017	0.003
1998	40065.46	10173.93	0.028	0.004
1999	7805.86	10405	0.005	0.004
2000	9391.27	15003.76	0.007	0.006
2001	39496.68	53595.67	0.026	0.020
2002	4446.09	5951.59	0.003	0.002
2003	9640.50	11699	0.005	0.004
2004	1816.50	8838	0.001	0.003

2.2 Anomalies among Data Sources

We now examine a striking anomaly across the data sources: the difference between the magnitudes of the sales/shipment data and the magnitudes of change in stocks of air-conditioning units from the household survey data.

The change in stock measures from the three SHS data series and shipments data from CAMA (for window units) or HRAI (for central units) are presented in Table 3. The year-to-year changes in stocks from the three SHS series are presented, and these changes in stock are also expressed as a ratio of the appropriate shipment data, for window and central air conditioners, respectively. Figures 3-5 illustrate these differences, both in terms of units (Figure 3 for window units, Figure 4 for central units) and ratios of changes in units to shipments (Figure 5). Table 4 contains the comparison of the SHEU stock data to the sales/shipment data.

The data from the three sources do not reconcile easily. In general, the changes in stock fall below the shipment/sales figures. This is not surprising in and of itself, as many units purchased by households will have been purchased as replacements, and all not sales will have been to the residential sector. Even so, it is obvious that the SHS data from 2000 and 2004 are anomalous, with abnormally 'low' values for changes in the stocks of window units and unusually 'high' values for central units.

Table 3: Changes in Stocks (SHS) and Shipments (CAMA, HRAI) by Year

Window AC	Shipment Year						
	1998	1999	2000	2001	2002	2003	2004
Canada							
Change in Stock	57072	87287	-117509	89873	134457	166735	-22457
Change in Stock / Shipments*	0.41	0.70	-0.80	0.60	0.70	0.63	-0.07
Ten Provinces							
Change in Stock	74027.41	55027.41	-120972.6	125027.41	123027.41	129027.41	-11000
Change in Stock / Shipments*	0.53	0.44	-0.82	0.83	0.64	0.49	-0.04
Standard Tables							
Change in Stock	74000	66000	-123000	115000	138000	142000	-20000
Change in Stock / Shipments*	0.53	0.53	-0.84	0.77	0.72	0.53	-0.07
* based on CAMA sales/shipment data							
Central AC							
Canada							
Change in Stock	98618	117937	183187	111385	133621	161703	348861
Change in Stock / Shipments†	0.65	0.64	1.02	0.76	0.60	0.70	1.79
Ten Provinces							
Change in Stock	109976.91	100976.91	204976.91	149976.91	85976.91	158976.91	354000
Change in Stock / Shipments†	0.73	0.55	1.14	1.02	0.39	0.69	1.82
Standard Tables							
Change in Stock	107000	105000	207000	133000	101000	171000	346000
Change in Stock / Shipments†	0.71	0.57	1.15	0.91	0.46	0.74	1.77
† based on HRAI sales/shipment data							

Figure 3: Changes in Stocks* vs. Shipments for Window AC Units
 (* based on SHS “Canada” series)

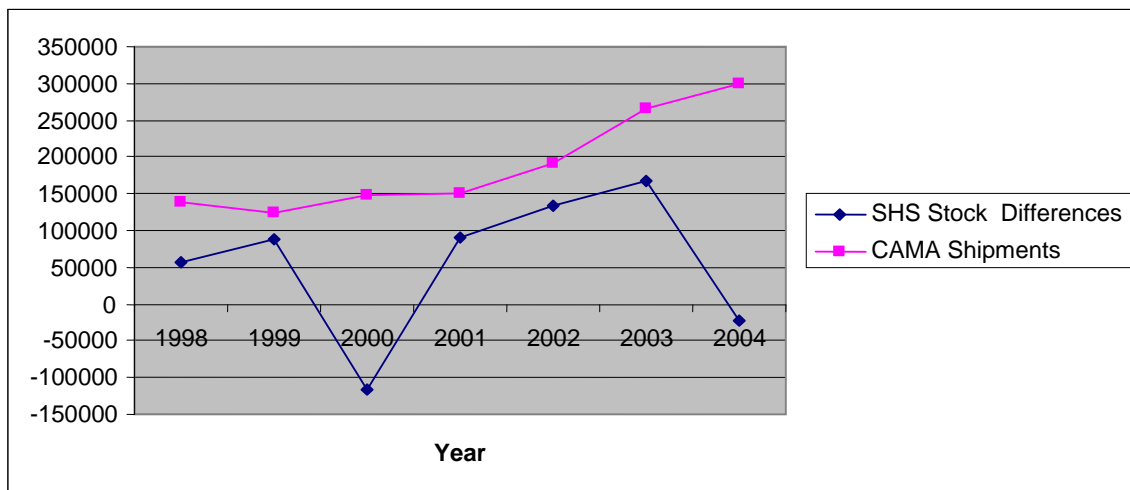


Figure 4: Changes in Stocks* vs. Shipments for Central AC Units
 (* based on SHS “Canada” series)

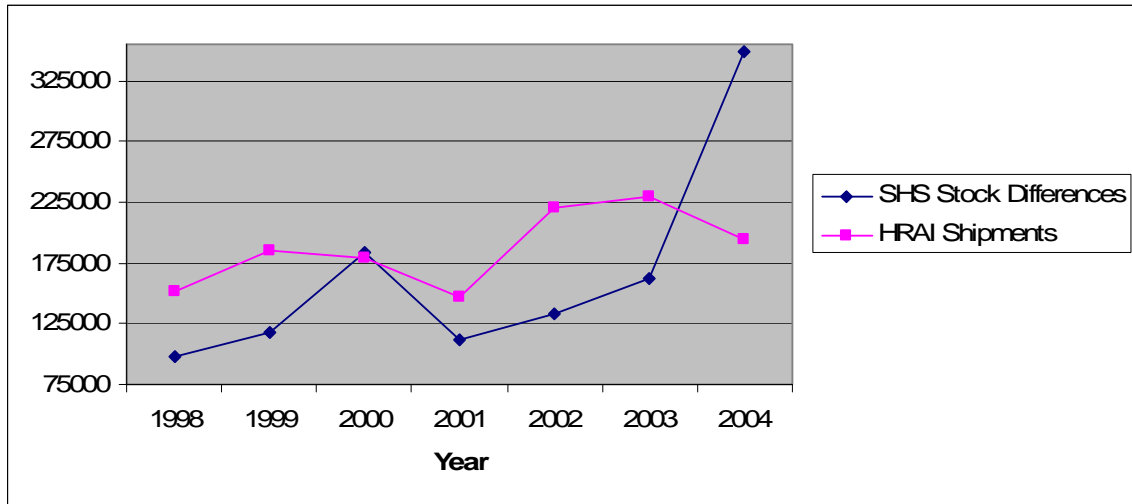


Figure 5: Ratios of Changes in Stocks* to Shipments for Window and Central Units
 (* based on SHS “Canada” series)

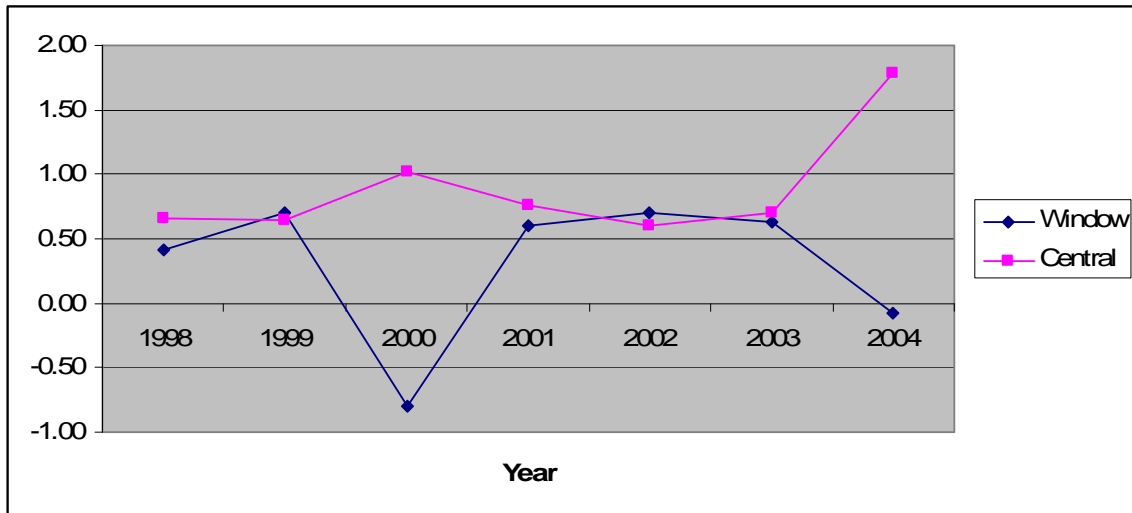


Table 4: Changes in SHEU Stock Data from 1997 to 2003

	Stock Difference (1997-2003)	Ratio of Stock Difference to Shipments
Window	1381765	1.3573334
Central	1160849	1.0424447

The SHEU data are interesting for two reasons. The first is that changes in air conditioner stocks based on the SHEU data track the sales/shipments more closely than the SHS data. The second is that, with SHEU data, the changes in stocks exceed shipments, while with the SHS data it is generally the other way around. These results are to be expected, given that the data from Table 1 indicate that the SHEU estimates of air-conditioning stocks are substantially lower than the SHS estimates for 1997 and much closer to the SHS estimates in 2003. The reasons for these differences across the two household surveys will be discussed in more detail in Section 3.

2.3 Key Questions

Given the characteristics of the data from the various available sources, we can identify two questions key to the reconciliation of this data:

- *Question 1: Why do data on changes in stocks and data on shipments differ as much as they do?*
- *Question 2: Why do SHS and SHEU data give us conflicting results on the sign and magnitude of these differences?*

One factor that contributes to these observed anomalies is the differences in the scopes and methodologies for the various surveys. These differences are discussed in the following section.

3. Differences in Survey Scope and Methodology

3.1 Target Populations and Survey Universe

The target populations and survey universe vary over the data sources. The stock data are generated based on household survey responses. The sales/shipment data are obtained from industry associations. Details regarding the various surveys follow.

3.1.1 Stock Data Sources

The target population for the SHS is defined as follows:¹

The Survey of Household Spending is carried out in private households in Canada. The following groups are excluded from the survey:

- those living on Indian reserves and crown lands;*
- official representatives of foreign countries living in Canada and their families;*
- members of religious and other communal colonies;*
- members of the Canadian Forces living in military camps;*
- people living in residences for senior citizens; and*
- people living full time in institutions: for example, inmates of penal institutions and chronic care patients living in hospitals and nursing homes.*

The survey covers about 98% of the population in the 10 provinces. Information is not gathered from persons temporarily living away from their families (for example, students at university), because it would be gathered from their families if selected. In this way, double counting of such individuals is avoided.

Data from part-year households are excluded from estimates of average household spending. However, these data are included in the estimates for dwelling characteristics and household equipment and in the calculation of the Survey of Household Spending response rate. Data from part-year households are also required as input into Statistics Canada's System of National Accounts. Part-year households are composed entirely of persons who were members of other households for part of the reference year.

¹ <http://www.statcan.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=3508&lang=en&db=IMDB&dbg=f&adm=8&dis=2>

The target population for the SHEU is defined as follows:²

The target population is comprised of dwellings that were occupied as primary residences in the ten Canadian provinces and that fit into one of the following categories: single detached, semi-detached, row, mobile, duplex or dwelling in a building with no more than four storeys (the last two categories were not covered in the 1998 edition of the SHEU). Specifically excluded from the survey's coverage were dwellings not mentioned above, dwellings located in a First Nation community or military base, businesses, institutions, demolished dwellings, dwellings under construction, seasonal or secondary residences, and dwellings occupied by individuals who work full-time within the Canadian Armed Forces.

Of note from these target populations is that, while the SHEU excludes the same types of dwellings the SHS excludes, the SHEU goes further in that its household coverage is more narrowly and specifically defined. Also noteworthy is that the included dwellings changed between the 1997 SHEU survey (the “1998 edition”) and the 2003 SHEU survey, with duplexes and dwellings in a building no more than four stories being included in the 2003 sample, but not in the 1997 sample. This change may bias upwards the differences in air conditioner stocks between 1997 and 2003 to the extent that these two dwelling types omitted from the 1997 survey owned window and/or central air conditioners. Some attempts at reconciling this fact are made in Section 3.4.

Also, because the SHEU has a narrower coverage of households, the estimates of air-conditioning stocks may be expected to differ from those obtained by SHS. This is expected to occur to the extent that residents of certain types of dwellings may be more or less likely to have air-conditioned living spaces.

3.1.2 Shipment Data Sources

Through correspondence with a representative from HRAI, we learned that their data is collected based on manufacturers’ first arms-length transaction, and covers approximately 98% of the market. The data in Table 1 refer to central air conditioning systems, which have been separated

² <http://www.statcan.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=4403&lang=en&db=IMDB&dbg=f&adm=8&dis=2>

out from ductless cooling and split systems. However, these latter systems are also capable of providing air conditioning. It may be the case that respondents to the SHS and SHEU surveys would claim to have central air conditioning when they have one of these other systems. As such, a potentially more accurate comparison of central air conditioner shipments to stock changes would be realized by adding these other systems to the HRAI data in Table 1. This reconciliation is made in Section 3.4. Another potential source of differences between the SHS, SHEU and HRAI data is the fact that not all sales are destined for use in the residential sector.

For the CAMA data, the survey universe is divided into “Retail Sales” and “Builder Sales”. According to CAMA:³

Retail Sales:

Include those by Canadian manufacturers and importers and/or their branches and distributors (if any) to Canadian retailers, government, agencies, builders and other consumers, but, does not include sales to branches, distributors or to other CAMA member companies.

Builder Sales:

Include those to home builders, motels, Governments, row house builders, trailer manufacturers and apartment house builders. Sales to utilities are not included.

Expansion Factors:

It is recognized that not all companies contribute their shipment data directly into the Association's statistical program. As a result of this, a consensus is reached based on a detailed review of both actual and import data, and a percentage of the overall market represented by the CAMA members is assigned in the program. This factor is then applied to extrapolate a total industry number.

Given the above information, it is conceivable that the CAMA data in Table 1 may include air conditioner shipments which were installed in dwellings not covered by the SHS or SHEU, and therefore bias these shipments upwards in terms of their comparability to the residential sector stock data.

³ http://www.electrofed.com/files/file.php?fileid=fileECExBEvZHI&filename=file_CAMA_Stats.pdf

3.2 SHS and SHEU Survey Questions

The SHS survey question asked with respect to air conditioners is “What type of air conditioner did you have?”, and the individual can select “Window type air conditioning unit(s),” “Central air conditioning,” or “None.” The SHEU survey asks about window and air conditioners separately, and for the 1997 data, the question was basically in line with the SHS question. However, in 2003, the question on window air conditioners changed from identification of ownership of a window air conditioning unit, as in the SHS and 1997 SHEU survey, to how many window air conditioning units, between zero and five, the household owns. This is another way in which the SHS and SHEU differ, and also biases the difference between 1997 and 2003 stocks upwards. This bias occurs because the 1997 value is reporting the number of households with window air conditioners, a number necessarily lower than the number of window air conditioners owned by households as long as at least one household owns more than one unit. We attempt to reconcile this bias in Section 3.4.

3.3 SHS and SHEU Weighting Procedures

The SHS and SHEU base their weighting procedures, used to extrapolate from their sample to the population, on different sources, which may contribute to their differences. The SHS weights are based on the Canadian Census, with years 1998-2002 based on the 1996 census, and years 2003-2004 based on the 2001 census. Comparing data, then, between 2002 and 2003 may be problematic, and as such 2003 values of the SHS change in stock data reported in Table 3 should be treated with some caution. The SHEU weighting procedure, on the other hand, is based on the *Canadian Community Health Survey*.

3.4 Reconciliations

Given the available data, it is possible to attempt to address, statistically, three of the issues raised in Sections 3.1 and 3.2. In Sections 3.4.1 and 3.4.2, we will address the two differences between the 1997 and 2003 SHEU data, namely the change in question regarding window air conditioners, and the change in dwellings included in the survey, respectively. In Section 3.4.3,

the heat pump and ductless split systems will be added to the HRAI data to see how this affects the difference between shipments and changes in stocks.

3.4.1 Differences in the 1997 SHEU and the 2003 SHEU

We will begin by addressing the change in window air conditioner stock question. There are two ways this can be approached. The first way to compensate for this change in the survey question is to apply the ratios of people who own 1, 2, or 3 window air conditioners in 2003 to the 1997 amounts, and adjust the data accordingly. This is done in Table 5.

Table 5: Adjusted SHEU Values for Window AC Units

# of Window Units Owned	% of 2003 Stock	Amount of 1997 Stock	Adjusted 1997 Amounts
1	87.49%	686370.469	686370.469
2	11%	86296.436	172592.871
3	1.50%	11767.696	35303.087
5	0.10%	784.513	3922.565
Adjusted 1997 Value:	898188.99	Adjusted Ratio:	1.245

Based on this adjusted figure, the ratio of the difference in window air conditioner stocks from 1997 to 2003 to the sum shipments from 1998 to 2003 is 1.245, which is closer to one than the unadjusted value found in Table 4.

3.4.2 SHEU Dwelling Coverage Change

In the 2003 survey, the SHEU target population increased to include duplexes and dwellings in a building no more than four stories. The effect on overall sample population by including these two new dwelling types is shown in Table 6, and it is evident that the inclusion of households in low rise buildings is quite significant. The respective contributions to total window and central air conditioner estimates in 2003 of each dwelling type are presented in Table 7.

Based on the last two rows of Table 7, we can now compare these adjusted differences to the shipment data. The new ratios of changes in stocks to shipments for window and central air

conditioner units are 0.704 and 0.957, respectively. The stock change – shipment ratio for window units is most glaring, as the removal of the two dwelling types not included in 1997 changes it from 1.35 to 0.704. This change is due to two factors: (1) we are dealing with a smaller population, and therefore it would be expected that changes in stocks would be less than shipments (as not all stocks are being accounted for), and (2) the removal of the upward bias on the difference between the 1997 and 2003 SHEU values caused by the difference in target populations.

Table 6: Percentages of SHEU Sample Population per Dwelling Type

Dwelling Type	1997	2003
Single Detached	85.43	69.7
Double	4.82	4.9
Row or Terrace	6.49	4.9
Mobile Home	3.27	2.9
Duplex	n/a	3.2
Low Rise < 5 Stories	n/a	14.3

Table 7: Number and Percent of Air Conditioners per Dwelling

Dwelling Type	# Window	% Window	# Central	% Central
1.Single Detached	839093	48.9	2403744	80.6
2.Double	69708	4.1	229947	7.7
3.Row or Terrace	83301	4.9	234889	7.9
4.Mobile Home	58581	3.4	17988	1.1
5.Duplex	110421	6.4	33878	2.1
6.Low Rise < 5 Stories	554751	32.3	61579	0.6
2003 SHEU w/o 5 and 6	Window:	1501106.5	Central	2886568
Adj. Diff b/w '03 and '07:	Window:	716593.4	Central	1065392

It would be most interesting to see what kind of effect adding these two dwelling types to the 1997 value would have on the ratio. While we do not have these data, we can roughly estimate the quantity of air conditioner units held by households in the omitted dwellings by assuming growth in air conditioner ownership in these dwellings was the same as other dwellings. That is, the ratio of 1997 stocks and 2003 stocks (with dwellings removed) is 0.522 and 0.631 for window and central units, respectively. Now, if we apply this ratio to the 2003 values for

duplexes and low rises, we obtain 347630 and 60223 for window and central units, respectively. These are the estimates for 1997 stocks in duplexes and low rises. Adding these values to the 1997 SHEU values (from Table 4) and calculating the new ratios of stocks to shipments as above (using the original 2003 SHEU values) yields ratios of 1.02 for window units and 0.988 for central units.

An alternative way to estimate how much the two omitted dwelling types affect the 1997 value is to use the relative percentages from Table 7. From Table 7, we know that the dwelling types which are included in 1997 make up 61.3% of total window air conditioner stocks and 97.3% of total central air conditioner stocks. Using the percentages to adjust the 1997 amounts accordingly, we get values of 1279793 and 1871712 for window and central units accordingly. The new ratios of stocks to shipments, using these adjusted 1997 values, are 0.871 and 0.997.

While the estimation methods above are far from perfect, as they involve simplifying assumptions, they do suggest that the dwellings omitted from the 1997 SHEU have a significant effect on the relationship between shipments and changes in stocks, especially for window units.

3.4.3 Adjusted HRAI Value

As noted in Section 3.1.2, it is possible the HRAI data in Table 1 are under-reporting central air conditioner shipments in terms of their comparability to the stock data collected by the SHS and SHEU. In this section we will add ductless split-system heat pumps and air conditioning units to the HRAI data to see how these additions affect the difference between shipments and changes in stock for central units. Unfortunately, these data are only available beginning in 1999. These results are included in Table 8 (for SHS data) and Table 9 (for the SHEU data), and are depicted in Figures 6 and 7.

Table 8: SHS Differences in Stocks vs. Adjusted Shipments

	1997	1998	1999	2000	2001	2002	2003	2004
Cooling only			1279	1916	1797	3436	7083	3132
Heat pumps			6566	12677	10192	17334	33409	30131
adjusted HRAI (+ cooling only)	110197	151002	191595	192280	156749	238451	263684	225145
Adjusted HRAI (+both)	110197	151002	192874	194196	158546	241887	270767	228277
SHS Stock Diff (Central)		98618	117937	183187	111385	133621	161703	348861
Ratio to Shipments (unadjusted)		0.65	0.64	1.02	0.76	0.60	0.70	1.79
Ratio to Shipments (+ cooling only)		0.65	0.62	0.95	0.71	0.56	0.61	1.55
Ratio to Shipments (+ both)		0.65	0.61	0.94	0.70	0.55	0.60	1.53

Table 9: SHEU Differences in Stocks vs. Adjusted Shipments

HRAI	SUM (98 to 03)	Ratio of stocks to shipments
Unadjusted Shipments	1113583	1.0424447
Adjusted (cooling only)	1193761	0.9724297
Adjusted (both)	1209272	0.9599566

Figure 6: SHS Changes in Stock vs. adjusted and non-adjusted shipments

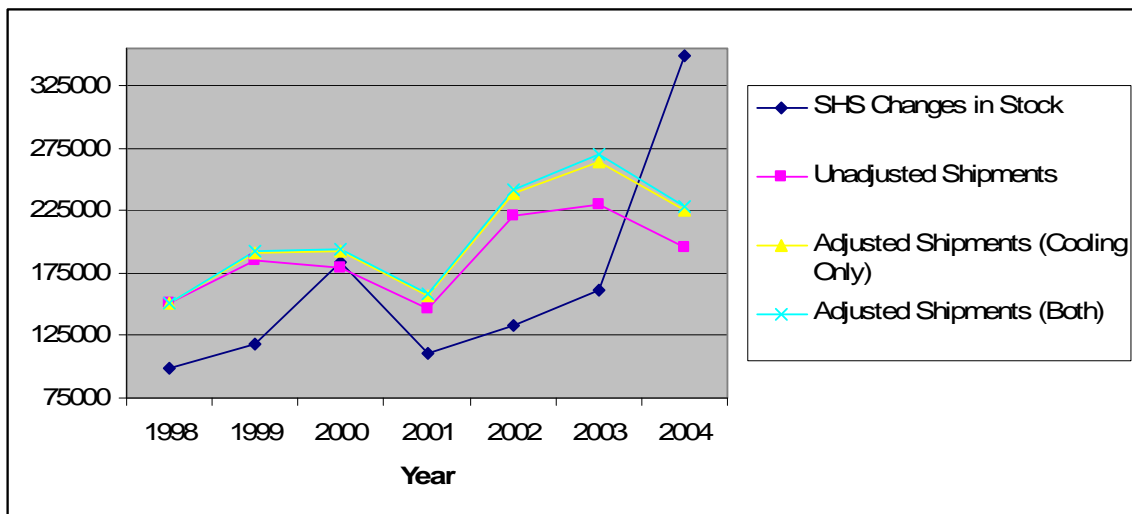
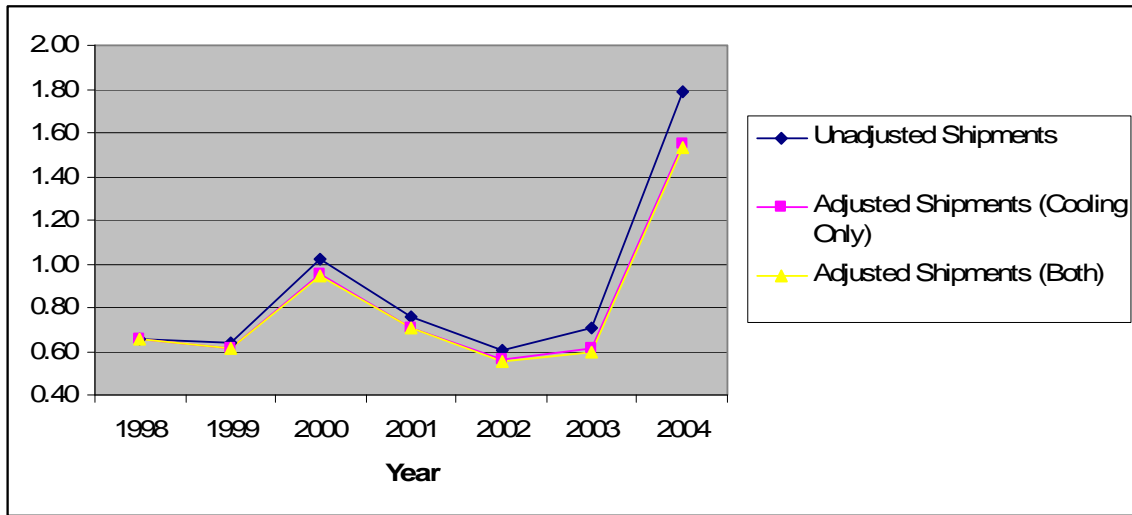


Figure 7: SHS Ratios of Change in Stock to adjusted and non-adjusted shipments



4. Statistical Error

In Table 10, the Coefficients of Variation (CV) for the SHS window and central air-conditioning data are given. These CVs are the standard errors for the stock estimates expressed as a percentage of the estimate. The CV can be interpreted as follows: the true value will lie within +/- one CV of the point estimate 68% of the time, and within +/- 1.96 CVs 95% of the time.

Table 10: SHS Coefficients of Variation

SHS CVs	1997	1998	1999	2000	2001	2002	2003	2004
Window Air Conditioners	3.22	3.77	3.19	3.96	3.41	3.43	3.37	3.85
Central Air Conditioners	2.48	2.90	2.58	2.95	2.48	2.52	2.33	2.37

Given the CVs in Table 10, we can create confidence intervals for both the window and central air-conditioning stock data from SHS. These are depicted in Figures 8 and 9.

Figure 8: Confidence Intervals for Window AC Stocks

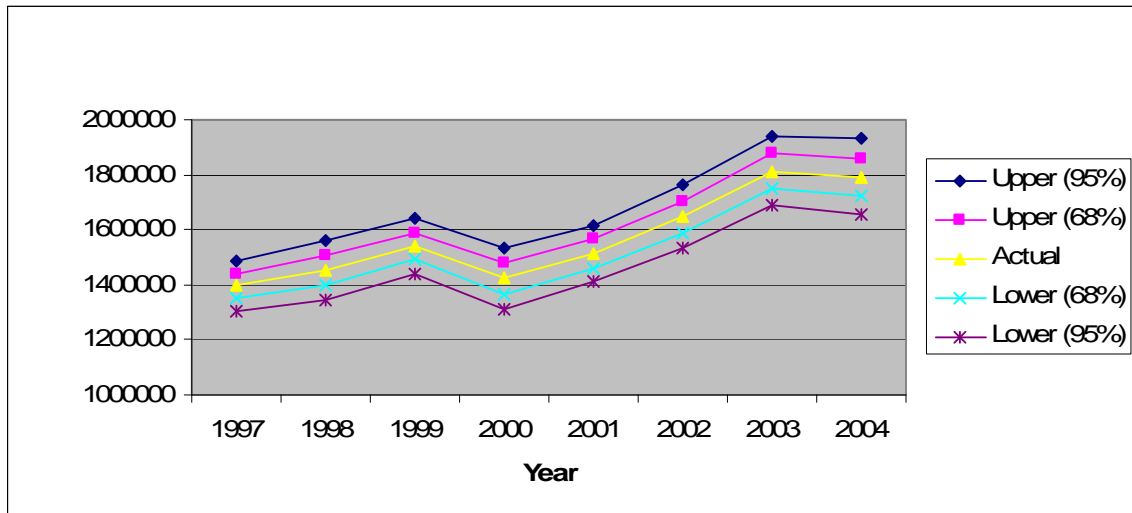
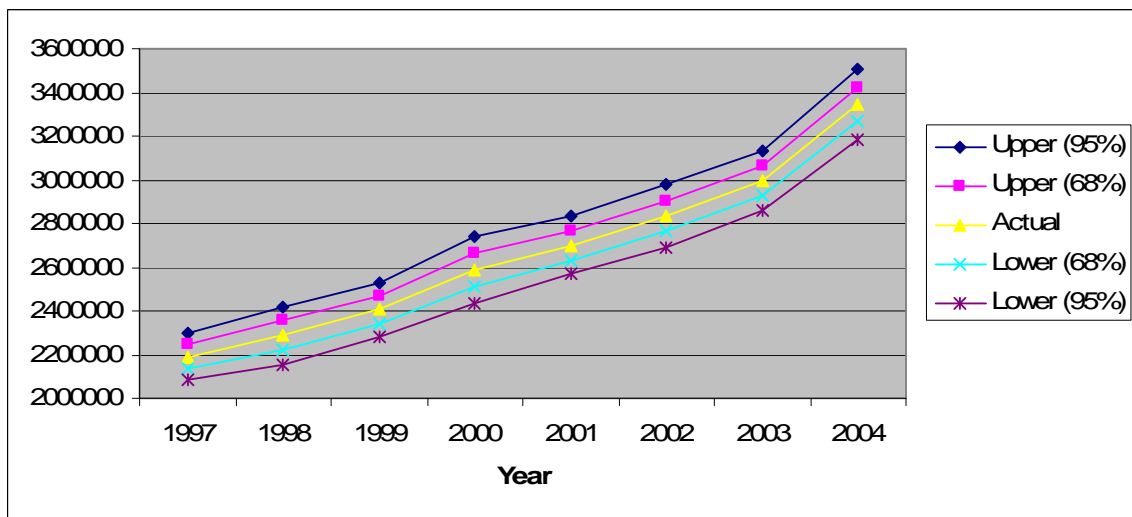


Figure 9: Confidence Intervals for Central AC Stocks



However, the more relevant confidence interval, in terms of the data anomalies observed in our comparison of sales/shipments quantities based on CAMA and HRAI data and the change in residential stocks based on the SHS data, would be for the change in the stock. This requires the calculation of the CV for the change in the stock from year to year. In principle, the relevant CV can be calculated based on the following formula, where $\text{Var}(\cdot)$ refers to a variance and $\text{Cov}(\cdot)$ refers to a covariance:

$$\text{Var}(\text{Stock}_t - \text{Stock}_{t-1}) = \text{Var}(\text{Stock}_t) + \text{Var}(\text{Stock}_{t-1}) - 2\text{Cov}(\text{Stock}_t, \text{Stock}_{t-1})$$

However, this would require information on the covariance of the estimates of the Stocks in consecutive years. Using a value of zero for the covariance, and given the magnitudes of the standard errors for the Stock values in any given year $[(CV_t/100)*Stock_t]$, the estimated standard errors for the change in stock variables are very large, leading to extremely broad confidence intervals (not reported)⁴. This indicates that statistical error could possibly be a large contributing factor to the observed differences in magnitudes of the sales/shipment data and the data on the change in stocks.

5. Role of Replacements

A third way of approaching the issue of yearly changes in stocks of air conditioners being different from shipments is to address the question of the magnitude of the “typical” difference between shipments and changes in stocks that results from replacement purchases. If a household replaces their air conditioner in a given year, this would add to the total number of air conditioner shipments, but not to the change in stock. We can write the relationship between shipments of air conditioners, the change in the stock of air conditioners, and the number of units replaced as:

$$\text{Shipments}_t = \Delta\text{Stock}_t + \text{Replacements}_t$$

Although we have data on shipments and stocks, there is no question in either the SHS or the SHEU surveys which asks if an air conditioner was replaced in any given year. The SHEU questionnaire asks how old a window or central unit is. The question is structured such that, for newer units, we only know if the current age is “3 years or less.” From this information we do not know if the unit has been purchased in the past year or whether the household is a first-time or replacement purchaser of the air conditioner in question. However, we do have an idea about how long air conditioners last and, given the SHS and SHEU data, we can determine whether the implied number of replacements $(\text{Shipments}_t - \Delta\text{Stock}_t)$ is reasonable given results in the literature that suggest window air conditioners have a lifespan of 10-12 years, and central systems have a lifespan of 14-15 years.

⁴ For the change in stock of window units between 1997 and 1998, the confidence interval ranges from -81839 to 195983 when a value of zero is used for the covariance between Stock_t and Stock_{t-1} .

To illustrate, consider the case of window units with a lifespan of 10 years. In order to estimate the magnitude of replacement purchases in 1998, for example, we can use linear regression methods, along with the stock data, to extrapolate our stock data back to 1988. For the purposes of generating our regression line, we drop the observations for 2000 and 2004 which are obvious outliers (see Figure 1). Based on these data, we obtain the following estimated relationship:

$$\hat{Stock}_t = -113748188.1 + 57654.5YEAR_t, \quad R^2 = 0.8235.$$

For YEAR=1988, our estimated value for the stock of window units is 868887. Given an average lifespan for window air conditioners of approximately 10 years, this means that we would expect approximately 86889 replacements in 1998. We can compare this estimate with the implied number of replacements from the relationship between shipments, stocks and replacements. From our window unit data in Table 1 we can calculate $(Shipments_t - \Delta Stock_t)$ for 1998 as 81928, which is quite close to the estimated value.

Table 11 contains the predicted numbers of window unit replacements based on an expected lifespan of 10 years and the stock from 10 years previous based on our regression line, along with the implied number of replacements based on the actual shipment and stock data for each year. From these calculations, we see that, for some years at least, replacement units may account for a large portion of the apparent discrepancy between the shipment and stock data.

Table 11: Predicted vs. Implied Replacements of Window Units

Year	Predicted Replacements (.1 $Stock_{t-10}$)	Implied Replacements ($Shipments_t - \Delta Stock_t$)
1998	86889	81928
1999	92654	37713
2000**	98420	264509
2001	104185	60127
2002	109950	56543
2003	115716	99265
2004**	121481	322457

** Outliers that are not included in the estimated relationship on which predictions are based.

From Table 11 we see that replacements do not explain away all of the differences, especially in 2000 and 2004 which are outliers compared to other years. This is not surprising given the issues discussed in Sections 3 and 4, and since the stock of air conditioners we are considering only covers the residential sector.

6. Conclusions

Based on the information presented in Sections 3, 4, and 5, we may now address the two questions posed at the end of Section 2.

Question 1: Why do changes in stocks and shipments differ as much as they do?

This is probably due to a number of factors, including:

- The surveys which measure stocks and those which record shipments may include different target populations in terms of where the shipments actually end up.
- Respondents were only asked to identify if they have window air conditioners, not how many units they may have, in the SHS and the 1997 SHEU, which may bias stocks downward.
- There may be some variation in terms of actual cooling units which may or may not be considered to be window or central air conditioning by respondents of surveys.
- The statistical error of the SHS, although these effects are difficult to quantify.
- We expect there is some natural difference between shipments and changes in stocks due to replacement purchases, and this natural difference could potentially vary quite significantly due to the varying age and lifetime of air conditioning units, growth rates of new purchasers from year to year, and the number of times households replace their air conditioners.

Question 2: Why do SHS and SHEU data give us conflicting results on the sign and magnitude of these differences?

This is also due to a variety of potential reasons:

- The SHEU survey could be biased upward due to two changes in the survey from 1997 to 2003. The first is the question pertaining to window air conditioners, from identification

to quantification. The second is the change in coverage, with the 2003 version including duplexes and dwellings in buildings no more than 4 storeys. This latter change seems to be particularly important.

- The weights which are used to extrapolate from sample to population are based on different sources for the SHS (which uses the Canadian Census) and the SHEU (which uses the Canadian Community Health Survey). This could potentially result in different values of the stocks created.
- The SHEU takes a more narrow definition of “household” than the SHS.
- The SHS does not ask how many air conditioners a given household has, only if they have any.
- The SHS data for 2000 and 2004 appear to be outliers when compared to other years.

Once these various factors have been taken into consideration, it is reasonable to conclude that many of the differences across the data sets can be explained. Unfortunately, the magnitudes of the various effects on the observed anomalies cannot be pinned down in an exact manner.

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