An Analysis on the Housing Market Prices in the Top 45 Cities in Canada

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STAT 344: Survey Sampling

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November 17th, 2024

Introduction

Objectives

The goal of this project is to estimate two key parameters related to the Canadian real estate market: the *average price of a property listing* and the *proportion of properties listed that have a price above $700,000* across the 45 largest cities in Canada. To achieve this, we will implement two sampling methods, simple random sampling (SRS) and stratified sampling by city, to provide insights into Canadian housing prices.

Background

The Canadian housing market faces growing concerns over rising prices, particularly in cities like Vancouver and Toronto, highlighting issues of affordability and access. We will use both simple random sampling and stratified sampling to make and compare estimates for the average listing price and the proportion of listings over $700,000. We can then use these results to explore key aspects of the Canadian housing market.

These insights can help governments design targeted policies to mediate rising prices through informed economic and social interventions, such as adjusting tax policies or incentivizing affordable housing projects, depending on the affordability in each city. Additionally, these findings can guide individuals in planning their housing decisions by providing a clearer picture of market trends and affordability in different regions.

Literature Review

According to the Canadian Real Estate Association, the average home price across Canada in October of 2021 was $716,585 (“2021 Already a Record Year for Canadian Home Sales,” 2021). Two other reports indicated that the average home price in May of 2021 was approximately $687,000 (“Canadian Housing Market Report Oct. 21st, 2024: Interactive Map,” 2024; Solomon, 2024). Based on this information, we will use a rounded approximate average listing price of $700,000 as the threshold for our proportion.

Singh (2022) stated, “Households face a greater likelihood of unaffordability in more populous provinces and larger CMAs [comparative market analyses] that struggle with the high cost of living, racial disparities and low income.” This emphasizes the importance of analyzing housing prices in larger cities to account for these regional affordability challenges in Canada.

In addition to the apparent challenges of high prices, we also know that local factors like construction costs, employment growth, and income growth significantly influence housing affordability (Allen et al., 2009). These factors drive our incentive to look at individual cities when stratifying data.

Data Collection and Summaries

The dataset captures Canadian property listings from 2021, with 35,768 listings across the 45 largest Canadian cities. Sourced from the 2021 Canadian Census and Simplemaps *Canada Cities Database,* each record includes the city, province, price, address, housing features (number of bedrooms, bathrooms), and contextual data (city population, median income, longitude, latitude).

For the purposes of this project, *we will consider this dataset as the population.* We typically would not expect to have access to the full population, so for the purposes of this study we will only use the full dataset to obtain a simple random sample and to obtain a stratified sample using proportional allocation.

Sampling Procedure

To avoid oversampling and to minimize the hypothetical cost of sampling, we will perform a sample size calculation to determine the minimum sample size needed to guarantee that the confidence interval for the proportion of listings above $700,000 has a width equal to or less than 0.04. The calculated sample size is 2401 (see Appendix A2) and will be used as the sample size for both the simple random sample and the stratified sample. We have chosen to ignore the finite population correction factor in the sample size calculation since we are treating the population, and thus the population size, as unknown. Additionally, it is reasonable to assume that the total number of listings in the top 45 Canadian cities is large enough such that we can ignore the finite population correction factor.

Simple Random Sampling

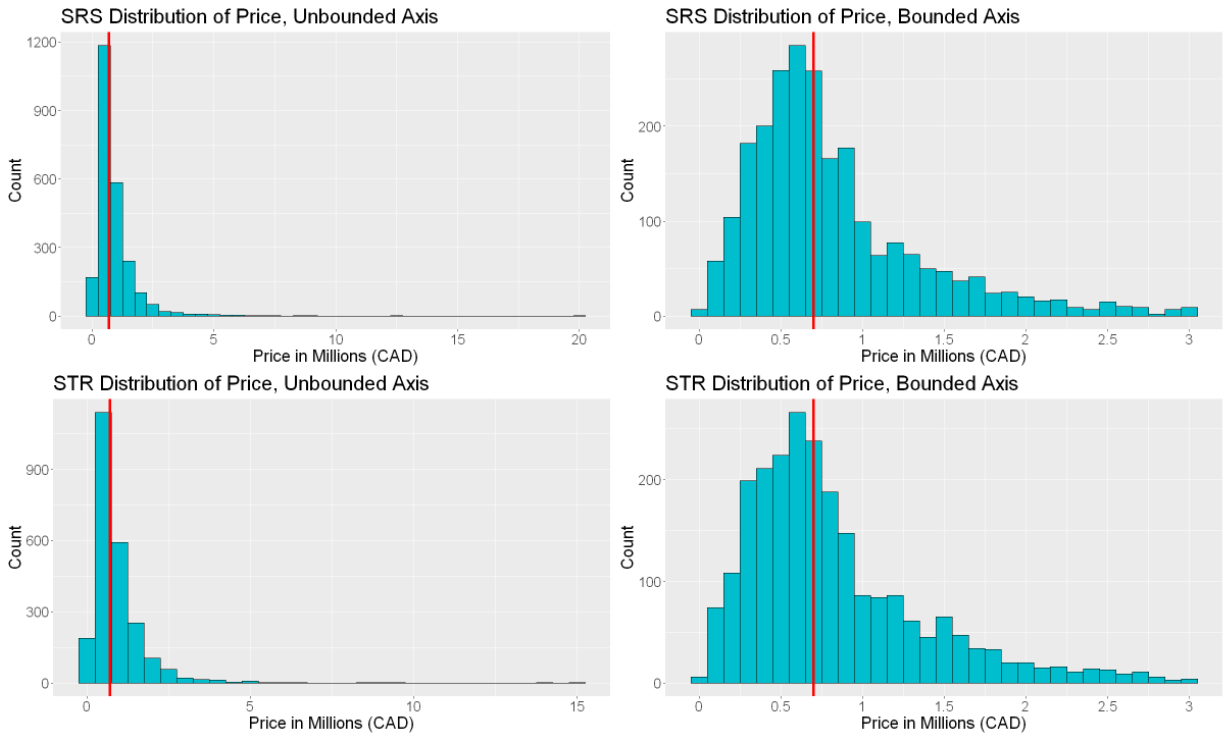
Our first sample is a simple random sample, obtained from random sampling without replacement from the population (see Appendix A3). From the simple random sample, we will estimate the average listing price via the *vanilla estimate*. While alternatives like ratio and regression estimates could potentially improve precision by leveraging relationships between variables, they are complex and require information about an auxiliary variable, which demands further research to determine a suitable variable. Thus, the simplicity and reliability of the vanilla estimate make it the best choice for our analysis.

Stratified Sampling

We are *stratifying by city* because housing markets vary significantly between cities due to differences in factors like population size, city-scale economy, infrastructure, and demand-supply dynamics (Allen et al., 2009). As such, we expect the average listing price for some cities to vary significantly compared to the average listing prices of the other cities. Stratifying by city ensures that we capture these regional differences, which allows for more precise and meaningful estimates of property prices and the proportion of high-priced properties.

Strata Sizes

To determine the sample size for each strata, we first consider optimal allocation. We will assume that the variance of listing price within each city will be similar between the top 45 cities, since these cities typically represent metropolitan areas with similar economic factors driving the housing market (as opposed to the factors driving the housing markets of smaller towns or rural areas). Additionally, we will assume that the sampling cost is the same across cities, since we do not expect the cost of sampling a listing to change from city to city. Under these assumptions, optimal allocation simplifies to proportional allocation, so we will use proportional allocation to determine the sample size for each city (see Appendix A4).



Figures 1-4. These histograms show the distribution of listing prices in the samples in millions (CAD). The vertical red lines on the graph indicate the listing prices of $700,000. The first two graphs show the distribution of listing prices in the simple random sampling; the latter two graphs show the distribution of listing prices in the stratified sample.

From Figures 1-4, we observe that the distribution of listing price is heavily right skewed for both the simple random sample and the stratified sample. For both samples, the distribution peaks roughly between $600,000 and $700,000. Since the distributions are right skewed, we would expect the average listing price across the top 45 Canadian cities to be significantly greater than $700,000, which is the average listing price across Canada.

Data Analysis

Assumptions

- All observations in the dataset are independent
- The sample size is sufficiently large
- We know, for a given city, the proportion of all house listings relative to the total population (from the top 45 cities across Canada).
- The population as defined by the dataset is complete, (i.e., we are not missing any data that causes our sampling to be biased due to underrepresentation)
- The strata are mutually exclusive (for stratified sampling)
- All strata sampling costs are equal (for stratified sampling)
- All cities have equal variance of housing costs (for stratified sampling)

I. Simple Random Sampling

A. Estimate for Average House Listing Price

The *vanilla estimate* for the average house listing price in the sample is calculated to be **$930,395.45** (see Appendix A5). This estimate represents the central tendency of property prices within the sample, providing an initial benchmark for understanding the overall housing market in Canada. The *standard error (SE)* of this estimate is **$19,088.64** (see Appendix A5), which indicates the level of uncertainty or variability associated with the estimate.

Combining the above, the resulting *95% confidence interval* for the estimate of the average house listing price is calculated to be **[$892,981.71, $967,809.19]** (see Appendix A5). An interpretation of this is that we are 95% confident that the true value of the average house listing price in the top 45 cities in Canada is between $892,981.71 and $967,809.19.

B. Estimate for Proportion of Houses Above $700,000

The *estimated proportion* of house listing prices above $700,000 is **0.4798**. In other words, approximately 48% of the homes listed for sale in the top 45 cities in Canada cost more than $700,000. The *standard error (SE)* of this estimate is **0.0102** (see Appendix A5), which indicates the level of uncertainty or variability associated with the estimate.

Combining the above, the resulting *95% confidence interval* is **[0.4598, 0.4998]** (see Appendix A5). So, we are 95% confident that the true proportion of houses listed above the price of $700,000 in the top 45 cities in Canada is between approximately 46% and 50%.

II. Stratified Sampling

A. Estimate for Average House Listing Price

The *stratified estimate* for the average house listing price in the sample is calculated to be **$926,995.74** (see Appendix A6). This estimate differs from the SRS vanilla estimate, as it was calculated using a stratified sample. The *standard error (SE)* of this estimate is **$16,168.81** (see Appendix A6), which indicates the level of uncertainty or variability associated with the estimate.

Combining the above, the resulting *95% confidence interval* for the estimate of the average house listing price can be calculated as **[$895,304.87, $958,686.61]** (see Appendix A6). Therefore, *based on a stratified sampling method,* we are 95% confident that the true average house listing price in the top 45 cities in Canada is between $895,304.87 and $958,686.61.

B. Estimate for Proportion of Houses Above $700,000

The *estimated proportion* of house listing prices above $700,000 *using stratified sampling* is **0.4932** (see Appendix A6)**.** In other words, *based on a stratified sampling method*, approximately 49% of the homes listed in the top 45 cities in Canada are above the price of $700,000. The *standard error (SE)* of this estimate is **0.0086** (see Appendix A6), which indicates the level of uncertainty or variability associated with the estimate.

Combining the above, the resulting *95% confidence interval* is **[0.4764, 0.5101]** (see Appendix A6)**.** So, *based on a stratified sampling method,* we are 95% confident that the true proportion of houses listed above the price of $700,000 in the top 45 cities in Canada is between approximately 47.6% and 51%.

These confidence intervals can be visualized using histograms (see Figures 5-8 in the Appendix).

Advantages and Disadvantages

Simple Random Sampling

Advantages	**Disadvantages**
- Easy to understand, simple to implement - No bias from researchers in selecting sample - Requires less information about population in advance of the study	- Possibly inefficient - Possibly less representative of population compared to other methods

Stratified Sampling

Advantages	Disadvantages
- Yields a sample that is more representative of the population - Reduces variability, thereby increasing precision - Allows us to conduct further studies on subgroups (strata)	- Additional complexity in managing strata - Requires more time and resources - Requires some knowledge about population in advance of the study

Conclusion

Summary

Sampling Method	Estimated Mean Price	SE	Lower CI	Upper CI
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
SRS	930395.5	19088.64	892981.7	967809.2
STR	926995.7	16168.81	895304.9	958686.6

Sampling Method	Estimated Proportion of Listings Above 700k	SE	Lower CI	Upper CI
<chr>	<dbl>	<dbl>	<dbl>	<dbl>
SRS	0.4798001	0.010195751	0.4598164	0.4997838
STR	0.4932235	0.008590149	0.4763868	0.5100602

Tables 1 and 2. The resulting estimates for each sampling method, along with their SE and confidence intervals.

Interpretation

Using *simple random sampling*, the vanilla estimate for the average house listing price in the sample was calculated to be $930,395.45 with an SE of $19088.64. Based on this vanilla estimate, we are 95% confident that the true value of the average house listing price in the top 45 cities in Canada is between $892,981.71 and $967,809.19. Additionally, approximately 48% of the homes listed for sale in the top 45 cities across Canada are above the price of $700,000 and we are 95% confident that the true proportion of houses listed above the price of $700,000 in the top 45 cities in Canada is between approximately 46% and 50%.

Using *stratified sampling*, the stratified estimate for the average house listing price in the sample is calculated to be $926,995.74 with an SE of $16168.81. Based on this stratified estimate, we are 95% confident that the true average house listing price in the top 45 cities across Canada is between $895,304.87 and $958,686.61. Additionally, approximately 49% of the homes listed in the top 45 cities in Canada are above the price of $700,000 and we are 95% confident that the true proportion of houses listed above the price of $700,000 in the top 45 cities in Canada is between approximately 47.6% and 51%.

Estimate Comparison

For the average house listing price estimation, the vanilla estimate gave a standard error of $19,088.64, while the stratified estimate gave a standard error of $16,168.81. The SE of the stratified estimate is approximately 15% smaller than the SE of the vanilla estimate. Therefore, stratified sampling gives a more precise estimate than simple random sampling. Stratified sampling provides a sample that is more representative of the population than the sample obtained using SRS because it is guaranteed that every city is present in the sample, and thus may give a more accurate estimate.

For the estimated proportion of house listing prices over $700,000, the vanilla estimate gave a standard error of 0.0102, while the stratified estimate gave a standard error of 0.0086. The SE of the stratified estimate is approximately 16% smaller than the SE of the vanilla estimate, so there is a significant difference between the precision of the estimates. Thus, stratified sampling provides a better estimation of the proportion of properties listed over the price of $700,000.

Affording a Home

Two key pieces of information that we gathered are that the average age of a first-time home buyer is 36 years old. (RE/MAX Canada, 2023), and the median salary in Canada for the 25-54 years age group for 2021 was $55,900 (Government of Canada, Statistics Canada, 2024). With this knowledge, we will find and compare our estimates to the salary of the average person in this particular age group, the most likely age group to be purchasing their first home.

Before taxes, the median salary is $55,900; this number is dwarfed in comparison to our stratified estimate of the average house listing price: $926,995.74. This is approximately equivalent to a 16.583:1 ratio, which means that the average listing price in a big Canadian city is over 16.5 times the total annual income of the average person. On the extreme end, one of the most expensive cities in terms of average listing price is Vancouver — with a average listing price of $1,763,509 (calculated from the stratified sample, see Appendix A8), the average listing price in Vancouver is approximately 31.5 times the total annual income of the average first-time home buyer. Similarly, Toronto, the largest city in Canada, is also quite expensive — with an average listing price of $1,124,805 (also calculated from the stratified sample, see Appendix A8). The average listing price is approximately 20.1 times the total annual income of the average

first-time home buyer. However, we can also appreciate that roughly half the listings, an estimated 49.3%, are above $700,000, so at the very least half the properties in big Canadian cities are over 12.5 times the total annual income of the average person.

Limitations

The results of our analysis provide valuable insights but come with certain limitations. The sample size we obtained by using the most conservative guess gave us a large sample size to work with. Although our large sample size allows us to accurately estimate population parameters, the implementation of the experiment in practice could prove to be costly.

Although our sample is assumed to be representative of the population, the population we sampled from does not cover all of Canada, so our findings can only be confidently extended to the top 45 cities in Canada. Additionally, the data was drawn from the 2021 Canadian Census and may not be completely representative of the current or future housing markets. Since we obtained the $700,000 average household threshold from a study that considers all of Canada, our average is higher as our analysis excluded rural areas, where property prices are typically lower.

We had to allocate our stratification proportionally rather than using optimal allocation. This required us to assume equal sampling costs across strata and equal variance within each stratum, which may not be true in reality and could introduce potential biases in our estimates.

Final Conclusion

This study provides crucial insights into regional variation within the Canadian real estate market in the top 45 cities in Canada. We estimated the *average of a property listing* and the *proportion of properties listed above $700,000* and found that the stratified sampling gave a more accurate estimate for both parameters. Overall, we were able to obtain estimates for both sampling methods, but we are unable to generalize our findings to a greater population.

Appendix

(A1) Dataset:

```
housing_raw <- read.csv("housing.csv")
head(housing_raw)
```

A data.frame: 6 × 10

	City	Price	Address	Number_Beds	Number_Baths	Province	Population	Latitude	Longitude	Median_Family_Income
	<chr>	<dbl>	<chr>	<int>	<int>	<chr>	<int>	<dbl>	<dbl>	<dbl>
1	Toronto	779900	#318 -20 SOUTHPORT ST	3	2	Ontario	5647656	43.7417	-79.3733	97000
2	Toronto	799999	#818 -60 SOUTHPORT ST	3	1	Ontario	5647656	43.7417	-79.3733	97000
3	Toronto	799900	#714 -859 THE QUEENSWAY	2	2	Ontario	5647656	43.7417	-79.3733	97000
4	Toronto	1200000	275 MORTIMER AVE	4	2	Ontario	5647656	43.7417	-79.3733	97000
5	Toronto	668800	#420 -388 RICHMOND ST	1	1	Ontario	5647656	43.7417	-79.3733	97000
6	Toronto	548000	#2503 -99 HARBOUR SQ	0	1	Ontario	5647656	43.7417	-79.3733	97000

(A2) Sample size calculation

```
#calculating recommended sample size to guarantee that the confidence interval
#for the proportion of listings above $700,000 has width equal to or less than 0.04
half.width <- 0.02
n <- ceiling(1.96^2 * (0.5) * (1-0.5) / half.width^2)
n
```

2401

```
#population size
N <- nrow(housing)
N
```

35768

(A3) Collecting simple random sample:

```
#obtaining SRS
set.seed(123)
srs.sample <- housing[sample(N, n), ]
head(srs.sample)
```

A tibble: 6 × 11

City	Price	Address	Number_Beds	Number_Baths	Province	Population	Latitude	Longitude	Median_Family_Income	above.threshold
<chr>	<dbl>	<chr>	<dbl>	<dbl>	<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
Calgary	1050000	132 Carrington Close NW	6	4	Alberta	1306784	51.0500	-114.0667	100000	1
Saint John	259900	9 Eastland Court	4	3	New Brunswick	69895	45.2806	-66.0761	74000	0
New Westminster	769900	1601-301 CAPILANO ROAD	2	2	British Columbia	78916	49.2069	-122.9111	82000	1
Calgary	429000	228 Rocky Ridge Court NW	3	2	Alberta	1306784	51.0500	-114.0667	100000	0
London	529000	384 WHARNCLIFFE Road S	5	3	Ontario	423369	42.9836	-81.2497	79500	0
Caledon	899000	8 WALLS CRES	3	3	Ontario	76581	43.8667	-79.8667	133000	1

(A4) Sample strata size calculation and collecting stratified sample:

```
num.strata <- 45

#determining sample size for each strata using proportional
#allocation, split into integer and decimal components
strata.sizes <- housing |>
    count(City) |>
    rename(N.h = n) |>
    mutate(N.prop.h = N.h/N) |>
    mutate(n.h = N.h*n/N) |>
    mutate(decimal = n.h - floor(n.h)) |>
    mutate(n.h = floor(n.h))

#remaining observations to allocate
leftover.obs <- n - sum(strata.sizes$n.h)

#Ranking strata by decimal component and allocating an extra observation to the
#strata with the largest decimal components. This ensures that the SRS and the
#stratified sample have the same sample size, which is not the case if we were to
#simply round the calculated sample size for each strata to the nearest integer.
ranks <- row_number(strata.sizes$decimal)
strata.sizes <- cbind(strata.sizes, ranks) |>
    mutate(extra.obs = if_else(ranks > num.strata - leftover.obs, 1, 0))

#population and sample size of each strata
strata.sizes <- strata.sizes |>
    mutate(n.h = n.h + extra.obs) |>
    select(City:n.h)

strata.sizes
```

A data.frame: 45 × 4

City	N.h	N.prop.h	n.h
<chr>	<int>	<dbl>	<dbl>
Abbotsford	755	0.021108253	51
Airdrie	225	0.006290539	15
Barrie	1012	0.028293447	68
Brantford	628	0.017557593	42
Burnaby	1334	0.037295907	89
⋮	⋮	⋮	⋮
Vancouver	1328	0.03712816	89
Victoria	1325	0.03704429	89
White Rock	1175	0.03285059	79
Windsor	720	0.02012972	48
Winnipeg	531	0.01484567	36

```
#obtaining stratified sample
str.sample <- NULL
strata.summaries <- NULL
set.seed(420)
for (i in 1:nrow(strata.sizes)) {
    pop.h <- filter(housing, City == strata.sizes$City[i])
    sample.h <- sample_n(pop.h, strata.sizes$n.h[i], replace = FALSE)
    str.sample <- rbind(str.sample, sample.h)
    summary <- summarize(sample.h, priceAVG = mean(Price), priceSE = sd(Price), prop = mean(above.threshold))
    strata.summaries <- rbind(strata.summaries, summary)
}
head(str.sample)
```

A tibble: 6 × 11

City	Price	Address	Number_Beds	Number_Baths	Province	Population	Latitude	Longitude	Median_Family_Income	above.threshold
<chr>	<dbl>	<chr>	<dbl>	<dbl>	<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
Abbotsford	565000	305-2565 CAMPBELL AVENUE	3	2	British Columbia	153524	49.05	-122.3167	91000	0
Abbotsford	950000	2699 MITCHELL STREET	5	3	British Columbia	153524	49.05	-122.3167	91000	1
Abbotsford	1130000	32098 AUSTIN AVENUE	5	2	British Columbia	153524	49.05	-122.3167	91000	1
Abbotsford	1349700	36090 SOUTHRIDGE PLACE	4	3	British Columbia	153524	49.05	-122.3167	91000	1
Abbotsford	849900	2052 OAKRIDGE CRESCENT	3	1	British Columbia	153524	49.05	-122.3167	91000	1
Abbotsford	989900	34898 LABURNUM AVENUE	3	2	British Columbia	153524	49.05	-122.3167	91000	1

(A5) Estimate calculations from simple random sample:

```
#SRS estimate of the mean price
srs.price.est <- mean(srs.sample$Price)
srs.price.est
```

930395.450982924

```
#SE for the mean price estimated via SRS
srs.price.SE <- sd(srs.sample$Price)/sqrt(n)
srs.price.SE
```

19088.642165758

```
#SRS confidence interval for the mean price
srs.price.lowerCI <- srs.price.est - 1.96 * srs.price.SE
srs.price.lowerCI
srs.price.upperCI <- srs.price.est + 1.96 * srs.price.SE
srs.price.upperCI
```

892981.712338038

967809.189627809

```
#SRS estimate of the proportion of listings greater than $700,000
srs.prop.est <- mean(srs.sample$above.threshold)
srs.prop.est
```

0.479800083298626

```
#SE for the proportion of listings greater than $700,000 estimated via SRS
srs.prop.SE <- sqrt(srs.prop.est * (1 - srs.prop.est)/n)
srs.prop.SE
```

0.0101957509537827

```
#SRS confidence interval for the proportion of listings greater than $700,000
srs.prop.lowerCI <- srs.prop.est - 1.96 * srs.prop.SE
srs.prop.lowerCI
srs.prop.upperCI <- srs.prop.est + 1.96 * srs.prop.SE
srs.prop.upperCI
```

0.459816411429211

0.49978375516804

(A6) Estimate calculations from stratified sample:

```
#stratified estimate of the mean price
str.price.est <- sum(strata.info$priceAVG*strata.info$N.prop.h)
str.price.est
```

926995.74167447

```
#SE for the mean price estimated via stratified sampling
str.price.SE <- sqrt(sum(strata.info$priceSE^2*strata.info$N.prop.h^2))
str.price.SE
```

16168.8112524246

```
#stratified confidence interval for the mean price
str.price.lowerCI <- str.price.est - 1.96 * str.price.SE
str.price.lowerCI
str.price.upperCI <- str.price.est + 1.96 * str.price.SE
str.price.upperCI
```

895304.871619718

958686.611729222

```
#stratified estimate of the proportion of listings greater than $700,000
str.prop.est <- sum(strata.info$prop*strata.info$N.prop.h)
str.prop.est
```

0.493223532824403

```
#SE for the proportion of listings greater than $700,000 estimated via stratified sampling
str.prop.SE <- sqrt(sum(strata.info$propSE^2*strata.info$N.prop.h^2))
str.prop.SE
```

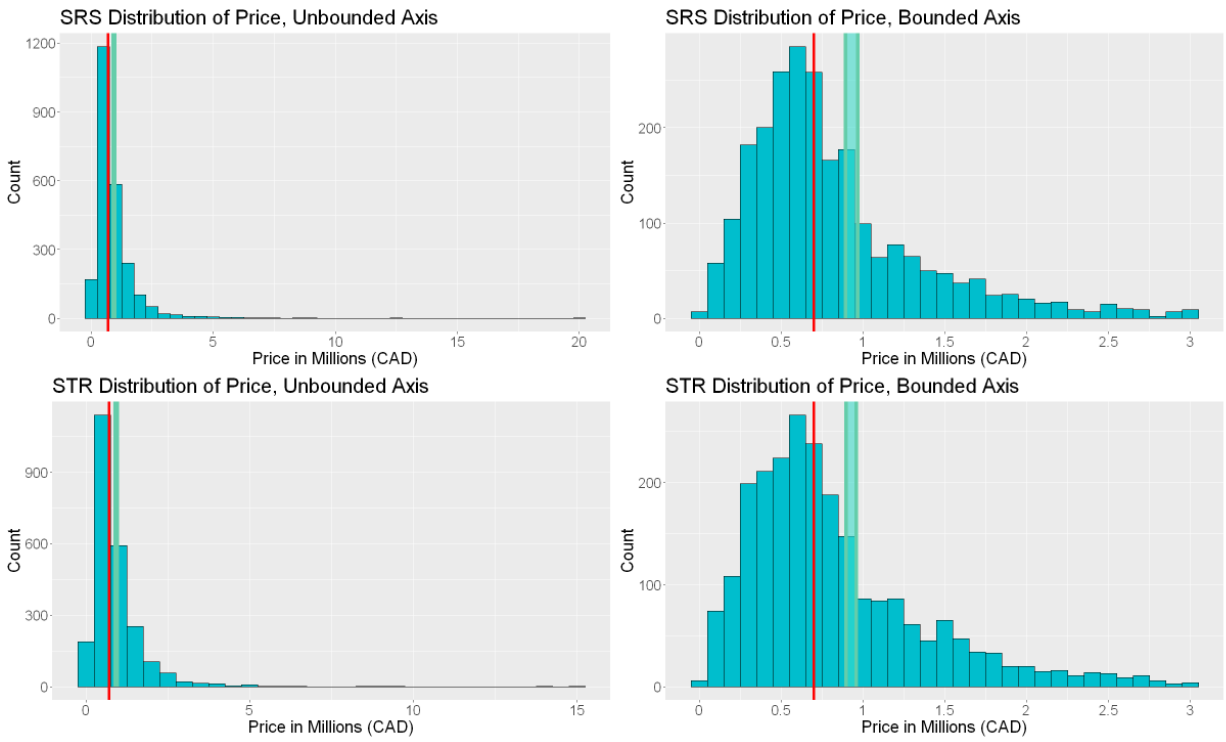
0.00859014915708563

```
#stratified confidence interval for the proportion of listings greater than $700,000
str.prop.lowerCI <- str.prop.est - 1.96 * str.prop.SE
str.prop.lowerCI
str.prop.upperCI <- str.prop.est + 1.96 * str.prop.SE
str.prop.upperCI
```

0.476386840476515

0.51006022517229

(A7) Histograms:



Figures 5-8. Histograms that show the distribution of listing prices in the samples in millions (CAD), a vertical red line that indicates the listing price of $700,000, and a shaded area representing the constructed 95% confidence intervals. The first two graphs show the distribution of listing prices in the simple random sampling; the latter two graphs show the distribution of listing prices in the stratified sample.

(A8) Individual Statistics for Vancouver and Toronto

```
#finding individual statistics for Vancouver and Toronto
YVR <- strata.info |>
filter(City == "Vancouver")
YYZ <- strata.info |>
filter(City == "Toronto")
YVR
YYZ
```

A data.frame: 1 × 8

City	priceAVG	priceSE	prop	N.h	N.prop.h	n.h	propSE
<chr>	<dbl>	<dbl>	<dbl>	<int>	<dbl>	<dbl>	<dbl>
Vancouver	1763509	129873	0.8426966	1328	0.03712816	89	0.0385931

A data.frame: 1 × 8

City	priceAVG	priceSE	prop	N.h	N.prop.h	n.h	propSE
<chr>	<dbl>	<dbl>	<dbl>	<int>	<dbl>	<dbl>	<dbl>
Toronto	1124805	87542.65	0.6627907	1276	0.03567435	86	0.0509787

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