FUNDAMENTAL STATISTICAL CONCEPTS

Analytics Primer

3 Main Pieces of Statistics

- Statistics and analytics in general boils down to three main pieces:
  1. Data Collection
  2. Data Analysis
  3. Inference

- Together these pieces summarize the data lifecycle from beginning to end.

3 Main Pieces of Statistics

- Statistics and analytics in general boils down to three main pieces:
  1. **Data Collection**
  2. Data Analysis
  3. Inference

- One of the most overlooked pieces, but the most important!
  - Bad data → Bad Results!

Populations vs. Samples

- **Population**
  - Set of all objects/individuals of interest
  - Usually too large to obtain information from entire population

- **Sample**
  - Subset of the population that information is actually obtained

Populations vs. Samples

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- **Sample**
  - Subset of the population that information is actually obtained
  - **Sampling frame** – actual list from which the sample is taken

Most of the time sampling frame = population

But this might not be the case.

Populations vs. Samples

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- **Sample**
  - Subset of the population that information is actually obtained
  - **Sampling frame** – actual list from which the sample is taken → MAY NOT EQUAL POPULATION

Parameters vs. Statistics

- **Parameter**
  - Measures computed from a population.

- **Statistic**
  - Measures computed from a sample.
  - Sample statistics is the **point estimate** of the population parameter.

Parameters vs. Statistics

Population	Sample
Parameter	Statistic

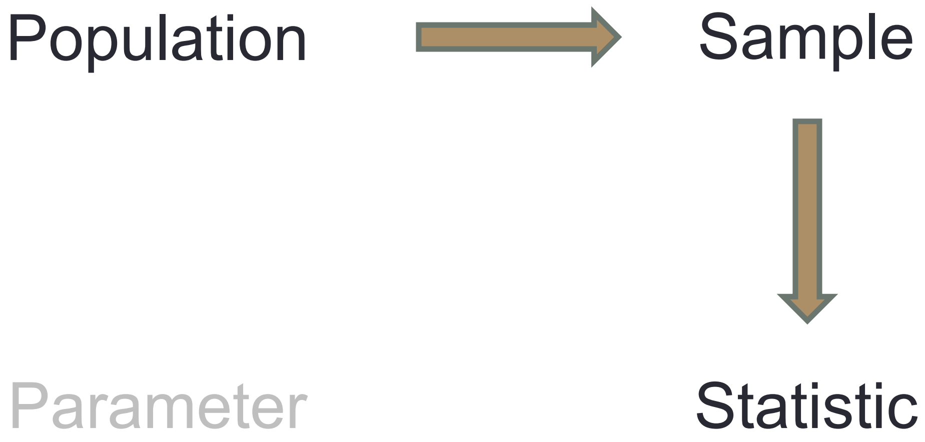
Parameters vs. Statistics

Population → Sample

Parameter

Statistic

Parameters vs. Statistics



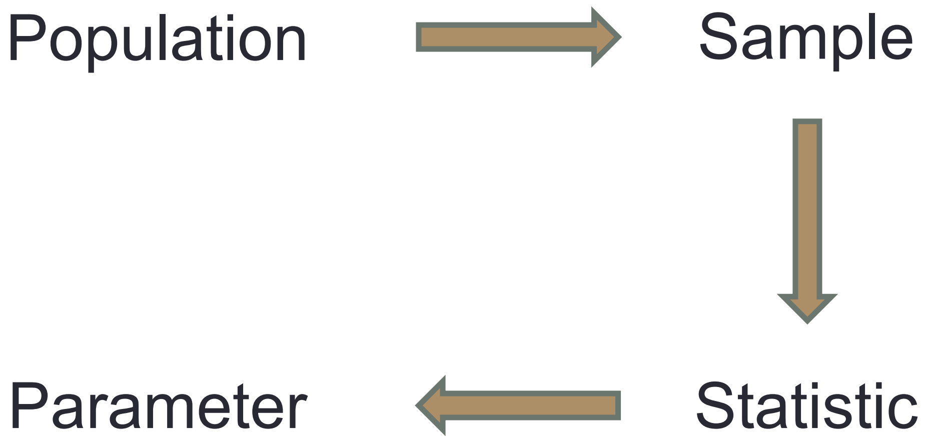
Population

Sample

Parameter

Statistic

Parameters vs. Statistics



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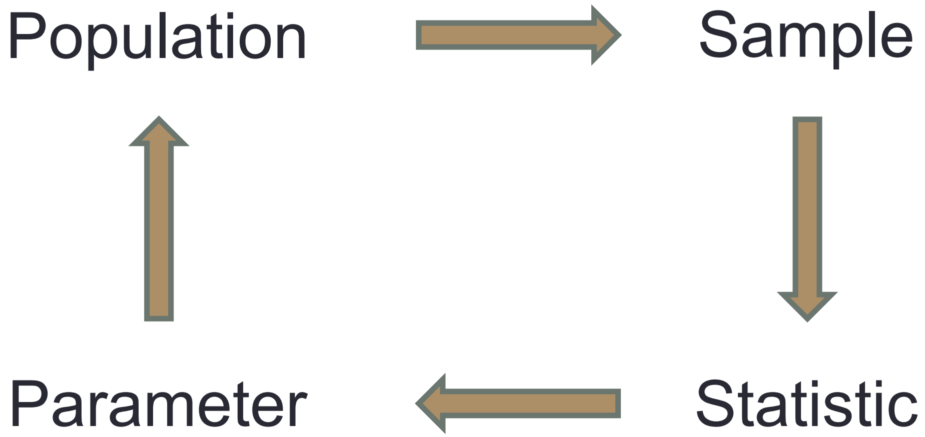

Population

Sample

Statistic

Parameter

Example

- A retail chain is trying to determine if a new product they introduced is selling well across their stores. The retail chain has 2135 stores nationwide. The analyst in charge of this project is tasked to estimate the average daily sales of this new product across all stores. Older computing technology forces the company to randomly pick 179 stores spread evenly throughout the nation to calculate gather data from. The average daily sales from these 179 stores is $129.19.

- Identify population, sample, parameter, statistic.
- Any sampling frame issues? No, because population and sample frame appear to be the same.

Example

- A retail chain is trying to determine if a new product they introduced is selling well across their stores. The retail chain has **2135 stores nationwide**. The analyst in charge of this project is tasked to estimate the average daily sales of this new product across all stores. Older computing technology forces the company to randomly pick 179 stores spread evenly throughout the nation to calculate gather data from. The average daily sales from these 179 stores is $129.19.

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- Any sampling frame issues?

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- Identify population, sample, **parameter**, statistic.
- Any sampling frame issues?

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- Identify population, sample, parameter, **statistic**.
- Any sampling frame issues?

Example

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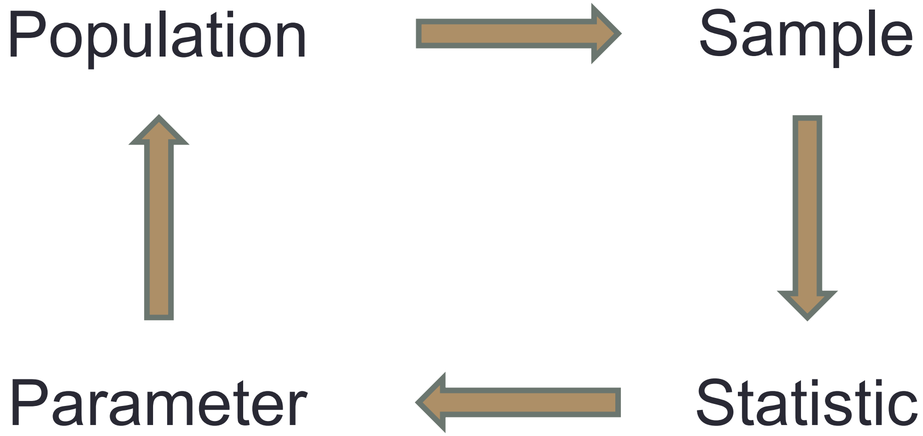
- Identify population, sample, parameter, statistic.
- Any sampling frame issues? **NO**

SAMPLING TECHNIQUES

Parameters vs. Statistics



Population

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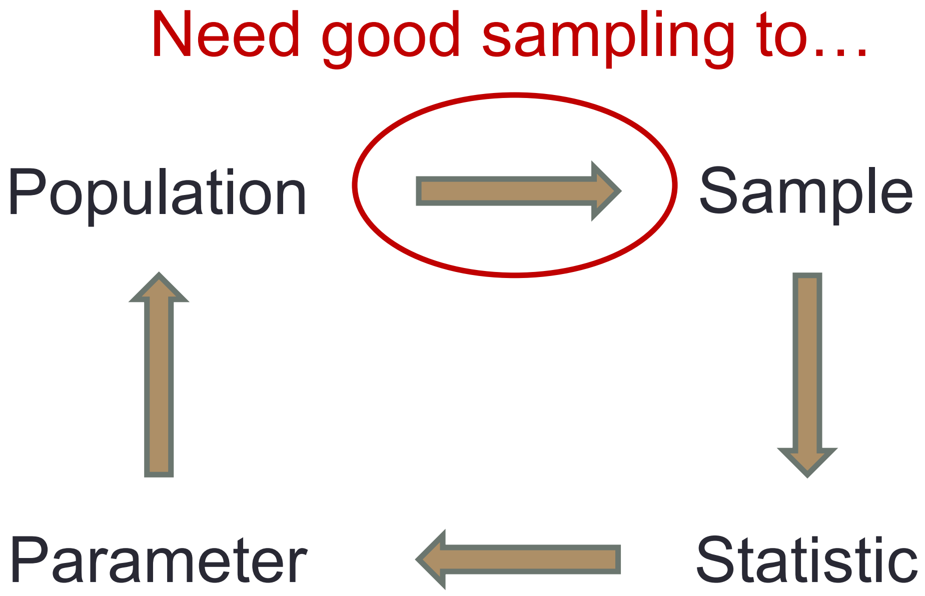
Parameters vs. Statistics



Need good sampling to…

Population

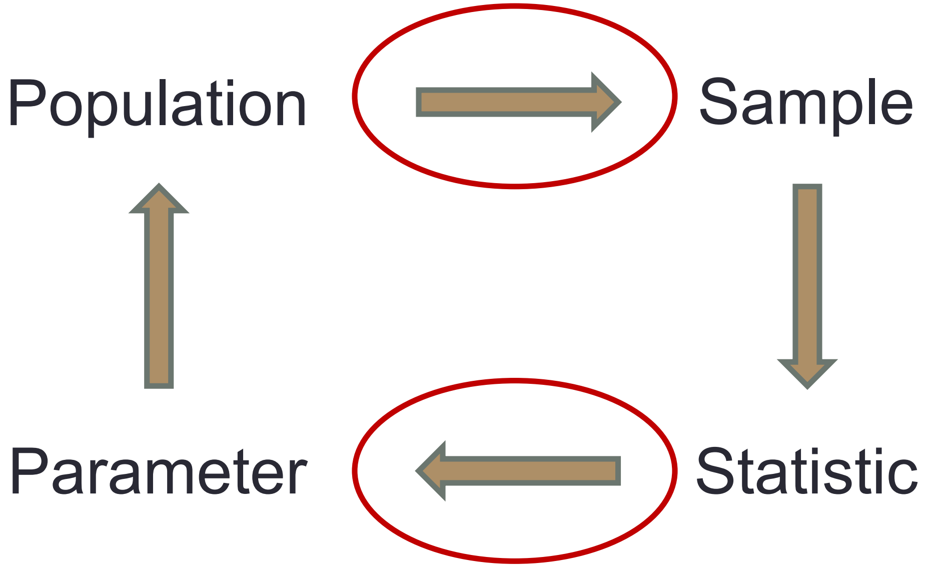
Sample

Statistic

Parameter

Parameters vs. Statistics

Need good sampling to…



…have good estimates.

Sampling

- There are many different ways to sample data from population.
- Mistakes in sampling can lead to bias in the sample.

- **Bias** – certain outcomes are favored over other outcomes in samples.

Types of Bias

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- 2 Common Types of Bias:
  1. Selection Bias
  2. Sampling Bias

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- 2 Common Types of Bias:
  1. Selection Bias
     a) **Undercoverage** – frame and population are not equal (ex. Phone book)
     b) **Nonresponse** – subject in sample cannot / will not respond or be measured (ex. Telemarketer)
  2. Sampling Bias

People who respond to telemarketers might have different demographic or socio-economic background than people who no respond.

Types of Bias

- **Bias** – certain outcomes are favored over other outcomes in samples.
- 2 Common Types of Bias:

1. Selection Bias

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Inference doesn't represent population!

2. Sampling Bias

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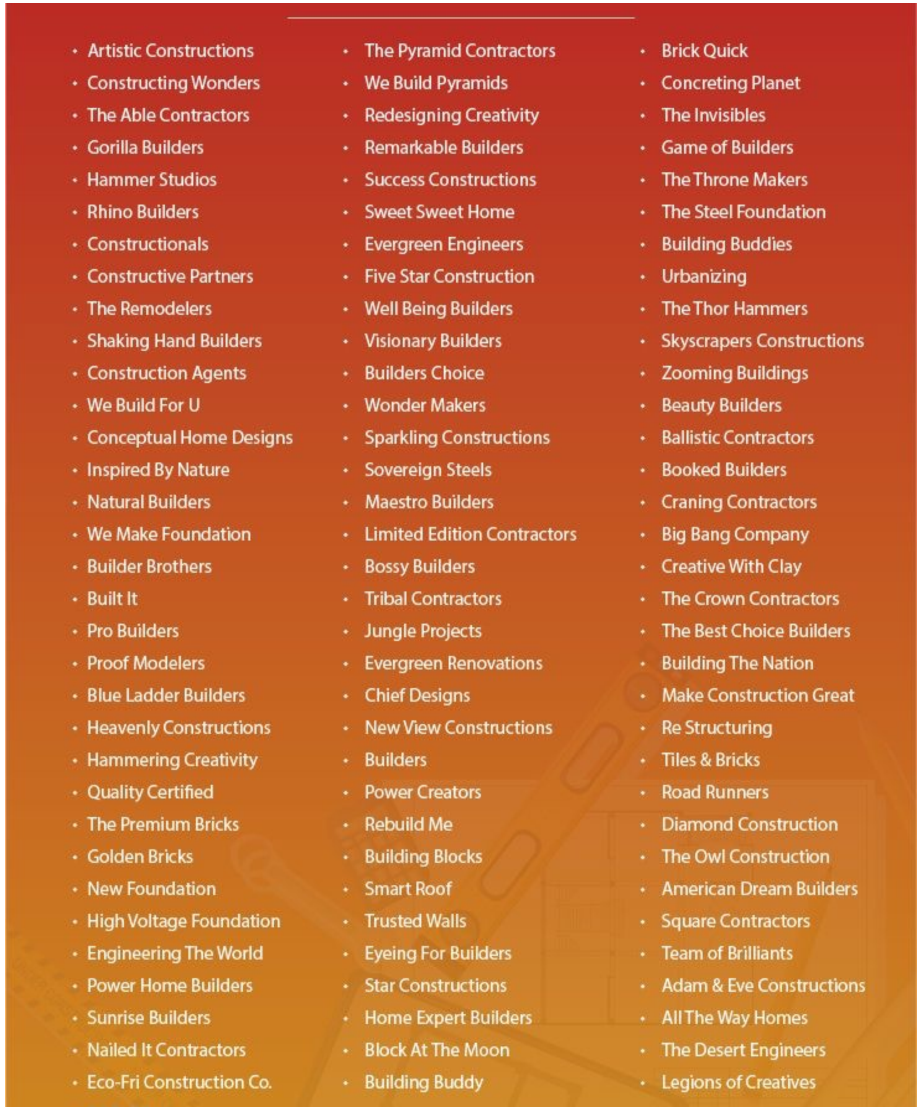
- **Bias** – certain outcomes are favored over other outcomes in samples.
- 2 Common Types of Bias:
  1. Selection Bias
  2. Sampling Bias
     a) **Convenience sampling** – technique that selects subjects from population based on accessibility and ease.
     b) **Voluntary sampling** – technique where subjects volunteer themselves to sample.

People who voluntarily respond might be different to those who don't respond. Similar to non-response

Statistical Techniques

- Statistical sampling techniques use selection methods based on chance selection instead of convenience or judgement.
- 4 Common Techniques:
    1. Simple Random Sampling (SRS)
    2. Stratified Random Sampling
    3. Cluster Sampling
    4. Systematic Sampling

Simple Random Sampling (SRS)



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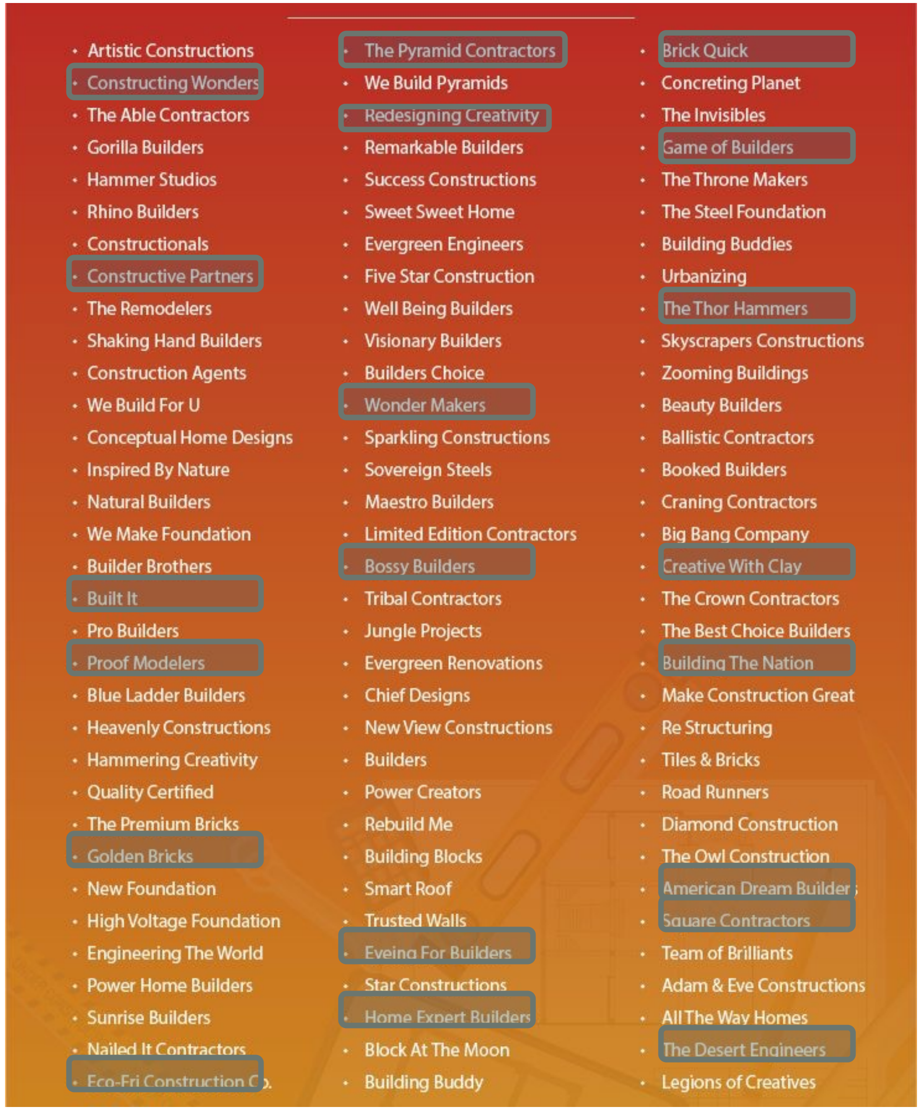
A method of sampling items from a population such that every possible sample of a specified size has an equal chance of being selected.

Simple Random Sampling (SRS)



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Simple Random Sampling (SRS)

A method of sampling items from a population such that every possible sample of a specified size has an equal chance of being selected.

Advantages: No statistical bias, no previous information about sample needed ahead of time

We cannot guarantee that the sample will be representative.

But statistically, there is no bias.

Good for small, condensed populations.

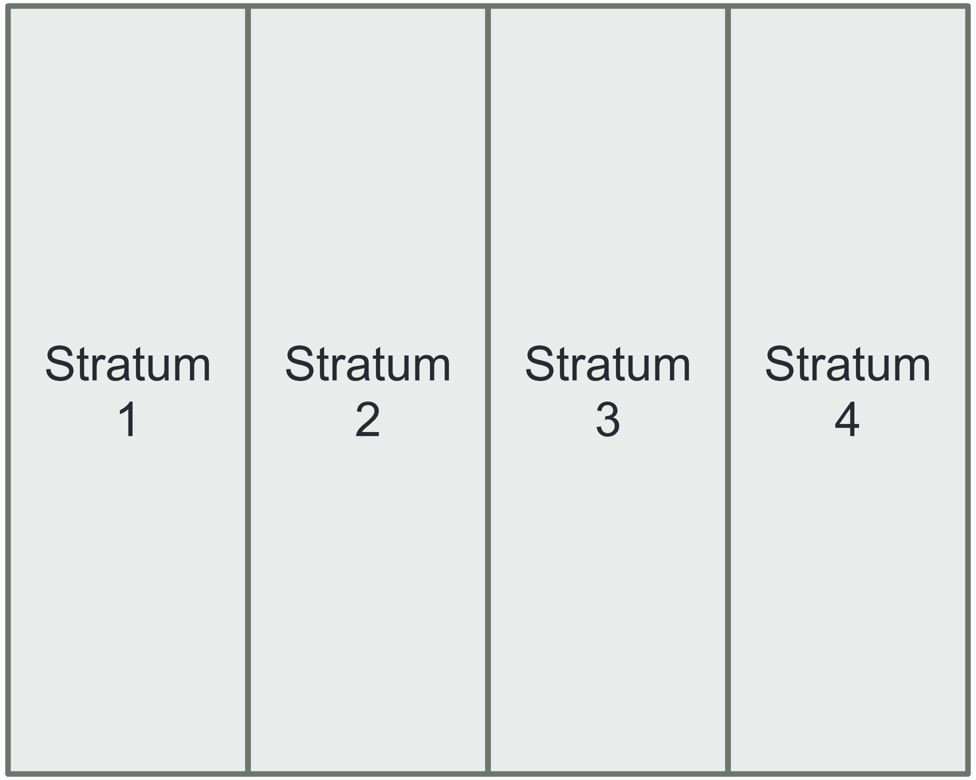
Disadvantages: Expensive, time consuming, hard to implement, need list of population

A large sample will be needed to get a representative sample.

Stratified Random Sampling (STS)

Strata: pre-determined groups.
Every strata becomes a small sample.

A method of sampling items where the population is divided *a priori* into subgroups, called **strata**, so that each member in the population belongs to only one strata. Sample items from **every** strata (with SRS for example).



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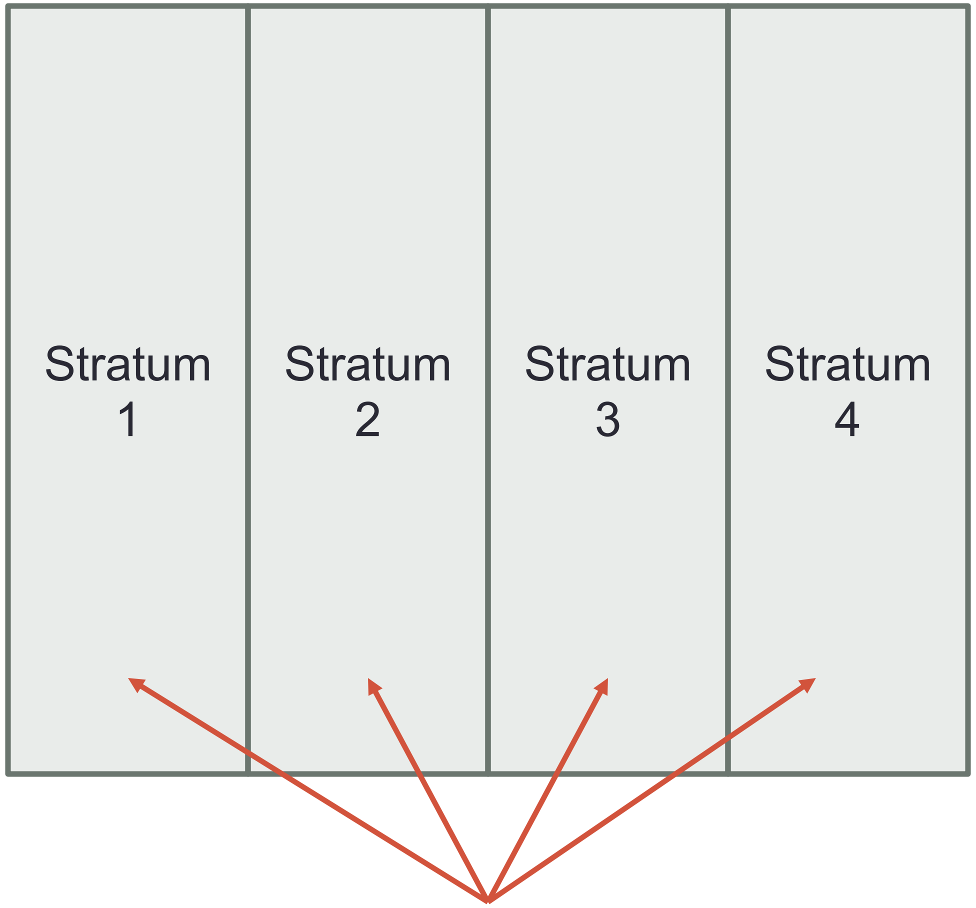

Take random sample from each!

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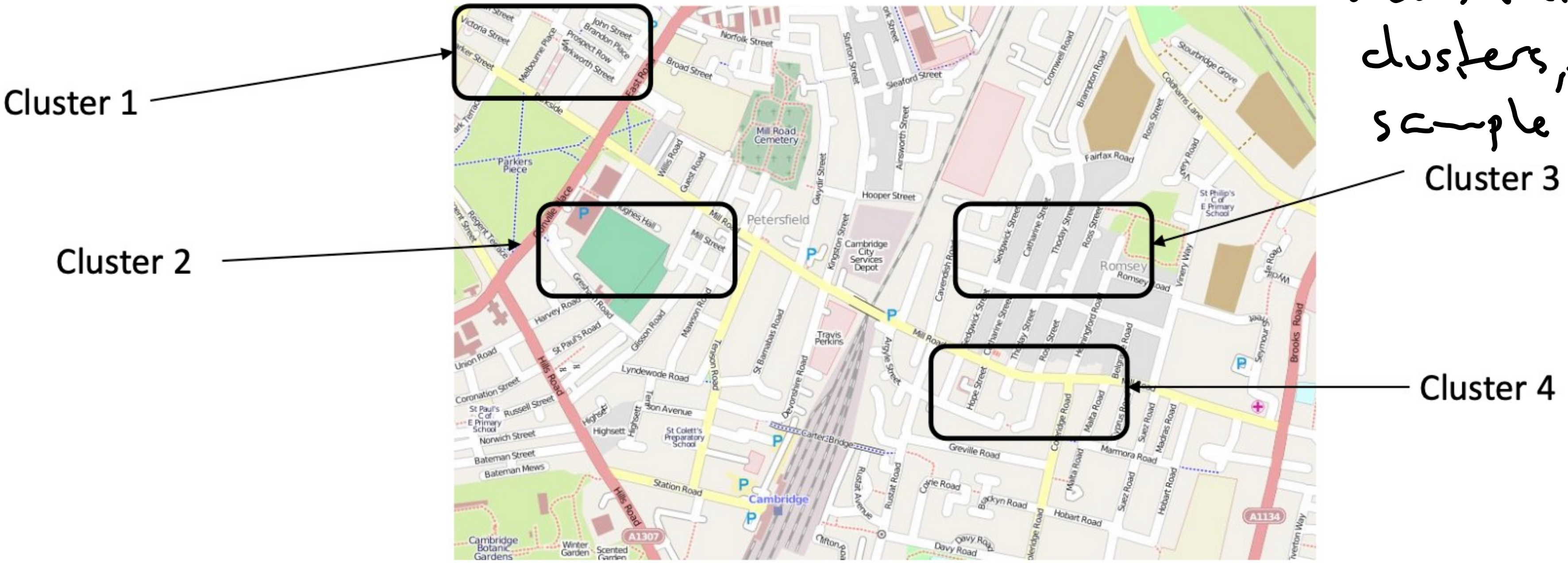
Advantages: Smaller sample sizes can achieve same accuracy as SRS, more information about parts of population

Disadvantages: Need information about population ahead of time to split on!

Cluster Sampling

A method of sampling items where the population is divided *a priori* into subgroups, called **clusters**, so that each member in the population belongs to only one cluster. Sample items from **a sample** of *m* clusters selected randomly.



Won't talk to all clusters, just a sample of them.

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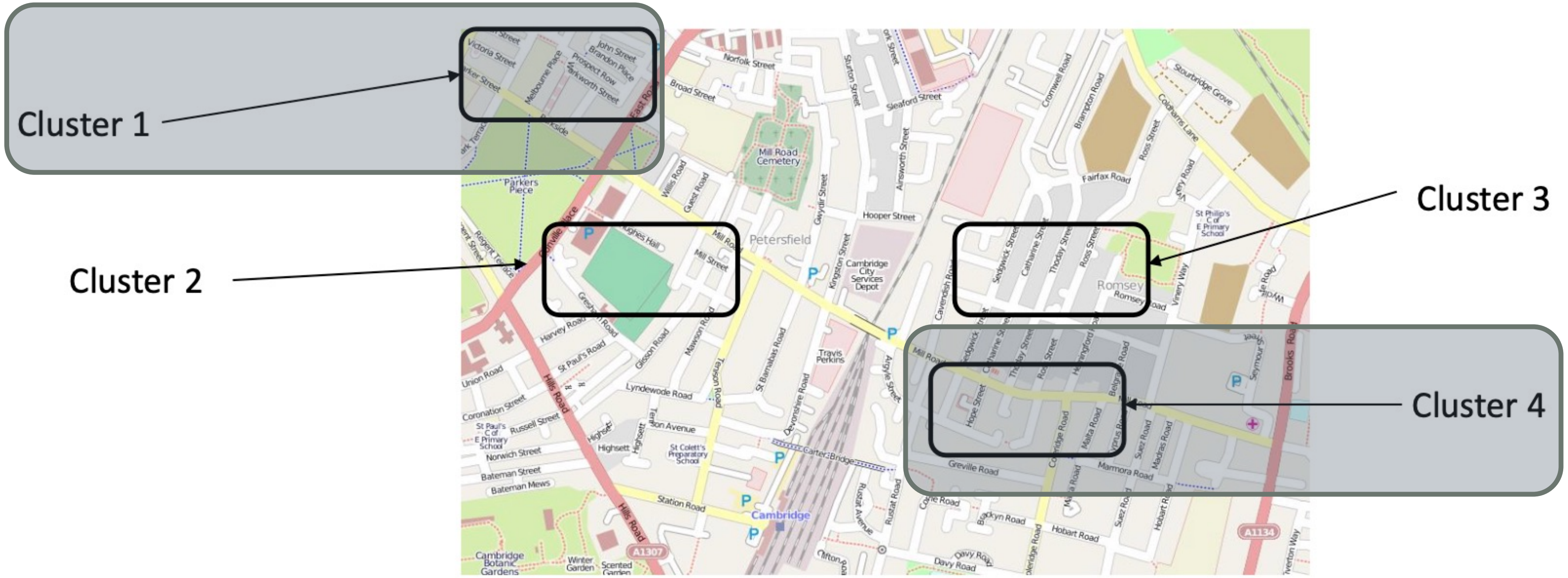

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Advantages: Overcome issues with travel, time, and expense; Easier to implement than SRS or STS

Disadvantages: Need information about population ahead of time to split on – but not total list!; May have slight bias if random clusters aren't representative

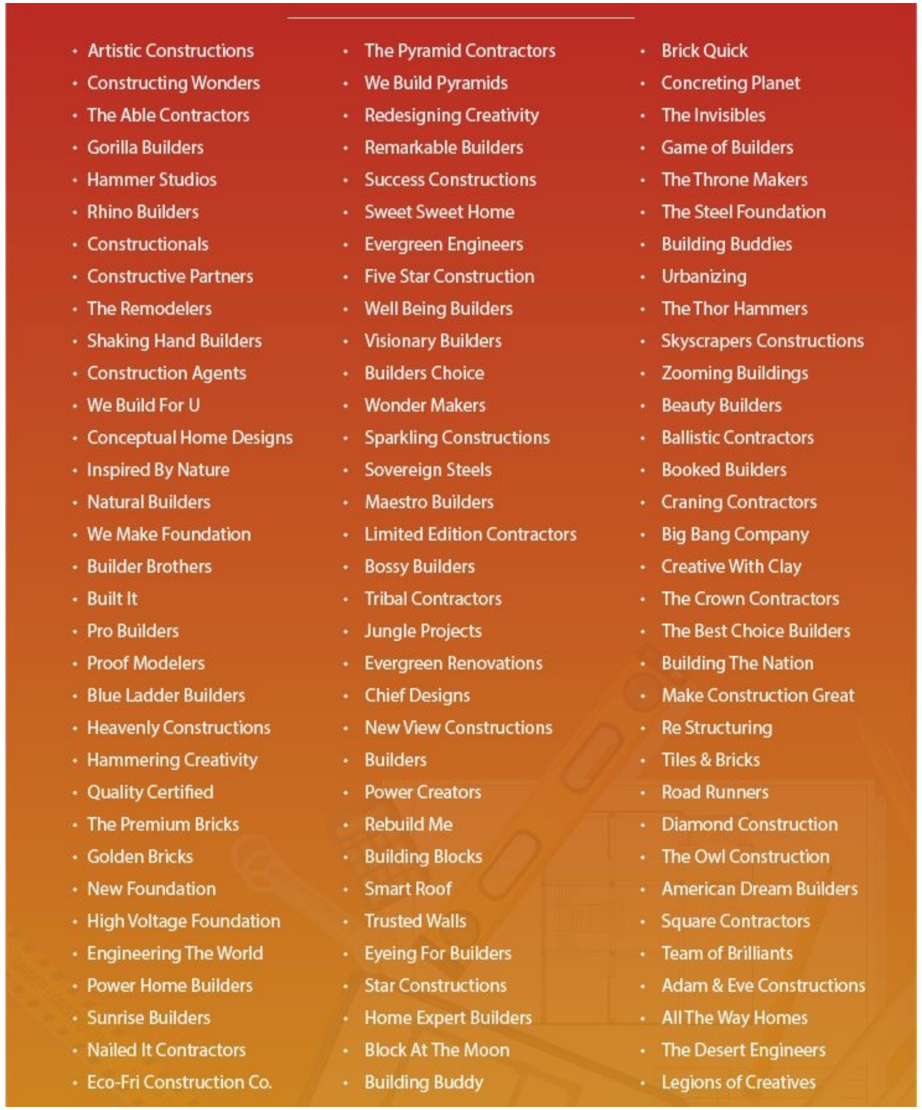
Systematic Sampling

A method of sampling items that involves selecting every k^{th} item in the population after randomly selecting a starting point between 1 and k. The value k is determined as the ratio of the population size over the desired sample size.

Advantages: Very easy to get sample

Disadvantages: May be biased, especially if order of list of population matters

Systematic Sampling



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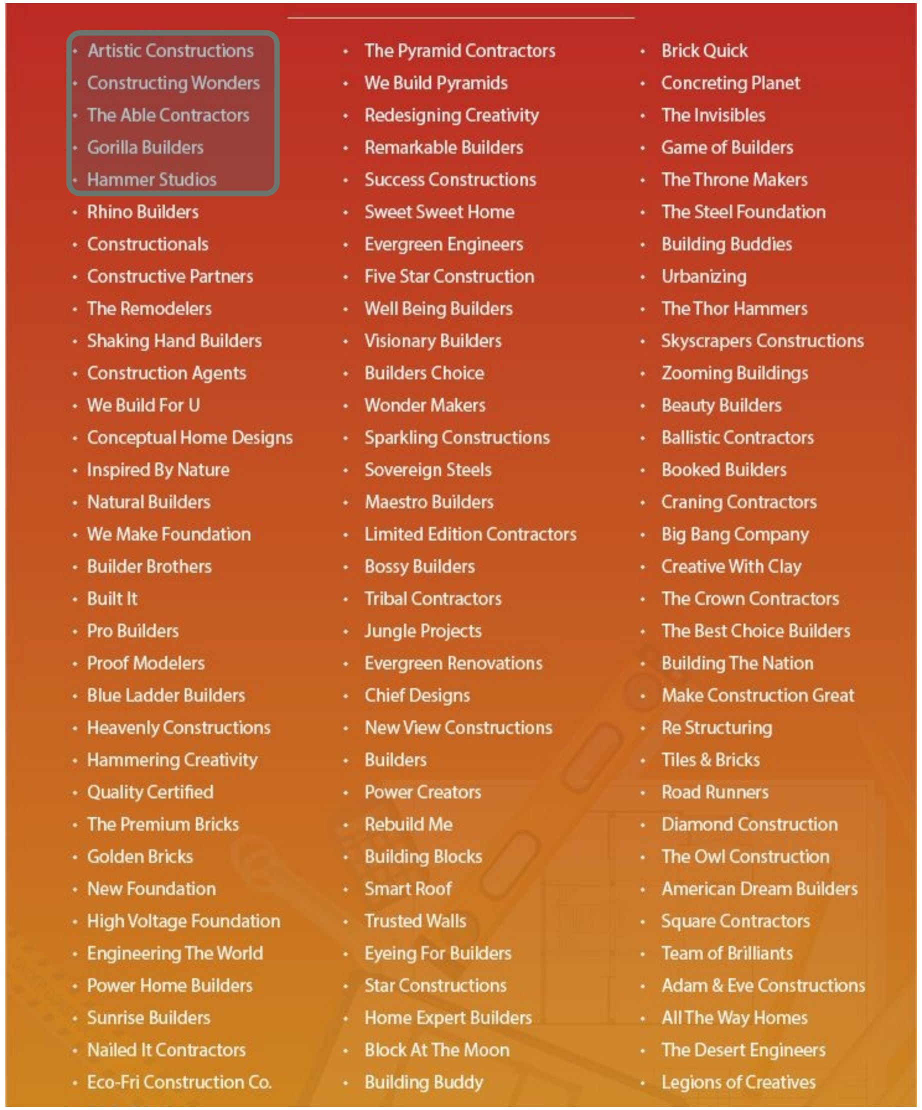
Within a group of let's say 6 people. Select randomly one person in that group (say the 3rd). Systematically, select every 5th person after that.

A method of sampling items that involves selecting every k^{th} item in the population after randomly selecting a starting point between 1 and k. The value k is determined as the ratio of the population size over the desired sample size.

Bias could arise if the order in the list matters.

↓

Systematic Sampling



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Example: select the same room in each floor. → sample might not be representative.

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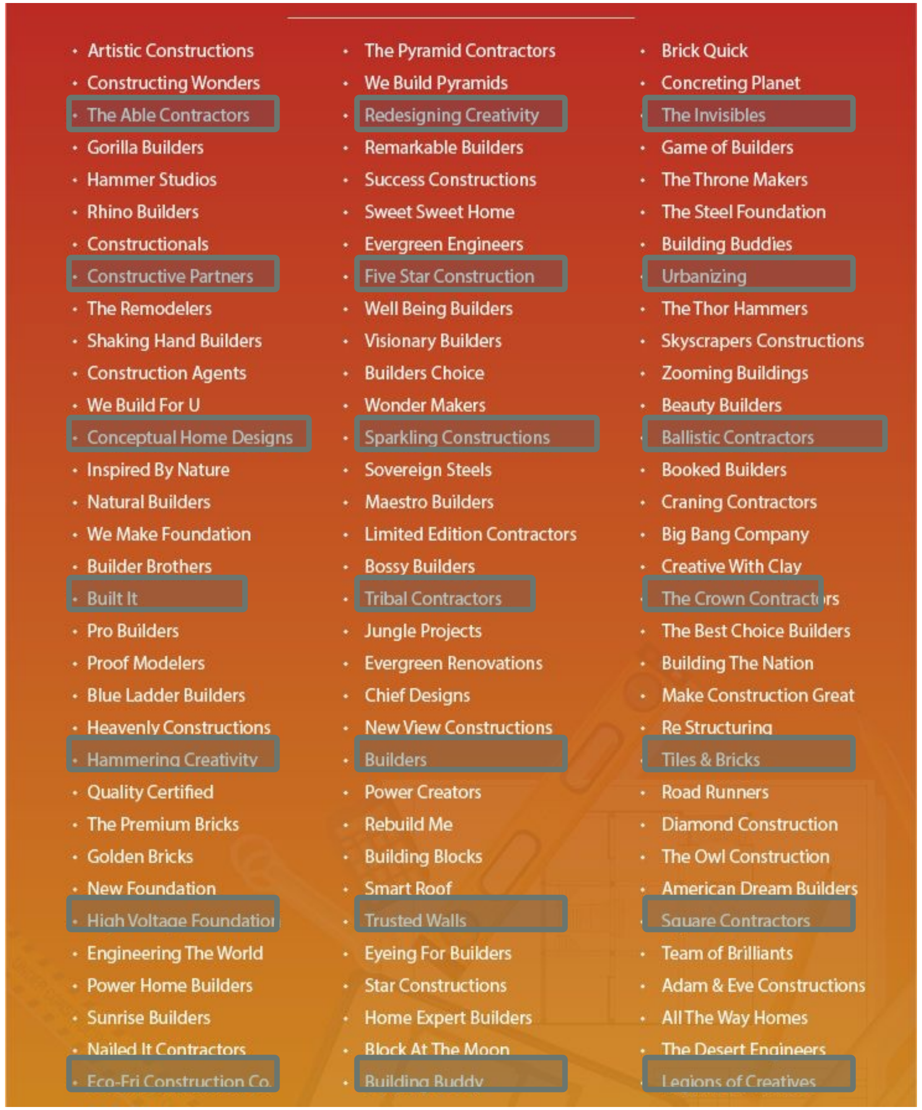
Systematic Sampling



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Advantages: Very easy to get sample

Disadvantages: May be biased, especially if order of list of population matters

Example

- A large worldwide financial company wants to develop a new retirement plan for the company. They want to survey different managers of branches around the world to find out the most important strategies the new retirement plan should contain. They have 5000 branches worldwide and want to personally interview these branch managers. They have information about the branch size (small, medium, large), and the state/province location of the branch. They want to talk to 50 branch managers.

- Develop four separate strategies to sample these branch managers based on the four different statistical sampling techniques discussed previously.

Example

- Develop four separate strategies to sample these branch managers based on the four different statistical sampling techniques discussed previously.
  1. SRS – Randomly sample 50 branches to interview their managers
  2. STS – Stratify by size and select SRS from each
  3. Cluster – Randomly select sample of states/provinces, then select branches at random from those states/provinces
  4. Systematic – Select every 100th branch in list of branches

TYPES OF DATA

4 Types of Data

- There are four main types of data people typically deal with in data analysis.
- These four types are split into two groups
  1. Qualitative vs. Quantitative
  2. Time Series vs. Cross-sectional

Quantitative vs. Qualitative

quantitative can become qualitative, but not the other way around.

- **Quantitative**:
  - Data that are numeric that define value or quantity.
  - Easy check → Must be able to do basic arithmetic and have it make sense.

basic arithmetic with the data : height, weight, profit

No : zipcodes, SSN because we cannot take avg from zipcodes and have something meaningful.

- **Qualitative**:
  - Data whose measurement scale is inherently categorical.
  - **Nominal** – categories with no logical ordering
  - **Ordinal** – categories with a logical order / only two ways to order the categories (binary IS ordinal)

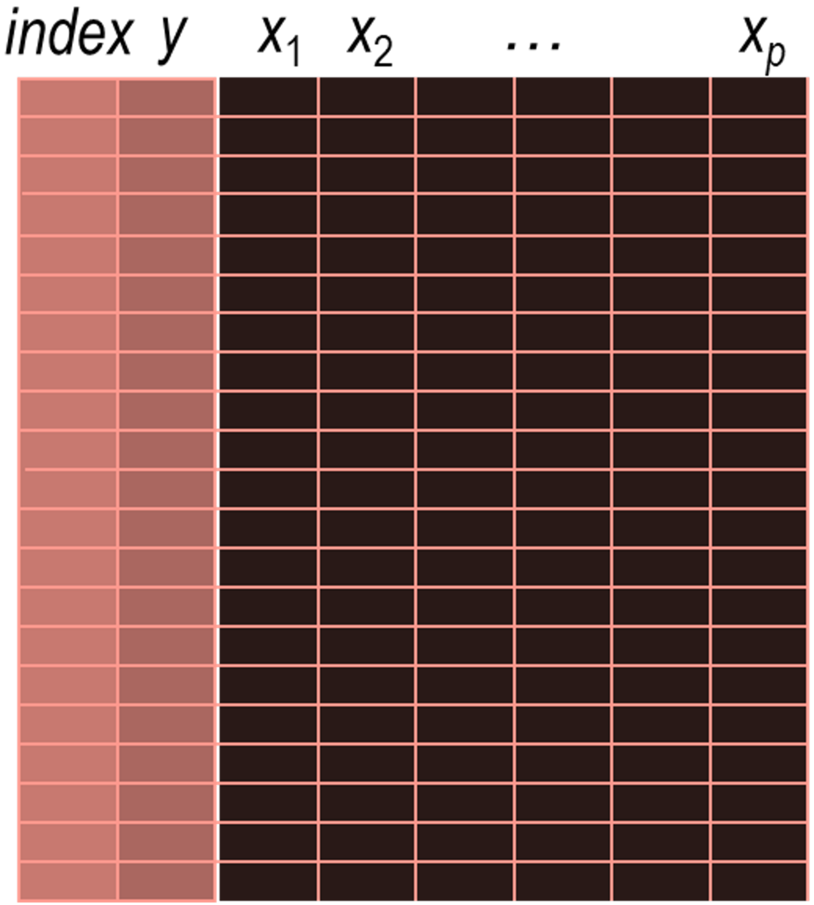
All binary variables are ordinal, because there are just 2 ways of writing them.

Time Series vs. Cross-sectional

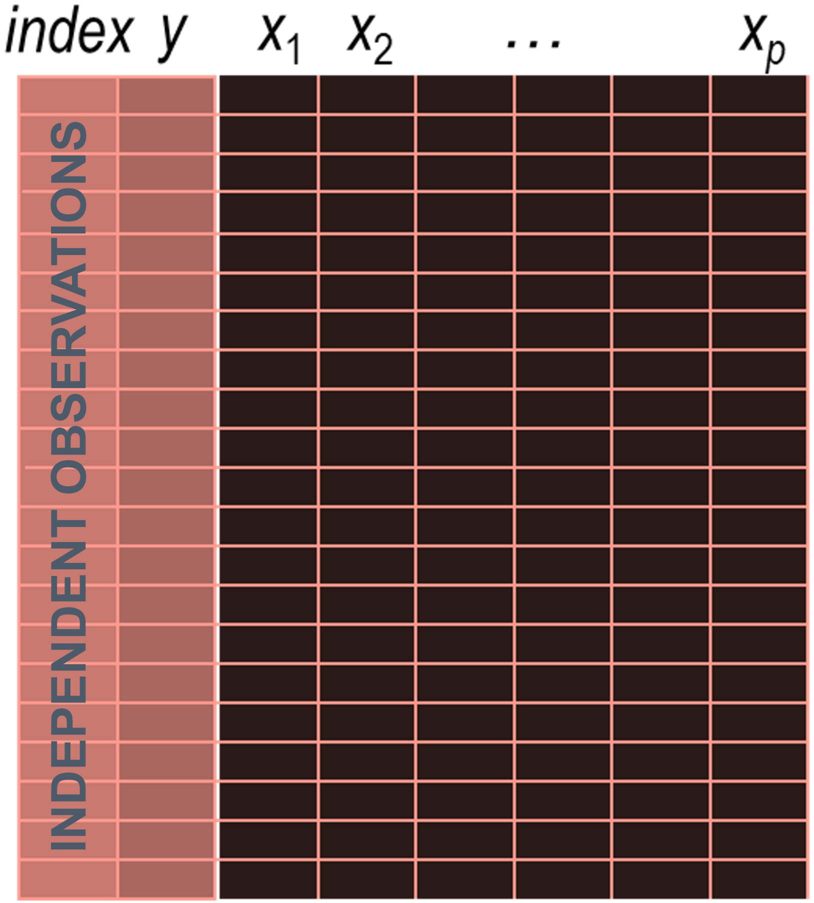
- **Time Series**:
  - Set of ordered data values observed at successive points in time.

- **Cross-sectional**:
  - Set of data values observed at a fixed point in time, or where time is of no significance.

Cross-sectional

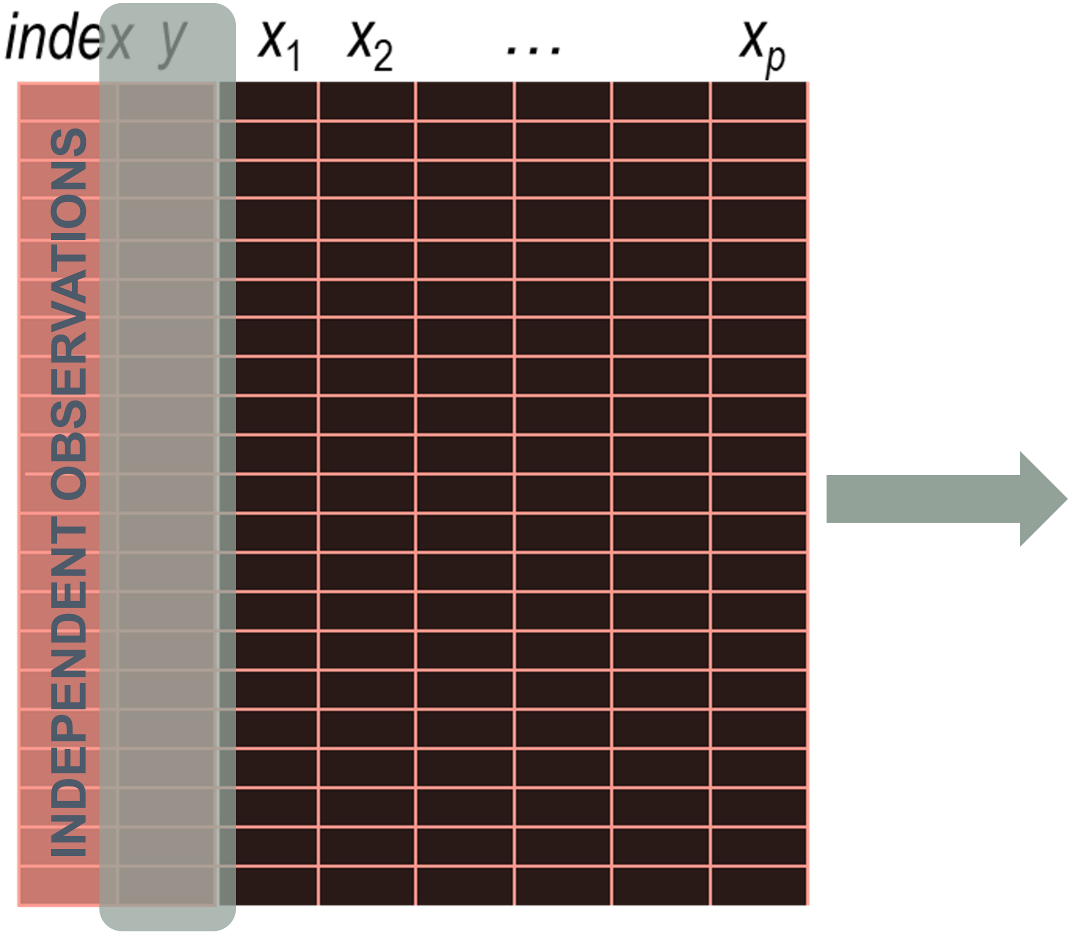


Cross-sectional

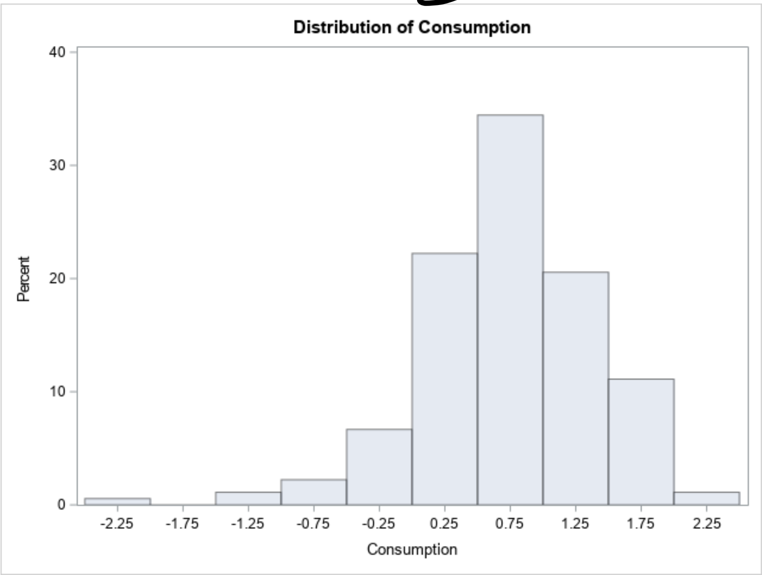


$\nexists$ dependency among raws.

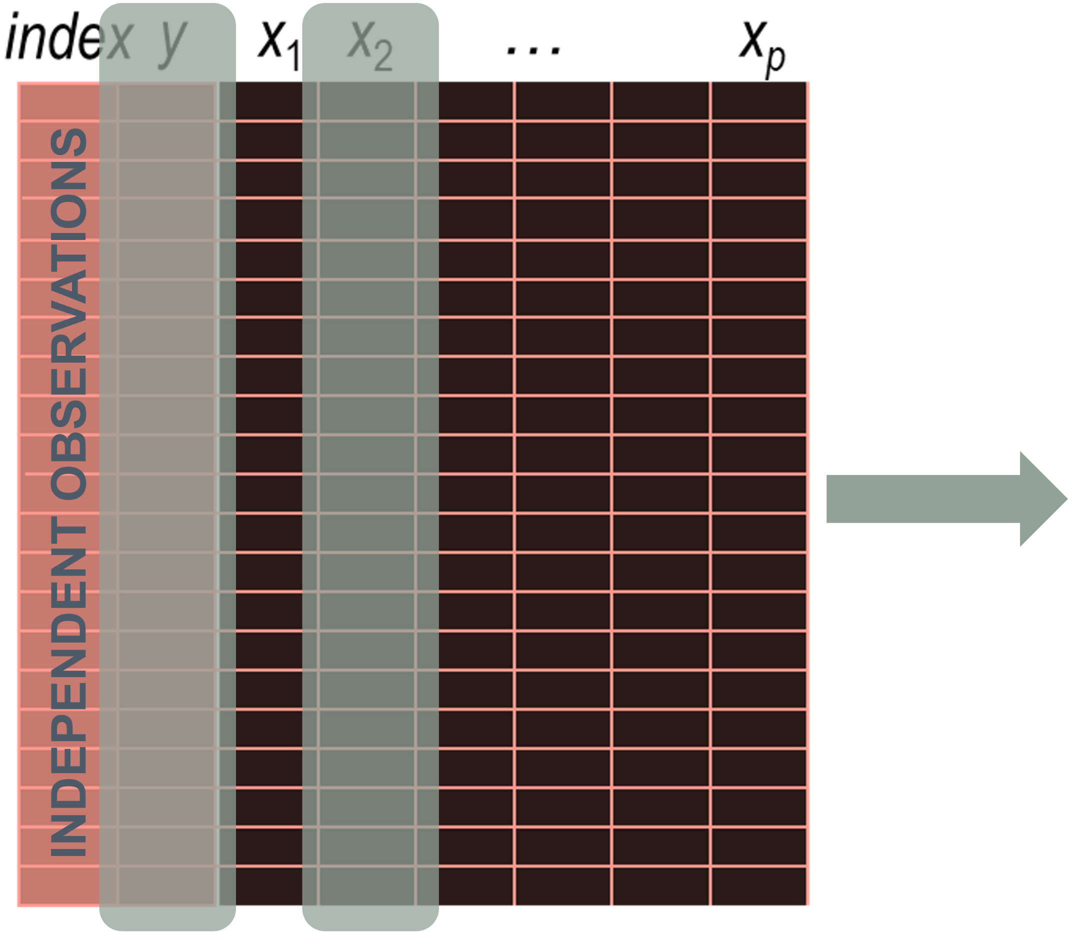
Cross-sectional



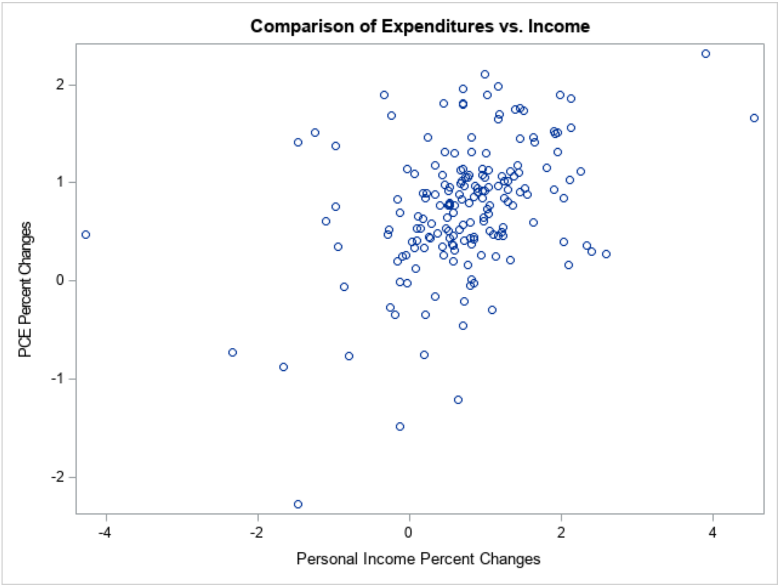
Histogram



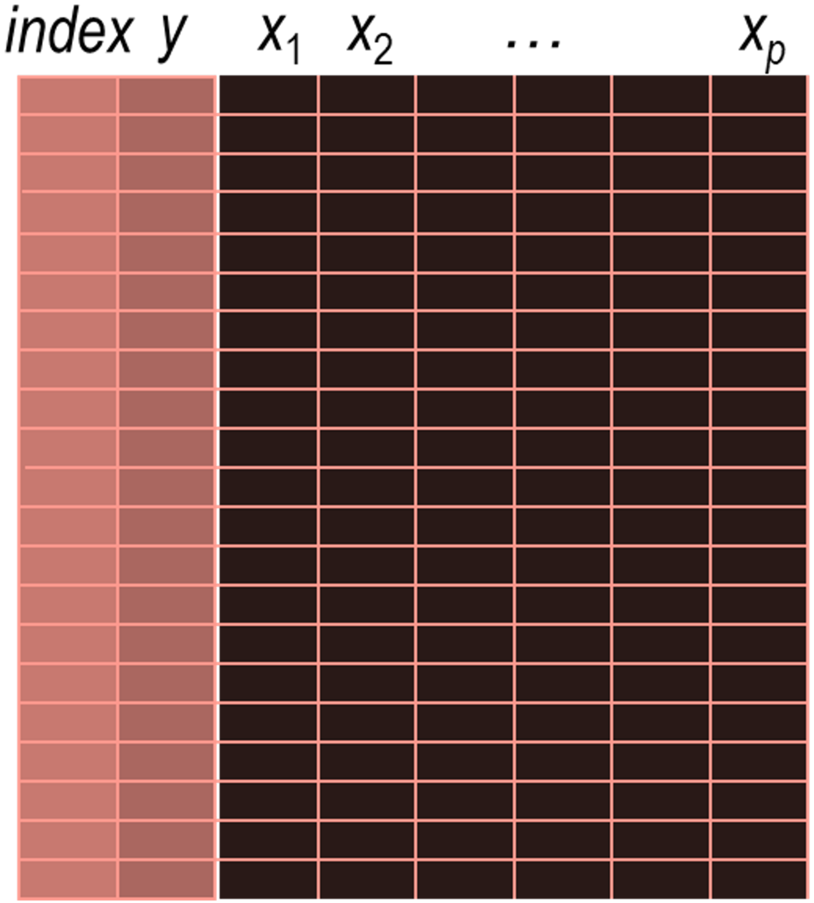
Cross-sectional



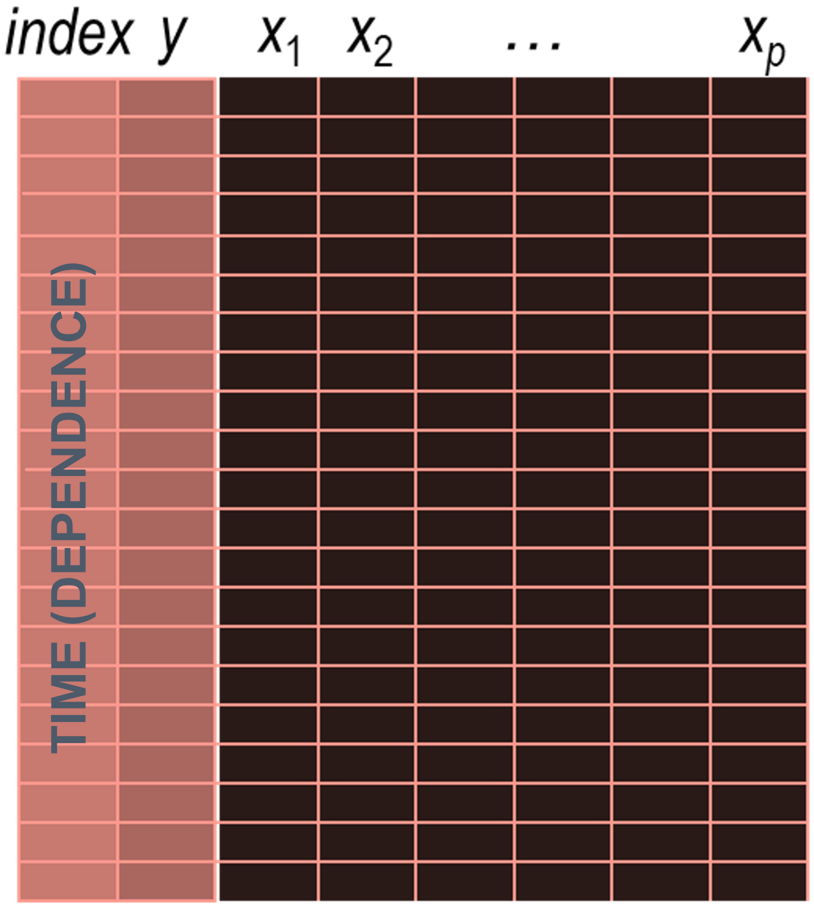
Scatter Plot



Time Series

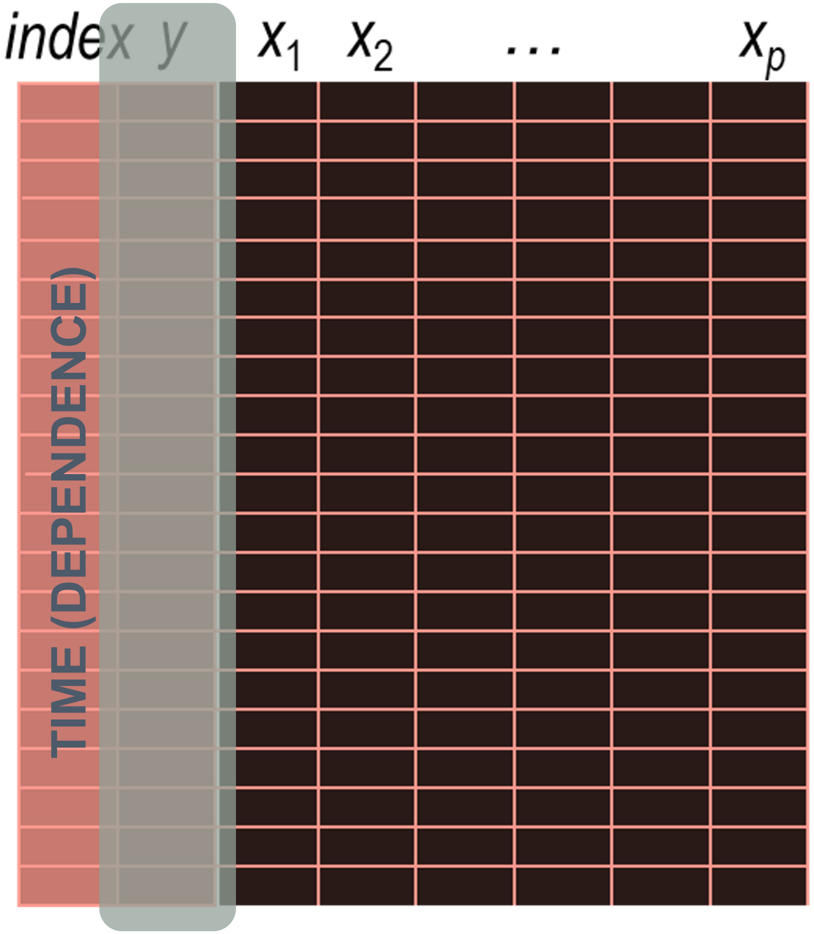


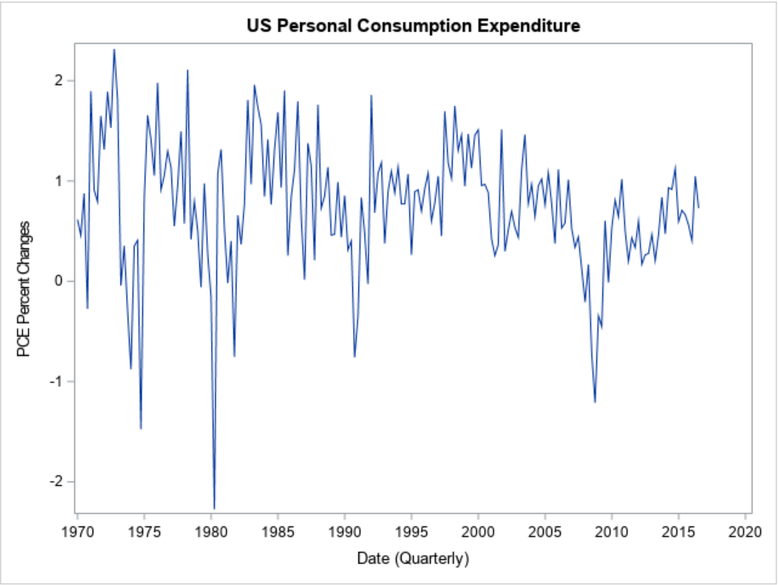
Time Series



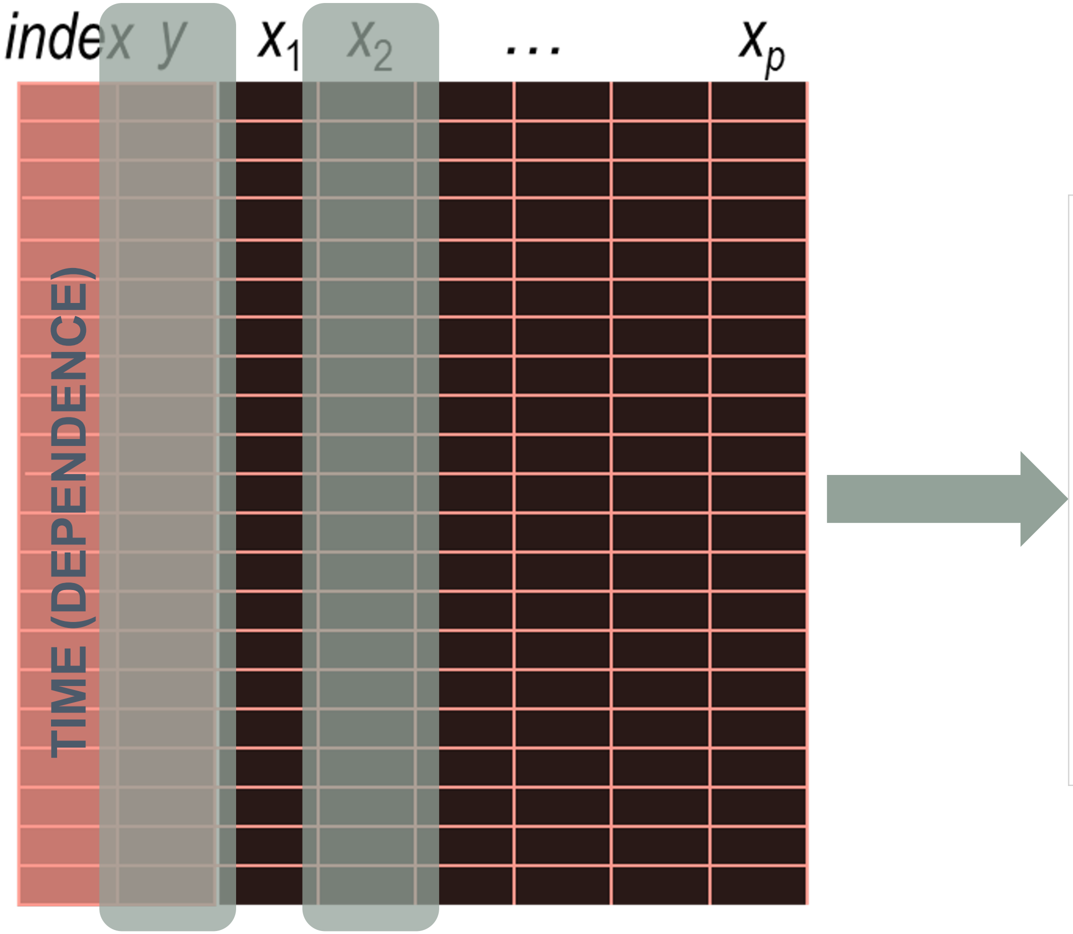
$\exists$ dependency among rows.

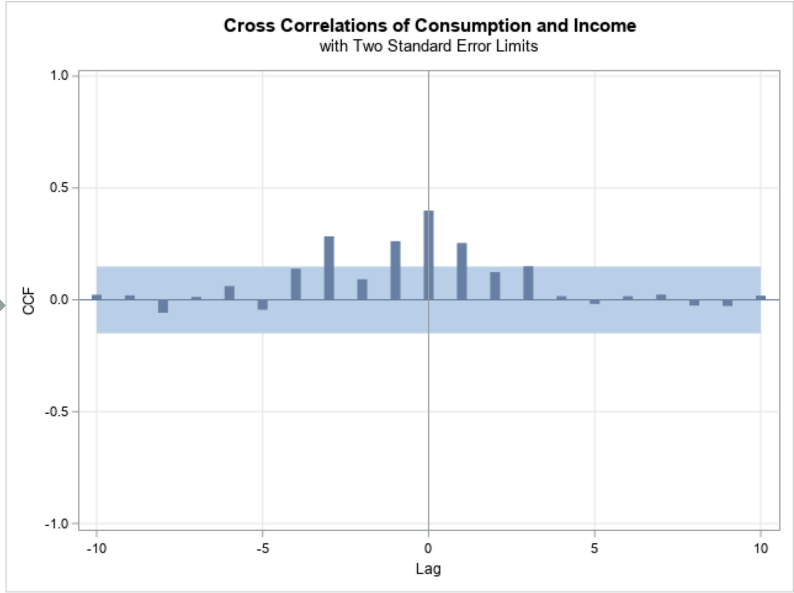
Time Series


index
y
x_1
x_2
. . .
x_p
TIME (DEPENDENCE)


US Personal Consumption Expenditure
PCE Percent Changes
2
1
0
-1
-2
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Date (Quarterly)

Time Series


index
y
x1
x2
. . .
xp
TIME (DEPENDENCE)


Cross Correlations of Consumption and Income
with Two Standard Error Limits
CCF
1.0
0.5
0.0
-0.5
-1.0
-10
-5
0
5
10
Lag