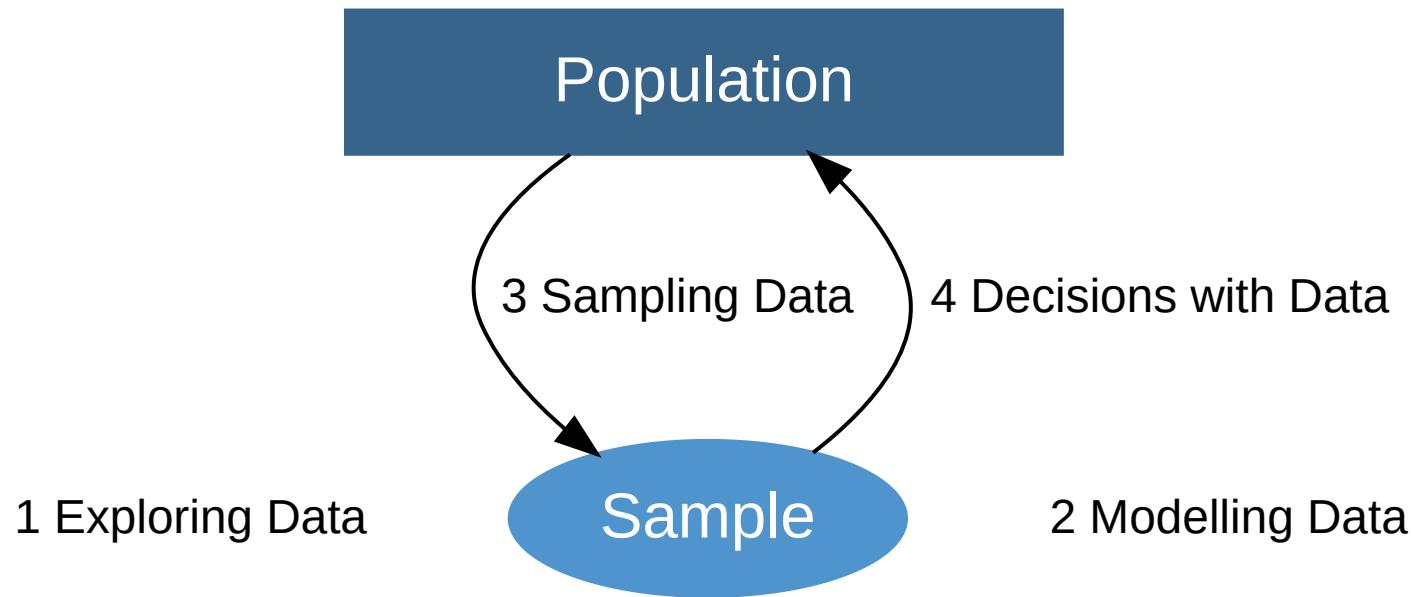


Measurement Error

Modelling data | Normal Model

Unit Overview





Module2 Modelling Data

Normal Model

What is the Normal Curve? How can we use it to model data?

Linear Model

How can we describe the relationship between 2 variables? When is a linear model appropriate?



Measurement Error

Data Story | Is Coles overcharging me?

Measurement Error

Chance Error

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Summary

Data Story

Is Coles overcharging me?



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Thousands of food products found to be underweight by the measurement authority



Esther Han

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Birthday sponge cakes sold at Woolworths and lamb chops prepared at Coles were among thousands of products found to be weighing less than what was promised on packaging, according to the National Measurement Institute.

In 2014–15, Australia's peak weights and measures body issued 3962 non-compliance notices to traders, up 13 per cent on the previous year's figure. It sent 139 warning letters and imposed 98 fines totalling \$92,650.



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Overcharging in Australia

- In 2014-15, Australia's peak weights and measures body issued 3962 non-compliance notices to traders, up 13 per cent on the previous year's figure. It sent 139 warning letters and imposed 98 fines totalling \$92,650.
- Nearly half of the breaches related to underweight or incorrectly labelled packaged products.
- Woolworths was found guilty and fined \$3000 for selling birthday mock cream sponge cakes, made and packed in-store, with shortfalls of up to 41 per cent.
- Coles was found guilty and hit with a \$3000 fine for using a weighing instrument not at zero that led to shortfalls of up to 9.4 per cent in prepacked lamb chops.
- Coles responded, “The issue, which resulted from a piece of fresh meat sticking to an automatic cutting and weighing machine between slices, was quickly corrected and no wrongly labelled items were sold to customers ... Coles takes its trade measurement responsibilities very seriously and has robust operational and compliance systems in place in every one of its stores right around Australia.”



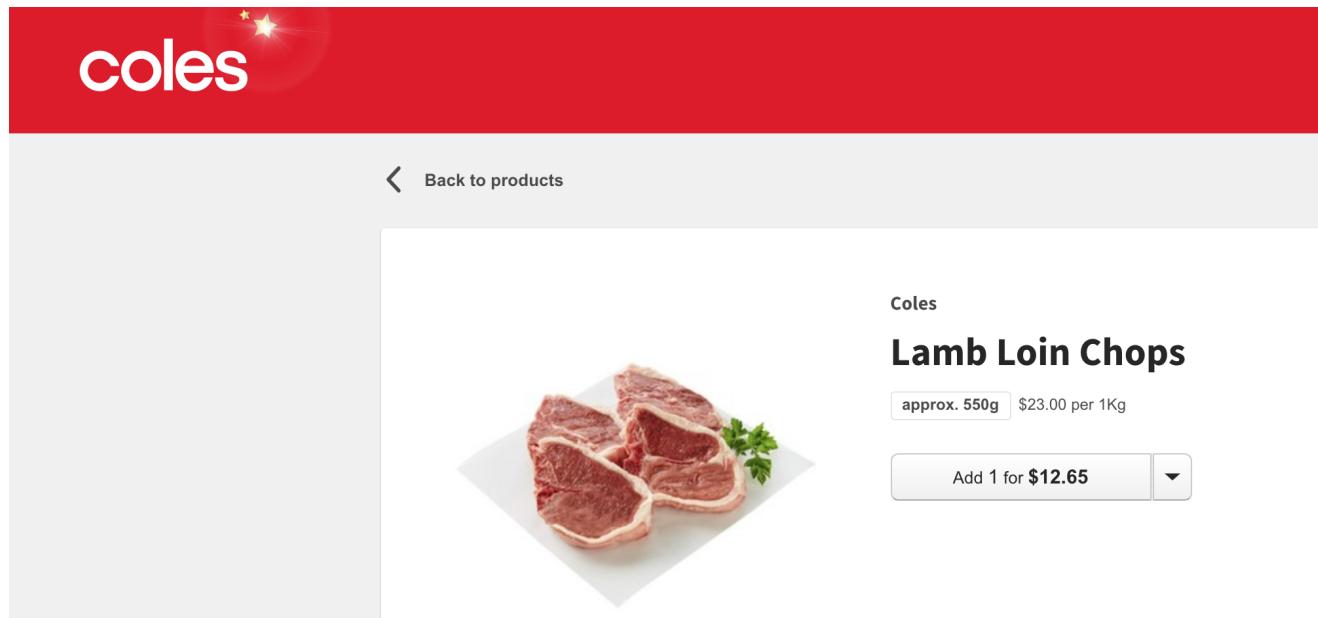
Statistical Thinking

Assume you are buying a tray of lamb chops at Coles.

- How is the price determined?
- If you weighed the tray twice, should you expect to get the same weight?
- How could Coles be over or under charging you?

Data

Here we simulate the weight of 20 trays of lamb chops from Coles, using pricing from 22/11/17.



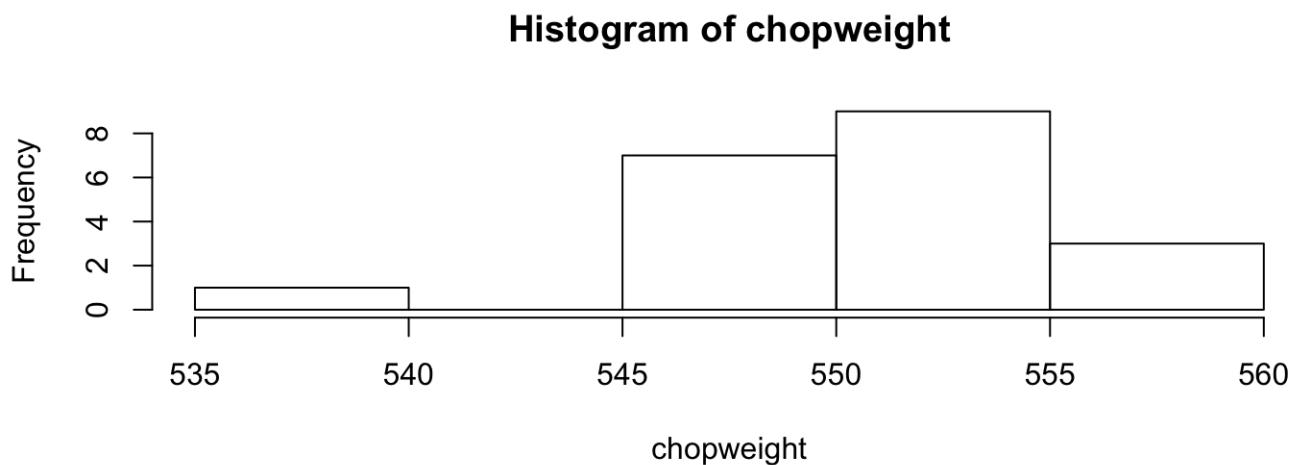
```
set.seed(1)  
chopweight = rnorm(20, 550, 5)
```

Data

```
chopweight
```

```
## [1] 546.8677 550.9182 545.8219 557.9764 551.6475 545.8977 552.4371 553.6916  
## [9] 552.8789 548.4731 557.5589 551.9492 546.8938 538.9265 555.6247 549.7753  
## [17] 549.9190 554.7192 554.1061 552.9695
```

```
hist(chopweight)
```



Measurement Error

Measurement Error



Measurement Error

An individual measurement often differs from the exact value:

Individual measurement = exact value + chance error + bias

So if we weigh the **same** tray of lamp chops from Coles 20 times, we would expect data like `chopweight`.



Why does chance error occur? How does bias occur?

Chance Error

Chance Error



Chance Error

No matter how carefully any measurement is made, it could have turned out differently. This is due to **chance error**.

The best way to estimate the chance error is to **replicate** the measurement under the same conditions, and calculate the **standard deviation**.

```
sd(chopweight)
```

```
## [1] 4.566269
```

Outliers

Outliers



Outliers

- In any large enough series of careful replicated measurements, we expect to see a small percentage of extreme measurements, called outliers.
- One common convention is to define outliers as measurements more than 3 standard deviations away from the mean. This assumes **Normality**.
- The mean and SD can be strongly influenced by outliers, making the Normal curve not fit well.



Is this convention sensible? What does it assume about the approximate shape of the histogram?

Distance of data from the mean (standard units)

```
standardunits = (chopweight - mean(chopweight))/sd(chopweight)  
standardunits
```

```
## [1] -0.894579096 -0.007534108 -1.123622566 1.538189109 0.152185414  
## [6] -1.107022329 0.325106999 0.599834216 0.421851526 -0.543016965  
## [11] 1.446758183 0.218251901 -0.888870682 -2.633686248 1.023162590  
## [16] -0.257822640 -0.226349080 0.824866429 0.690604708 0.441692638
```

```
max(abs(chopweight-550))*0.001*23.00 # convert to kilograms, and multiply by $23/kg
```

```
## [1] 0.2546905
```



Which measurement was most extreme in the data? Does it represent over or under charging? By how much?

Bias

Bias



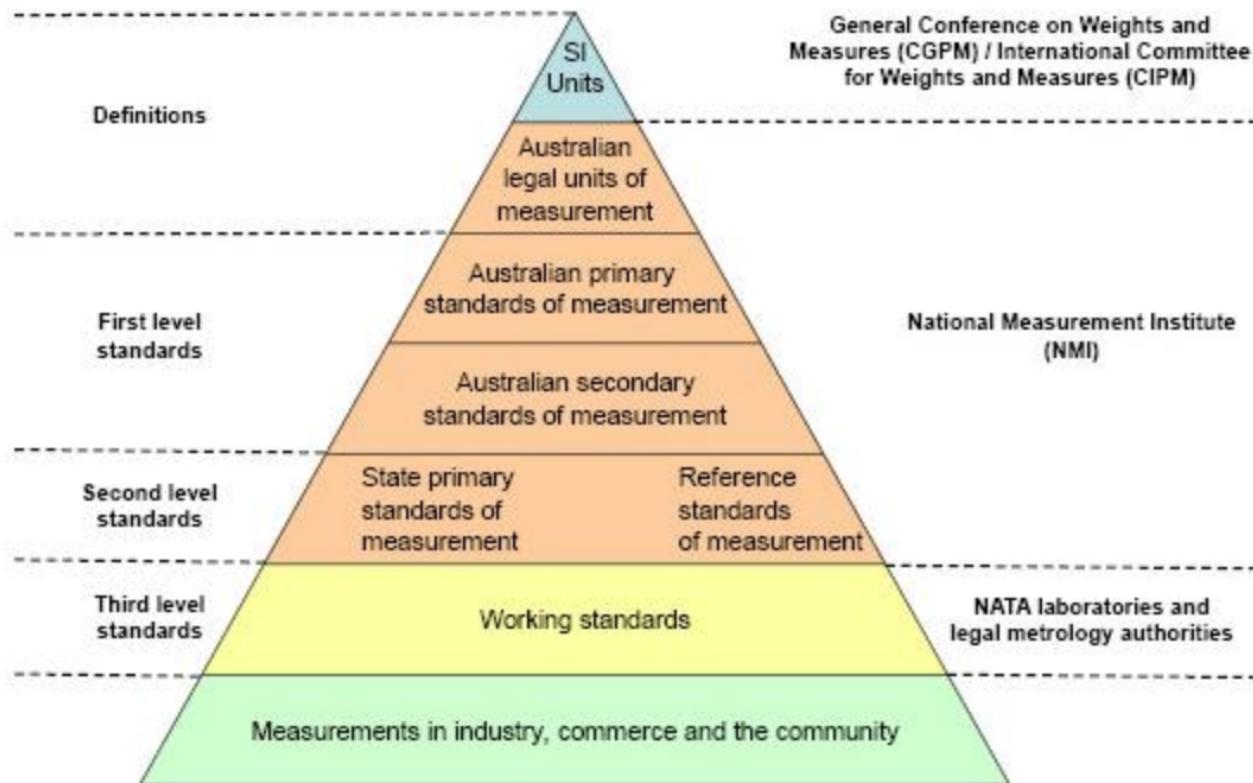
Bias (Systematic error)

- Bias is a **constant amount** added to or subtracted from each measurement.
- Bias can be deliberate or accidental.
- Bias cannot be estimated by replicating the measurements.



What did Coles claim about the bias in their lamb chop weights?

Australian Standards



Australian Standards

To determine whether a measuring instrument is calibrated properly, we compare it to a working standard (3rd level standard), which is then compared to national (1st & 2nd level) and international standards.

- But this process of comparison is itself subject to measurement error!



Australian Standards for meat



Coles is expected to comply with the following regulations:

- packages are correctly labelled – with weight statements and packer identification
- the net contents (excluding packaging material) of the package are not less than the stated weight
- measuring instruments used for sales direct to the purchaser are approved and have been verified by a licensed technician (servicing licensee).

In addition, the weight statement must be:

- clear to read, at least 2 mm from the edge of the principal display panel and at least 2 mm from other graphics
- in the same direction as the brand or product name
- in a colour that provides a distinct contrast with the colour of the background.
- the total price and price per kilogram must be marked either: on the package in the same format as the weight statement; or immediately adjacent to the package in characters at least 10 mm high.



Summary

Any measurement could have turned out differently due to chance error, and there is always the possibility of bias. Even in careful measurement work, we expect a small percentage of outliers which affects the mean, standard deviation and shape of histogram.

Individual measurement = exact value + chance error + bias