See chapter 2 in Regression and Other Stories.

Widen the notebook.

```
html"""
<style>
    main {
        margin: 0 auto;
        max-width: 2000px;
        padding-left: max(160px, 10%);
        padding-right: max(160px, 10%);
    }
</style>
"""
```

```
using Pkg ✓ , DrWatson ✓
```

A typical set of Julia packages to include in notebooks.

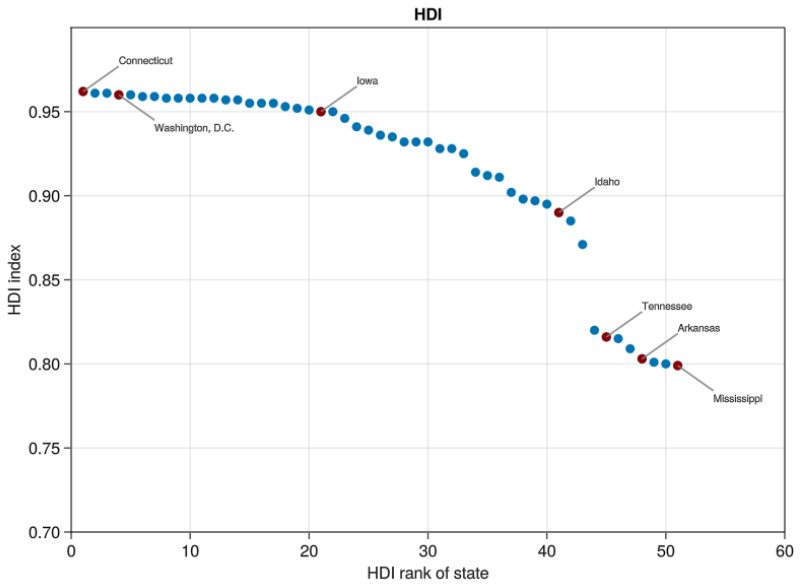
```
begin
    # Specific to this notebook
    using GLM ✓

    # Specific to ROSStanPluto
    using StanSample ✓

    # Graphics related
    using GLMakie ✓

    # Common data files and functions
    using RegressionAndOtherStories ✓
end
```

2.1 Examining where data come from.

hdi =

	rank	state	hdi	canada
1	1	"Connecticut"	0.962	2
2	2	"Massachusetts"	0.961	2
3	3	"New Jersey"	0.961	2
4	4	"Washington, D.C."	0.96	4
5	5	"Maryland"	0.96	3
6	6	"Hawaii"	0.959	2
7	7	"New York"	0.959	1
8	8	"New Hampshire"	0.958	1
9	9	"Minnesota"	0.958	1
10	10	"Rhode Island"	0.958	3
⋮	more			
51	51	"Mississippi"	0.799	5

```
hdi = CSV.read(ros_datadir("HDI", "hdi.csv"), DataFrame)
```




```
let
    f = Figure()
    ax = Axis(f[1, 1]; title = "HDI",
        xlabel = "HDI rank of state",
        ylabel = "HDI index")
    limits!(ax, 0, 60, 0.7, 1)
    scatter!(hdi.rank, hdi.hdi)
    selection = 1:20:50
    scatter!(hdi.rank[selection],
    hdi.hdi[selection]; color=:darkred)
    for i in selection
        lines!([hdi.rank[i], hdi.rank[i] +
        3],
            [hdi.hdi[i], hdi.hdi[i] +
            0.015]; color=:grey)
        annotations!(hdi.state[i],
            position = (hdi.rank[i] + 3,
            hdi.hdi[i] + 0.015),
            textsize = 10)
    end
    selection = [4, 51]
    scatter!(hdi.rank[selection],
    hdi.hdi[selection]; color=:darkred)
    for i in selection
        lines!([hdi.rank[i], hdi.rank[i] +
        3],
            [hdi.hdi[i], hdi.hdi[i] -
            0.015]; color=:grey)
        annotations!(hdi.state[i],
            position = (hdi.rank[i] + 3,
```

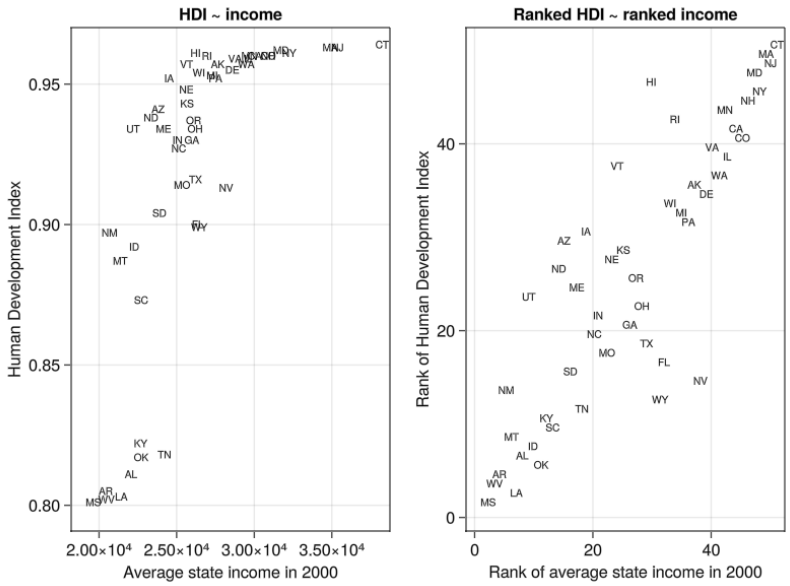
```
            hdi.hdi[i] - 0.023),
            textsize = 10)
    end
    selection = 45:3:50
    scatter!(hdi.rank[selection],
    hdi.hdi[selection]; color=:darkred)
    for i in selection
        lines!([hdi.rank[i], hdi.rank[i] +
        3],
            [hdi.hdi[i], hdi.hdi[i] +
            0.015]; color=:grey)
        annotations!(hdi.state[i],
            position = (hdi.rank[i] + 3,
            hdi.hdi[i] + 0.015),
            textsize = 10)
    end
    f
end
```

	st_state	st_stateabb	st_income
1	"Alabama"	"AL"	21656.2
2	"Alaska"	"AK"	27209.7
3	"Arizona"	"AZ"	23381.0
4	"Arkansas"	"AR"	19977.9
5	"California"	"CA"	29581.4
6	"Colorado"	"CO"	30406.0
7	"Connecticut"	"CT"	37808.2
8	"Delaware"	"DE"	28128.1
9	"Florida"	"FL"	25977.8
10	"Georgia"	"GA"	25502.2
⋮	more		
50	"Wyoming"	"WY"	25934.1

```
begin
    votes = CSV.read(ros_datadir("HDI",
    "votes.csv"), DataFrame;
        delim=",", stringtype=String,
        pool=false)
    votes[votes.st_year .== 2000,
    [:st_state, :st_stateabb, :st_income]]
end
```

	rank	state	hdi	canada.dis
1	1	"Connecticut"	0.962	2
2	2	"Massachusetts"	0.961	2
3	3	"New Jersey"	0.961	2
4	5	"Maryland"	0.96	3
5	6	"Hawaii"	0.959	2
6	7	"New York"	0.959	1
7	8	"New Hampshire"	0.958	1
8	9	"Minnesota"	0.958	1
9	10	"Rhode Island"	0.958	3
10	11	"California"	0.958	3
⋮	more			
50	51	"Mississippi"	0.799	5

```
let
    tmp = votes[votes.st_year .== 2000,
    [:st_state, :st_stateabb, :st_income]]
    votes2 = DataFrame(state=tmp.st_state,
    abbr=tmp.st_stateabb,
        income=tmp.st_income)
    global hdivotes = innerjoin(hdi,
    votes2, on = :state)
end
```


HDI ~ income
Human Development Index
Average state income in 2000
0.95
0.90
0.85
0.80
2.00×10⁴
2.50×10⁴
3.00×10⁴
3.50×10⁴
Ranked HDI ~ ranked income
Rank of Human Development Index
Rank of average state income in 2000
40
20
0
0
20
40

```
let
    f = Figure()
    ax = Axis(f[1, 1]; title = "HDI ~
    income",
        xlabel = "Average state income in
        2000",
        ylabel = "Human Development Index")
    for i in 1:size(hdivotes, 1)
        if length(hdivotes.abbr[i]) > 0
            annotations!(hdivotes.abbr[i],
                position =
                (hdivotes.income[i],
                hdivotes.hdi[i]),
                textsize = 10)
        end
    end
    hdivotes.rank_hdi =
    sortperm(hdivotes.hdi)
    global hdivotes2 = sort(hdivotes,
    :income)
    ax = Axis(f[1, 2]; title = "Ranked HDI
    ~ ranked income",
        xlabel = "Rank of average state
        income in 2000",
        ylabel = "Rank of Human
        Development Index")
    for i in 1:size(hdivotes2, 1)
        if length(hdivotes2.abbr[i]) > 0
            annotations!(hdivotes2.abbr[i],
                position = (i,
                hdivotes2.rank_hdi[i]),
                textsize = 10)
        end
    end
    current_figure()
end
```

	rank	state	hdi	canada.dis
1	51	"Mississippi"	0.799	5
2	50	"West Virginia"	0.8	3
3	48	"Arkansas"	0.803	4
4	40	"New Mexico"	0.895	4
5	42	"Montana"	0.885	1
6	49	"Louisiana"	0.801	5
7	47	"Alabama"	0.809	5
8	29	"Utah"	0.932	2
9	41	"Idaho"	0.89	1
10	46	"Oklahoma"	0.815	4
⋮	more			
50	1	"Connecticut"	0.962	2

```
hdivotes2
```

```
stan2_1 = "
data {
    int N;
    vector[N] rank_hdi;
    vector[N] rank_income;
}
parameters {
    real a;
    real b;
    real<lower=0> sigma;
}
model {
    vector[N] mu;
    mu = a + b * rank_income;
    a ~ normal(0, 5);
    b ~ normal(0, 5);
    sigma ~ exponential(1);
    rank_hdi ~ normal(mu, sigma);
}";
```

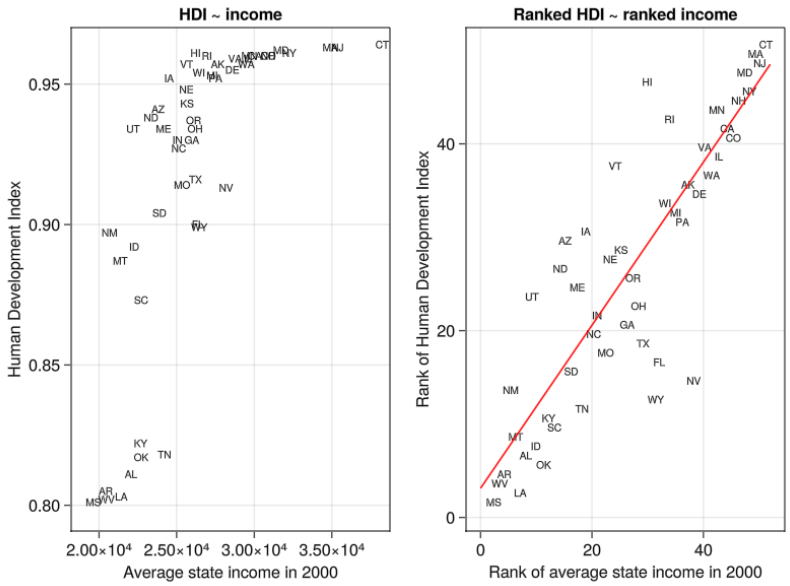
	parameters	mean	mcse	std	5%
1	"lp__"	-132.24	0.04	1.27	-134
2	"a"	3.16	0.05	1.93	-0.0
3	"b"	0.87	0.0	0.07	0.76
4	"sigma"	7.21	0.01	0.68	6.19

```
let
    data = (N = size(hdivotes2, 1),
    rank_income =
    collect(1:size(hdivotes2, 1)),
    rank_hdi = hdivotes2.rank_hdi)
    global m2_1s = SampleModel("hdi",
    stan2_1)
    global rc2_1s = stan_sample(m2_1s;
    data)
    success(rc2_1s) && describe(m2_1s,
    [:lp__, :a, :b, :sigma])
end
```

```
/var/folders/l7/pr04h0650q5dvqttnvs8s2c00000gn
dated.
```

	parameters	median	mad_sd	mean	st
1	"a"	3.124	1.844	3.156	1.93
2	"b"	0.873	0.066	0.872	0.06
3	"sigma"	7.173	0.653	7.213	0.68

```
if success(rc2_1s)
    post2_1s_df = read_samples(m2_1s,
    :dataframe)
    ms2_1s = model_summary(post2_1s_df,
    [:a, :b, :sigma])
end
```


HDI ~ income
Human Development Index
Average state income in 2000
0.95
0.90
0.85
0.80
2.00×10⁴
2.50×10⁴
3.00×10⁴
3.50×10⁴
Ranked HDI ~ ranked income
Rank of Human Development Index
Rank of average state income in 2000
40
20
0
0
20
40

```
let
    ā, b̄, σ = ms2_1s[:, :median]
    f = Figure()
    ax = Axis(f[1, 1]; title = "HDI ~
    income",
        xlabel = "Average state income in
        2000",
        ylabel = "Human Development Index")
    for i in 1:size(hdivotes, 1)
        if length(hdivotes.abbr[i]) > 0
            annotations!(hdivotes.abbr[i],
                position =
                (hdivotes.income[i],
                hdivotes.hdi[i]),
                textsize = 10)
        end
    end
    ax = Axis(f[1, 2]; title = "Ranked HDI
    ~ ranked income",
        xlabel = "Rank of average state
        income in 2000",
        ylabel = "Rank of Human
        Development Index")
    for i in 1:size(hdivotes2, 1)
        if length(hdivotes2.abbr[i]) > 0
            annotations!(hdivotes2.abbr[i],
                position = (i,
                hdivotes2.rank_hdi[i]),
                textsize = 10)
        end
    end
    x = 0:52
    lines!(x, ā .+ b̄ .* x; color=:red)
    f
end
```

2.2 Validity and reliability.

	survey	regicert
1	"june08voter"	"absolutely certain"
2	"aug08relig"	"absolutely certain"
3	"aug08relig"	"absolutely certain"
4	"aug08relig"	"absolutely certain"
5	"june08voter"	"absolutely certain"
6	"july08poli-econ"	"absolutely certain"
7	"june08voter"	"absolutely certain"
8	"aug08relig"	"absolutely certain"
9	"june08voter"	"absolutely certain"
10	"july08poli-econ"	"absolutely certain"
⋮	more	
31201	"sept08forpoli"	"absolutely certain"

```
begin
    pew_pre_raw =
    CSV.read(ros_datadir("Pew",
    "pew.csv"), DataFrame;
    missingstring="NA", pool=false)
    pew_pre = pew_pre_raw[:, [:survey,
    :regicert,  :party, :state, :heat2,
    :heat4, :income2, :party4, :date,
        :weight, :voter_weight2, :pid,
        :ideology, :inc]]
end
```

```
pid_incprob =
```

	Column1	V1	V2	V3	V
1	1	0.0	0.0	0.0	0.0
2	2	0.434068	0.410585	0.40081	0.3
3	3	0.583262	0.54593	0.51899	0.5
4	4	0.780714	0.717176	0.67472	0.6
5	5	0.849178	0.818929	0.778284	0.7
6	6	1.0	1.0	1.0	1.0

```
pid_incprob = CSV.read(ros_datadir("Pew", "pid_incprop.csv"), DataFrame; missingstring="NA", pool=false)
```

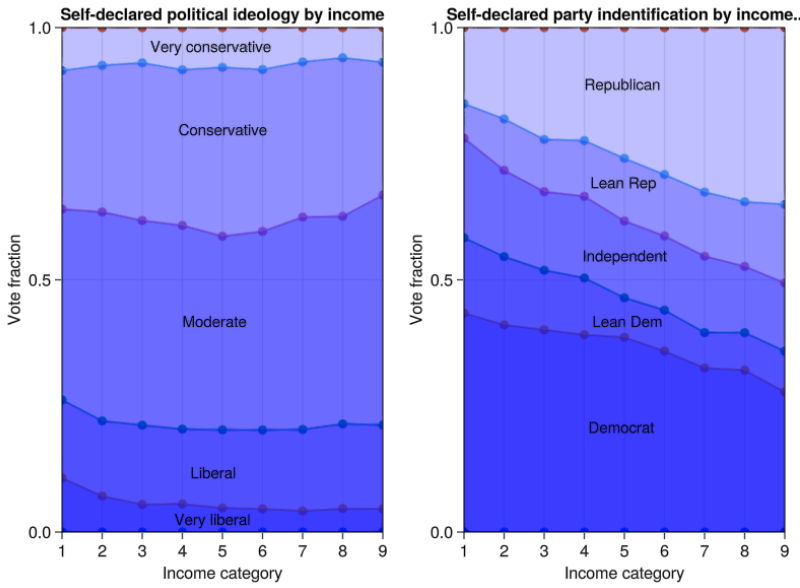
```
ideo_incprob =
```

	Column1	V1	V2	V3	
1	1	0.0	0.0	0.0	0
2	2	0.10736	0.0713431	0.0545858	0
3	3	0.261838	0.220291	0.211839	0
4	4	0.640184	0.634329	0.617531	0
5	5	0.914783	0.925208	0.930161	0
6	6	1.0	1.0	1.0	1

```
ideo_incprob = CSV.read(ros_datadir("Pew", "ideo_incprop.csv"), DataFrame; missingstring="NA", pool=false)
```

```
3×3 Matrix{Float64}:
 0.00984338  0.00647884  0.00217881
 0.00367166  0.0158111   0.00531952
 0.00075453  0.00769068  0.0152036
```

```
begin
    party_incprob_df =
    CSV.read(ros_datadir("Pew",
    "party_incprop.csv"), DataFrame;
    missingstring="NA", pool=false)
    party_incprob =
    reshape(Array(party_incprob_df)[:,
    2:end], :, 3, 9)
    party_incprob[:, :, 9]
end
```




```
let
    x1 = 1.0:1.0:9.0
    f = Figure()
    ax = Axis(f[1, 1], title = "Self-
    declared political ideology by
    income",
        xlabel = "Income category", ylabel
        = "Vote fraction")
    limits!(ax, 1, 9, 0, 1)
    for i in 1:6
        sca1 = scatter!(x1,
        Array(ideo_incprob[i, 2:end]))
        lin = lines!(x1,
        Array(ideo_incprob[i, 2:end]))
        band!(x1, fill(0, length(x1)),
```

```
            Array(ideo_incprob[i, 2:end]);
                color = (:blue, 0.25), label =
                "Label")
        end
        annotations!("Very conservative",
        position = (3.2, 0.945), textsize=15)
        annotations!("Conservative", position
        = (3.9, 0.78), textsize=15)
        annotations!("Moderate", position =
        (4.0, 0.4), textsize=15)
        annotations!("Liberal", position =
        (4.2, 0.1), textsize=15)
        annotations!("Very liberal", position
        = (3.8, 0.0075), textsize=15)
        ax = Axis(f[1, 2], title = "Self-
        declared party indentification by
        income..",
            xlabel = "Income category", ylabel
            = "Vote fraction")
        limits!(ax, 1, 9, 0, 1)
        for i in 1:6
            sca1 = scatter!(x1,
            Array(pid_incprob[i, 2:end]))
            lin = lines!(x1,
            Array(pid_incprob[i, 2:end]))
            band!(x1, fill(0, length(x1)),
            Array(pid_incprob[i, 2:end]);
                color = (:blue, 0.25), label =
                "Label")
        end
        annotations!("Republican", position =
        (4.0, 0.87), textsize=15)
        annotations!("Lean Rep", position =
        (4.15, 0.675), textsize=15)
        annotations!("Independent", position =
        (3.95, 0.53), textsize=15)
        annotations!("Lean Dem", position =
        (4.2, 0.4), textsize=15)
        annotations!("Democrat", position =
        (4.1, 0.19), textsize=15)
        current_figure()
    end
```

2.3 All graphs are comparisons.

health =

	country	spending	lifespan
1	"Australia"	3357	81.4
2	"Austria"	3763	80.1
3	"Belgium"	3595	79.8
4	"Canada"	3895	80.7
5	"Czech"	1626	77.0
6	"Denmark"	3512	78.4
7	"Finland"	2840	79.5
8	"France"	3601	81.0
9	"Germany"	3588	80.0
10	"Greece"	2727	79.6
⋮	more		
30	"USA"	7290	78.1

```
health = CSV.read(ros_datadir("HealthExpenditure", "healthdata.csv"), DataFrame; missingstring="NA", pool=false)
```

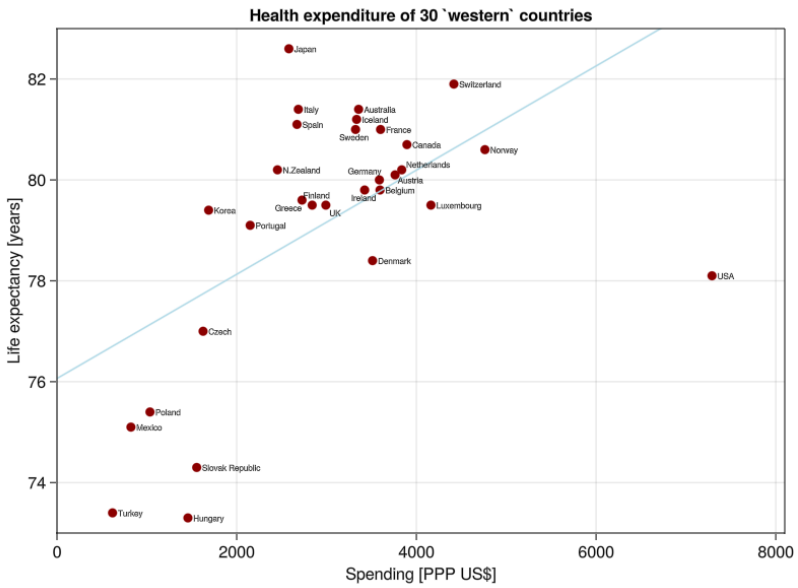
```
expm =
StatsModels.TableRegressionModel{LinearModel{GL

lifespan ~ 1 + spending

Coefficients:
```

	Coef.	Std. Error	t	Pr
(Intercept)	76.0642	0.95546	79.61	
spending	0.00103241	0.00029198	3.54	

```
expm = lm(@formula(lifespan ~ spending),
health)
```

▸ [76.0642, 0.00103241]

```
â, b̂ = coef(expm)
```




```
let
    x = 0:8000
    f = Figure()
    ax = Axis(f[1, 1], title = "Health
    expenditure of 30 `western`
    countries",
        xlabel = "Spending [PPP US\$]",
        ylabel = "Life expectancy
        [years]")
    limits!(ax, 0, 8100, 73, 83)
    sca = scatter!(health.spending,
    health.lifespan; color=:darkred)
    lin = lines!(x, â + b̂ * x;
```

```
    lin = lines!(x, a .+ b * x,
    color=:lightblue)
    for i in 1:nrow(health)
        if health.country[i] == "UK"
            annotations!(health.country[i],
            position =
            (health.spending[i]+40,
            health.lifespan[i]-0.25),
            textsize=8)
        elseif health.country[i] ==
        "Finland"
            annotations!(health.country[i],
            position =
            (health.spending[i]-100,
            health.lifespan[i]+0.1),
            textsize=8)
        elseif health.country[i] ==
        "Greece"
            annotations!(health.country[i],
            position =
            (health.spending[i]-300,
            health.lifespan[i]-0.25),
            textsize=8)
        elseif health.country[i] ==
        "Sweden"
            annotations!(health.country[i],
            position =
            (health.spending[i]-180,
            health.lifespan[i]-0.25),
            textsize=8)
        elseif health.country[i] ==
        "Ireland"
            annotations!(health.country[i],
            position =
            (health.spending[i]-150,
            health.lifespan[i]-0.25),
            textsize=8)
        elseif health.country[i] ==
        "Netherlands"
            annotations!(health.country[i],
            position =
            (health.spending[i]+50,
            health.lifespan[i]+0.01),
            textsize=8)
        elseif health.country[i] ==
        "Germany"
```

```
            Germany
                annotations!(health.country[i],
                position =
                (health.spending[i]-350,
                health.lifespan[i]+0.08),
                textsize=8)
            elseif health.country[i] ==
            "Austria"
                annotations!(health.country[i],
                position =
                (health.spending[i]+30,
                health.lifespan[i]-0.2),
                textsize=8)
            else
                annotations!(health.country[i],
                position =
                (health.spending[i]+60,
                health.lifespan[i]-0.1),
                textsize=8)
            end
        end
        current_figure()
    end
```

Names example.

cleannames =

	X	name	sex	X1880	X18
1	1	"Mary"	"F"	7065	691
2	2	"Anna"	"F"	2604	269
3	3	"Emma"	"F"	2003	203
4	4	"Elizabeth"	"F"	1939	185
5	5	"Minnie"	"F"	1746	165
6	6	"Margaret"	"F"	1578	165
7	7	"Ida"	"F"	1472	143
8	8	"Alice"	"F"	1414	130
9	9	"Bertha"	"F"	1320	132
10	10	"Sarah"	"F"	1288	122
⋮ more					
98012	98148	"Zzyzx"	"M"	0	0

```
cleannames = CSV.read(ros_datadir("Names", "allnames_clean.csv"), DataFrame)
```

```
(98012, 134)
```

```
size(cleannames)
```

```
["X", "name", "sex", "X1880", "X1881", "X1882"
```

```
names(cleannames)
```

df =

	name	sex	X1906	X1956	X200
1	"John"	"M"	8263	80735	15140
2	"William"	"M"	6567	58927	18915
3	"James"	"M"	5908	84840	16213
4	"Charles"	"M"	3607	35198	7999
5	"George"	"M"	4201	17228	2699
6	"Frank"	"M"	2798	11126	1399
7	"Joseph"	"M"	3527	32706	18395
8	"Thomas"	"M"	2177	44785	9493
9	"Henry"	"M"	2111	5951	4661
10	"Robert"	"M"	3636	83869	9874
⋮	more				
36659	"Zzyzx"	"M"	0	0	0

```
df = cleannames[cleannames.sex .== "M",
["name", "sex", "X1906", "X1956",
"X2006"]]
```

```
letters = 'a':'z';
```

```
count_letters (generic function with 1 method)
```

```
function count_letters(df::DataFrame,
years::Vector{String})
    letter_counts = DataFrame()
    for year in Symbol.(years)

        !(year in Symbol.(names(df))) &&
        begin
            @warn "The year $(year) is not
            present in df."
            continue
        end

        tmpdf = df[:, [:name, year]]

        yrcounts = zeros(Int,
        length(letters))
        for (ind, letter) in
        enumerate(letters)
            yrcounts[ind] = sum(filter(row
            -> row.name[end] == letter,
            tmpdf)[:, 2])
        end
        letter_counts[!, year] = 100 *
        yrcounts / sum(yrcounts)
    end
    letter_counts
end
```

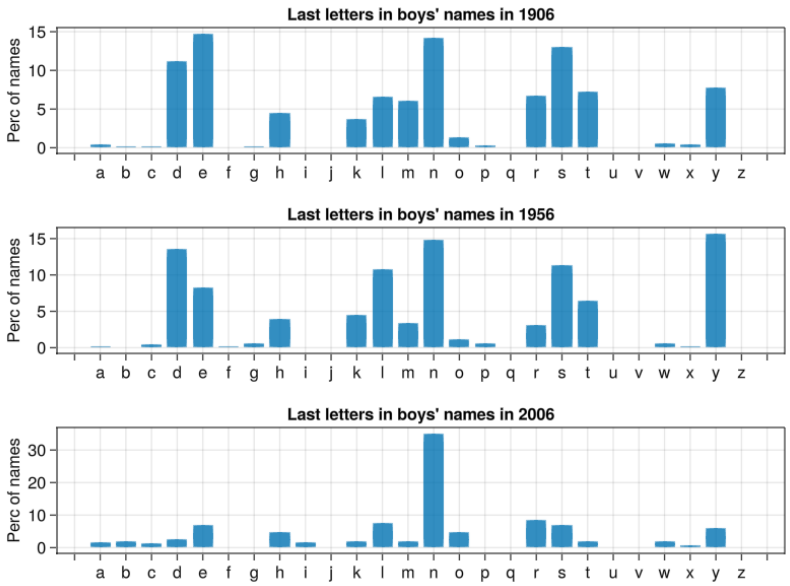
letter_count =

	X1906	X1956	X2006
1	0.473516	0.201557	1.76002
2	0.208106	0.0938356	2.07864
3	0.237512	0.466714	1.29964
4	11.2287	13.5269	2.50852
5	14.7936	8.31948	6.97453
6	0.104807	0.13137	0.0960275
7	0.200566	0.562255	0.0941245
8	4.5082	3.9746	4.79937
9	0.0806786	0.054927	1.63744
10	0.0	0.0	0.0605539
⋮	more		
26	0.0180961	0.0176297	0.15058

```
letter_count = count_letters(df, ["X1906", "X1956", "X2006"])
```

▸ [100.0, 100.0, 100.0]

```
sum.(eachcol(letter_count))
```




```
let
    f = Figure()
    for (ind, year) in enumerate(["X1906",
    "X1956", "X2006"])
        ax = Axis(f[ind, 1], title="Last
        letters in boys' names in
        $(year[2:end])",
            ylabel="Perc of names")
        ax.xticks = (0:27, vcat(" ",
        string.(letters), " "))
        barplot!(f[ind, 1], 1:26,
        letter_count[:, Symbol(year)],
        width=0.8, gap=0.01)
    end
    f
end
```

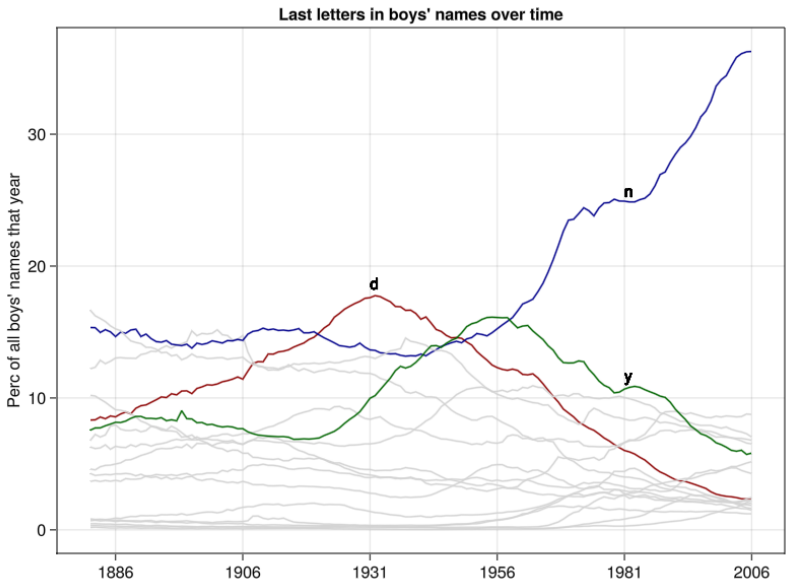
all_letter_count =

	X1880	X1881	X1882	X1883
1	0.683795	0.738044	0.675187	0.703254
2	0.461607	0.467494	0.446011	0.433066
3	0.316504	0.329235	0.307625	0.286475
4	8.32253	8.34229	8.55178	8.42755
5	12.2122	12.3229	12.855	12.602
6	0.0979441	0.0825575	0.118995	0.10156
7	0.133313	0.145222	0.128691	0.129345
8	3.66383	3.74095	3.66858	3.74142
9	0.181378	0.204902	0.182459	0.160005
10	0.0	0.0	0.0	0.0
⋮	more			
26	0.0262998	0.00795735	0.0273248	0.011497

```
all_letter_count = count_letters(cleannames[cleannames.sex .== "M", :], names(cleannames[:, vcat(4:end)]))
```

▸ [0.473516, 0.208106, 0.237512, 11.2287, 14.793

```
all_letter_count[:, "X1906"]
```


Last letters in boys' names over time
Perc of all boys' names that year
30
20
10
0
1886
1906
1931
1956
1981
2006
n
d
y

```
let
    f = Figure()
    ax = Axis(f[1, 1], title="Last letters
    in boys' names over time",
        ylabel="Perc of all boys' names
        that year")
    ax.xticks = (6:25:131, ["1886", "1906",
    "1931", "1956", "1981", "2006"])

    for l in 1:length(letters)
        col = :lightgrey
        if letters[l] == 'n'
            col = :darkblue
        elseif letters[l] == 'd'
            col = :darkred
        elseif letters[l] == 'y'
            col = :darkgreen
        end
        if maximum(Array(all_letter_count)
        [l,:]) > 1
            lines!(1:size(all_letter_count,
            2), Array(all_letter_count)
            [l,:], color=col)
        end
        annotations!("n", position = (106,
        25), textsize=15)
        annotations!("d", position = (56,
        18), textsize=15)
        annotations!("y", position = (106,
        11), textsize=15)

    end
    current_figure()
end
```

2.4 Data and adjustment.

Not yet done.