How to live longer ?

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Who wants to live forever ?

Figure: Queen's song *who wants to live forever*

Data and Hypothesises

- Data for the 50 US States, in years 2019, 2010 and 2000
- Harvested on America's Health Rankings and CDC websites

Hypothesis 1

The richest states have a higher life expectancy

Hypothesis 2

States with the healthiest lifestyle have a higher life expectancy

Hypothesis 3

Sunniest states have a higher life expectancy

Life expectancy by state

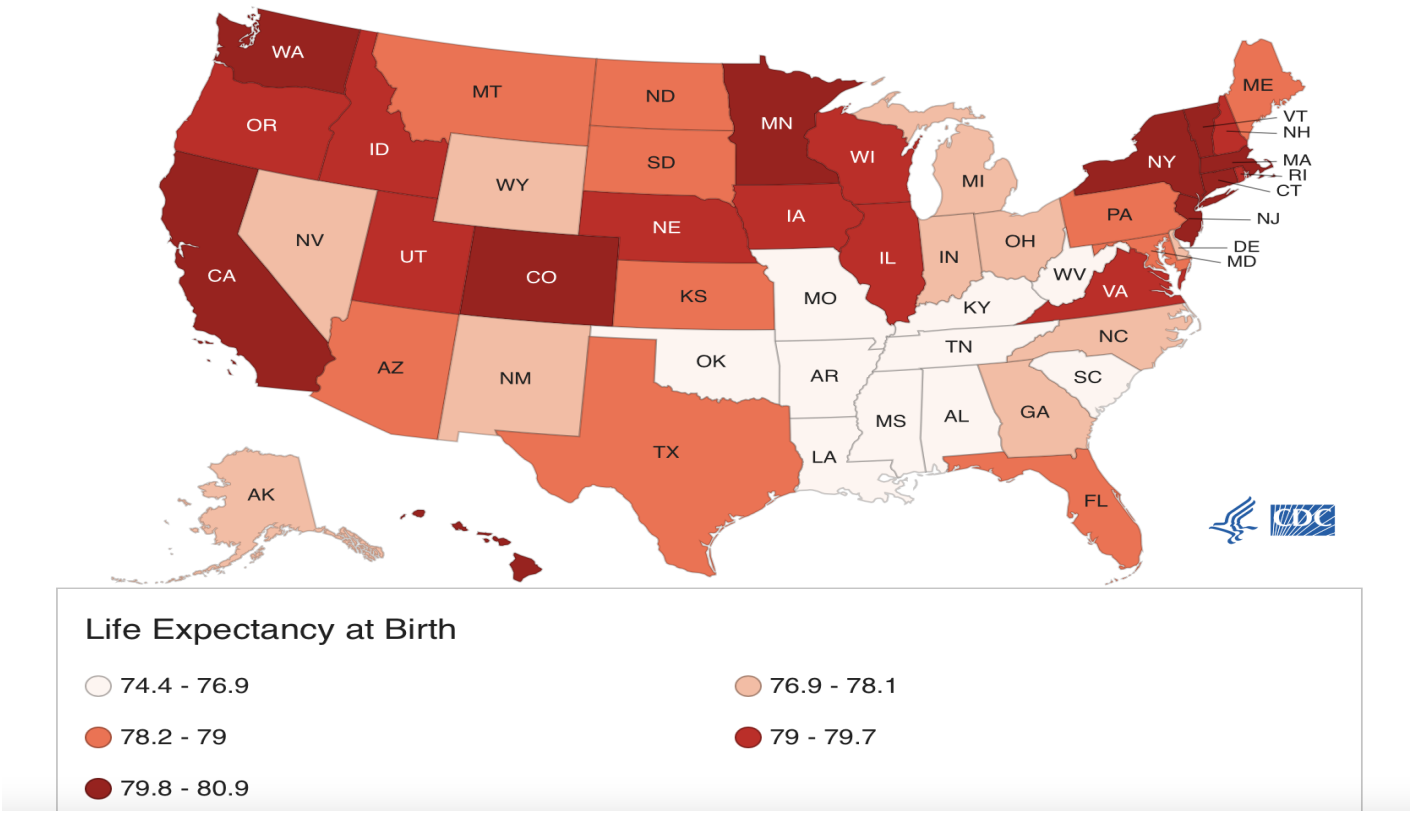


Figure: life expectancy by state in 2019

Descriptive statistics

Data	**Highest value**	**Mean value**	**Lowest score**
GDP	California (3 052 645)	421 962,5	Vermont(34 127,5)
Smoking	West Virginia (25,2%)	16,65%	Utah (9%)
med	Rhode Island (274,9)	156,5	Idaho(96,6)
Drinking	North Dakota(22,2%)	16,7%	Utah(11,2%)
over weight	Mississippi(40,8%)	32%	Colorado(23,8%)
nb sunny day	Arizona(193)	103	VT and WA(58)
air pol($\mu g/m^3$)	California(12,6)	7,276	New Hampshire(4,1)
Inactivity	Indiana(30,9%)	27,5%	Arizona(24,1%)

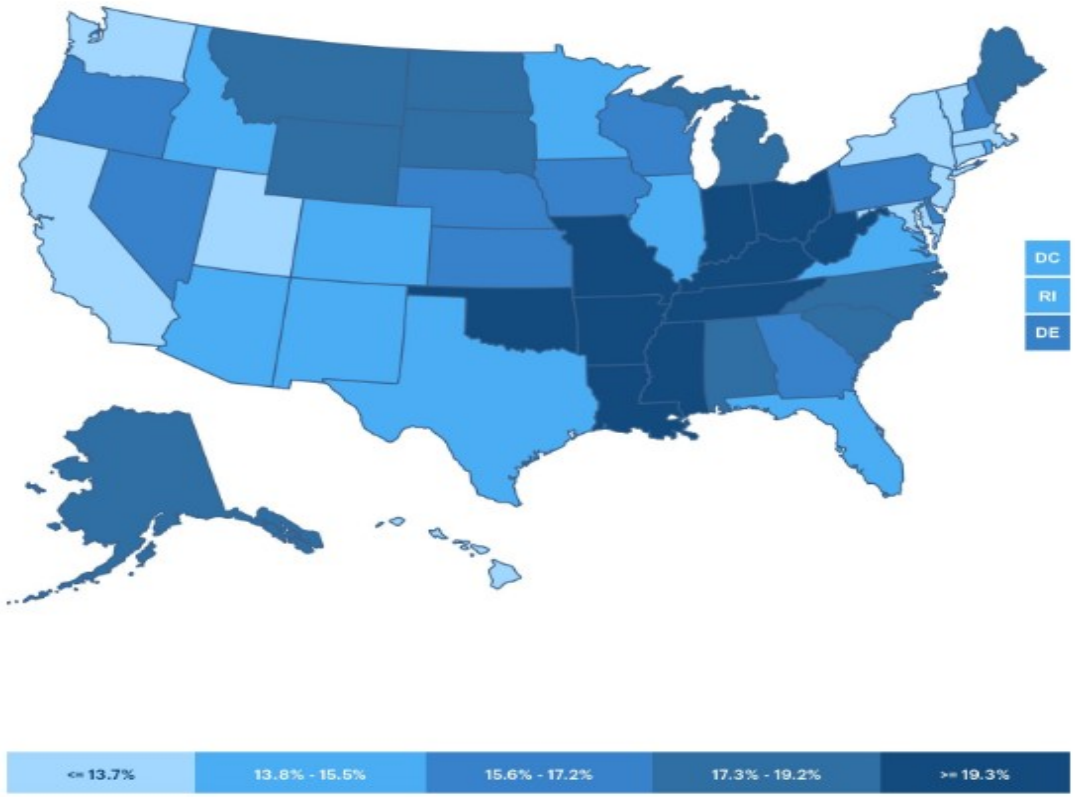
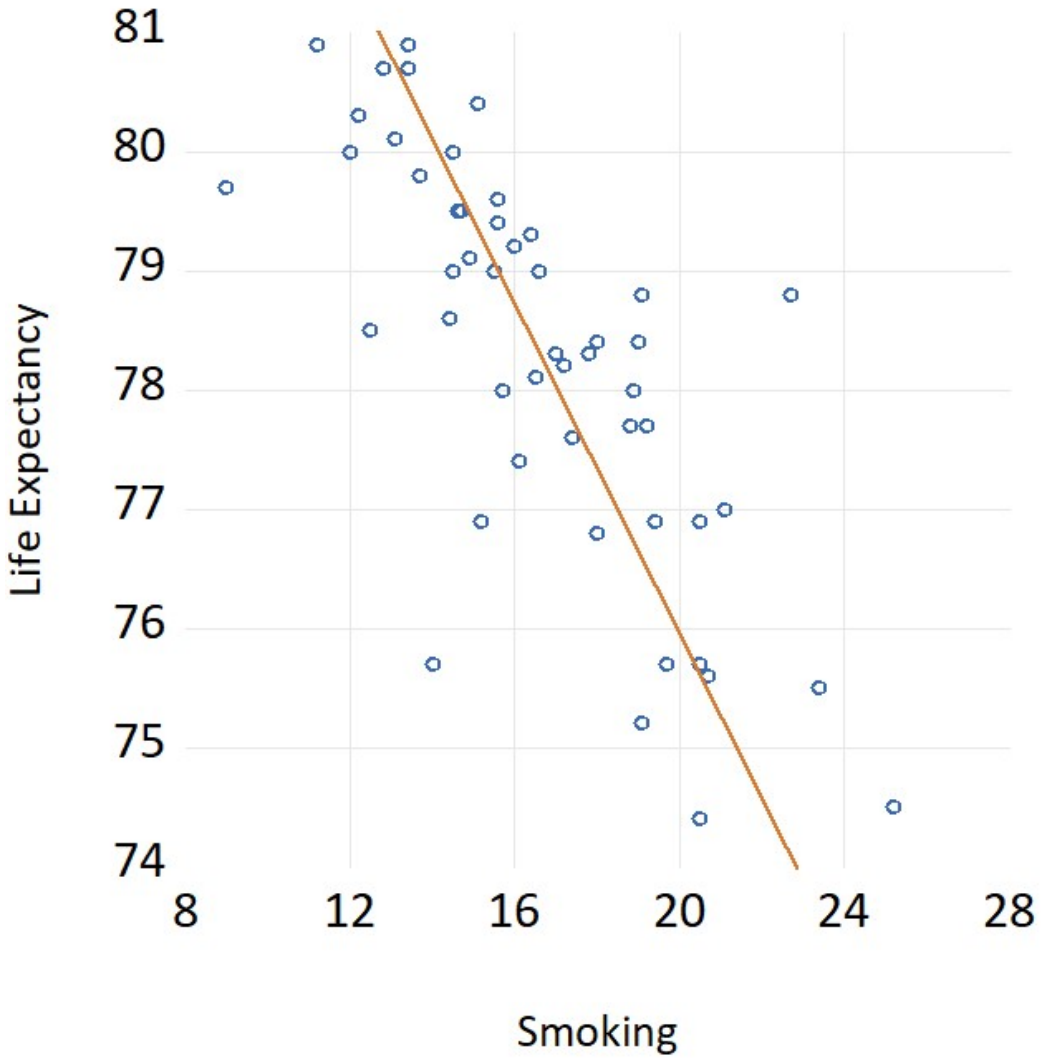


Figure: Percentage of adults who reported smoking at least 100 cigarettes in their lifetime and currently smoke daily or some days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Life Expectancy
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Smoking

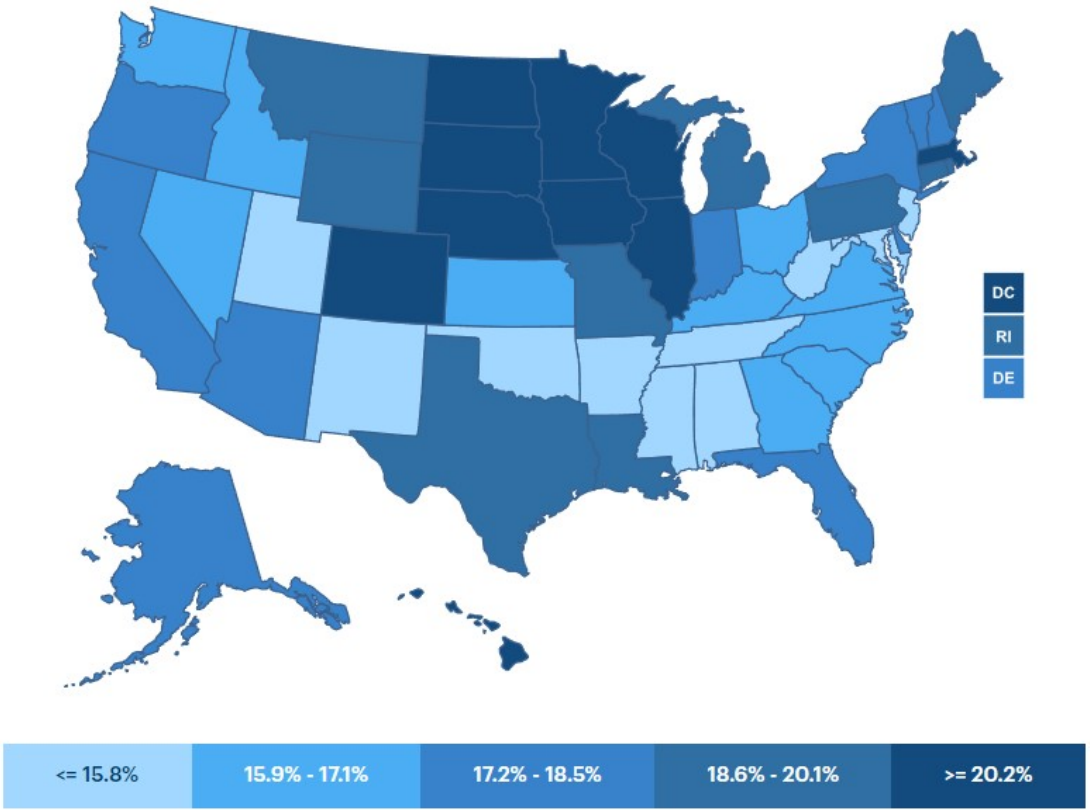


Figure: Percentage of adults who reported binge drinking (four or more [females] or five or more [males] drinks on one occasion in the past 30 days) or heavy drinking (eight or more [females] or 15 or more [males] drinks per week)

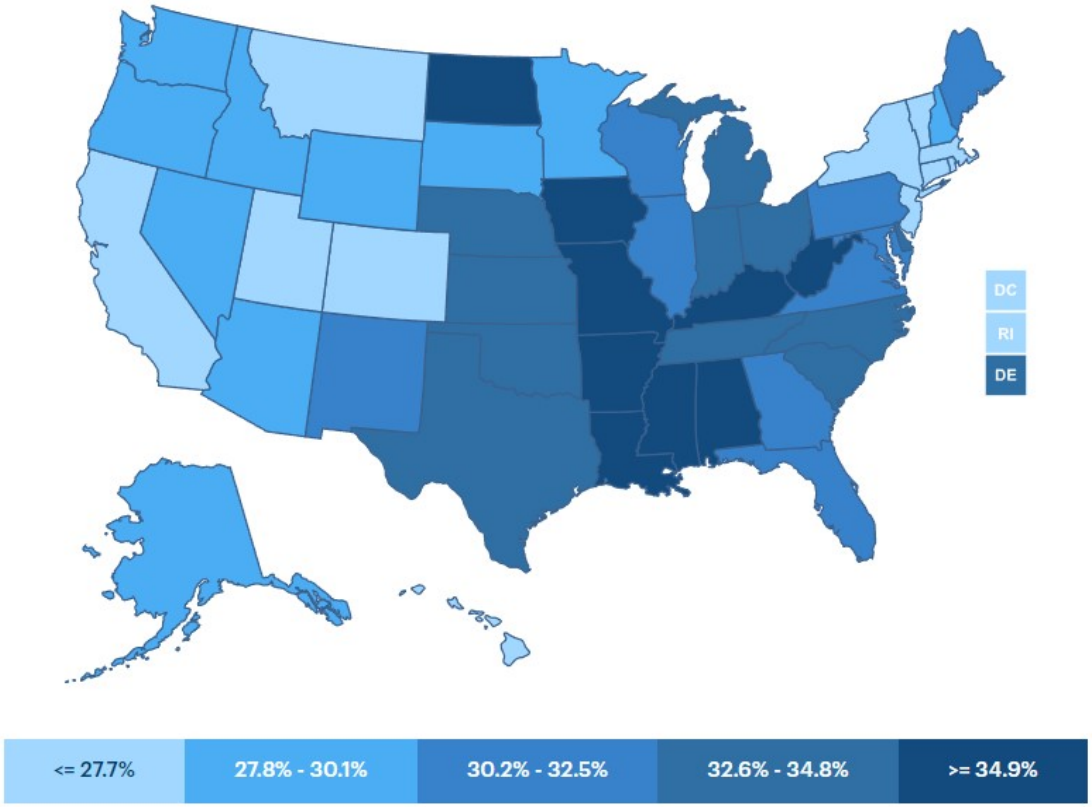


Figure: Percentage of adults with a body mass index of 30.0 or higher based on reported height and weight

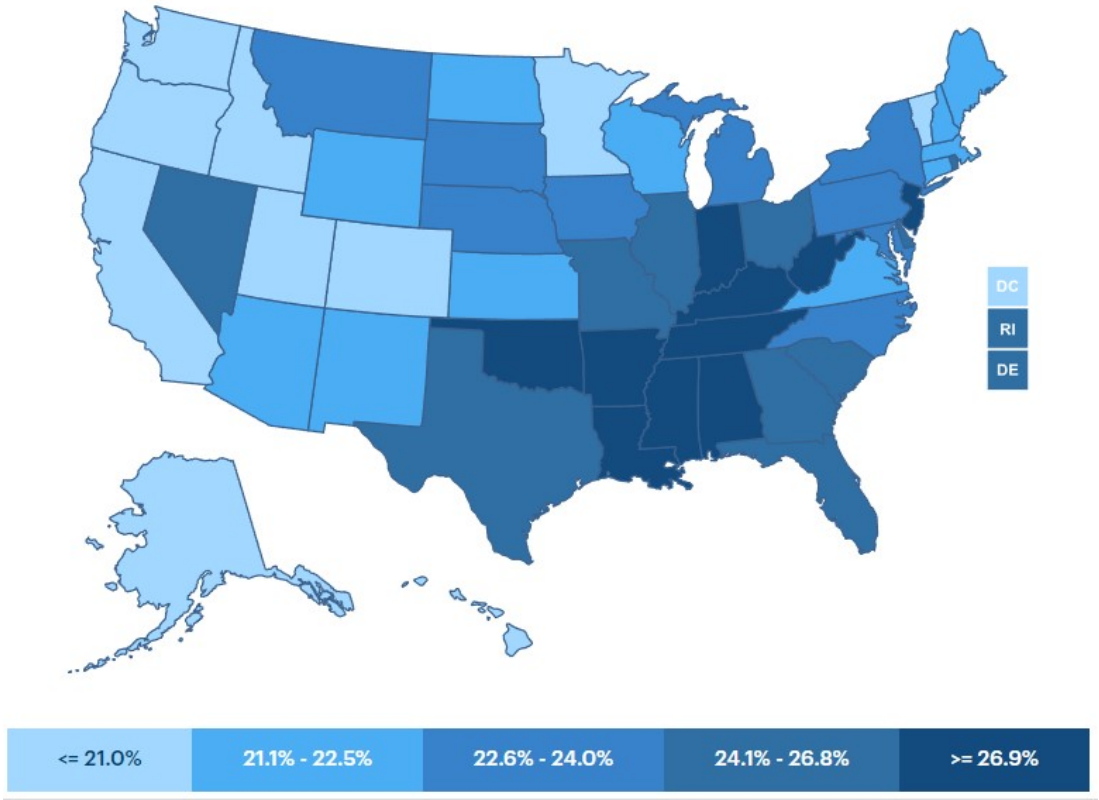
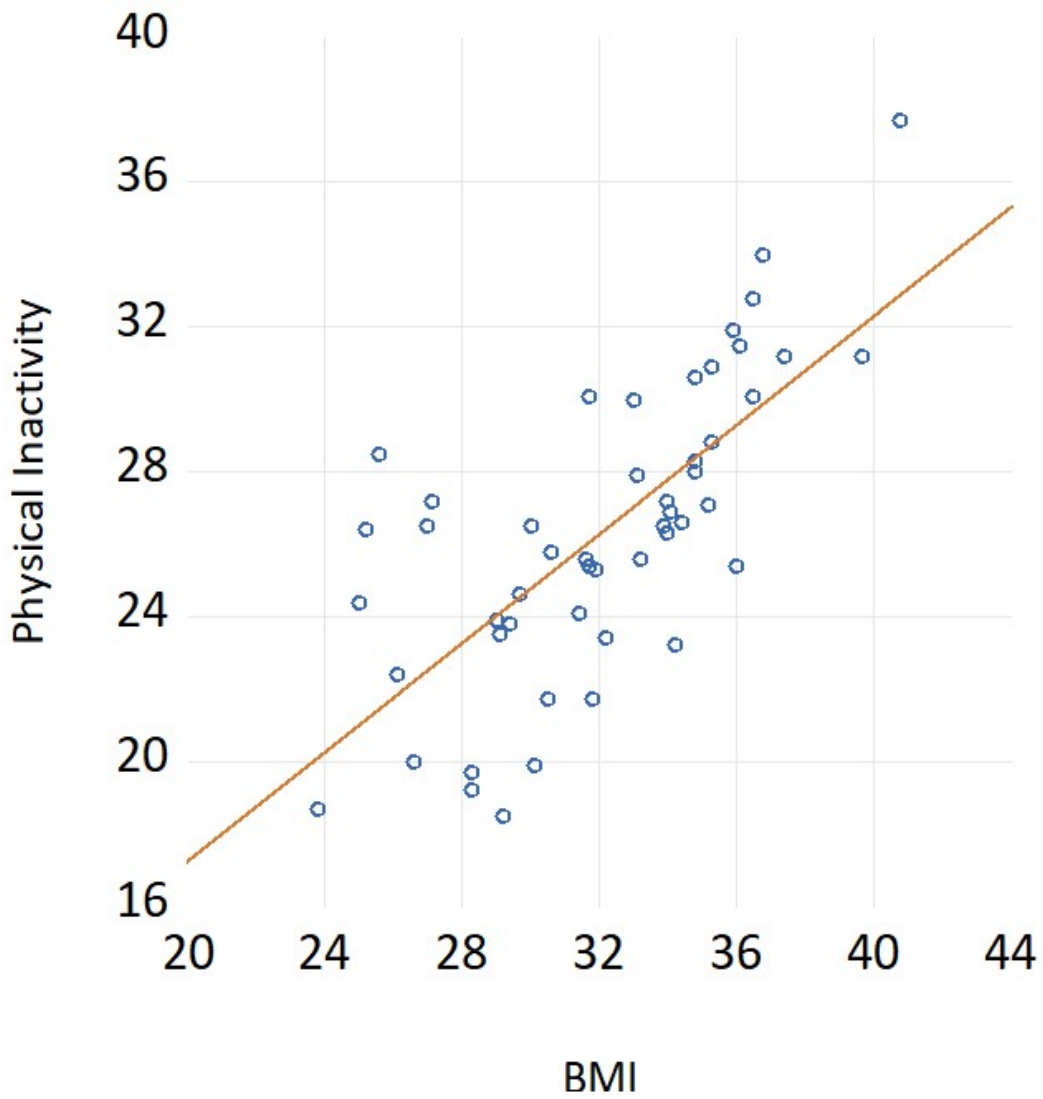


Figure: Percentage of adults who reported doing no physical activity or exercise other than their regular job in the past 30 days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Physical Inactivity
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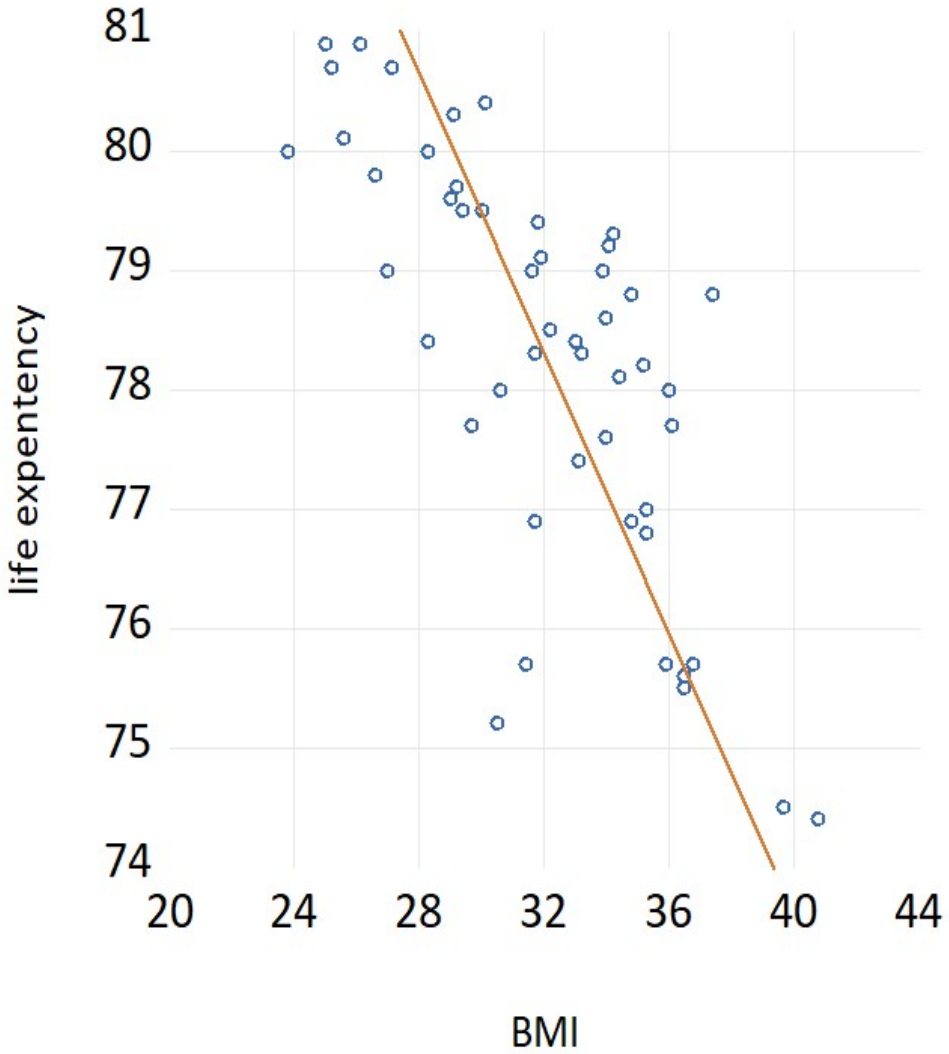
40
44
BMI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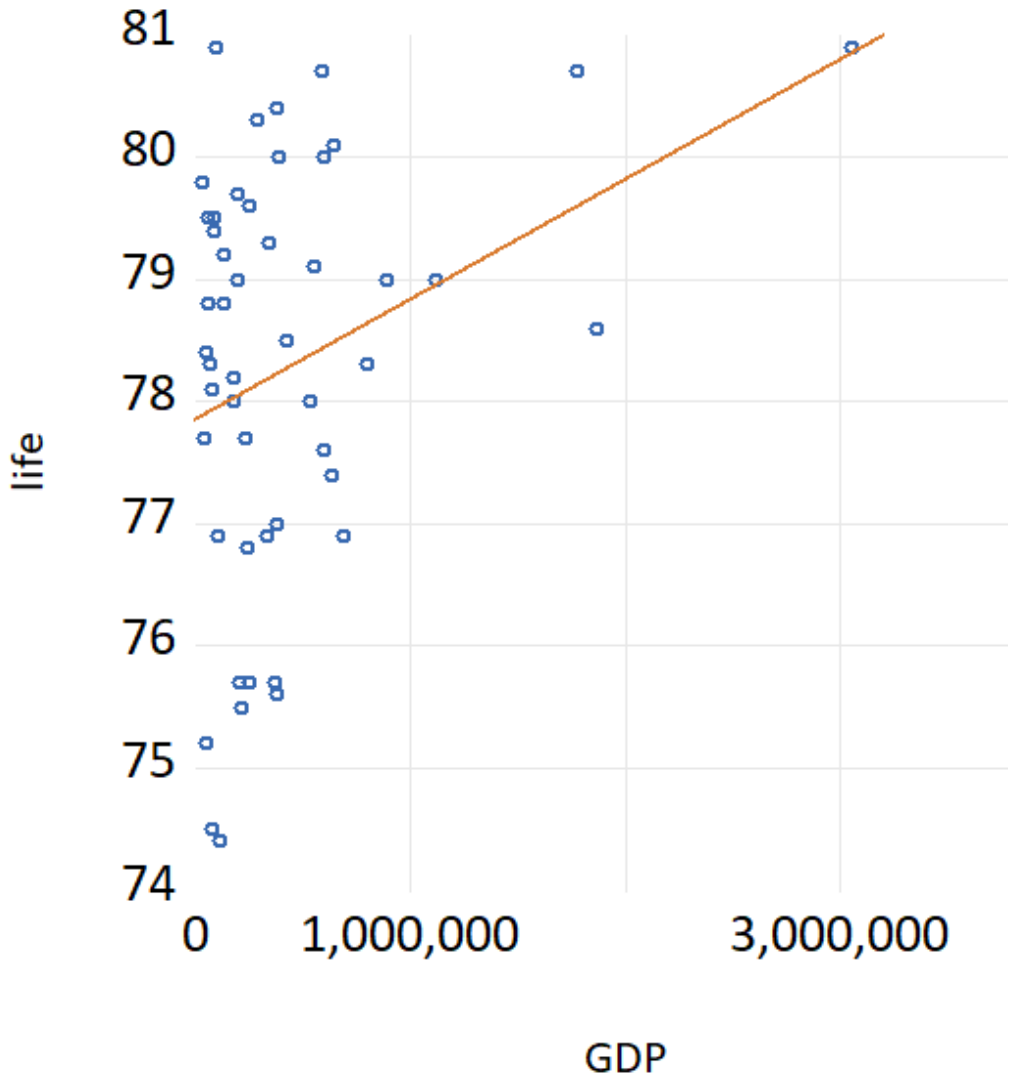
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1,000,000
3,000,000
GDP

Equation 01

- We want to model life expectancy across the different states
- The equation of our model can be written as :

$$life = \beta_0 + \beta_1 gdp * 10^{-7} + \beta_2 cig + \beta_3 drink + \beta_5 obesity + \beta_6 med + \beta_7 sun + \beta_8 air + \beta_9 inac \quad \text{(E1)}$$

First regression : 2019

Dependent Variable: LIFE
Method: Least Squares
Date: 04/23/22 Time: 11:37
Sample: 1 50
Included observations: 50

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.77736	2.086976	40.62210	0.0000
GDP*10^(-7)	3.718542	3.654006	1.017662	0.3148
CIG	-0.298394	0.082457	-3.618781	0.0008
DRINK	0.156719	0.057350	2.732660	0.0092
OBESITY	-0.100781	0.063834	-1.578806	0.1221
MED	0.001556	0.004507	0.345190	0.7317
SUN	-0.010428	0.006235	-1.672371	0.1021
AIR	-0.117225	0.134418	-0.872097	0.3882
INAC	0.022916	0.056487	0.405686	0.6871

R-squared	0.740513	Mean dependent var	78.27400
Adjusted R-squared	0.689881	S.D. dependent var	1.712715
S.E. of regression	0.953782	Akaike info criterion	2.904786
Sum squared resid	37.29772	Schwarz criterion	3.248950
Log likelihood	-63.61966	Hannan-Quinn criter.	3.035846
F-statistic	14.62548	Durbin-Watson stat	2.138598
Prob(F-statistic)	0.000000		

Figure: Eq01 output for 2019

First regression : 2010

Dependent variable: LIFE
Method: Least Squares
Date: 04/23/22 Time: 11:40
Sample (adjusted): 1 50
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.76046	1.375318	61.62970	0.0000
GDP*10^(-7)	2.603469	2.497063	1.042612	0.3032
CIG	-0.226087	0.035945	-6.289886	0.0000
DRINK	0.127895	0.025944	4.929651	0.0000
OBESITY	-0.088982	0.043919	-2.026064	0.0493
MED	0.005141	0.003644	1.410616	0.1659
SUN	-0.003601	0.003192	-1.127951	0.2659
AIR	-0.006666	0.047430	-0.140548	0.8889
INAC	-0.077000	0.039928	-1.928476	0.0607

R-squared	0.927244	Mean dependent var	78.55400
Adjusted R-squared	0.913047	S.D. dependent var	1.631728
S.E. of regression	0.481159	Akaike info criterion	1.536313
Sum squared resid	9.492089	Schwarz criterion	1.880477
Log likelihood	-29.40782	Hannan-Quinn criter.	1.667372
F-statistic	65.31566	Durbin-Watson stat	1.994644
Prob(F-statistic)	0.000000		

Figure: Eq01 output for 2010

First regression : 2000

Dependent Variable: LIFE
Method: Least Squares
Date: 04/23/22 Time: 11:26
Sample (adjusted): 1 50
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.99268	1.509687	56.29819	0.0000
GDP*10^(-7)	0.259226	5.178626	0.050057	0.9603
CIG	-0.180654	0.053430	-3.381110	0.0015
DRINK	0.129312	0.040215	3.215513	0.0025
OBESITY	-0.239124	0.062137	-3.848310	0.0004
SUN	-0.004790	0.004492	-1.066516	0.2921
INAC	-0.021824	0.034460	-0.633310	0.5299

R-squared	0.711663	Mean dependent var	76.87200
Adjusted R-squared	0.671430	S.D. dependent var	1.452379
S.E. of regression	0.832519	Akaike info criterion	2.600455
Sum squared resid	29.80276	Schwarz criterion	2.868138
Log likelihood	-58.01138	Hannan-Quinn criter.	2.702391
F-statistic	17.68849	Durbin-Watson stat	2.572830
Prob(F-statistic)	0.000000		

Figure: Eq01 output for 2000

Robustness

Variables	**Units**	**2019**	**2010**	**2000**
GDP	Current million USD	+	+	+
CIG	Percentage smoking adults	-	-	-
DRINK	Percentage binge-drinking	+	+	+
OBESITY	Percentage $BMI > 30$	-	-	-
MED	Number per 100,000	+	+	NA
SUN	Number of clear days	-	+	-
AIR	Exposure in $\mu g/m^3$	-	+	NA
INAC	Percentage inac last 30 days	+	+	-

Table: Signs of the variables' coefficients

Robustness

- The coefficient of SUN has opposite signs from a year to another
- Let's add a new variable, SUN^2, and test whether or not this new model is better
- $life = \beta_0 + \beta_1 gdp * 10^{-7} + \beta_2 cig + \beta_3 drink + \beta_5 obesity + \beta_6 med + \beta_7 sun + \beta_8 sun^2 + \beta_9 air + \beta_{10} inac$

Second regression : 2019

Dependent Variable: LIFE
Method: Least Squares
Date: 04/23/22 Time: 13:19
Sample: 1 50
Included observations: 50

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	81.04376	2.186425	37.06680	0.0000
GDP*10^(-7)	3.774097	3.278331	1.151225	0.2565
CIG	-0.235444	0.076388	-3.082205	0.0037
DRINK	0.110179	0.053343	2.065467	0.0454
OBESITY	-0.111910	0.057369	-1.950692	0.0581
MED	0.004466	0.004138	1.079333	0.2869
SUN	0.076759	0.026951	2.848075	0.0069
SUN^2	-0.000370	0.000112	-3.307017	0.0020
AIR	-0.073286	0.121326	-0.604042	0.5492
INAC	-0.042906	0.054447	-0.788027	0.4353

R-squared	0.796226	Mean dependent var	78.27400
Adjusted R-squared	0.750377	S.D. dependent var	1.712715
S.E. of regression	0.855711	Akaike info criterion	2.703089
Sum squared resid	29.28966	Schwarz criterion	3.085493
Log likelihood	-57.57722	Hannan-Quinn criter.	2.848711
F-statistic	17.36624	Durbin-Watson stat	1.995720
Prob(F-statistic)	0.000000		

Figure: Eq02 output for 2019

F test

- We assume that all CAs hold
- We want to test if the general model (Eq02) can be nested within the restricted model (Eq01)
- $H_0 : R\beta = r, H_1 : /H_0$
  $F = \left(\frac{\widehat{u'_R}\widehat{u_R}}{\widehat{u'}\widehat{u}} - 1 \right) \left(\frac{n-k}{q} \right) \overset{H_0}{\sim} F(q, n-k)$
- if CA5 fails : $qF \overset{H_0}{\sim} \chi^2(q)$ *as* $n \to \infty$

F test

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	1.005003	Prob. F(9,40)	0.4521
Obs*R-squared	9.221148	Prob. Chi-Square(9)	0.4171
Scaled explained SS	21.24619	Prob. Chi-Square(9)	0.0116

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/23/22 Time: 20:00
Sample: 1 50
Included observations: 50

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.961223	4.055199	0.237035	0.8138
GDP*10^(-7)	0.544378	6.080377	0.089530	0.9291
CIG	0.280574	0.141678	1.980358	0.0546
DRINK	-0.156442	0.098937	-1.581232	0.1217
OBESITY	-0.048239	0.106404	-0.453363	0.6527
MED	-0.000929	0.007674	-0.121076	0.9042
SUN	0.029503	0.049987	0.590205	0.5584
SUN^2	-0.000116	0.000207	-0.558840	0.5794
AIR	0.008710	0.225026	0.038707	0.9693
INAC	-0.096736	0.100984	-0.957937	0.3438

R-squared	0.184423	Mean dependent var	0.585793
Adjusted R-squared	0.000918	S.D. dependent var	1.587831
S.E. of regression	1.587102	Akaike info criterion	3.938553
Sum squared resid	100.7557	Schwarz criterion	4.320958
Log likelihood	-88.46383	Hannan-Quinn criter.	4.084175
F-statistic	1.005003	Durbin-Watson stat	2.108650
Prob(F-statistic)	0.452107		

Figure: Eq02 : BPG test for heteroscedasticity

F test

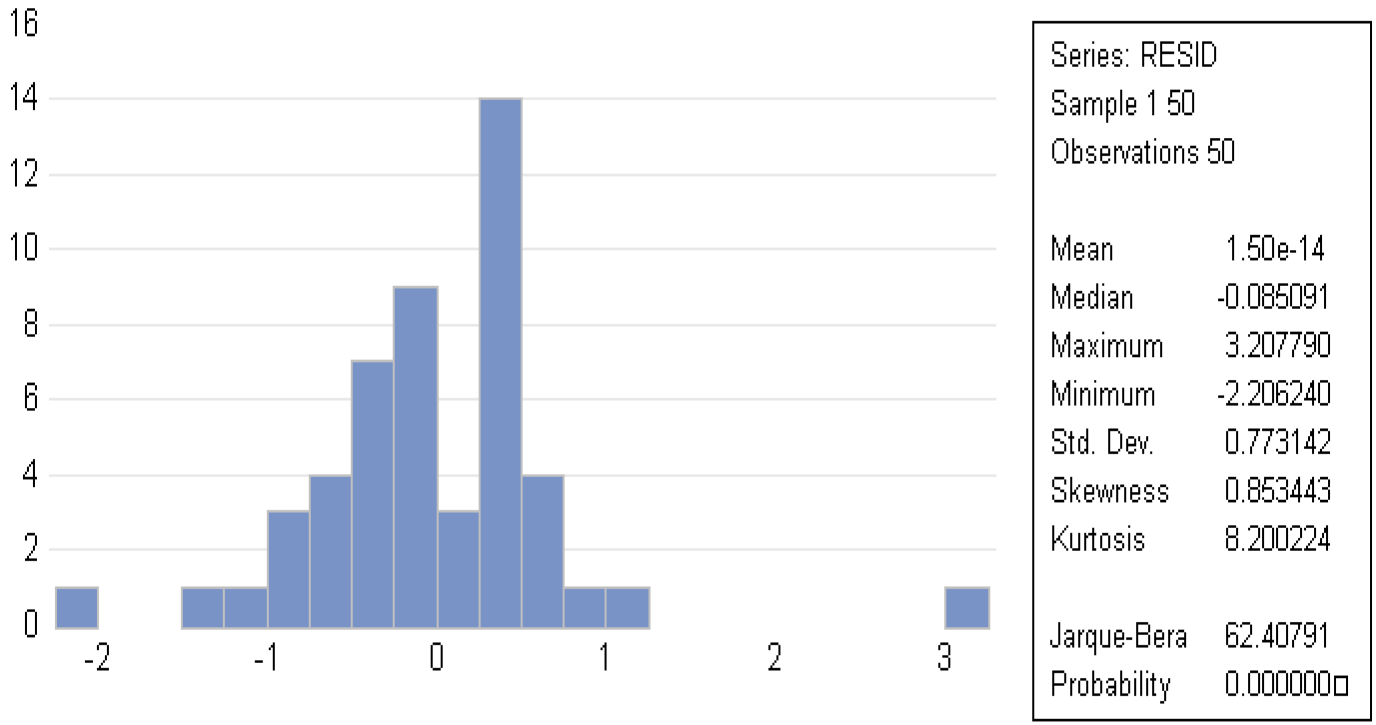


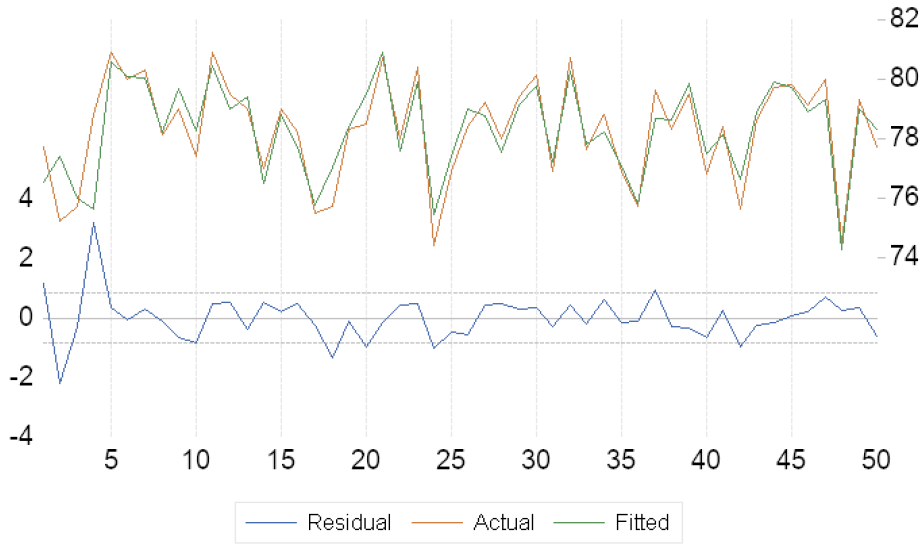
Figure: Eq02 : Jarque-Berra test

F test

- n = 50, k = 10, q = 1, $\widehat{u'_R}\widehat{u_R} = 37.29772$, $\widehat{u'}\widehat{u} = 29.28966$
- so $qF = 10.94 > \chi^2_{0.99} = 6.635$
- we rH_0 and Eq02 cannot be restricted into Eq01
- Inverse quadratic : Life expectancy will grow with sun until a specific value

Residuals

- For example, the model is underestimating the life expectancy of Arkansas ($\widehat{u}_4 = y_4 - \widehat{y}_4 > 0$)
- Although it is one of the poorest states, it is known for its beautiful lakes, rivers, and hot springs which could maybe affect life expectancy



sun

- $\frac{\partial life}{\partial sun} = -0.00074 sun + 0.077$
- 100 sunny days more per year on average will result in an increase of $3 * 10^{-3}$ in life expectancy
- 250 sunny days more per year on average will result in a decrease of -0.11 in life expectancy
- We must be careful with these results

smoking

- $\frac{\partial life}{\partial cig} = -0.24$
- 10 % more smokers in a state will result in a decrease of -2.4 years in its average life expectancy
- It seems logic, this is what we would expect

obesity

- $\frac{\partial life}{\partial obesity} = -0.11$
- 10 % more obese people in a state will result in a decrease of -1.1 years in its average life expectancy
- It seems logic, this is what we would expect

Figure: Queen celebrates 96th birthday in Sandringham