DATA 605 - Assignment 12

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Objective

- 1. Provide a scatterplot of LifeExp~TotExp, and run simple linear regression. Do not transform the variables. Provide and interpret the F statistics, R^2, standard error,and p-values only. Discuss whether the assumptions of simple linear regression met.
- 2. Raise life expectancy to the 4.6 power (i.e., LifeExp^4.6). Raise total expenditures to the 0.06 power (nearly a log transform, TotExp^.06). Plot LifeExp^4.6 as a function of TotExp^.06, and r re-run the simple regression model using the transformed variables. Provide and interpret the F statistics, R^2, standard error, and p-values. Which model is "better?"
- 3. Using the results from 3, forecast life expectancy when TotExp^.06 =1.5. Then forecast life expectancy when TotExp^.06=2.5.
- 4. Build the following multiple regression model and interpret the F Statistics, R^2, standard error, and p-values. How good is the model?
  LifeExp = b0+b1 x PropMd + b2 x TotExp +b3 x PropMD x TotExp
- 5. Forecast LifeExp when PropMD=.03 and TotExp = 14. Does this forecast seem realistic? Why or why not?

Import dataset

Data Dictionary

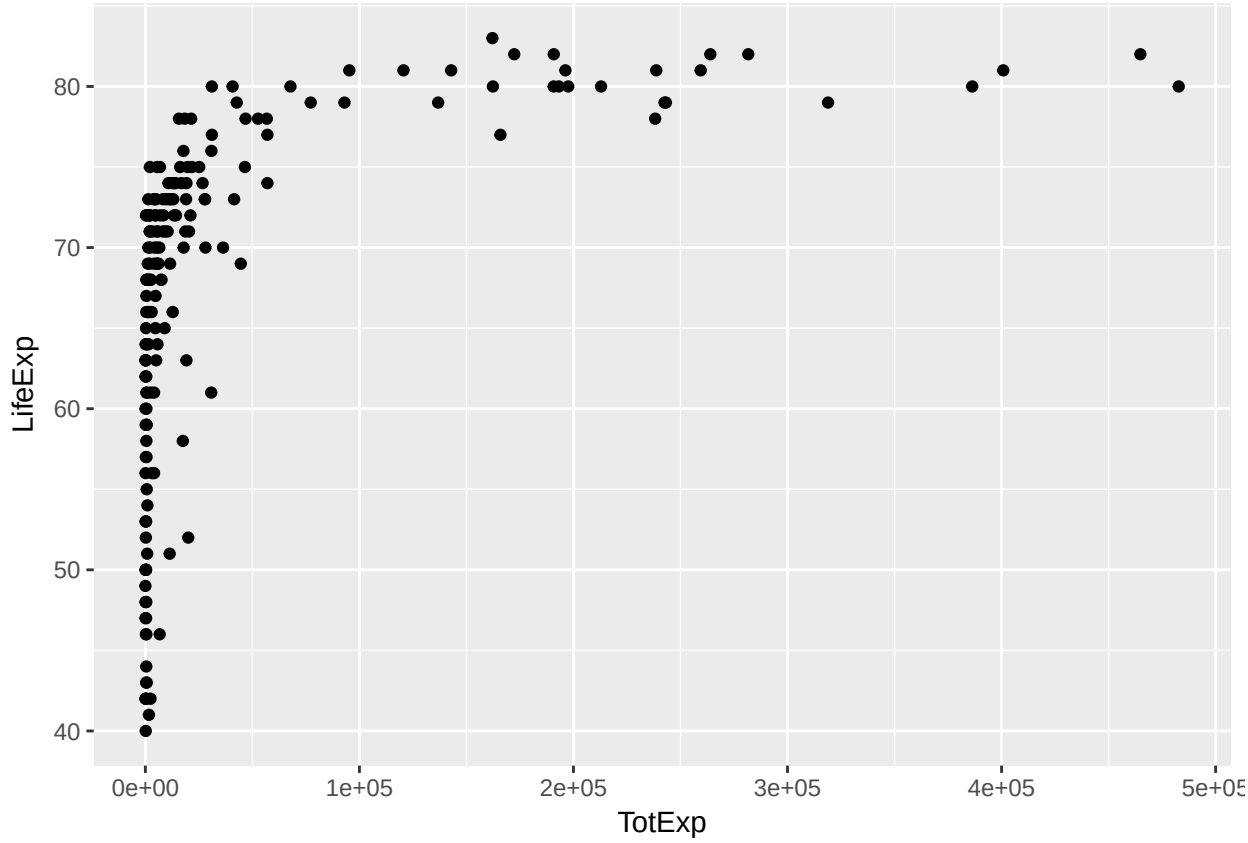
Variable Name	Definition
Country	Name of the country
LifeExp	Average life expectancy for the country in years
InfantSurvival	Proportion of those surviving to one year or more
Under5Survival	Proportion of those surviving to five years or more
TBFree	Proportion of the population without TB
PropMD	Proportion of the population who are MDs
PropRN	Proportion of the population who are RNs
PersExp	Mean personal expenditures on healthcare in US dollars at average exchange rate
GovtExp	Mean government expenditures per capita on healthcare, US dollars at average exchange rate
TotExp	Sum of personal and government expenditures

Data Structure

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Country*	1	190	9.550000e+01	5.499242e+01	9.55000e+01	9.550000e+01	70.4235000	1.00e+00	1.90000e+02	1.89000e+02	0.0000000	-1.2189633	3.9895697
LifeExp	2	190	6.737895e+01	1.084785e+01	7.00000e+01	6.847368e+01	10.3782000	4.00e+01	8.30000e+01	4.30000e+01	-0.7973539	-0.2456855	0.7869854
InfantSurvival	3	190	9.624474e-01	3.817270e-02	9.78500e-01	9.689276e-01	0.0244629	8.35e-01	9.98000e-01	1.63000e-01	-1.3392518	1.1070308	0.0027693
Under5Survival	4	190	9.459421e-01	6.288300e-02	9.74500e-01	9.584079e-01	0.0289107	7.31e-01	9.97000e-01	2.66000e-01	-1.5708451	1.7147500	0.0045620
TBFree	5	190	9.980375e-01	2.450900e-03	9.99215e-01	9.984857e-01	0.0010156	9.87e-01	9.99980e-01	1.29800e-02	-1.6601038	2.6962678	0.0001778
PropMD	6	190	1.795400e-03	3.627600e-03	1.04740e-03	1.308700e-03	0.0013654	1.96e-05	3.51290e-02	3.51094e-02	7.5169037	64.2463055	0.0002632
PropRN	7	190	4.133600e-03	6.060400e-03	2.75840e-03	3.259200e-03	0.0030487	8.83e-05	7.08387e-02	7.07504e-02	7.2505578	74.8125351	0.0004397
PersExp	8	190	7.420000e+02	1.353999e+03	1.99500e+02	3.866974e+02	256.4898000	3.00e+00	6.35000e+03	6.34700e+03	2.4790093	5.6380247	98.2294089
GovtExp	9	190	4.095349e+04	8.614065e+04	5.38500e+03	1.767133e+04	7692.4701000	1.00e+01	4.76420e+05	4.76410e+05	2.8602374	8.3912307	6249.2993052
TotExp	10	190	4.169549e+04	8.744985e+04	5.54100e+03	1.806003e+04	7899.2928000	1.30e+01	4.82750e+05	4.82737e+05	2.8511964	8.3228612	6344.2791865

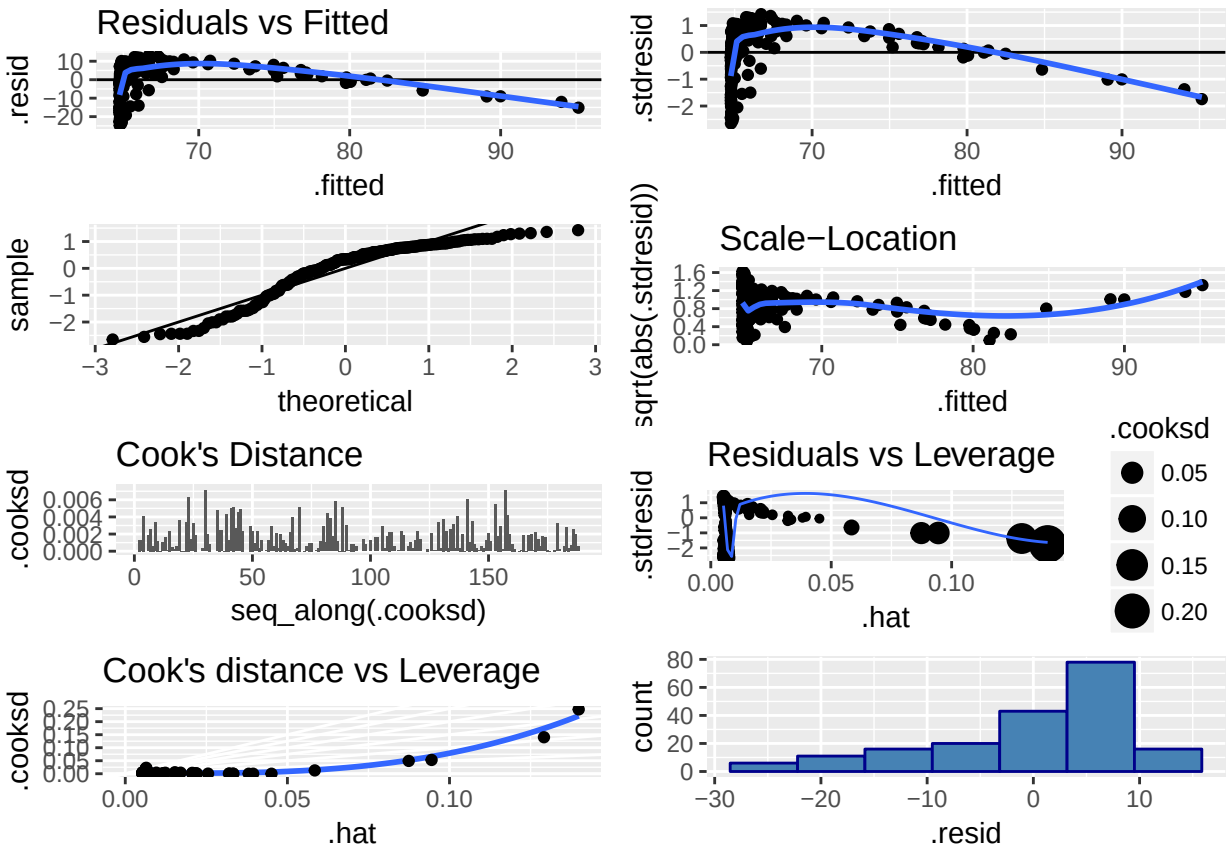
The dataset has 9 predictor variables, and 190 cases. Each case represents a country in the world, with different statistics about their quality of healthcare.

1.




```
##
## Call:
## lm(formula = LifeExp ~ TotExp, data = who)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -24.764  -4.778   3.154   7.116  13.292
##
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 6.475e+01  7.535e-01  85.933  < 2e-16 ***
## TotExp      6.297e-05  7.795e-06   8.079 7.71e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.371 on 188 degrees of freedom
## Multiple R-squared:  0.2577, Adjusted R-squared:  0.2537
## F-statistic: 65.26 on 1 and 188 DF,  p-value: 7.714e-14
```



The F-statistic for this model is 65.2641982, and the p-value is $7.7139931 \times 10^{-14}$. This tells us that the relationship between the variables `LifeExp` and `TotExp` is likely not due to chance.

With a low r-squared value of 0.2576922, the model is only able to explain $\approx 25\%$ of the variability. Furthermore, since the residuals are not normally distributed, as can be seen in the plots, this model is insufficient to explain the relationship between the data.

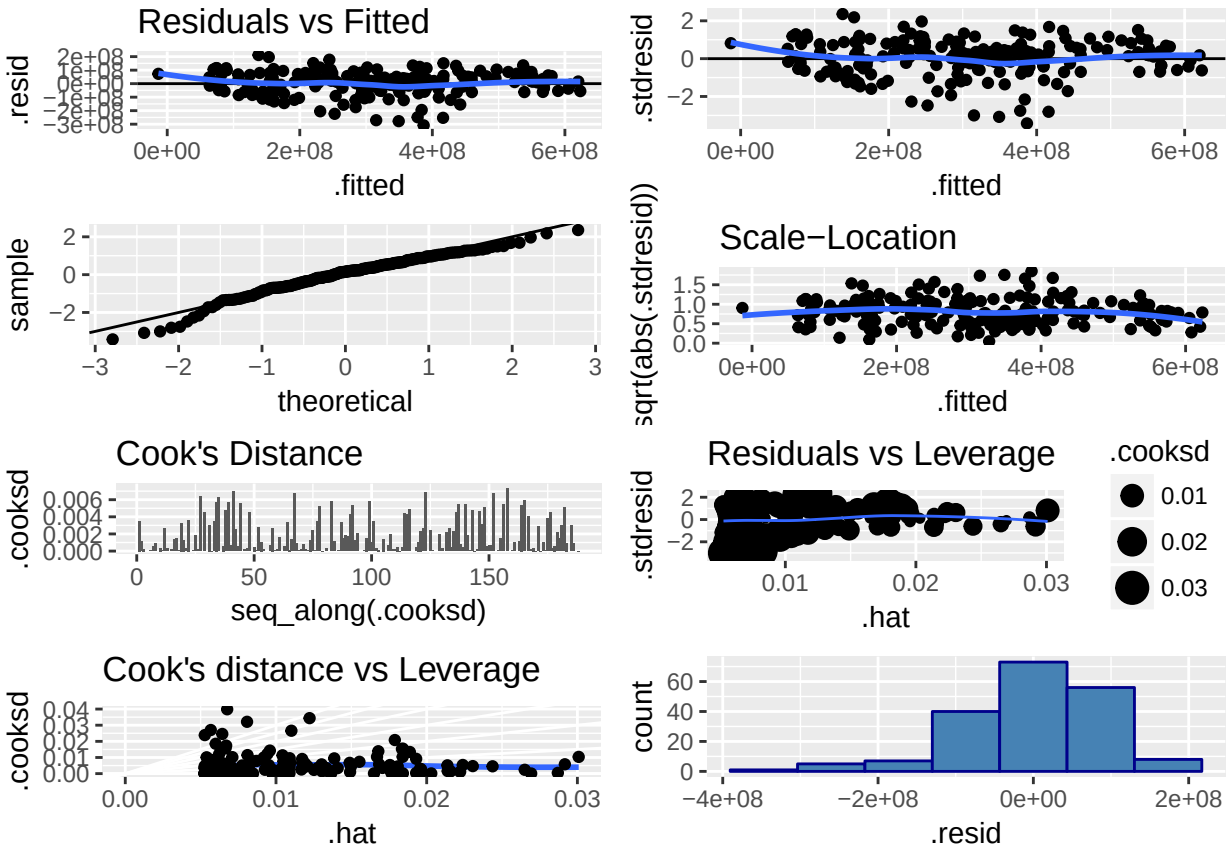
We can make use of the `gvlma` package to confirm our interpretation.

```
##
## Call:
## lm(formula = LifeExp ~ TotExp, data = who)
##
## Coefficients:
## (Intercept)       TotExp
##   6.475e+01    6.297e-05
##
##
```

```
## ASSESSMENT OF THE LINEAR MODEL ASSUMPTIONS
## USING THE GLOBAL TEST ON 4 DEGREES-OF-FREEDOM:
## Level of Significance =  0.05
##
## Call:
##  gvlma(x = model1)
##
##                      Value   p-value                   Decision
## Global Stat        56.737011 1.405e-11 Assumptions NOT satisfied!
## Skewness           30.532757 3.283e-08 Assumptions NOT satisfied!
## Kurtosis            0.002804 9.578e-01    Assumptions acceptable.
## Link Function      26.074703 3.285e-07 Assumptions NOT satisfied!
## Heteroscedasticity  0.126747 7.218e-01    Assumptions acceptable.
```

2.

```
##
## Call:
## lm(formula = m2.LifeExp ~ m2.TotExp)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -308616089  -53978977   13697187   59139231  211951764
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -736527910   46817945  -15.73   <2e-16 ***
## m2.TotExp    620060216   27518940   22.53   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 90490000 on 188 degrees of freedom
## Multiple R-squared:  0.7298, Adjusted R-squared:  0.7283
## F-statistic: 507.7 on 1 and 188 DF,  p-value: < 2.2e-16
```




```
##
## Call:
## lm(formula = m2.LifeExp ~ m2.TotExp)
##
## Coefficients:
## (Intercept)    m2.TotExp
##  -736527909    620060216
##
##
## ASSESSMENT OF THE LINEAR MODEL ASSUMPTIONS
## USING THE GLOBAL TEST ON 4 DEGREES-OF-FREEDOM:
## Level of Significance =  0.05
##
## Call:
##  gvlma(x = model2)
##
##                      Value   p-value                   Decision
## Global Stat        27.8117 1.362e-05 Assumptions NOT satisfied!
## Skewness           17.1372 3.478e-05 Assumptions NOT satisfied!
## Kurtosis            7.4581 6.315e-03 Assumptions NOT satisfied!
## Link Function       2.9866 8.396e-02    Assumptions acceptable.
## Heteroscedasticity  0.2299 6.316e-01    Assumptions acceptable.
```

Other than the higher standard error of 90492392, this model performs considerably better than the original one. It has an f-statistic of 507.6967054 and a p-value of 0. It has a much higher r-squared value of 0.7297673, which tells us that it's significantly better at explaining the variability in the data. From the summary plots, the residuals appear more normal, and randomly distributed, than in the first model.

In summary, this model outperforms the first by most measures, but still fails most assumptions needed for linear regression.

3.

3.1

The equation from model 2 is $y^{4.6}$ = -736527909 + 620060215$\cdot x^{0.06}$.

$y^{4.6}$ = -736527909 + 620060215 $\cdot(1.5)$ $\rightarrow$ 193562413

y = LifeExp = $\sqrt[4.6]{193562414} \approx 63.3115334$

3.2

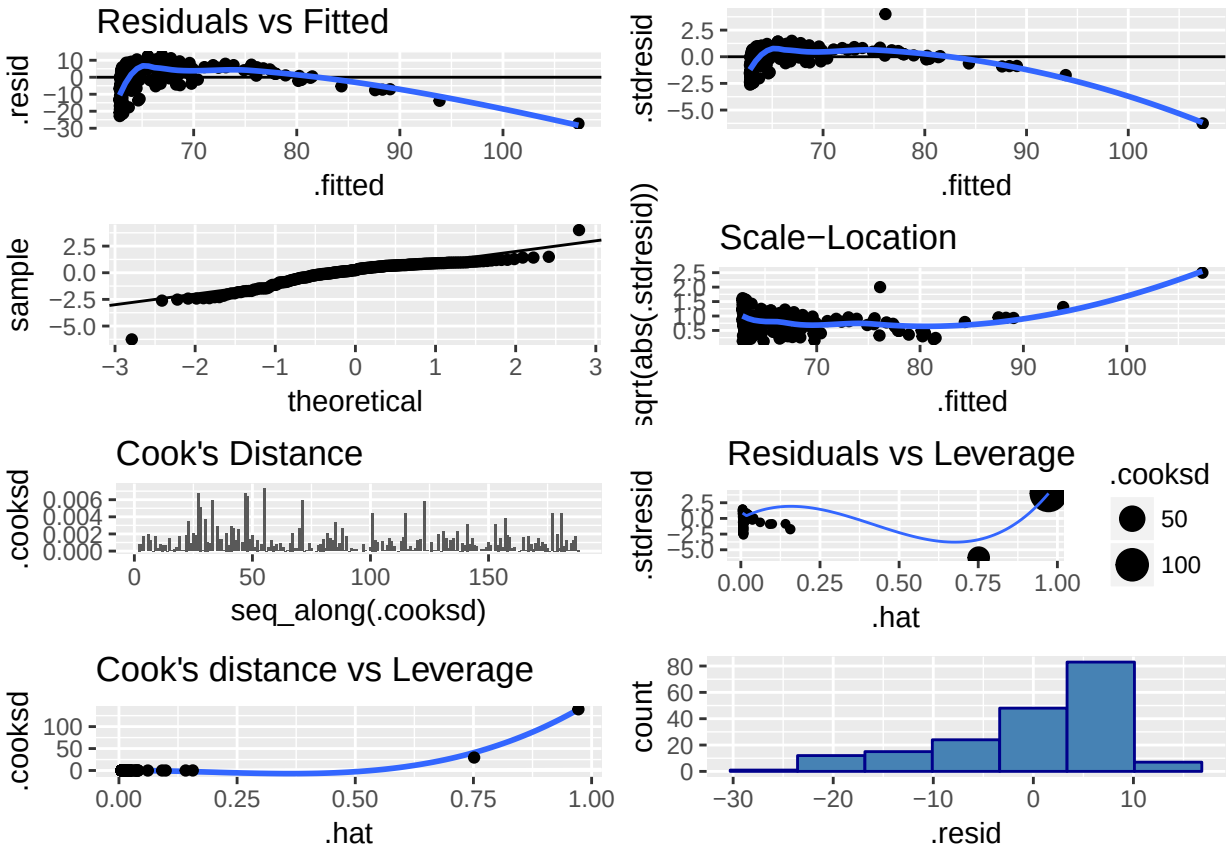
$y^{4.6}$ = -736527909 + 620060215 $\cdot(2.5)$ $\rightarrow$ 813622629

y = LifeExp = $\sqrt[4.6]{813622629} \approx 86.5064485$

4.

We want to build the model LifeExp = b0+b1 x PropMd + b2 x TotExp +b3 x PropMD x TotExp.

```
##
## Call:
## lm(formula = LifeExp ~ PropMD + TotExp + PropMD * TotExp, data = who)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -27.320  -4.132   2.098   6.540  13.074
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    6.277e+01  7.956e-01  78.899  < 2e-16 ***
## PropMD         1.497e+03  2.788e+02   5.371 2.32e-07 ***
## TotExp         7.233e-05  8.982e-06   8.053 9.39e-14 ***
## PropMD:TotExp -6.026e-03  1.472e-03  -4.093 6.35e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.765 on 186 degrees of freedom
## Multiple R-squared:  0.3574, Adjusted R-squared:  0.3471
## F-statistic: 34.49 on 3 and 186 DF,  p-value: < 2.2e-16
```




```
##
## Call:
## lm(formula = LifeExp ~ PropMD + TotExp + PropMD * TotExp, data = who)
##
## Coefficients:
##   (Intercept)         PropMD         TotExp  PropMD:TotExp
##     6.277e+01      1.497e+03      7.233e-05     -6.026e-03
##
##
## ASSESSMENT OF THE LINEAR MODEL ASSUMPTIONS
## USING THE GLOBAL TEST ON 4 DEGREES-OF-FREEDOM:
## Level of Significance =  0.05
##
## Call:
##  gvlma(x = model3)
##
##                      Value   p-value                   Decision
## Global Stat        87.0703 0.000e+00 Assumptions NOT satisfied!
## Skewness           33.4219 7.418e-09 Assumptions NOT satisfied!
## Kurtosis            0.5600 4.543e-01    Assumptions acceptable.
## Link Function      52.7284 3.830e-13 Assumptions NOT satisfied!
## Heteroscedasticity  0.3599 5.486e-01    Assumptions acceptable.
```

The F-statistic for this model is 34.4883268, and the p-value is 0. With a low r-squared value of 0.2576922, the model is only able to explain $\approx 35\%$ of the variability. There are a few outliers in this model, which introduces a lot of skew in the residual plots, making them not normally distributed. Overall, this model fared similarly to the first, and worse than the second.

5.

PropMD = 0.03, TotExp = 14.

Using model 3:

LifeExp = 62.7727033 + 1497.4939525·(0.03) + 10^{-4}·(14) -0.0060257·(0.03 · 14)

LifeExp ≈ 107.7010653.

This prediction does not seem realistic, since the total personal and government expenditure is near the minimum, yet life expentancy exceeds that of any country in the dataset.