modelacion_chile

November 14, 2025

[41]:
```
# Limpieza de la base de datos
import pandas as pd
import numpy as np

df = pd.read_csv(  # Lectura de datos
    "../archive/BBDD Población Chile (1b).xlsx - Tabla ajustada población .csv",
    index_col=0
)



df = df.T  # Transposicion

# notacion europea a float
for col in df.columns:
    df[col] = (
        df[col]
        .astype(str)
        .str.replace(".", "", regex=False)
        .str.replace(",", ".", regex=False)
    )

df = df.replace(["NaN", "nan", "NAN", "None", ""], np.nan)
df = df.fillna(0)

df = df.apply(pd.to_numeric)




print(df)

df.to_csv("../data/output.csv")
```

```
      Población total de jovenes (0-14)  Población total de adultos (15-64)  \
2002                          4156812.0                          10288683.0
2003                          4116188.0                          10456445.0
2004                          4057629.0                          10640163.0
2005                          3991476.0                          10826184.0
```

```
2006                          3921521.0                          11017529.0
2007                          3864328.0                          11200341.0
2008                          3823083.0                          11375175.0
2009                          3792259.0                          11541067.0
2010                          3767767.0                          11697176.0
2011                          3748933.0                          11851404.0
2012                          3732105.0                          11998670.0
2013                          3712426.0                          12125123.0
2014                          3698929.0                          12251374.0
2015                          3695756.0                          12369304.0
2016                          3692751.0                          12488678.0
2017                          3689702.0                          12658694.0
2018                          3696140.0                          12890070.0
2019                          3714172.0                          13132822.0
2020                          3738038.0                          13361656.0
2021                          3745665.0                          13473999.0
2022                          3739366.0                          13528576.0
2023                          3722867.0                          13573894.0
2024                          3698025.0                          13619165.0

      Poblacion total mayores (65+ años)      dJ        dA        dM
2002                           1246206.0       0       0.0       0.0
2003                           1284344.0 -40624  167762.0   38138.0
2004                           1324341.0 -58559  183718.0   39997.0
2005                           1365829.0 -66153  186021.0   41488.0
2006                           1408840.0 -69955  191345.0   43011.0
2007                           1453264.0 -57193  182812.0   44424.0
2008                           1499496.0 -41245  174834.0   46232.0
2009                           1547752.0 -30824  165892.0   48256.0
2010                           1598984.0 -24492  156109.0   51232.0
2011                           1653822.0 -18834  154228.0   54838.0
2012                           1712716.0 -16828  147266.0   58894.0
2013                           1774353.0 -19679  126453.0   61637.0
2014                           1837314.0 -13497  126251.0   62961.0
2015                           1906363.0  -3173  117930.0   69049.0
2016                           1985718.0  -3005  119374.0   79355.0
2017                           2070796.0  -3049  170016.0   85078.0
2018                           2165195.0   6438  231376.0   94399.0
2019                           2260222.0  18032  242752.0   95027.0
2020                           2358616.0  23866  228834.0   98394.0
2021                           2458699.0   7627  112343.0  100083.0
2022                           2560621.0  -6299   54577.0  101922.0
2023                           2664128.0 -16499   45318.0  103507.0
2024                           2769187.0 -24842   45271.0  105059.0
```

[42]:
```
#regresion
import statsmodels.api as sm
```

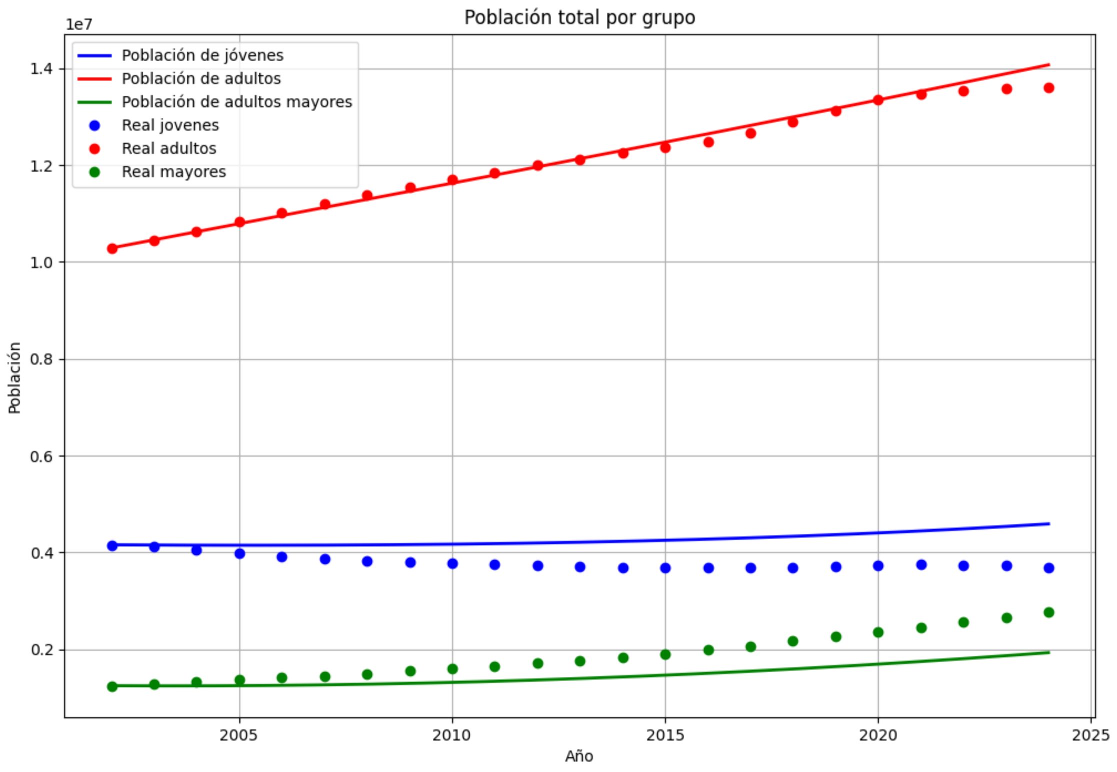
```
 #Modelo jovenes

x_J=df[["Población total de adultos (15-64)","Población total de jovenes␣
 ↪(0-14)"]]
y_J=df["dJ"]
#x_J=sm.add_constant(x_J,prepend=False)
modelo_J = sm.OLS(y_J,x_J).fit()
coef_j=modelo_J.params.to_dict()

# Modelo adultos

x_A=df[["Población total de jovenes (0-14)","Población total de adultos␣
 ↪(15-64)"]]
y_A=df["dA"]
#x_A=sm.add_constant(x_A,prepend=False)
modelo_A=sm.OLS(y_A,x_A).fit()
coef_A=modelo_A.params.to_dict()

# Modelo mayores

x_E=df[["Población total de adultos (15-64)","Poblacion total mayores (65+␣
 ↪años)"]]
y_E=df["dM"]
x_E=sm.add_constant(x_E,prepend=False)
modelo_E=sm.OLS(y_E,x_E).fit()
coef_E=modelo_E.params.to_dict()

print(modelo_J.summary())
print(modelo_A.summary())
print(modelo_E.summary())
```

```
                               OLS Regression Results
================================================================================
=======
Dep. Variable:                     dJ   R-squared (uncentered):
0.650
Model:                            OLS   Adj. R-squared (uncentered):
0.616
Method:                 Least Squares   F-statistic:
19.48
Date:                Fri, 14 Nov 2025   Prob (F-statistic):
1.64e-05
Time:                        09:12:00   Log-Likelihood:
-259.39
No. Observations:                  23   AIC:
522.8
```

```
Df Residuals:                      21   BIC:
525.1
Df Model:                           2
Covariance Type:            nonrobust
================================================================================
======================
                                         coef    std err          t      P>|t|
[0.025      0.975]
--------------------------------------------------------------------------------
----------------------
Población total de adultos (15-64)     0.0113      0.003      3.872      0.001
0.005       0.017
Población total de jovenes (0-14)     -0.0411      0.009     -4.423      0.000
-0.060      -0.022
==============================================================================
Omnibus:                        4.824   Durbin-Watson:                   0.477
Prob(Omnibus):                  0.090   Jarque-Bera (JB):                2.800
Skew:                           0.684   Prob(JB):                        0.247
Kurtosis:                       4.024   Cond. No.                         29.6
==============================================================================

Notes:
[1] R² is computed without centering (uncentered) since the model does not
contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                                 OLS Regression Results
================================================================================
=======
Dep. Variable:                     dA   R-squared (uncentered):
0.847
Model:                            OLS   Adj. R-squared (uncentered):
0.832
Method:                 Least Squares   F-statistic:
57.93
Date:                Fri, 14 Nov 2025   Prob (F-statistic):
2.83e-09
Time:                        09:12:00   Log-Likelihood:
-286.27
No. Observations:                  23   AIC:
576.5
Df Residuals:                      21   BIC:
578.8
Df Model:                           2
Covariance Type:            nonrobust
================================================================================
======================
                                         coef    std err          t      P>|t|
[0.025      0.975]
-------------------------------------------------------------------------------------
---------------------
Población total de jovenes (0-14)      0.0392      0.030      1.313      0.203
-0.023      0.101
Población total de adultos (15-64)    -0.0004      0.009     -0.043      0.966
-0.020      0.019
==============================================================================
Omnibus:                        3.462   Durbin-Watson:                   0.614
Prob(Omnibus):                  0.177   Jarque-Bera (JB):                2.013
Skew:                          -0.702   Prob(JB):                        0.365
Kurtosis:                       3.364   Cond. No.                         29.6
==============================================================================

Notes:
[1] R² is computed without centering (uncentered) since the model does not
contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
                            OLS Regression Results
==============================================================================
Dep. Variable:                     dM   R-squared:                       0.939
Model:                            OLS   Adj. R-squared:                  0.933
Method:                 Least Squares   F-statistic:                     153.0
Date:                Fri, 14 Nov 2025   Prob (F-statistic):           7.53e-13
Time:                        09:12:00   Log-Likelihood:                -235.49
No. Observations:                  23   AIC:                             477.0
Df Residuals:                      20   BIC:                             480.4
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
=====================
                                         coef    std err          t      P>|t|
[0.025      0.975]
-------------------------------------------------------------------------------------
---------------------
Población total de adultos (15-64)     0.0207      0.007      3.066      0.006
0.007      0.035
Poblacion total mayores (65+ años)     0.0107      0.015      0.696      0.494
-0.021      0.043
const                              -2.048e+05   5.43e+04     -3.774      0.001
-3.18e+05   -9.16e+04
==============================================================================
Omnibus:                       10.927   Durbin-Watson:                   1.261
Prob(Omnibus):                  0.004   Jarque-Bera (JB):               10.908
Skew:                          -0.979   Prob(JB):                      0.00428
Kurtosis:                       5.747   Cond. No.                     4.41e+08
==============================================================================
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The condition number is large, 4.41e+08. This might indicate that there are
strong multicollinearity or other numerical problems.
```

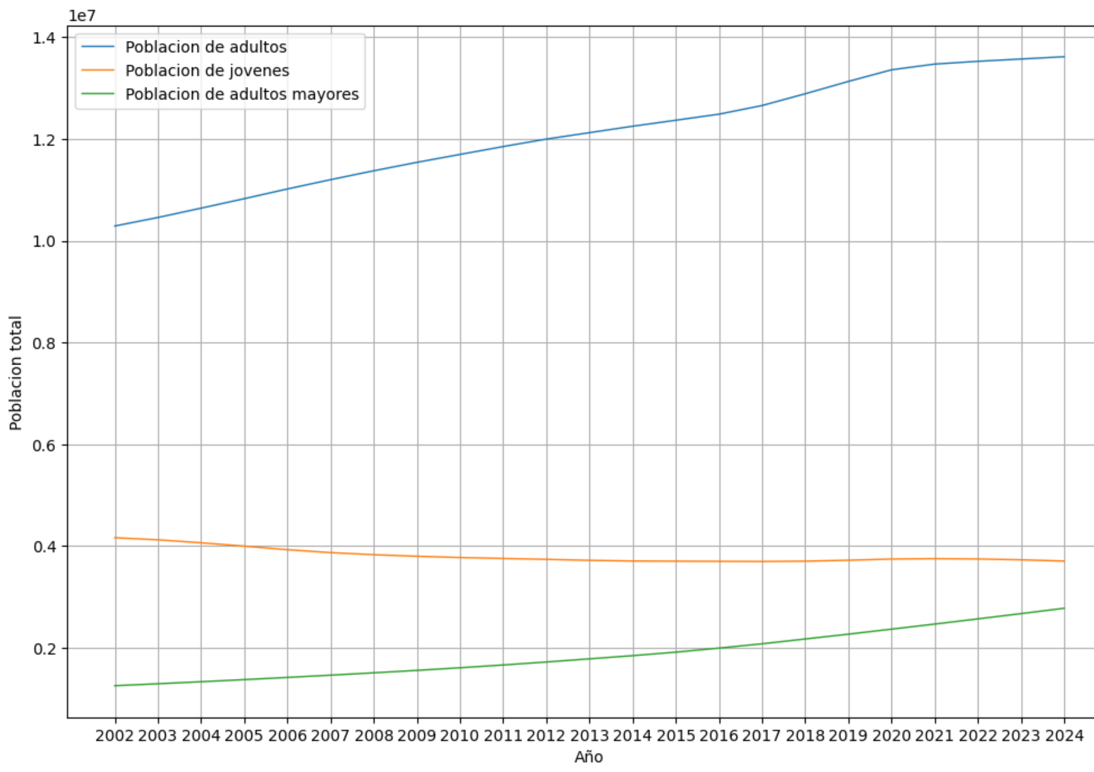
[46]:
```
# Graficación por Runge-Kutta 4 (consistente en el orden del estado)
import numpy as np
import matplotlib.pyplot as plt

def sistema_edos(t, y):
    # y = [J, A, E]
    jt, at, et = y

    # COEFICIENTES
    c1 = 0.0113 # tasa de natalidad
    c2 = -0.0411  # tasa de mortalidad jóvenes
    const1 = -2.929e+05
    tj= 0.0392 # transicion jovenes
    c3 =  -0.0004  # tasa de mortalidad adultos
    #const2= 1.442e+06
    ta=0.0207 # transicion adultos
    c4 = 0.0107  # tasa de mortalidad mayores
    const3=-2.048e+05

    # ECUACIONES
    dyJ = c1*at-c2*jt+const1
    dyA = tj*jt-c3*at#+const2
    dyE = ta*at-c4*et+const3
    return [dyJ, dyA, dyE]

def RK4(func, y0, t0, tf, h):
    t_values = np.arange(t0, tf + h, h)
    n = len(t_values)
    y_values = np.zeros((n, len(y0)), dtype=float)
    y_values[0] = y0

    for i in range(1, n):
        k1 = np.array(func(t_values[i-1], y_values[i-1]))
        k2 = np.array(func(t_values[i-1] + h/2, y_values[i-1] + h*k1/2))
        k3 = np.array(func(t_values[i-1] + h/2, y_values[i-1] + h*k2/2))
        k4 = np.array(func(t_values[i-1] + h,   y_values[i-1] + h*k3))
        y_values[i] = y_values[i-1] + h*(k1 + 2*k2 + 2*k3 + k4)/6

    return t_values, y_values
```

```
# y0 = [J, A, E] en 2002
y0 = [4156812.0, 10288683.0, 1246206.0]
t0, tf, h = 0, 22, 0.01

t, y = RK4(sistema_edos, y0, t0, tf, h)

years = 2002 + t
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
# Datos del modelo

ax.plot(years, y[:, 0], 'b-', linewidth=2, label='Población de jóvenes')
ax.plot(years, y[:, 1], 'r-', linewidth=2, label='Población de adultos')
ax.plot(years, y[:, 2], 'g-', linewidth=2, label='Población de adultos mayores')

# Datos reales

years_real =  df.index.astype(int)

ax.plot(years_real,df["Población total de jovenes␣
↪(0-14)"],'bo',markersize=6,label="Real jovenes")
ax.plot(years_real,df["Población total de adultos␣
↪(15-64)"],'ro',markersize=6,label="Real adultos")
ax.plot(years_real,df["Poblacion total mayores (65+␣
↪años)"],'go',markersize=6,label="Real mayores")

ax.set_title('Población total por grupo')
ax.set_xlabel('Año')
ax.set_ylabel('Población')
ax.grid(True)
ax.legend()
plt.show()
```



```
[26]: # hacer la grafica de los datos reales
      fig,ax = plt.subplots(1,1,figsize=(12,8))
      ax.plot(df["Población total de adultos (15-64)"],linewidth=1,label="Poblacion de␣
       ↪adultos")
      ax.plot(df["Población total de jovenes (0-14)"],linewidth=1,label="Poblacion de␣
       ↪jovenes")
      ax.plot(df["Poblacion total mayores (65+ años)"],linewidth=1,label="Poblacion de␣
       ↪adultos mayores")
      ax.set_xlabel("Año")
      ax.set_ylabel("Poblacion total")
      ax.grid(True)
      ax.legend()
      plt.show
```

```
[26]: <function matplotlib.pyplot.show(close=None, block=None)>
```



[18]:
```
print(df.index)
```

```
Index(['2002', '2003', '2004', '2005', '2006', '2007', '2008', '2009', '2010',
       '2011', '2012', '2013', '2014', '2015', '2016', '2017', '2018', '2019',
       '2020', '2021', '2022', '2023', '2024'],
      dtype='object')
```