**The Program Code Of GDIM**

# Factor decomposition of CO2 emissions by GDP, Energy, and Investment, their carbonization

# intensities, GDP per investment and Energy intensity of GDP

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program\_start\_time<- Sys.time() # timer - total time

# -------------------------------------------------------------------------------

# ------Input to the program -----------------------------------------------

# -------------------------------------------------------------------------------

yearB<-2029 #Base year

year<- 2030#Year of calculations

C0 <-316388.6# CO2 emissions, base year

C1 <-314951.8# CO2 emissions, calculations' year

G0 <-424656.9# GDP, base year

G1 <-443519.3# GDP, calculations' year

E0 <-201724.2# Energy, base year

E1 <-202488.8# Energy, calculations' year

P0 <-395764.8# Investment, base year

P1 <-419510.7# Investment, calculations' year

eps<- 10^-7 # preciseness of integration

# --------- Data in terms of the base year --------------------------------

z1 <- C1/C0 # CO2 emissions in terms of the base year

x1<- G1/G0 # GDP in terms of the base year

x3<- E1/E0 # Energy in terms of the base year

x5<- P1/P0 # Investment in terms of the base year

# ----- Relative indicators in terms of the base year ----------------------

x2<- z1/x1 # CO2/GDP

x4<- z1/x3 # CO2/Energy

x6<- z1/x5 # CO2/Investment

x7<- x1/x5 #GDP/Investment

x8<- x3/x1 #Energy/GDP

# --------------------------------------------------------------------------------

# - GDIM algorithm. Exponential dynamics assumed. In terms of base year -

zf<- function(t)(C1/C0)^t #CO2

x1f <- function(t) (G1/G0)^t #GDP

x3f <- function(t) (E1/E0)^t #Energy

x5f <- function(t) (P1/P0)^t #Investment

x2f <- function(t) zf(t)/x1f(t) #CO2/GDP

x4f <- function(t) zf(t)/x3f(t) #CO2/Energy

x6f <- function(t) zf(t)/x5f(t) #CO2/Investment

x7f <- function(t) x1f(t)/x5f(t) #GDP/Investment

x8f <- function(t) x3f(t)/x1f(t) #Energy/GDP

# ---- Projection operator --------------------------------------------------

Bij<- function(t,i1,j1){

IdM<- array(1:64, dim=c(8,8)) # Identity matrix（

IdM[] <- 0

for (ii in 1:8) {IdM[ii,ii] <-1}

PhiX<- array(1:32, dim=c(8,4)) # Jacobian matrix

PhiX[] <- 0

PhiX[1,1] <- x2f(t)

PhiX[2,1] <- x1f(t)

PhiX[3,1] <- -x4f(t)

PhiX[4,1] <- -x3f(t)

PhiX[1,2] <- x2f(t)

PhiX[2,2] <- x1f(t)

PhiX[5,2] <- -x6f(t)

PhiX[6,2] <- -x5f(t)

PhiX[1,3] <- 1

PhiX[5,3] <- -x7f(t)

PhiX[7,3] <- -x5f(t)

PhiX[1,4] <- -x8f(t)

PhiX[3,4] <- 1

PhiX[8,4] <- -x1f(t)

PhiXT<- t(PhiX) # PhiX transposed

Prod\_PT\_Px<- array(1:16, dim=c(4,4))

Prod\_PT\_Px[] <- 0

Prod\_PT\_Px<- PhiXT %\*% PhiX # Product of Phi\_X\_T\*Phi\_X

PT\_P\_1 <- solve(Prod\_PT\_Px) # Inverse of the Phi\_X\_T\*Phi\_X

# ------------------------------------------------------------------------------

B <- array(1:64, dim=c(8,8))

B[] <- 0

B <- IdM - PhiX %\*% PT\_P\_1 %\*% PhiXT

return(B[i1,j1])}

Dz\_vect<- array(1:8, dim=c(8))

Dz\_vect[] <- 0

for (i\_ind in (1:8)) {

if (i\_ind == 1)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x1f(t)\*log(x1)

else

if (i\_ind == 2)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x2f(t)\*log(x2)

else

if (i\_ind == 3)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x3f(t)\*log(x3)

else

if (i\_ind == 4)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x4f(t)\*log(x4)

else

if (i\_ind == 5)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x5f(t)\*log(x5)

else

if (i\_ind == 6)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x6f(t)\*log(x6)

else

if (i\_ind == 7)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x7f(t)\*log(x7)

else

if (i\_ind == 8)

try <- function(t) (x1f(t)\*Bij(t,2,i\_ind)+x2f(t)\*Bij(t,1,i\_ind))\*x8f(t)\*log(x8)

else {print("Error in the number of factors");stop}

# ------------ Numerical integration using the Simpson's method ------------

a <- 0 # initial point

b <- 1 # endpoint

n <- 2 # to begin iterations

y0 <- try(a)

yn<- try(b)

ymid<- try((a+b)/2)

del\_x<- (b-a)/n

k <- del\_x/3

Int\_0 <- k\*(y0+4\*ymid + yn)

err<- eps+1 # Initializing the error to start

Int\_n<- Int\_0

IntSimp<- Int\_0

while (err >eps){

n <- 2\*n

del\_x<- (b-a)/n

k <- del\_x/3

Int\_2n <- 0

for (ni in (1:n-1)){Int\_2n <- Int\_2n + try(a + ni\*del\_x)\*(2+(1+(-1)^(ni+1)))}

Int\_2n <- k\*(Int\_2n + y0 + yn)

err<- abs(Int\_2n - Int\_n)/15

if (err <eps) {IntSimp<- Int\_2n; break}

else {Int\_n<- Int\_2n}}

Dz\_vect[i\_ind] <- IntSimp

} # end of the loop by indicators

sum\_fact<- 0; for (i\_sum in 1:8) sum\_fact<- sum\_fact + Dz\_vect[i\_sum]

# --- Print out input data, results, and control numbers ----------------------

"Input data"

"Base year"; yearB

"Year of calculations"; year

"CO2 emissions, base year"; C0

"CO2 emissions, calculations year"; C1

"GDP, base year"; G0

"GDP, calculations year"; G1

"Energy, base year"; E0

"Energy, calculations year"; E1

"Investment, base year"; P0

"Investment, calculations year";P1

# ------------------------------------------------------------------------------

"In terms of the base year"

"CO2 emissions"; z1

"GDP"; x1

"Energy"; x3

"Investment"; x5

"Relative indicators in terms of the base year"

"CO2/GDP"; x2

"CO2/Energy"; x4

"CO2/Investment"; x6

"GDP/Investment"; x7

"Energy/GDP"; x8

# ------------------------------------------------------------------------------

"Output data"

"Contributions to the rate of change in CO2 emissions"

"yearB, year, GDP, GDP carbon intensity, Energy, energy carbon intensity, Investment,

Investment carbon intensity, GDP per investment, Energy intensity of GDP, Control number"

# --- Control number should be equal to the rate of change in the CO2 emissions -------------------

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yearB; year; "GDP"; Dz\_vect[1];"CO2/GDP";Dz\_vect[2]; "Energy"; Dz\_vect[3];"CO2/Energy";

Dz\_vect[4];"Investment"; Dz\_vect[5];"CO2/Investment"; Dz\_vect[6]; "GDP/Investment";

Dz\_vect[7];"Energy/GDP"; Dz\_vect[8]; "Check sum"; sum\_fact; "Actual rate of change in

CO2"; z1-1

"Contributions to the change in the CO2 emissions"

yearB; year; "GDP"; Dz\_vect[1]\*C0;"CO2/GDP";Dz\_vect[2]\*C0; "Energy";

Dz\_vect[3]\*C0;"CO2/Energy"; Dz\_vect[4]\*C0;"Investment"; Dz\_vect[5]\*C0;"CO2/Investment";

Dz\_vect[6]\*C0; "GDP/Investment"; Dz\_vect[7]\*C0; "Energy/GDP"; Dz\_vect[8]\*C0; "Check

sum"; sum\_fact\*C0; "Actual change in CO2"; (z1-1)\*C0

program\_end\_time<- Sys.time()

# ------------------------------------------------------------------------------

"Preciseness of integration"; eps

program\_time<- program\_end\_time - program\_start\_time

"Time of calculations" ;program\_time