Using Matrix Mathematics to Find Price Indices for any Base Year During a Specific Time Series, based on Pre-Prepared Base Year Price Indices

By

Khaled S. Al-Sulami

Department of General Studies, Technical College of Communication and Information, Jeddah, Saudi Arabia, TV Street, P.O.Box 22334

Abstract :The study dealt with how to find the price indices for any base year for a specific time series in the Saudi economy (a model), relying on the price indices for a pre-prepared base year, selected by the Central Bank of Saudi Arabia according to the approved economic and statistical criteria, using some mathematical laws and matrices. And based on the Central Bank of Saudi Arabia data for standard prices at the base year (2013 ,(100 = the price indices were found at the base year (2007 = 100), and the price indices were found at the base year (2018=100). And by comparing the results that we reached by mathematical methods with the results of the Saudi Central Bank for indices at the base year (2007 = 100) and the price indices in the base year (2018 = 100), the study concluded that the results obtained by mathematical methods match the results approved by the Saudi Central Bank for indices For prices in the two base years (2007 = 100), (2018 = 100) with a slight difference in some years following the base year, which allows researchers to study and discover it later.

Keywords :Base Period ,Time Series, Matrix Approach, Price Indices.

Introduction:

In standard studies, researchers tend to use fixed prices in the standard model instead of current prices in order to avoid reaching shady results that do not reflect the true picture of the case to be studied.

When there is a specific time series of length n, the researcher uses constant prices in this case to take into account the impact of inflation that occurred during this time period according to a specific base year. Choosing the base year is very important, as it takes into account that the chosen year is a period of relative economic stability. So that no related economic activities or phenomena were recorded, such as inflationary processes, political unrest ,periods of economic recession, etc. It is also necessary to take into account the existence of good statistical information in general.[1]

1- The official website of the General Authority for Statistics in the Kingdom of Saudi Arabia (www.stats.gov.sa).

Since the economic phenomena can be traced through the digital image, because that image provides a degree of accuracy and clarity that enables real knowledge of these phenomena, so it does not bear guesswork or relativism.

It is difficult for the researcher in economics or the economic decision-maker to study economic phenomena without the help of numerical data and statistics. Economics researchers routinely use mathematics, ranging from simple mathematical expressions to complex concepts in differential topology ,in order to express their theories. Social scientists, including economists ,have also found that mathematics provides them with two benefits. A tool for extracting deep concepts from massive piles of raw data.[2]

The study used matrices in the formulation of mathematical laws to find the indices for any base year based on the price indices for a specific base year.

This is due to the great role that matrix mathematics plays in life ,as it is used in many applied fields in order to facilitate calculations and avoid errors and inaccurate outputs.

It is often used in the economic aspects in order to know the calculation of the variables that occur in the economic process, such as calculating expenses and monthly or annual costs, as well as to know the extent of the loss or success of the process and some other variables.

The importance of the research lies in knowing the extent to which matrix mathematics is used in economic sciences as an effective means, in order to replace the traditional methods of finding the base year and calculating traditional indices, which may be affected by some errors resulting from data collection by simple mathematical operations, in addition to shortening the time and giving the results more clearly. and accuracy. The study aimed to find a mathematical method through which the base year is determined.

2- Al-Hayali: Ali Darb Kassar, "Mathematical Economics", Department of Agricultural Economics, College of Agriculture, University of Baghdad, undated, unprinted, p 12.

This study was divided into three parts. In addition to the introduction, the first part reviews the method used to find the base year mathematically, and the second part deals with the numerical application of this method and the comparison between the results obtained from the mathematical method and the data of the Central Bank of

Saudi Arabia, while the third part included the conclusion and conclusions.

Methods:

First: the method:

We assume a miniature model that is a time series (n = 1,2,3,4,5 (and we assume that the base year is (n = 3) and the price indices for this time period are as follows:

Year	1	2	3	4	5
Price index	P31	P32	p33=100	P34	p35

We find the rate of change in the price index between the comparison year (n=1,2,3,4,5) and the base year (n=3) using the rule (inflation calculation law).

$$Ri = \frac{P3i - P33}{P33} = \frac{P3i-100}{100}, \quad i=(1,2,3,4,5,), p33=100)$$

We get from him $R_1, R_2, R_3=(0, R_4, R_5)$

We will have a matrix of rank (5×5) and call it the price indices matrix as follows:

$$\begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{14} & P_{15} \\ P_{21} & P_{22} & P_{23} & P_{24} & P_{25} \\ P_{31} & P_{32} & P_{33} & P_{34} & P_{35} \\ P_{41} & P_{42} & P_{43} & P_{44} & P_{45} \\ P_{51} & P_{52} & P_{53} & P_{54} & P_{55} \end{pmatrix}$$

Whereas , $P_{33}=100$, P_{3i}, $i=1,2,3,4,5$ is price index for the year i , when the price index for the base year is $P_{33}=100$

In general if the price index in the base year (n = 3) is equal to y, then the price index in the comparison year is given with the following relationship

$X_1=y+yR_1 \rightarrow x_1=y(1+R_1) \rightarrow y_1=x_1/(1+R_1)$

$X_2=y+yR_2 \rightarrow x_2=y(1+R_2) \rightarrow y_2=x_2/(1+R_2)$

$X_3=y+yR_3 \rightarrow x_3=y(1+R_3) \rightarrow y_3=x_3/(1+R_3)$

$X_4=y+yR_4 \rightarrow x_4=y(1+R_4) \rightarrow y_4=x_4/(1+R_4)$

$X_5=y+yR_5 \rightarrow x_5=y(1+R_5) \rightarrow y_5=x_5/(1+R_5)$

Whereas is the price index for the comparison year i=1,2,3,4,5

when the price index in the base year is y, Also **y** i is the price index in the base year when the price index in the comparison year is, **X** i , (i = 1,2,3,4,5)

in general

$$X= y+ yR \rightarrow y = x /(1+R) \rightarrow (1)$$

We put the records in the comparison years

$(P_{11}=P_{22}=P_{44}=P_{55}=100)$

$$\begin{pmatrix} 100 & P_{12} & P_{13} & P_{14} & P_{15} \\ P_{21} & 100 & P_{23} & P_{24} & P_{25} \\ P_{31} & P_{32} & 100 & P_{34} & P_{35} \\ P_{41} & P_{42} & P_{43} & 100 & P_{45} \\ P_{51} & P_{52} & P_{53} & P_{54} & 100 \end{pmatrix}$$

From it we find the price indices) elements of the third column in the matrix) in the base year (n (3 = according to rule (1), as follows.

$P_{11}=100 \rightarrow p_{13}= 100/(1+R_1)$
$P_{22}=100 \rightarrow p_{23}= 100/(1+R_2)$
$P_{33}=100 \rightarrow p_{33}= 100/(1+R_3) \rightarrow P_{33}=100/(1+0)=100, R_3=0$
$P_{44}=100 \rightarrow p_{43}= 100/(1+R_4)$
$P_{55}=100 \rightarrow p_{53}= 100/(1+R_5)$

And from it we get the following matrix

$$\begin{pmatrix} 100 & P_{12} & \frac{100}{1+R1} & P_{14} & P_{15} \\ P_{21} & 100 & \frac{100}{1+R2} & P_{24} & P_{25} \\ P_{31} & P_{32} & 100 & P_{34} & P_{35} \\ P_{41} & P_{42} & \frac{100}{1+R4} & 100 & P_{45} \\ P_{51} & P_{52} & \frac{100}{1+R5} & P_{54} & 100 \end{pmatrix}$$

From the price indices in the third column , (P 13,P23, P 43,P53) we find the rest of the price indices in each row of the matrix from the relationship (1)

$$X = y+ yR$$

for example:

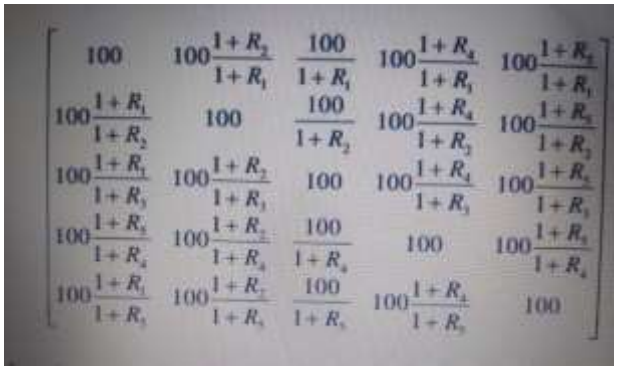
P13=100/(1+R_1) →P12= p13 (1+R_2) → p12=100/(1+R_1) (1+ R_2)→ p_12=100×(1+R_2)/(1+R_1)

Where (R2) is The rate of change in the price index between the base year (n=3) and the comparison year(n=2)

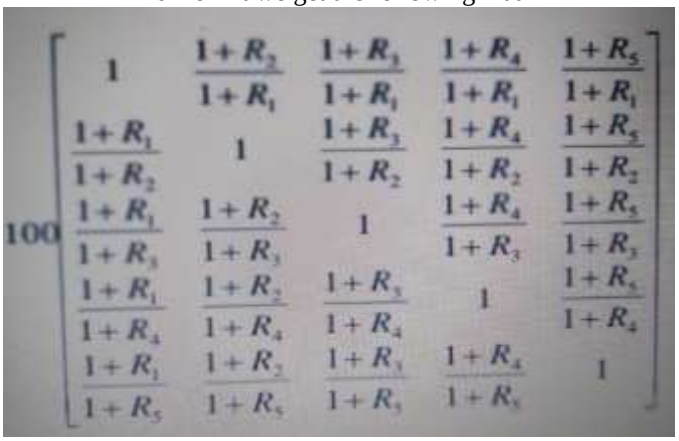
In general, the price index, (p i j) where stands for row and stands for column, ,(i j = 1,2,3,4,5) is given as follows :

P ij=100×(1+R_j)/(1+R_i)

Where (R j) is the rate of change in the price index between the base year (n = 3) and the comparison year (n = j) and (Ri) is the rate of change in the price index between the base year (n = 3) and the comparison year (n = i), and from it we get The matrix of price indices is as follows:



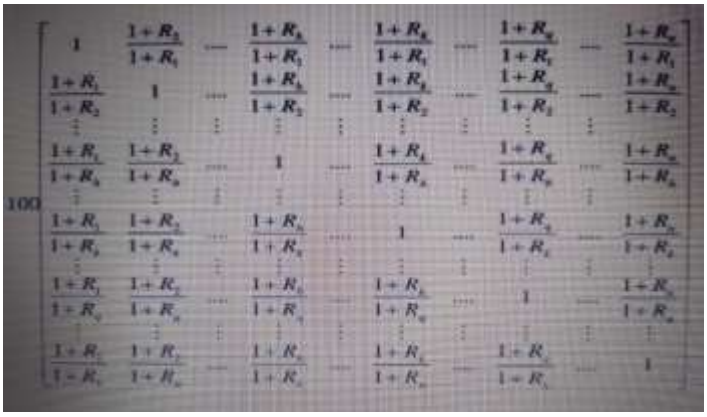
And from it we get the following matrix:



Note that(R3=0)

In general, if we have the price indices for a time series (N=1,2, 3… ,h, ….k,…q….n) where the base year is (k), then the matrix of the price indices for the time series is complete as the years The base is (1,2,3,…h,….k,…q….n) given as follows:

We take (100) as a common factor and put it outside the matrix .[3]



in general :

If we have the price indices for a time series(N=1,2,3,…h,….k,…q….n) where the base year is (k), then the matrix of the price indices for the time series is complete when the base years are …,1,2,3)h,….k,…q….n) is a square matrix of order (n×n) whose main diagonal elements are equal to one and each of its elements is given by the relationship where is the rate of change in the index For prices between the base year()n=k) and the comparison year (n=j), and is the rate of change in the price index between the base year (n=k) and the comparison year (n=i), this matrix is multiplied by the number (100), and it is considered The first row has the price indices for the base year (n=1), the h row has the price indices for the base year (n=h), and so on .

3- Shaeng: Alpha, "Basic Methods in Mathematical Economics", translated by: Nematullah Najib Ibrahim, reviewed by Hadi Majeed Haddad, Mars Publishing House, 2016, p 109.

Second: numerical application

Example: Based on the data of the General Authority for Statistics in the Kingdom of Saudi Arabia, we took the following data:

Year	Base year (2007=100)	Base year (2013=100)	Base year (2018=100)
2001	92	72.6	
2002	92.1	72.7	
2003	92.6	73.1	
2004	92.9	73.3	
2005	93.4	73.7	
2006	95.2	75.1	
2007	100	78.9	
2008	106.1	83.7	
2009	110.5	87.2	
2010	114.7	90.5	
2011	119	93.9	
2012	122.4	96.6	
2013	126.7	100	93.2
2014	130.1	102	95.2
2015	132.9	103.5	96.4
2016	137.6	105.6	98.4
2017	137.2	104.7	97.6
2018		107.3	100
2019			97.9
2020			101.3
2021			104.4
2022			106.9

Based on the price index when the base year is (100 = 2013), find the price index when the base year is (2007 = 100) and also when the base year is (100 = 2018), then compare the obtained results with the data in the table above?

The solution:

A- Base year (2007=100)

We find the rate of change in the price index between the comparison year (n=2001, …..2018) and the base year (n=2013) using the rule:

R i=(P i-100)/100 ,(i=2001,…2018,),(p_2013=100)

The values are as follows :

R2001	R2002	R2003	R2004	R2005	R2006	R2007	R2008	R2009
0.274	0.273	0.269	0.267	0.263	0.249	0.211	0.163	0.128
R2010	R2011	R2012	R2013	R2014	R2015	R2016	R2017	R2018
0.095	0.069	0.03	0	0.02	0.03	0.06	0.05	0.07

We find the indices for the years (i=2001……, 2018) when the base year is (100=2007) using the rule :

R i=(P i-100)/100 ,(i=2001,…2018,),(p 2013=100)

The values are as follows:

R2001	R2002	R2003	R2004	R2005	R2006	R2007	R2008	R2009
92.02	92.14	92.6	92.9	93.4	95.18	100	106.08	110.5
R2010	R2011	R2012	R2013	R2014	R2015	R2016	R2017	R_2018
114.7	119.01	122.4	126.7	129.6	131.14	133.9	132.7	136.01

B- Base year (2018=100)

We find the rate of change in the price index between the comparison year (n=2001, …..2018 (and the base year (n=2013) using the rule:

R i=(P i-100)/100 ,(i=2001,…2018,),(p 2013=100)

The values are as follows:

R2001	R2002	R2003	R2004	R2005	R2006	R2007	R2008	R2009
-0.274	-0.273	-0.269	-0.267	-0.263	-0.249	-0.211	-0.163	-0.128
R2010	R2011	R2012	R2013	R2014	R2015	R2016	R2017	R_2018
-0.095	-0.069	-0.03	0	0.02	0.03	0.06	0.05	0.07

We find the indices for the years (i=2001……, 2018) when the base year is (100=2018) using the rule :

P i=100×(1+R i)/(1+R 2018) (i=2001……,2018)

The values are as follows:

R2001	R2002	R2003	R2004	R2005	R2006	R2007	R2008	R2009
67.65	67.7	68.1	68.3	68.68	69.98	73.5	77.99	81.3
R2010	R011	R2012	R2013	R2014	R2015	R2016	R2017	R_2018
84.3	87.5	90.02	93.2	95.27	96.4	98.4	97.59	100

Results:

We compare the results obtained from the numerical example and the basic data of the Saudi Central Bank.

A- Base year (2007=100)

Year	Basic Information	Resulting Data
2001	92	92.02
2002	92.1	92.14
2003	92.6	92.6
2004	92.9	92.9
2005	93.4	93.4
2006	95.2	95.18
2007	100	100
2008	106.1	106.08
2009	110.5	110.5
2010	114.7	114.7
2011	119	119.01
2012	122.4	122.4
2013	126.7	126.7
2014	130.1	129.6
2015	132.9	131.14
2016	137.6	133.9
2017	137.2	132.7
2018		136.01

B-Base year(100=2018)

Year	Basic Information	Resulting Data
2001		67.65
2002		67.7
2003		68.1
2004		68.3
2005		68.68
2006		69.98
2007		73.5
2008		77.99
2009		81.3
2010		84.3
2011		87.5
2012		90.02
2013	93.2	93.2
2014	95.3	95.27
2015	96.4	96.4
2016	98.4	98.4
2017	97.6	97.59
2018	100	100

We conclude that there is a huge correspondence between the results obtained in the numerical example and the basic data in the Saudi Central Bank.

Discussions:

The study used matrices in the formulation of mathematical laws to find the indices for any base year based on the price indices for a specific base year. This is due to the great role that matrix mathematics plays in life , as it is used in many applied fields in order to facilitate calculations and avoid errors and inaccurate outputs. It is often used in the economic aspects in order to know the calculation of the variables that occur in the economic process, such as calculating expenses and monthly or annual costs, as well as to know the extent of the loss or success of the process and some other variables.

When comparing the results obtained using mathematical laws to determine the base year with the data of the Central Bank of Saudi Arabia, we found a great match between the results and the data, with some differences . Where the study started from the data of the Central Bank of Saudi Arabia for the price indices at the base year (2013 = 100) and the time period extended from 2001 to 2018. The price indices were found at the base year (2007 = 100 (and for the same time period, and the results were identical with a slight difference In the years following the base year (2013 = 100). As for the base year (2018 ,(100 = the results were identical according to the available data, which was from 2013 to 2018. As for the years from 2019 to 2022, we cannot find them mathematically because the study depends on the standard numbers for the base year (2013 = 100) and its time period extends from 2001 to 2018.

Conclusion and limitation of the study:

The study dealt with how to find the price indices for any base year for a specific time series in the Saudi economy (a model), relying on the price indices for a pre-prepared base year, selected by the Central Bank of Saudi Arabia according to the approved economic and statistical criteria, using some mathematical laws and matrices.

Where the study started from the data of the Central Bank of Saudi Arabia for the price indices at the base year (2013 = 100) and the time period extended from 2001 to 2018. The price indices were found at the base year (2007 = (100and for the same time period, and the results were identical with a slight difference In the years following the base year (2013 = 100). As for the base year (2018 = 100), the results were identical according to the available data, which was from 2013 to 2018. As for the years from 2019 to 2022, we cannot find them mathematically because the study depends on the standard numbers for the base year (2013 = 100) and its time period extends from 2001 to .2018.

Therefore, the study supports the importance of using mathematical methods to determine price indices for the base year instead of the traditional methods, or rather it supports the results obtained for choosing the base year and finding price indices by traditional methods. The study also supports the continuation of research and development to discover mathematical methods that give results correctly and accurately.

References and Sources :

.[1]Al-Hayali :Ali Darb Kassar, "Mathematical Economics", Department of Agricultural Economics, College of Agriculture, University of Baghdad, undated, unprinted.

.[2]Shaeng :Alpha, "Basic Methods in Mathematical Economics", translated by Nematullah Najib Ibrahim, reviewed by Hadi Majeed Haddad, Mars Publishing House, 2016, p 109.

.[3]The official website of the General Authority for Statistics in the Kingdom of Saudi Arabia www.stats.gov.sa)

.[4]The official website of the Saudi Central Bank (www.sama.gov.sa)

.[5]Fadam :Intisar Oraibi, "Index Numbers in Calculating Economic Indicators," Department of Economic Studies, University of Baghdad, College of Administration and Economics, Department of Statistics, 2017.

.[6]Samara :Ashraf, "Guide to Price Statistics and Index Numbers," Palestinian Central Bureau of Statistics, 2011.

.[7]Al-Zaini :Abdul Hussein Zaini, "Standard Numbers," Ministry of Higher Education ,University of Baghdad, Higher Education Press, 1988.

.[8]Taher ,Jamil and Al-Asfoor, Saleh, "The Unified Guide to Planning Concepts and Terminology in the Gulf Cooperation Council Countries," the Arab Planning Institute in Kuwait and the General Secretariat of the Gulf Cooperation Council, 1996.

.[9]Juhayma :Ramadan Muhammad and Owain: Ali Muhammad "Algebra Matrices - For the University Stage", Dar Al-Kitab Al-Jadeed United, 2005.

.[10]Al-Azzawi :Rahim Younis Crowe, "Matrices and Determinants", Dar Dijla, 2008.

.[11]Younis :Al-Mabrouk Ali, "Fundamentals of Linear Algebra",Dar Al-Kitab Al-Jadeed United, 2002.

.[12]Annual report of the Central Bank of Saudi Arabia for the year 2007.

.[13]Annual report of the Central Bank of Saudi Arabia for the year 2010.

.[14]Annual report of the Central Bank of Saudi Arabia for the year 2013.

.[15]Annual report of the Central Bank of Saudi Arabia for the year 2018.