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Time Series Analysis For Forecasting Mortality In Egypt

By

*Mounira A. Hussein** *Youssef M. Mahgoub***

Summary

The Egyptian population is making a noticeable progress concerning health and mortality. This progress has started as early as the Second World War. In this study, some mortality indicators were selected. The data available for those indicators all over the past century were collected. The available studies and researches were reviewed in order to identify high risk factors affecting mortality in general and those affecting infant mortality in particular. Using time series analysis, the best model for each indicator was estimated and checked. These models were used to get predictions till 2010. The steps as well as the methods for selecting the best model are presented. The predicted values for the mortality measures are given.

Introduction:

Mortality levels have been declining in both developed and developing countries.Chamie Joseph stated that:" It is important to acknowledge that considerable progress has been achieved in the area of health and mortality. In the twentieth century, mortality rates have declined in virtually every corner of the world. By and large, people are healthier and living longer than ever before". United Nations Symposium on Health and Mortality, Brusseles, .Belguim 19-22 November 1997. Egypt has been experiencing steady mortality decline through the last few decades. This trend is obvious for the different mortality measures where time series data are available. In this paper three mortality measures will be used for mortality predictions up to 2010.These mortality measures are crude death rate (CDR), infant mortality rate (IMR) and life expectancy at birth (LE). For crude death rate, the data are available from the begining of the past century til year 2000. Data for infant mortality rate started from 1947. Life expectancy at birth was available only from 1975. As expected data for infant mortaliy rate had suffered from huge descrepancies among different data sources.

The epidemiological transition - the shift from the predominance of infectious and parasitic diseases to that of chronic and degenerative diseases of adulthood as the main causes of death is now under way in all regions of the world. (United Nations 1998).

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* Mounira A. Hussein is an assistant professor, college of Commerce, Munufia University.
**Youssef M. Mahgoub is an assistant professor, ISSR, Cairo University.

Objectives:

We planned that this study must serve the following goals:

1- To review the recent studies and researches to recognize high risk factors as well as major causes of death.

2- To use the available time series data for estimating the best statistical model for each indicator.

3- These fitted models will be used to get predicted values for each of the three mortality indicators till 2010.

4- These fitted values may be used as a reliable tools for policy implications.

Data Sources:

The time series data shown in Table (1) for the three mortality measures: CDR, IMR and LE had been gathered from many sources. CAPMAS is the first source for CDR data. It is worth noting that CDR data are consistent and relatively reliable than IMR data. There are smoe huge gaps between CAPMAS and DHS data cocerning infant mortality which pinpoints to serious problem of underregistration. Life expectancy at birth data were collected mainly from 'national human development reports' published by the national planning institute, as well as the statistical yearbook published by CAPMAS.

Table 1: CDR, IMR and LE in Egypt from 1900 - 2000.

Year	CDR	IMR	LE	Year	CDR	IMR	LE	Year	CDR	IMR	LE	Year	CDR	IMR	LE	Year	CDR	IMR	LE
1900	32.0			1920	28.4			1940	28.5			1960	16.9	109		1980	10.0	76	57
1901	22.4			1921	25.3			1941	27.9			1961	15.8	108		1981	10.0	71	57
1902	27.7			1922	25.2			1942	30.5			1962	17.9	134		1982	10.0	71	57
1903	23.6			1923	25.7			1943	30.4			1963	15.4	118		1983	9.7	65	58
1904	27.5			1924	24.6			1944	28.6			1964	15.7	117		1984	9.5	62	58
1905	25.5			1925	26.0			1945	30.2			1965	14.0	113		1985	9.4	49	57
1906	25.1			1926	26.3			1946	27.5			1966	16.8	127		1986	9.2	47	61
1907	28.3			1927	24.5			1947	21.4	127		1967	14.2	116		1987	9.1	49	61
1908	26.3			1928	26.3			1948	20.4	139		1968	16.1	131		1988	8.1	43	63
1909	27.9			1929	27.6			1949	20.5	135		1969	14.5	119		1989	8.1	40	60
1910	37.6			1930	24.9			1950	19.0	130		1970	15.1	116	52	1990	7.5	38	60
1911	29.0			1931	26.6			1951	19.2	129		1971	13.2	103		1991	7.5	36	61
1912	25.9			1932	28.5			1952	17.8	127		1972	14.5	116		1992	9.0	36	62
1913	26.8			1933	27.5			1953	19.6	146		1973	13.1	98		1993	8.0	32	64
1914	28.5			1934	27.8			1954	17.9	138		1974	12.7	101		1994	6.4	31	64
1915	29.4			1935	26.4			1955	17.6	136		1975	12.2	89	55	1995	6.7	30	64
1916	31.3			1936	28.8			1956	16.4	124		1976	11.8	87	55	1996	6.5	29	67
1917	30.8			1937	27.1			1957	17.8	130		1977	11.8	85		1997	6.5	30	68
1918	39.7			1938	26.3			1958	16.6	112		1978	10.5	74		1998	6.5	27	68
1919	29.8			1939	25.9			1959	16.3	109		1979	10.9	76		1999	6.5	26	69
																2000	6.2	25	65

Crude Death Rate (CDR)

Introduction:

Crude death rate has been declining steadily from the middle of 1940's to the end of the twentieth century. This is partially due to the improvement in health status as well as the progress that has been realized in the standard of living in Egypt over time.

Step 1: Model Identification:

To identify the best model, the time series of CDR should be plotted against time to recognize its change pattern. Figure (1) shows that CDR had almost the same level (30 -40 per thousand) from the beginning of the twentieth century till the middle of 1940's. After the Second World War, crude death rate started to decline gradually until it reached 6.2 in year 2000. Figure (1) shows that CDR changes with time which means that the series is non-stationary. The succive differences transform the series into stationary (Abraham & Ledolter 1983). Figure (1) shows also that the variance changes with time. The natural logarithmic transformation proved to stabilize the variance. Thus, we will use the successive differences in the natural logarithmic form for model selection. The order of the ARMA model is found by examining the autocorrelations and partial autocorrelations of the stationary series (Makridakis S. &Insead M. 1997). Figures (2) &(3) show the autocorrelation and the partial autocorrelatios respectively.

Figure (1) Plot of CDR against time.

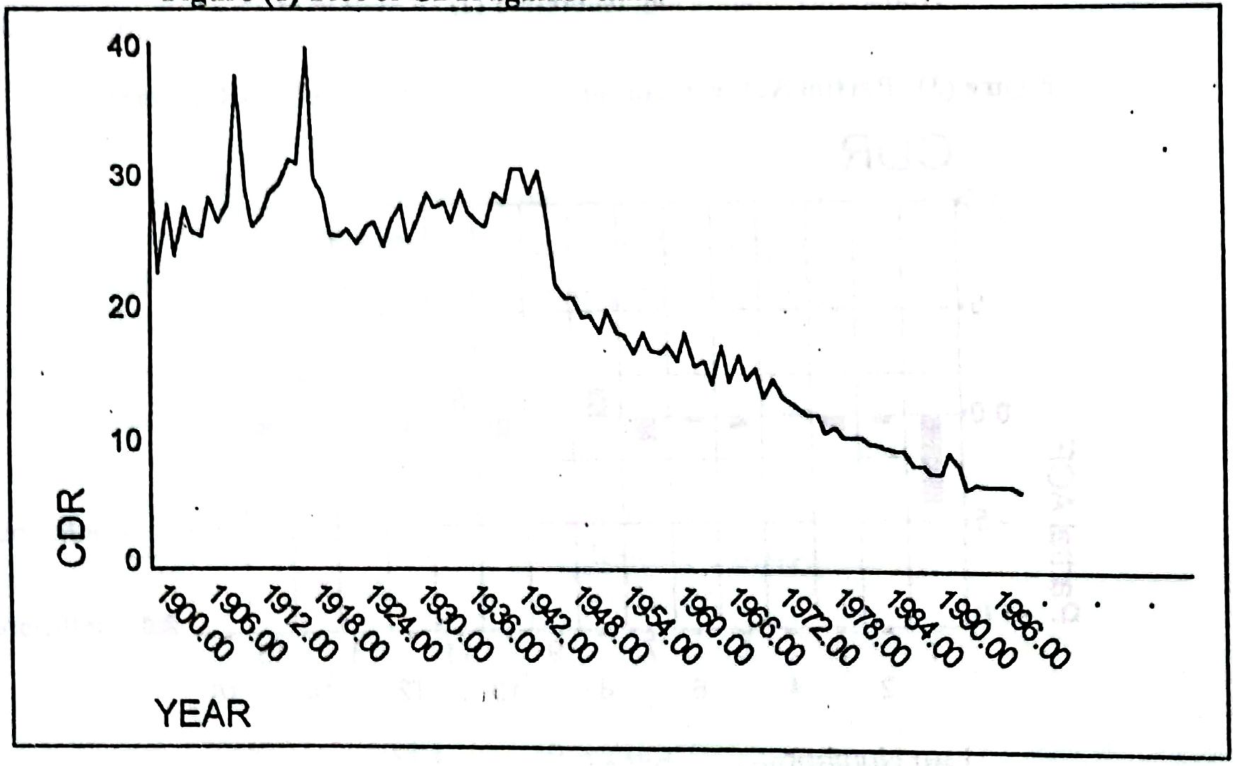


Figure (2): Autocorrelation of the natural log of CDR differences

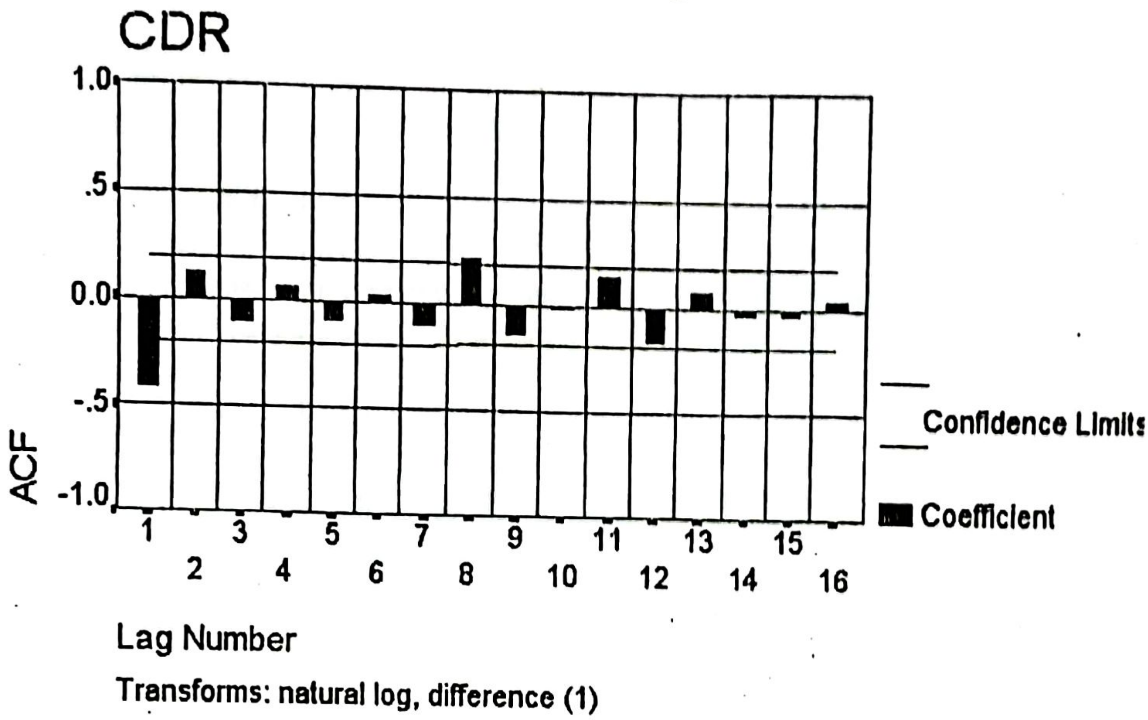


Figure (3): Partial Autocorrelation of the natural log of CDR differences

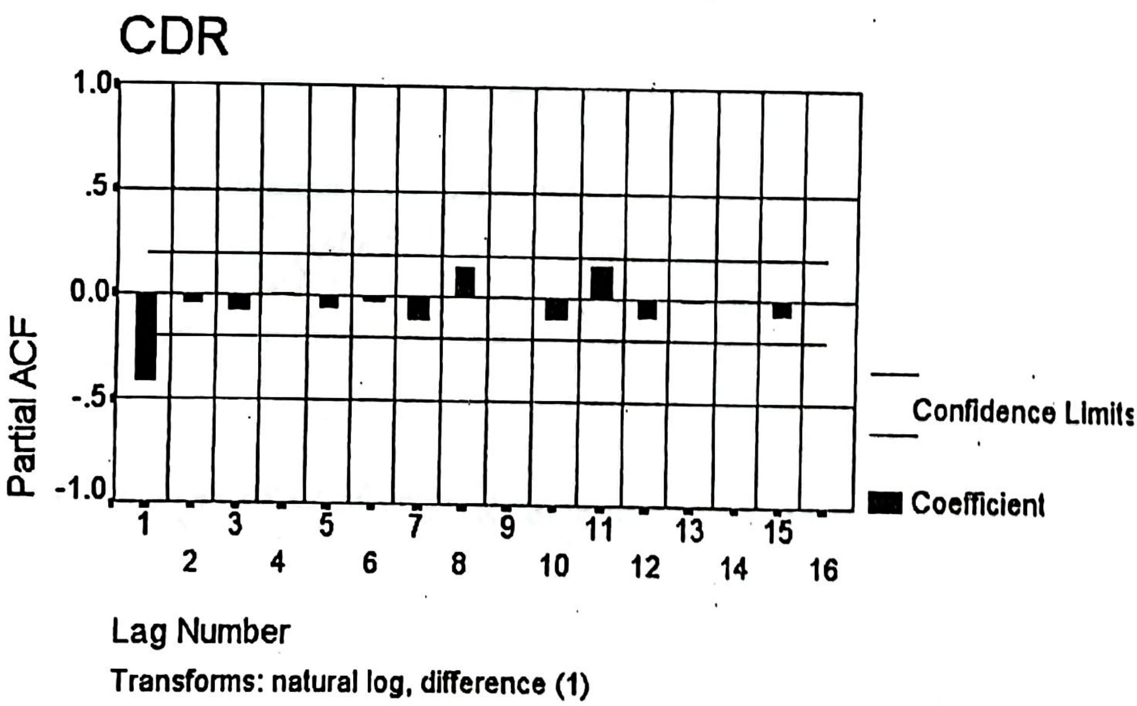


Figure (2) shows the autocorrelations of the natural logarithmic transformation of CDR differences. It is obvious that the autocorrelation decay in an oscillatory pattern. Figure (3) shows the partial autocorrelations of the natural logarithmic transformation of CDR differences. This figure shows that partial autocorrelatios cutt off after lag 1.These results suggest that ARIMA (1,1,0) is the model to be considered. We will introduce this model as follows:

Model 1:

$$(\Delta \ln z_t - \mu) - \phi(\Delta \ln z_{t-1} - \mu) = a_t$$

which can be defined as:

$$(1 - \phi\beta)(\Delta \ln z_t - \mu) = a_t .$$

Where :

z_t is the observed time series at time t.

Δ is the difference operator.

μ is $E(z_t)$

ϕ is the autoregressive parameter such as $|\phi| < 1$.

β is backword shift operator that shifts time one step back.

a_t is the error at time t.

Step 2: Model Estimation:

Table (2) shows the final parameters estimates for Model 1. This table shows that the autoregressive parameter ϕ is highly significant (p-value = .00000189). The mean of the series μ which is the constant in the model is also significant (p-value = 0.02513). Therefore, ARIMA (1,1,0) seems to be a good model for CDR data.

Table (2): Final Parameters Estimates, Model 1, CDR

Number of residuals	99
Standard error	.095697
Log likelihood	92.720644

Analysis of Variance

	DF	Adj. Sum of Squares	Residual Variance
Residuals	97	.89041882	.00915792

Variables in the Model

	ϕ	SEϕ	T-RATIO	APPROX. PROB.
AR1	-.45664984	.08997158	-5.0754899	.00000189
CONSTANT	-.01506631	.00662377	-2.2745829	.02513356

Step 3: Model Checking:

The most important step in model building is to check the adequacy of the model and asses its goodness of fit. Figure (4) shows plots of the observed time series against the predicted values for Model 1. Figures (5) &(6) show the plots of autocorrelation functin and partial autocorrelation function for the errors with their probability limits respectively. Inspection of these figures shows that the model suggested is a good one. Figure (4) shows that the observed and the predicted values for CDR are very close. Figures (5) and (6) show that the autocorrelation and the partial autocorrelation functions are within the confidence limits.

Step 4: Prediction:

The predicted values till 2010 for CDR and their lower and upper confidence limits are shown in Table (5). These values decrease gradually and slowly since CDR reached to a significant low figure (slightly higher than 5 per thousand).

Figure (4): plot of observed time series & predicted values of Model 1 (CDR)

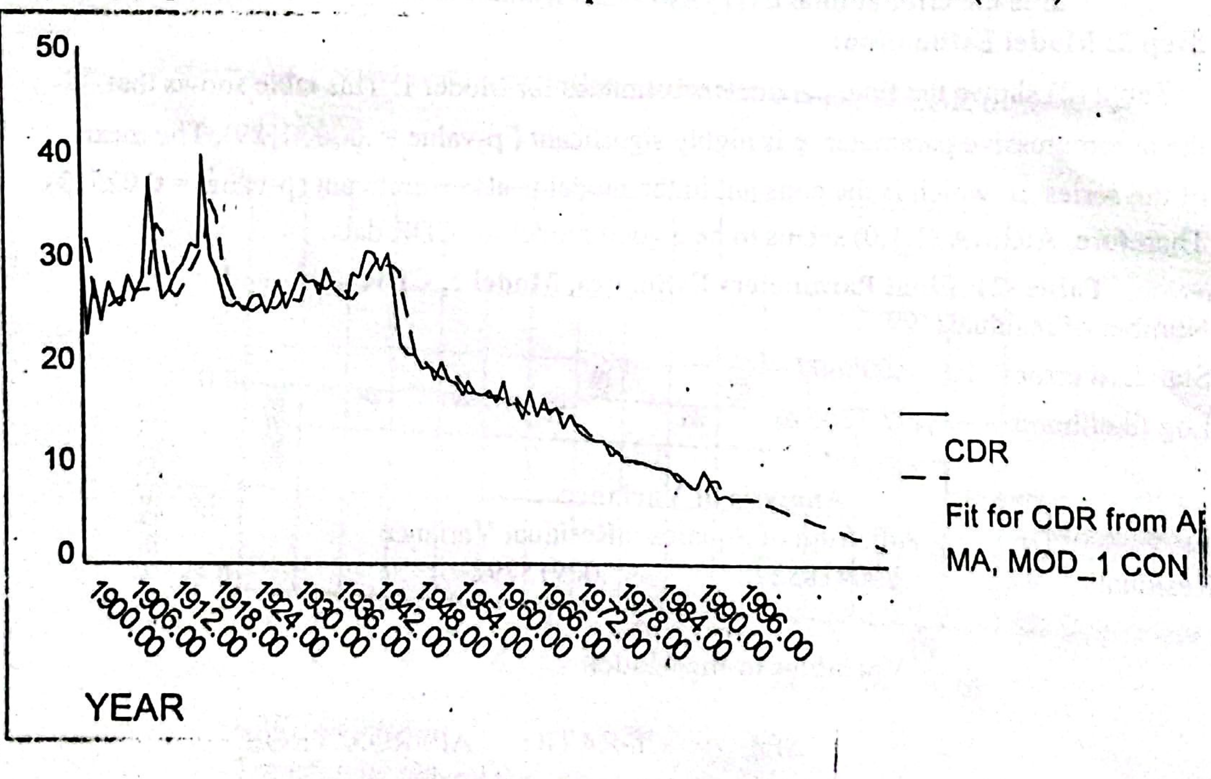


Figure (5): Autocorrelations for the errors of Model 1 (CDR)

Error for CDR from ARIMA, MOD_1 CON

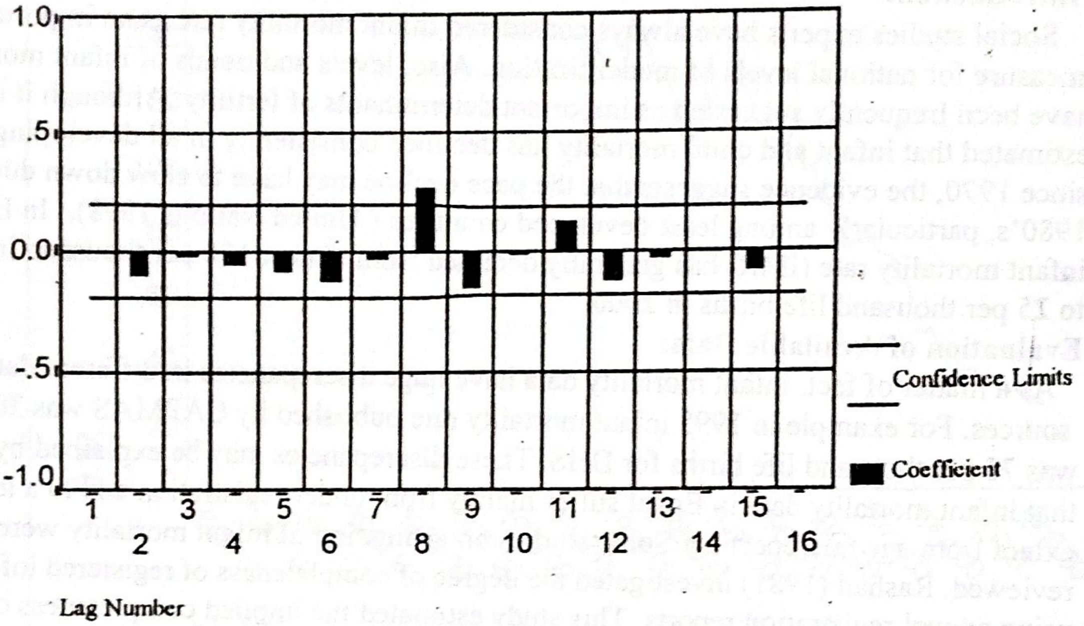
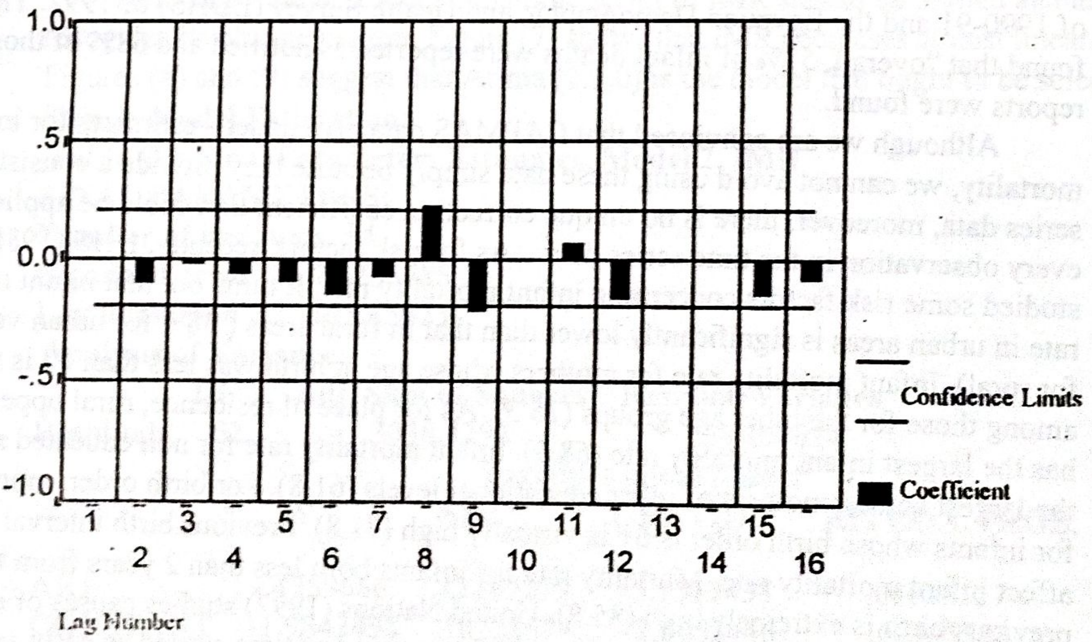


Figure (6): Partial autocorrelations for the errors of Model 1 (CDR)

Error for CDR from ARIMA, MOD_1 CON



Infant Mortality Rate (IMR)

Introduction:

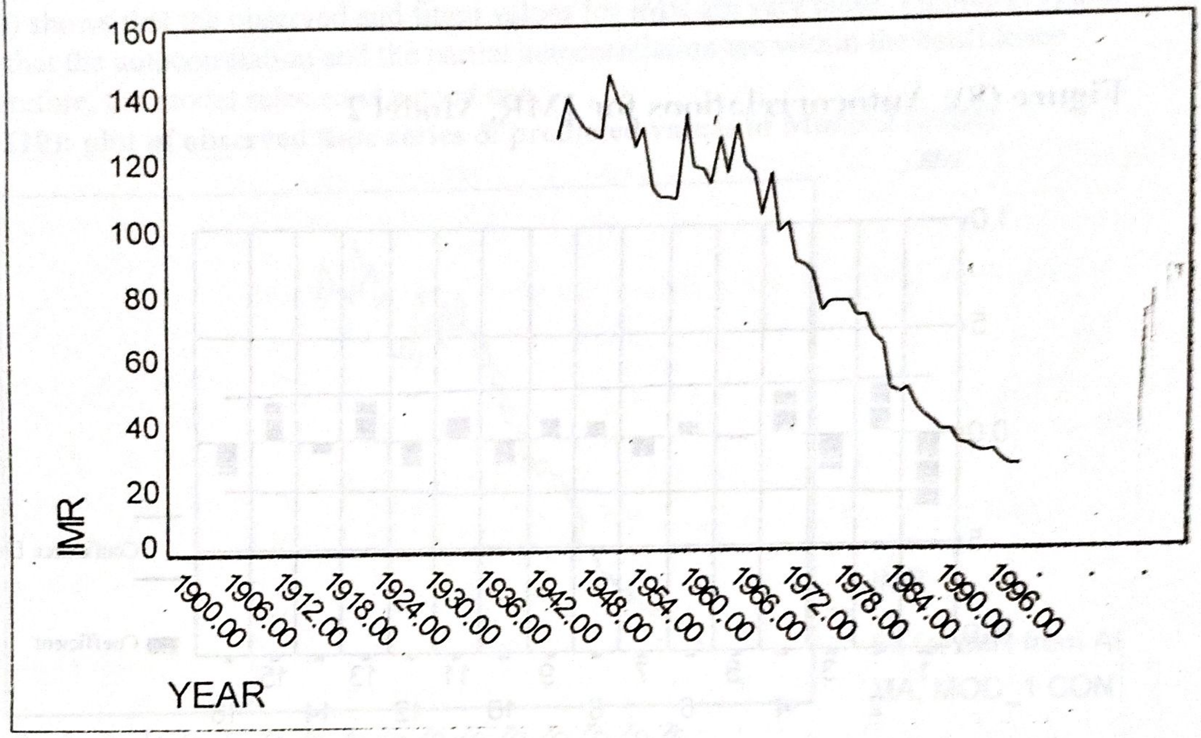
Social studies experts have always considered infant mortality rate as an important measure for national levels of modernization. Also, levels and trends of infant mortality have been frequently suggested as important determinants of fertility .Although it is estimated that infant and child mortality has declined consistently in all developing regions since 1970, the evidence suggests that the pace decline may have to slow down during 1980's, particularly among least developed countries (United Nations 1998). In Egypt infant mortality rate (IMR) has generally declined from almost 130 per thousand in 1940's to 25 per thousand life births in 2000.

Evaluation of Available Data:

As a matter of fact, infant mortality data have huge discrepancies in different data sources. For example in 1995 infant mortality rate published by CAPMAS was 30 while it was 75 per thousand life births for DHS. These discrepancies may be explained by the fact that infant mortality data in Egypt suffer mainly from under registration and to a lesser extent from age misreporting. Some studies on evaluation of infant mortality were reviewed. Rashad (1981) investigated the degree of completeness of registered infant deaths using annual registration reports. This study estimated the implied completeness of registration of infant deaths at only 75 percent. Becker S, et Al (1996) evaluated the completeness of registration of infant and child deaths in Egypt. This study reinterviewed families who had reported a death of a child under age 5 in the five years before the survey of 1990-91 and the Egyptian Demographic and Health Survey (EDHS) of 1992. This study found that "overall, 57% of infant deaths were reported as notified and 68% of those death reports were found.

Although we are convinced that CAPMAS data give under - estimates for infant mortality, we can not avoid using these data simply because they provide a consistent time series data, moreover, there is no unique correction coefficient that could be applied to every observation in the time series data. As for risk factors, recently, DHS (1988) has studied some risk factors concerning infant mortality rate. It turns out that infant mortality rate in urban areas is significantly lower than that in rural areas (38.1 for urban versus 58.6 for rural). Infant mortality rate for mothers whose age at birth was less than 20 is the largest among those for the other age groups (75.3). As for place of residence, rural upper Egypt has the largest infant mortality rate (68.5). Infant mortality rate for non educated mothers is the largest among mothers of other educational levels (61.8). For birth order, mortality rates for infants whose birth order is 6+ is virtually high (71.8). Previous birth interval proved to affect infant mortality rate. Mortality rate for infants born less than 2 years from the previous birth is extremely high (85.8). United Nations (1997) studies causes of infant deaths in some countries all ov r the world for a period of time started as early as 1951 and ended in 1989. This study had : n ›wn that when levels of infant mortality were high, the main cause of death was infecti : is and parasitic disease. Only when infant mortality is very low do chronic disease start to ı count for a high proportion of deaths.

Figure (7): Plot of IMR against Time



Step 1: Model Identification:

To identify the best model, the time series of IMR should be plotted against time to recognize its change pattern. Figure (7) shows that IMR decreases almost linearly with time. Figures (8) and (9) suggest that Arima (1,1,0) is the model that ought to be selected.

Step 2: Model Estimation:

Table (3): Final Parameters Estimates, Model 2, IMR

FINAL PARAMETERS:

Number of residuals 54

Standard error 7.6258785

Log likelihood -185.45023

Analysis of Variance:

	DF	Adj. Sum of Squares	Residual Variance
Residuals	52	3038.4292	58.154024

Variables in the Model:

	ϕ	SEϕ	T-RATIO	APPROX. PROB.
AR1	-.4759666	.12107279	-3.9312438	.00025127
CONSTANT	-1.9842498	.70733574	-2.8052446	.00705582

Figure (8): Autocorrelations for IMR, Model 2

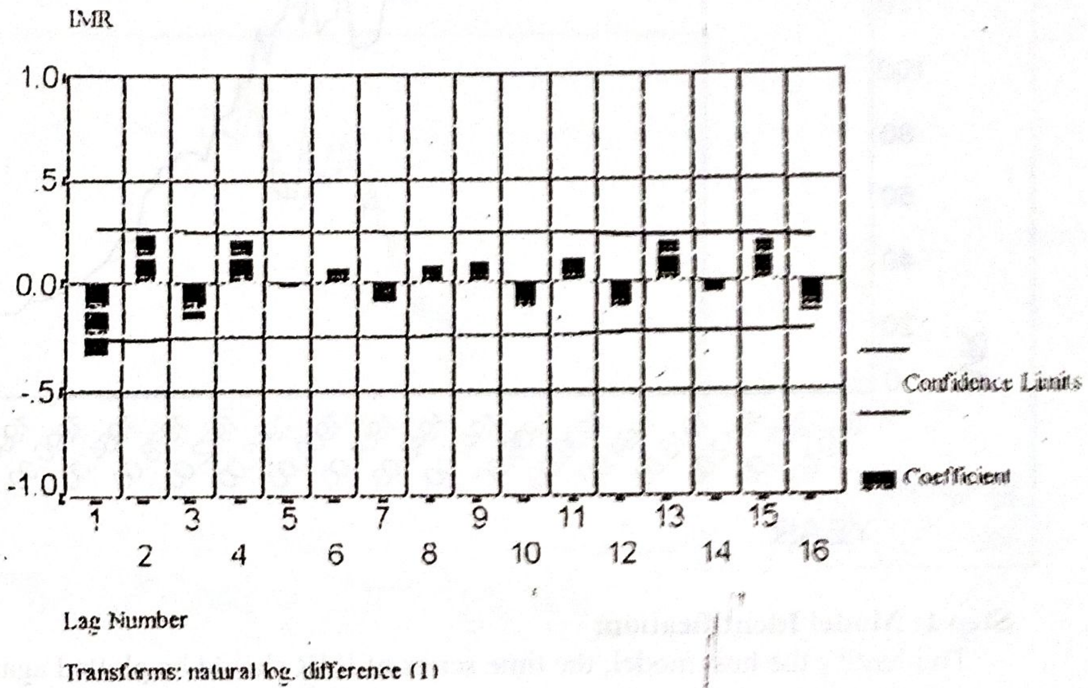
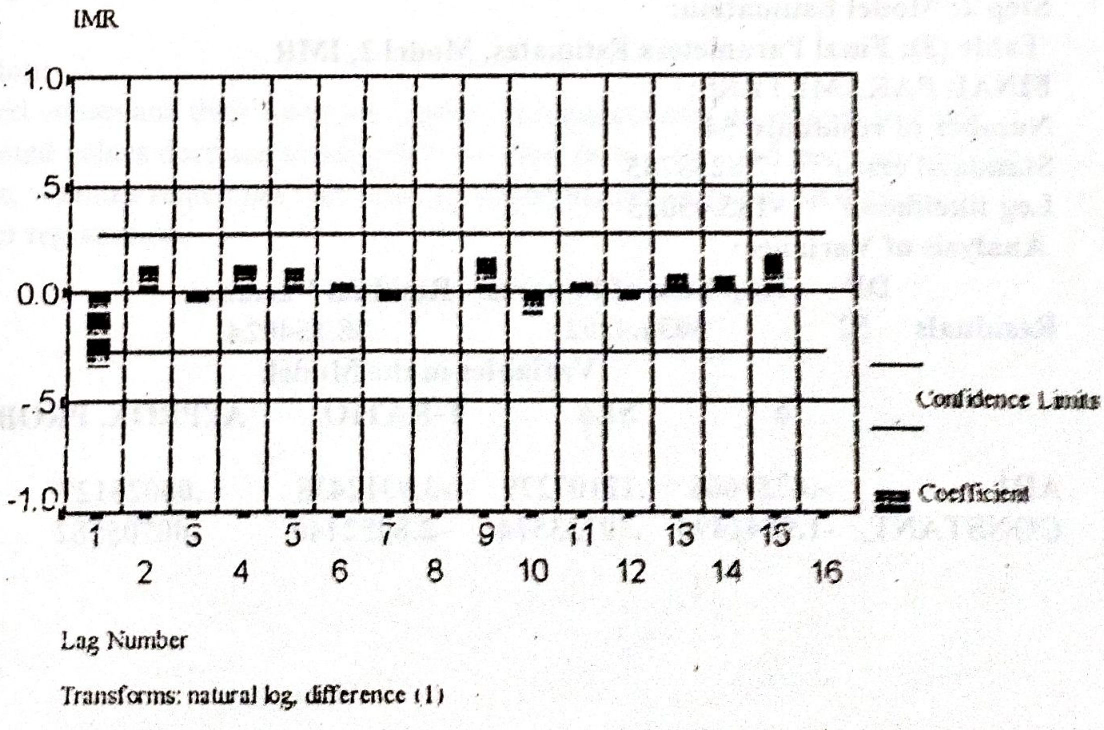


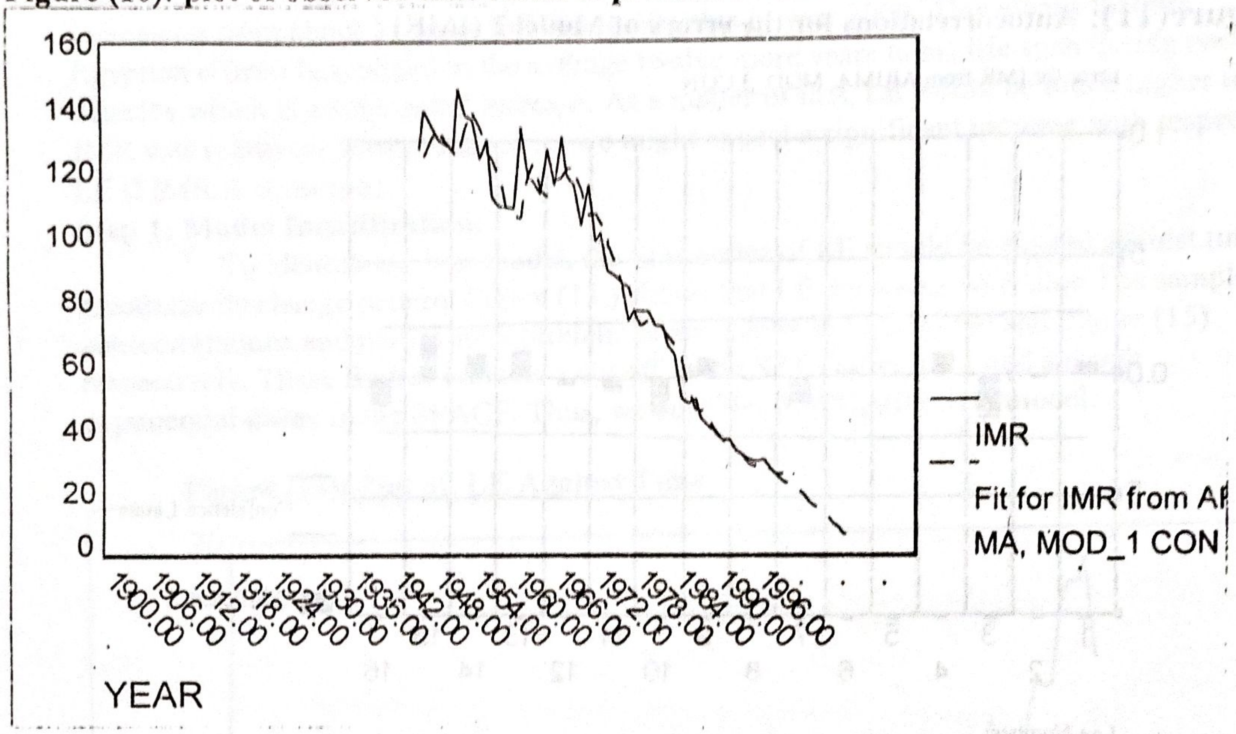
Figure (9): Partial autocorrelations for IMR, Model 2



Step 3: Model Checking:

Figure (10) shows that the observed and fitted values for IMR are very close. Figures (11) and (12) show that the autocorrelation and the partial autocorrelation are within the confidence limits. Therefore, the model selected is a good one.

Figure (10): plot of observed time series & predicted values of Model 2 (IMR)



Step 4: prediction:

The predicted values and their lower and upper confidence limits are shown in Table (5). Those predicted values decrease steadily to a very low level (almost 5 per thousand life births). However, we must remember that those predicted values are based on data hat suffer from under registration.

Figure(11): Autocorrelations for the errors of Model 2 (IMR)

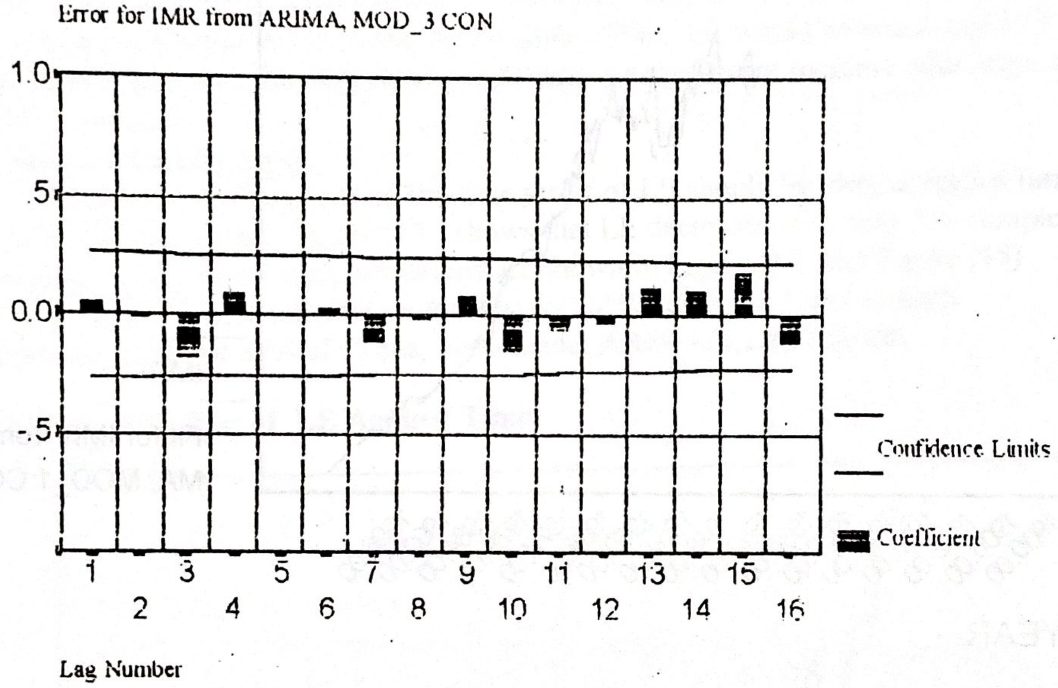
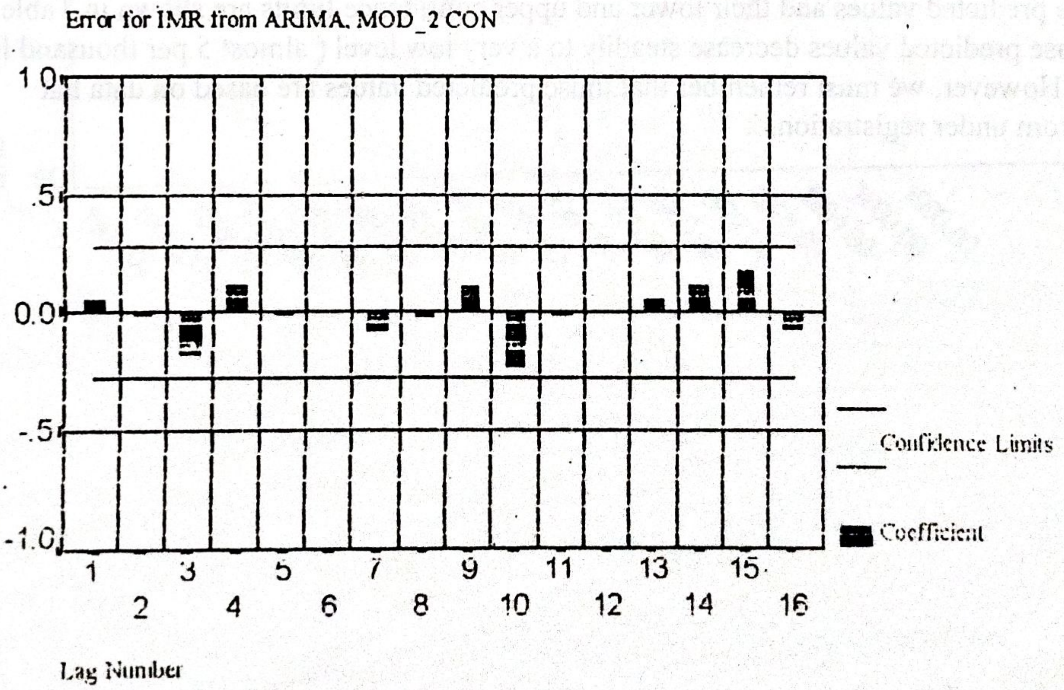


Figure (12): Partial autocorrelations for the errors of Model 2 (IMR)



Life Expectancy at Birth (LE)

In the period 1990-1995, for example, the global average life expectancy at birth is estimated to have been 64.3 years, a level typical for the more developed countries in the early 1950's. "United Nations(1999)". Life expectancy at birth (LE) in Egypt has been increasing from about 57 years in 1980 to 69 years in year 2000. This means that the Egyptian citizen has gained in the average twelve more years to his life span during two decades which is a substantial increase. As a matter of fact, LE would be much higher if IMR was relatively lower. Therefore, we might expect a significant increase with respect to LE if IMR is controlled.

Step 1: Model Identification:

To identify the best model, the time series of LE should be plotted against time to recognize its change pattern. Figure (13) shows that LE decreases with time.The sample autocorrelations and partial autocorrelations are shown in Figure (14) and Figure (15) respectively. These figures indicate a cut off in the SACF after lag 1 and a rough exponential decay in the SPACF. Thus, we consider ARIMA(0,1,1,1) model.

Figure (13): Plot of LE Against Time

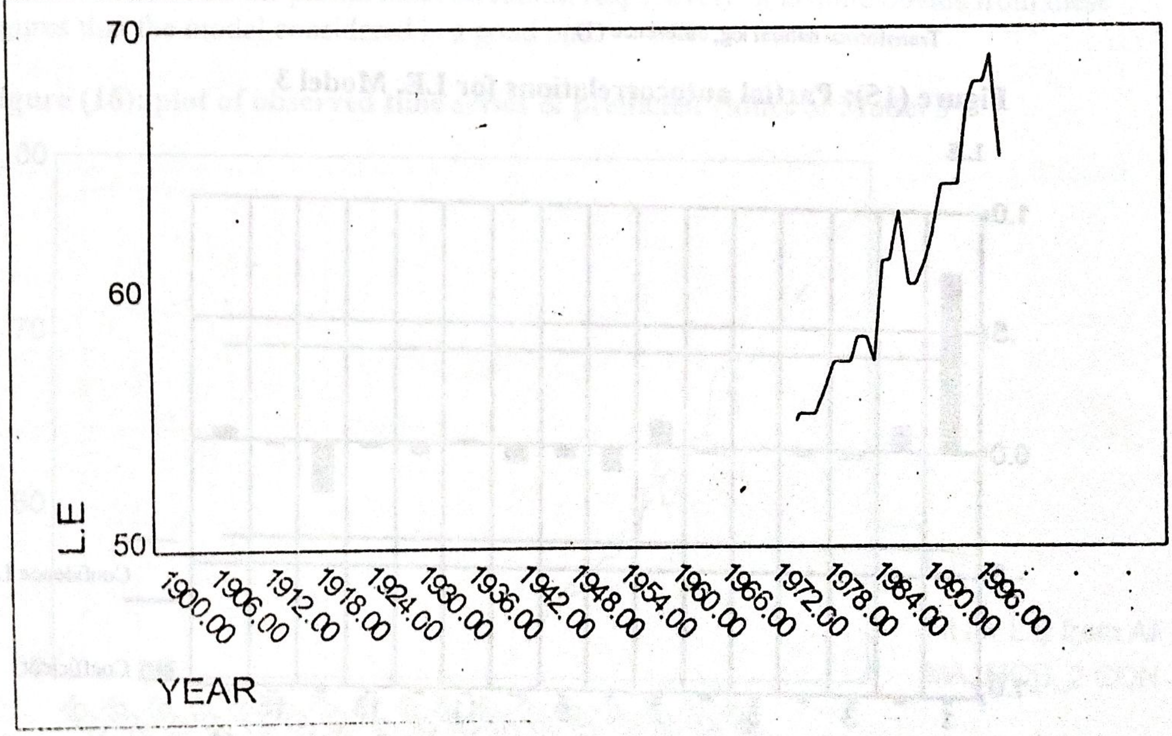


Figure (14): Autocorrelations for LE, Model 3

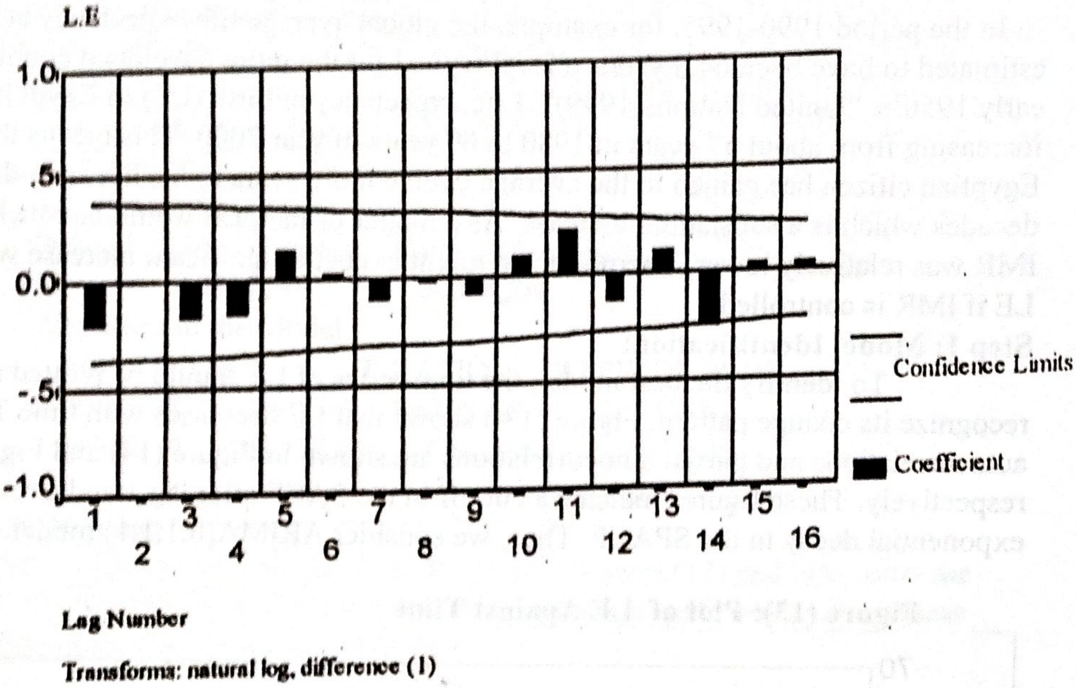
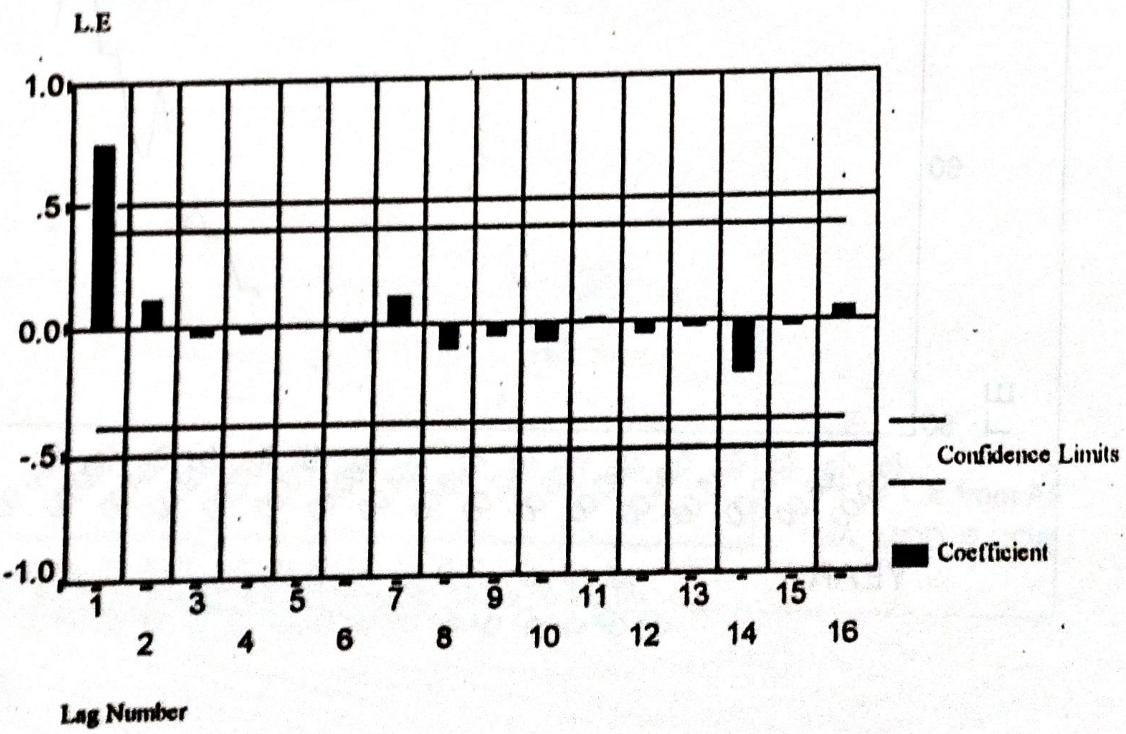


Figure (15): Partial autocorrelations for LE, Model 3



Step 2: Model estimation:

Model 3: $(\Delta \ln z_t - \mu) = (1 - \theta\beta)\, a_t$

where : θ is the moving average parameter such as $|\theta| < 1$.

Table (4): Final Parameters Estimates, Model 3, LE

Number of residuals 23

Standard error .02104844

Log likelihood 56.931406

Analysis of Variance:

	DF	Adj. Sum of Squares	Residual Variance
Residuals	21	.00951144	.00044304

Variables in the Model:

	θ	SEθ	T-RATIO	APPROX. PROB.
MA1	.63099485	.18297345	3.4485597	.00240705
CONSTANT	.01002252	.00175527	5.7099628	.00001145

Step 3: Model Checking:

Figure (16) shows the observed and fitted values for LE. Figures (17) and (18) show the autocorrelation and the partial autocorrelation respectively. It is quite obvios from these figures that the model considered is a good one.

Figure (16): plot of observed time series & predicted values of Model 3

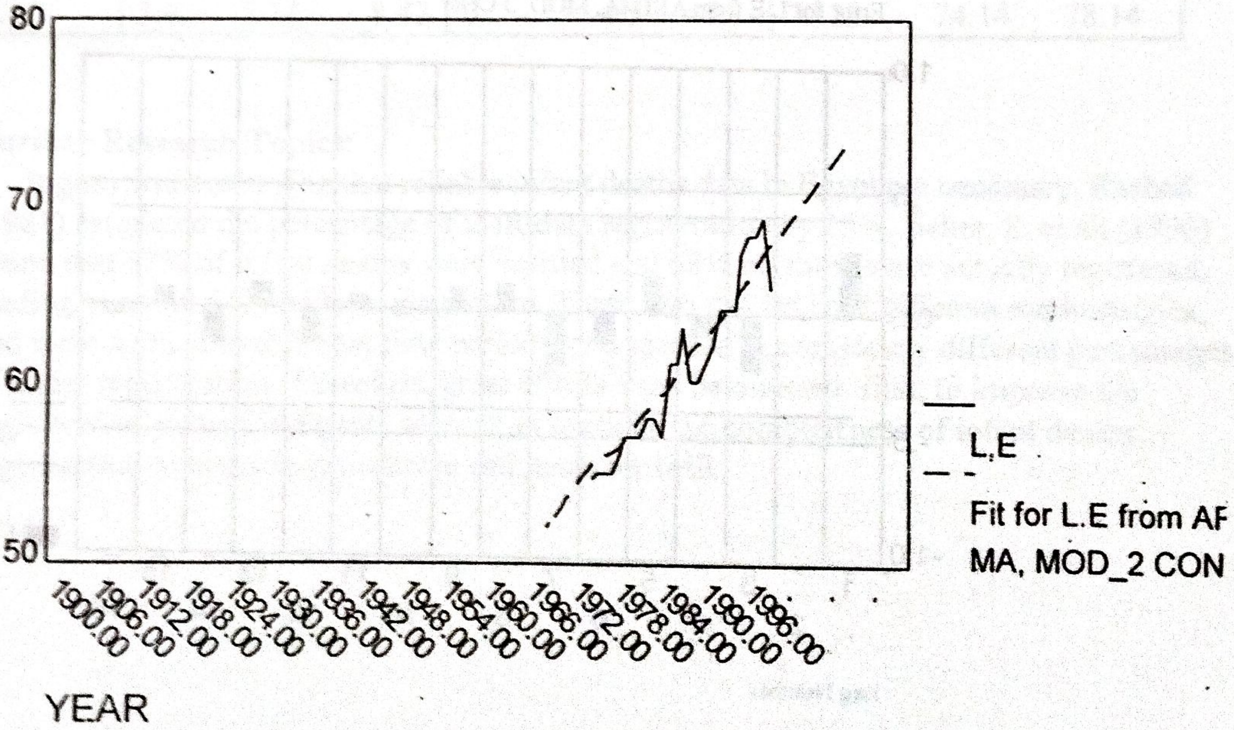


Figure (17): Autocorrelations for the errors of Model 3 (LE)

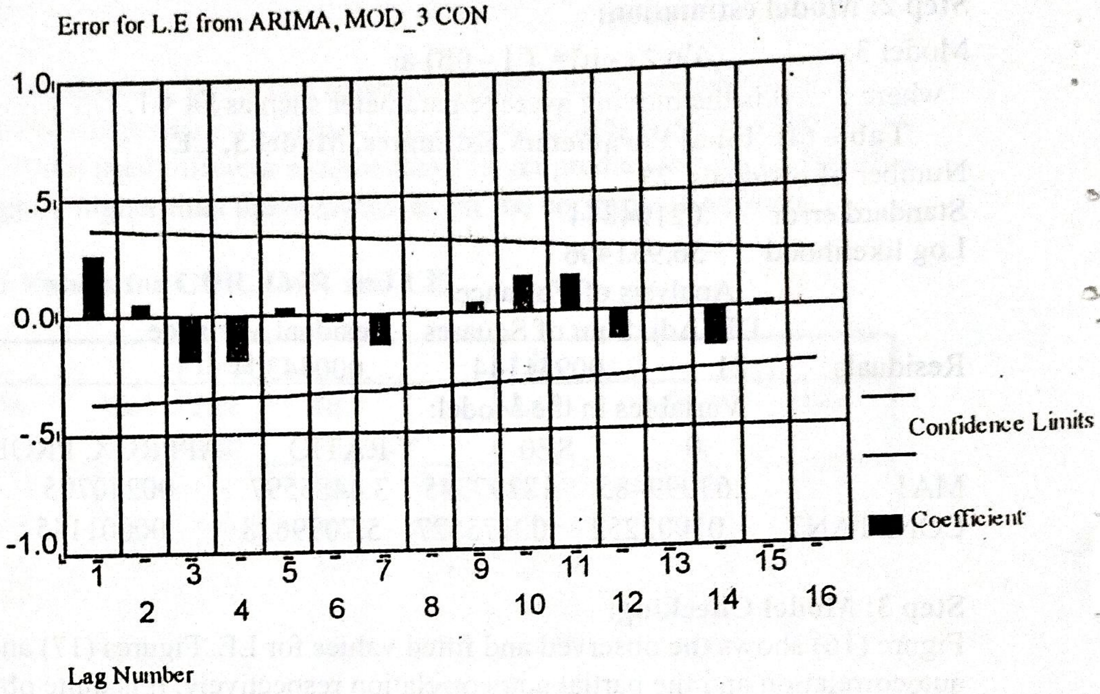
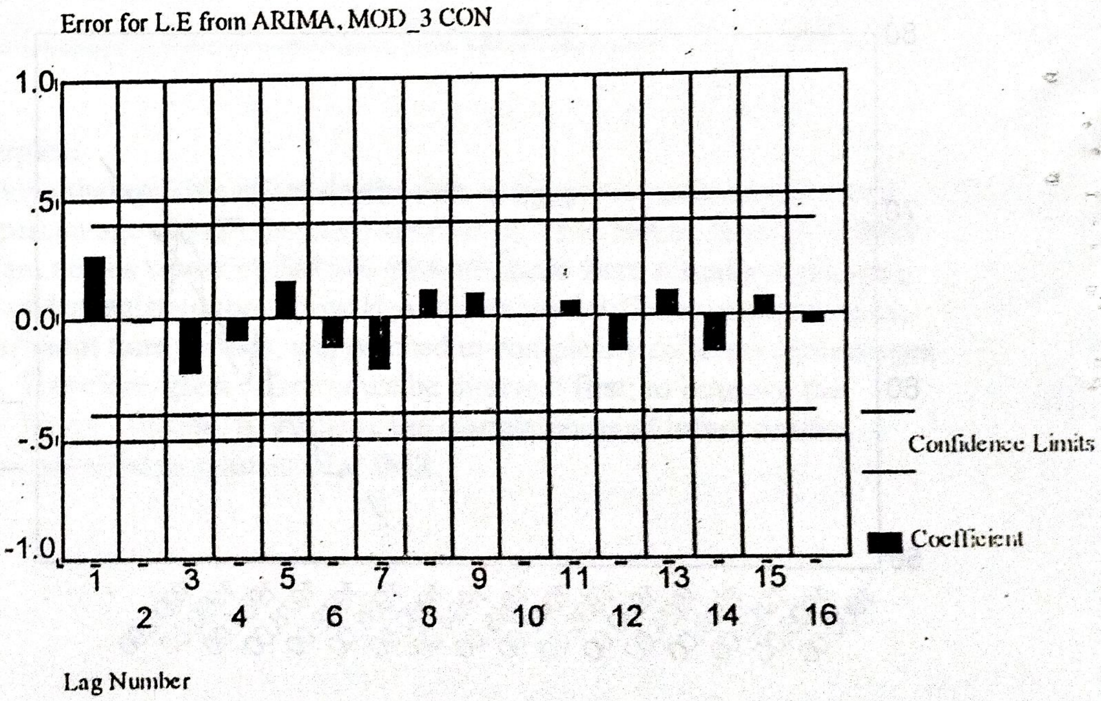


Figure (18):Partial autocorrelations for the errors of Model 3 (LE)



Step 4: Forecasting:

The predicted values with their lower and upper confidence limits are presented in Table (5) . It is clear that the predicted values are increasing almost linearly. Maklouf H. and Abdel Kader F. (2000) used different methodology to get predictions for LE till 2021. Our estimates are slightly higher than those estimates for the corresponding years.

Table (5): Predicted Values for CDR, IMR and LE

Year	CDR			IMR			LE		
	Lcl	fit	Ucl	Lcl Ucl	fit		Lcl	fit	Ucl
2001	5.12	6.20	7.49	6.6	22.1	37.5	65.10	68.35	71.75
2002	4.88	6.06	7.53	3.0	20.5	38.1	65.67	68.97	72.43
2003	4.61	5.99	7.78	0	18.3	39.6	66.24	69.59	73.11
2004	4.40	5.89	7.88	0	16.5	40.2	66.81	70.22	73.81
2005	4.20	5.80	8.01	0	14.4	40.8	67.39	70.86	74.51
2006	4.03	5.71	8.11	0	12.5	41.2	67.97	71.50	75.22
2007	3.86	5.63	8.20	0	10.5	41.5	68.56	72.15	75.94
2008	3.71	5.54	8.28	0	8.5	41.7	69.14	72.81	76.67
2009	3.57	5.46	8.36	0	6.5	41.8	9.74	73.47	77.40
2010	3.43	5.38	8.42	0	4.5	47.7	70.33	74.14	78.14

Further Research Topics:

It goes without saying that reliable infant deaths data in Egypt are necessary. Rashad (1981) estimated the percentage of IMR data registeration by 75%. Beker, S. et all (1996) found that 57% of infant deaths were notified and 68% of those were actually registered, leading to about 61% under registeration. These two studies used different methodolgies, and were applied to different time periods, and reached to completely different percentages of under registeration. Therefore, great efforts must be directed: first; to improve the registeration system in Egypt , second; to evaluate the completeness of infant deaths registeration in order to get reliable estimates for IMR.

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