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Time Series Analysis For Forecasting Both Fertilit And Mortality Levels in Egypt Until Year 2010

by

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Summary

Egypt's population has rapidly increased since the beginning of the twentieth century. This rapid increase reflects mainly both fertility and mortality. Here, a class of autoregressive integrated moving average (ARIMA) model is used to analyze a time series of crude birth rate (CBR) and crude death rate (CDR). Predicted values for both CBR and CDR in Egypt for the time period 1992 - 2010 are derived. We used these predictions to get predicted values for Natural Increase Rate (NIR) for the time period 1992 - 2010. Needless to say that these predictions are of great value for policy makers and workers in family planning field.

Introduction:

Fertility as measured by crude birth rate (CBR) has declined substantially from 41.6 per thousand in 1900 to 30.8 per thousand in 1991, but it is still much higher than what is hoped for. Table 1 shows that crude birth rate goes upwards and downwards in the short run, but it obviously decreases in the long run. This substantial decrease is due to socioeconomic development that took place in the Egyptian society during this century. as well as family planning programs. Family planning programs probably had an effect on decreasing crude birth rate in Egypt after 1960 (El-deeb 1990). However, changes in age structure of females in the reproductive age group (15 - 49) eliminated a great part of the negative effect of family planning programs (El-deeb 1990).

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Forecasting is an important part of decision making and many decisions concerning family planning are based on predictions of future crude birth rate.

Mortality as measured by crude death rate (CDR) has also declined.substantially from 32 per thousand in 1900 to 7.5 per thousand in 1991. This decline is so clear after Second World War because of the improvement in the overall health status that occured in the Egyptian society. It goes without saying that the prediction of the future crude death rate is vital. Using predicted values for both crude birth rate and crude death rate ,naturat increase rate (NIR) is estimated.

Table 1 : CBR and CDR in Egypt from 1900 - 1991.

Year	cbr	cdr	Year	cbr	cdr	Year	cbr	cdr	Year	cbr	cdr
1900	43.1	32.0	1923	43.0	25.7	1946	41.2	27.5	1969	37.0	14.5
1901	41.7	22.4	1924	43.3	24.6	1947	43.7	21.4	1970	35.1	15.1
1902	43.5	27.7	1925	42.5	26.0	1945	42.6	20.4	1971	35.2	13.2
1903	43.7	23.6	1926	43.3	26.3	1949	41.6	20.5	1972	34.5	14.5
1904	46.8	27.5	1927	42.7	24.5	1950	44.2	19.0	1973	35.9	13.1
1905	44.5	25.5	1928	43.6	26.3	1951	44.6	19.2	1974	35.8	12.7
1906	46.3	25.1	1929	44.2	27.6	1952	45.2	17.8	1975	36.2	12.2
1907	45.8	28.3	1930	45.4	24.9	1953	42.6	19.6	1976	36.6	11.8
1908	47.5	26.3	1931	44.5	26.6	1954	42.6	17.9	1977	37.5	11.8
1909	44.4	27.9	1932	42.5	28.5	1955	40.3	17.6	1978	37.4	10.5
1910	45.8	37.6	1933	43.8	27.5	1956	40.7	16.4	1979	40.2	10.9
1911	45.4	29.0	1943	42.8	27.8	1957	38.0	17.8	1980	37.5	10.0
1912	44.8	25.9	1935	41.3	26.4	1958	41.1	16.6	1981	36.8	10.0
1913	44.1	26.8	1936	44.2	28.8	1959	42.8	16.3	1982	36.2	10.0
1914	44.7	28.5	1937	43.4	27.1	1960	43.1	16.9	1983	36.8	9.7
1915	43.9	29.4	1938	43.2	26.3	1961	43.9	15.8	1984	38.6	9.5
1916	42.1	13.3	1939	42.0	25.9	1962	41.3	17.9	1985	39.8	9.4
1917	42.2	30.8	1940	41.3	28.5	1963	42.8	15.4	1986	38.7	9.2
1918	39.0	39.7	1941	40.4	27.9	1964	42.0	15.7	1987	37.4	9.1
1919	38.3	29.8	1942	37.6	30.5	1963	41.4	14.0	1988	36.6	8.1
1920	42.8	28.4	1943	38.7	30.4	1966	41.0	16.8	1989	33.3	8.1
1921	42.3	25.3	1944	39.8	28.6	1967	39.2	14.2	1990	32.2	7.5
1922	43.2	25.2	1945	42.7	30.2	1968	38.2	16.1	1991	30.8	7.5

Data Sources:

The long time series data for both crude birth rate and crude death rate shown in table 1 have been collected from different sources. The main sources were Vital Statistics and Statistical Yearbooks issued by the Central Agency for Public Mobilization and Statistics (CAPMAS) listed in the references below.

Objectives:

This study aims at three important objectives. First, it makes use of this long time series (1900 - 1991) for both crude birth rate and crude death rate to pick up the best model that fits each of them. Second, these fitted models will be used to predict future estimates for both crude birth rate and crude death rate as well as to get future estimates for natural increase rate. Third, it will provide a wealthy information that may play an important role in developing programmes and policies to reduce natural increase rate.

In this study, a time series analysis approach to forecast a single time series is used. We used the class of autoregressive integrated moving average (ARIMA) models which can represent many stationary and non stationary stochastic process. The data on both crude birth rate and crude death rate presented in table 1 were applied to suggest the most adequate mosel for each time series. The best model was selected through iterative steps of model identification, estimation, and model checking which will be illustrated in the following sections.

Section 1 : Model Identification:

The first step in model identification is to plot the series of both crude birth rate and crude death rate as shown in Figure 1 and Figure 2 respectively. The plot of the crude death rates show a steady but slow decline since World War II , while the plot of the crude birth rates goes up and down. These different patterns will surely lead to different models. These plots show that the levels of the two series change with time, which means that the two series are non-stationary (Abraham & Ledolter 1983). To verify these patterns we inspected the autocorrelation function (ACF) for each time series as shown in figure 3 and figure 4 respectively. The ACF plot for each time series started out with large positive value, which died out very slowly. This pattern confirms that the two series are not stationary , and that we must take differences when analyzing them. The plots of the two series indicated that the

Figure 1

PLOT OF CBR WITH YEAR

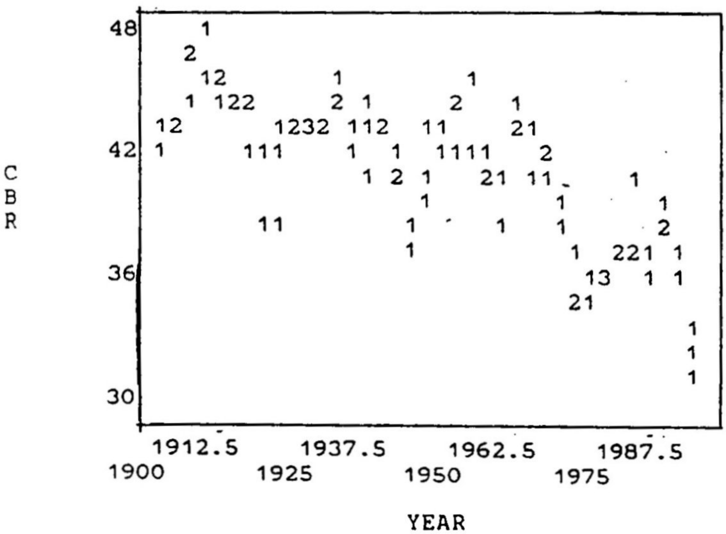

Figure 2

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PLOT OF CDR WITH YEAR

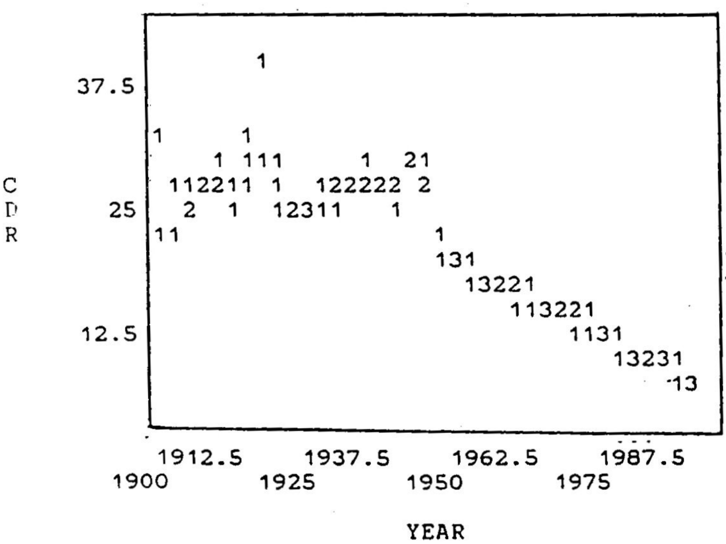

Figure 3

Trasformations : CDR

Lag	Auto-Corr.	Stand. Err.	Box-Ljung	Prob.
1	.846	.103	67.972	.000
2	.745	.102	121.340	.000
3	.612	.101	157.686	.000
4	.535	.101	185.782	.000
5	.465	.100	207.282	.000
6	.440	.100	226.746	.000
7	.427	.099	245.256	.000
8	.394	.099	261.276	.000
9	.348	.098	273.871	.000
10	.292	.097	282.875	.000
11	.267	.097	290.510	.000
12	.253	.096	297.405	.000
13	.301	.096	307.291	.000
14	.314	.095	318.199	.000
15	.302	.094	328.464	.000
16	.299	.094	338.665	.000

Plot Symbols: Autocorrelations * Two Standard Error Limits .

Figure 4

Autocorrelations : CDR

Lag	Auto-Corr.	Stand. Err.	Box-Ljung	Prob.
1	.920	.103	80.476	.000
2	.903	.102	158.880	.000
3	.852	.101	229.358	.000
4	.822	.101	295.719	.000
5	.782	.100	356.440	.000
6	.747	.100	412.505	.000
7	.732	.099	467.069	.000
8	.697	.099	517.116	.000
9	.672	.098	564.206	.000
10	.634	.097	606.615	.000
11	.613	.097	646.696	.000
12	.563	.096	681.000	.000
13	.539	.096	712.850	.000
14	.515	.095	742.288	.000
15	.478	.094	767.917	.000
16	.457	.094	791.706	.000

Plot Symbols: Autocorrelations * Two Standard Error Limits .

variance changes with time, therefore , the natural logarithmic transformation (base e) is used to stabilize the variance. Consequently, we considered the natural logarithmic transformation of the two series.

The second step in model identification is to plot the autocorrelation function as well as the partial autocorrelation function (PACF) for the difference of the natural logarithmic transformation for the two series. Figures 5 and 6 show these plots for crude birth rate, while figures 7 and 8 show these plots for crude death rate. As for crude birth rate both ACF and PACF show exponential decay alternating between positive and negative values. This trend suggests a model with both autoregressive and moving average components. Therefore, ARIMA (1,1,1) model for the natural logarithmic transformation is considered for crude birth rate, taking into consideration that the difference was suggested earlier.

As for crude death rate, the plots of ACF indicated exponential decay alternating between positive and negative values. Moreover, the plot of PACF showed cut off after lag 1. Therefore, ARIMA (1,1,0) for the natural logarithmic transformation is highly suggested. The two models for crude birth rate and crude death rate can be illustrated as follows:

Model 1: Crude Birth Rate

$$(\Delta \ln z_t - \mu) - \phi(\Delta \ln z_{t-1} - \mu) = a_t - 0\, a_{t-1}$$

which can be simplified to:

$$(1 - \phi\beta)(\Delta \ln z_t - \mu) = (1 - 0\beta)\, a_t$$

Model 2: Crude Death Rate

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

which can be simplified to:

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

where : z_t *is the observed time series at time t.*

Δ *is the difference operator.*

μ *is* $E(z_t)$.

a_t *is the error at time t.*

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

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

0 *is the moving average parameter such that* $|0| < 1$.

Figure 5

Autocorrelations: CBR

Transformations: natural log, difference (1)

Lag	Auto-Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1	Box-Ljung	Prob.
1	-.148	.103	.***I .	2.058	.151
2	.189	.103	. I****	5.442	.066
3	-.119	.102	. **I .	6.815	.078
4	-.048	.101	. *I .	7.039	.134
5	-.131	.101	.***I .	8.727	.120
6	-.035	.100	. *I .	8.848	[illegible]
7	.025	.100	. * .	8.910	.259
8	-.024	.099	. * .	8.969	.345
9	.030	.098	. I* .	9.060	.432
10	-.135	.098	.***I .	10.960	.361
11	-.014	.097	. * .	10.982	.445
12	-.187	.097	****I .	14.732	.256
13	.048	.096	. I* .	14.978	.309
14	.090	.095	. I** .	15.877	.321
15	-.061	.095	. *I .	16.295	.363
16	.148	.094	. I***.	18.774	.281

Figure 6

Partial Autocorrelations: CBR

Transformations: natural log, difference (1)

Lag	Pr-Aut-Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1
1	-.148	.105	.***I .
2	.170	.105	. I***.
3	-.075	.105	. *I .
4	-.109	.105	. **I .
5	-.123	.105	. **I .
6	-.051	.105	. *I .
7	.045	.105	. I* .
8	-.032	.105	. *I .
9	-.021	.105	. * .
10	-.154	.105	.***I .
11	-.072	.105	. *I .
12	-.167	.105	.***I .
13	-.020	.105	. * .
14	.130	.105	. I***.
15	-.129	.105	.***I .
16	.036	.105	. I* .

Figurs 7

Autocorrelations: CDR
Transformation: natural log, difference (1)

Lag	Auto-Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1	Box-Ljung	Prob.
1	-.478	.103	xxxxxx.xxx٣	21.457	.000
2	.329	.103	. ٣xxx.xxx	31.765	.000
3	-.200	.102	xxxx٣ .	35.625	.000
4	.121	.101	. ٣xx .	37.053	.000
5	-.058	.101	. x٣ .	37.389	.000
6	-.126	.100	.xxx٣ .	38.962	.000
7	.088	.100	. ٣xx .	39.747	.000
8	-.048	.099	. x٣ .	39.980	.000
9	.115	.098	. ٣xx .	41.342	.000
10	-.164	.098	.xxx٣ .	44.164	.000
11	.226	.097	. ٣xxx.x	49.571	.000
12	-.178	.097	xxxx٣ .	52.952	.000
13	.038	.096	. ٣x .	53.106	.000
14	.018	.095	. x .	53.141	.000
15	-.071	.095	. x٣ .	53.705	.000
16	.015	.094	. x .	53.729	.000

Figurs 8

Partial Autocorrelations : CDR
Transformations: natural log, difference (1)

Lag	Pr-Aut- Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1
1	-.478	.105	.xxxxxx.xxx٣ .
2	.131	.105	. ٣xxx.
3	-.001	.105	. x .
4	-.007	.105	. x .
5	.021	.105	. x .
6	-.208	.105	xxxx٣ .
7	-.037	.105	. x٣ .
8	.063	.105	. ٣x .
9	.108	.105	. ٣xx .
10	-.100	.105	. xx٣ .
11	.108	.105	. ٣xx .
12	-.032	.105	. x٣ .
13	-.155	.105	.xxx٣ .
14	.098	.105	. ٣xx .
15	-.028	.105	. x٣ .
16	-.125	.105	. xx٣ .

Table 2 : Final Parameters estimates, Model 1, Crude Birth Rate.

Number of Residuals	91
Standard error	0.0387
Log likelihood	167.8469

Analysis of Variance

	DF	Adj. Sum of Squares	Residual Variance
Residuals	89	0.1332	0.0015

Variables in the Model

	β	$SE\beta$	T-RATIO	APPROX. PROB.
AR1	-0.7382	0.2766	-2.6689	0.0090
MA1	-0.5914	0.3296	-1.7945	0.0761

Table 3 : Final Parameters estimates, Model 2 Crude Death Rate.

Number of Residuals	91
Standard error	0.0817
Log likelihood	99.6368

Analysis of Variance

	DF	Adj. Sum of Squares	Residual Variance
Residuals	89	0.5963	0.0067

Variables in the Model

	β	$SE\beta$	T-RATIO	APPROX. PROB.
AR1	-0.5509	0.0878	-6.2718	0.0000
constant	-0.0147	0.0055	-2.6456	0.0096

Section 2 : Model Estimation :

Tables 2 illustrates the parameter estimates for Model 1 (ARIMA (1,1,1)) for the natural logarithmic transformation of the crude birth rate. The results have shown that the estimate of ϕ is significant (p_value = 0.07) and the estimate of θ is highly significant but the mean of the series μ is not significant. Therefore, we dropped the constant μ from Model 1 and tried that Model *without it. Table 3 illustrates the parameter estimates for Model 2 (ARIMA (1,1,0)) for the natural logarithmic transformation of the crude death rate. The results have shown that the estimates of both the mean of the series μ and the autoregressive parameter ϕ are significant.*

Section 3 : Model Checking :

The most important step in model building is to check the adequacy of the model and asses its goodness of fit. First, we got the plot of the observed against the predicted values for each model. Figures 9 and 11 show these plots for Model 1 and Model 2 respectively. Second, we got the plot of the sample autocorrelation function (ACF) for the errors with their probability limits. Figures 10 and 12 show these plots for Model 1 and Model 2 respectively. The residual ACF is acceptable since Box-Ljung statistic is not statistically significant at any lag.

Section 4 : Forecasting :

Farnum, N.R. and Stanton, L.W. (1989) illustrated the concepts and details that arise in ARIMA foracasting using familiar ARIMA models. We applied their approach to get predicted values for Model 1 and Model 2 for crude birth rate and crude death rate respectively. By subtraction, we got estimates for natural increase rate (NIR = CBR - CDR).

Table 4 : Predicted Values for Crude Birth Rate (CBR) and Crude Death Rate (CDR) and Natural Increase rate (NIR) estimates for The Time Period 1992- 2010

Year	VBR	CDR	NIR	Year	CBR	CDR	NIR
1992	34.64	7.33	24.13	2002	31.19	6.35	24.84
1993	30.97	7.26	23.71	2003	31.17	6.26	24.91
1994	31.33	7.13	24.20	2004	31.19	6.16	25.03
1995	31.06	7.04	24.02	2005	31.17	6.07	25.10
1996	31.26	6.93	24.33	2006	31.18	5.90	25.28
1997	31.11	6.94	24.17	2007	31.17	5.81	25.36
1998	31.22	6.73	24.49	2008	31.18	5.76	25.45
1999	31.14	6.64	24.50	2009	31.18	5.64	25.54
2000	31.20	6.54	24.66	2010	31.18	5.56	25.62
2001	31.16	6.44	24.72				

Section 5 : Results and Conclusion:

Table 4 shows that the predicted values for crude birth rate and crude death rate as well as natural increase rate estimates. The predicted values for crude death rate show a steady but slow decline which coincides with the original crude death rate time series since World War II. But the predicted values for crude birth rate goe up and down exactly as the original data behave reaching approximately 31 per thousand which is still very high. Accordingly, the natural increase rate seems to stay high reaching approximately 26 per thousand for year 2010. Obviously, the crude death rate has already declined to a reasonable level. Therefore, to reduce the natural increase rate, the national policies and programmes should focus on reducing crude birth rate which is still extremely high. If the goal is to reduce natural increase rate to reach 10 per thousand per year , the crude birth rate should be reduced by approximately one per thousnd annualy which is a feasible target. Reducing infant mortality rate and enhancing family planning programmes as well as improving socioeconomic levels are the main tools for reducing crude birth rate.

Figure 9

SPLOT Display

The following plot symbols are used:
C - Variable CBR
F - Variable FIT#1
M - Missing Data (placed on the horizontal axis)
$ - Multiple Hits

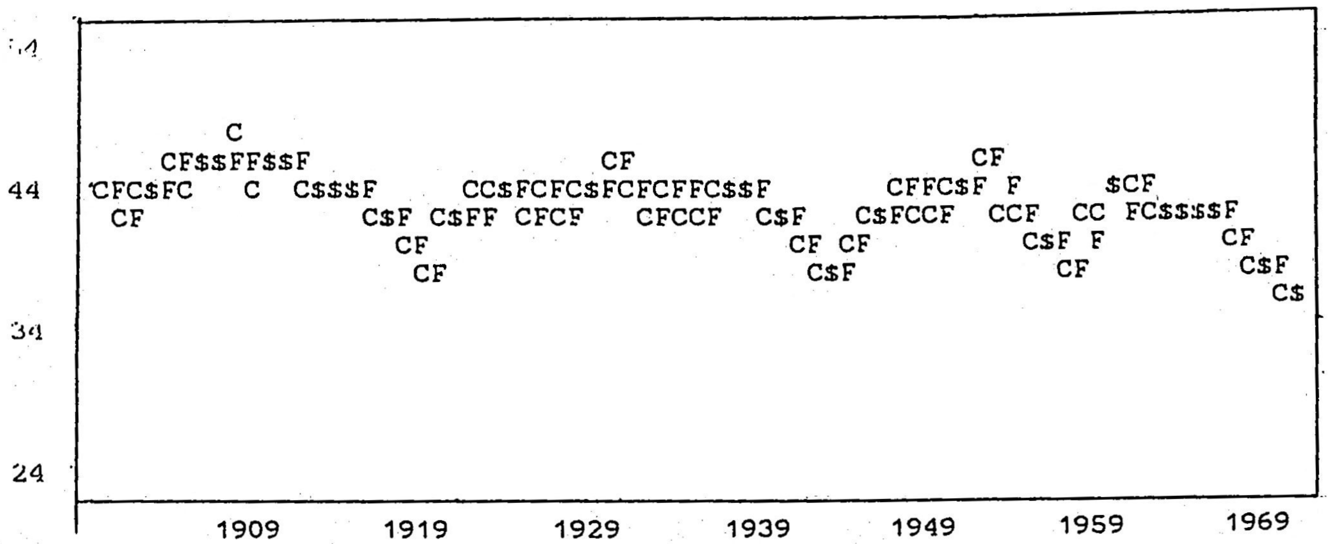

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Figure 9

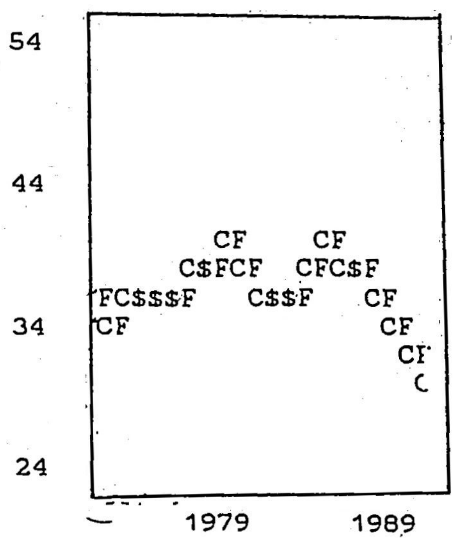


Figure 10
Autocorrelations: ERR#1 Error for CBR from ARIMA, MOD_8 LN NOCON

Lag	Auto-Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1	Box-Ljung	Prob.
1	.031	.103	. ١* .	.091	.763
2	.073	.103	. ٣* .	.595	.743
3	-.041	.102	. *٣ .	.758	.859
4	-.132	.101	.***٣ .	2.455	.653
5	-.121	.101	. **٣ .	3.885	.566
6	-.065	.100	. *٣ .	4.304	.636
7	.034	.100	. ٣* .	4.417	.731
8	-.013	.099	. * .	4.435	.816
9	.009	.098	. * .	4.443	.880
10	-.133	.098	.***٣ .	6.293	.790
11	-.057	.097	. *٣ .	6.632	.828
12	-.204	.097	.****٣ .	11.109	.520
13	.053	.096	. ٣* .	11.415	.576
14	.094	.095	. ٣** .	12.392	.575
15	-.036	.095	. *٣ .	12.538	.638
16	.136	.094	. ٣***.	14.637	.551

Plot Symbols: Autocorrelations * Two Standard Error Limits .

Figure 12
Autocorrelations: ERR#1 Error for CDR from ARIMA, MOD_12 LN CON

Lag	Auto-Corr.	Stand. Err.	-1 -.75 -.5 -.25 0 .25 .5 .75 1	Box-Ljung	Prob.
1	.142	.103	. ٢---.	1.883	.170
2	.072	.103	. ٣* .	2.382	.304
3	-.016	.102	. * .	2.407	.492
4	.021	.101	. * .	2.451	.654
5	-.101	.101	. **٣ .	3.463	.629
6	-.190	.100	****٣ .	7.040	.317
7	.025	.100	. ٣* .	7.104	.418
8	.064	.099	. ٣* .	7.526	.481
9	.043	.098	. ٣* .	7.713	.563
10	-.034	.098	. *٣ .	7.835	.645
11	.137	.097	. ٣***.	9.825	.546
12	-.110	.097	. **٣ .	11.132	.518
13	-.050	.096	. *٣ .	11.403	.577
14	.007	.095	. * .	11.409	.654
15	-.097	.095	. **٣ .	12.447	.645
16	-.063	.094	. *٣ .	12.899	.680

Plot Symbols: Autocorrelations * Two Standard Error Limits .

Figure 11

The following plot symbols are used:
C - Variable CDR
F - Variable FIT#1
M - Missing Data (placed on the horizontal axis)
$ - Multiple Hits

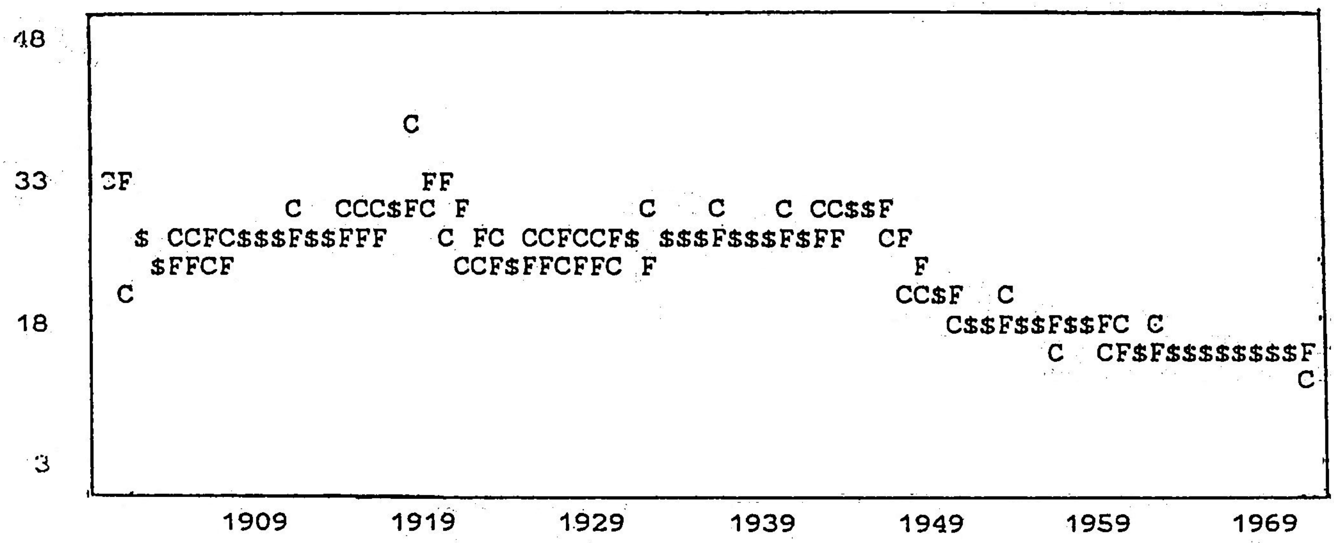
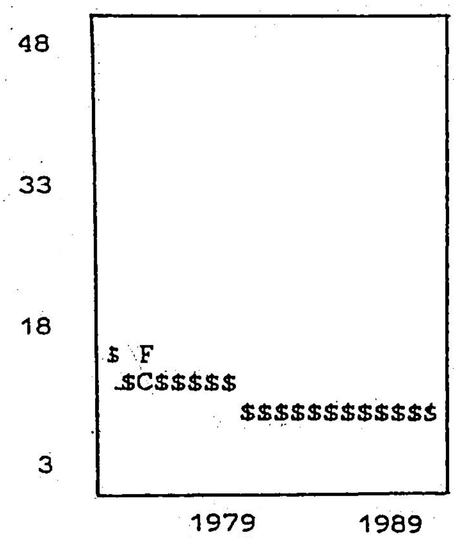


Figure 11



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