Renewable Energy and Development Summer School

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The political and economic determinants of CO_2 emissions: Evidence from Iran

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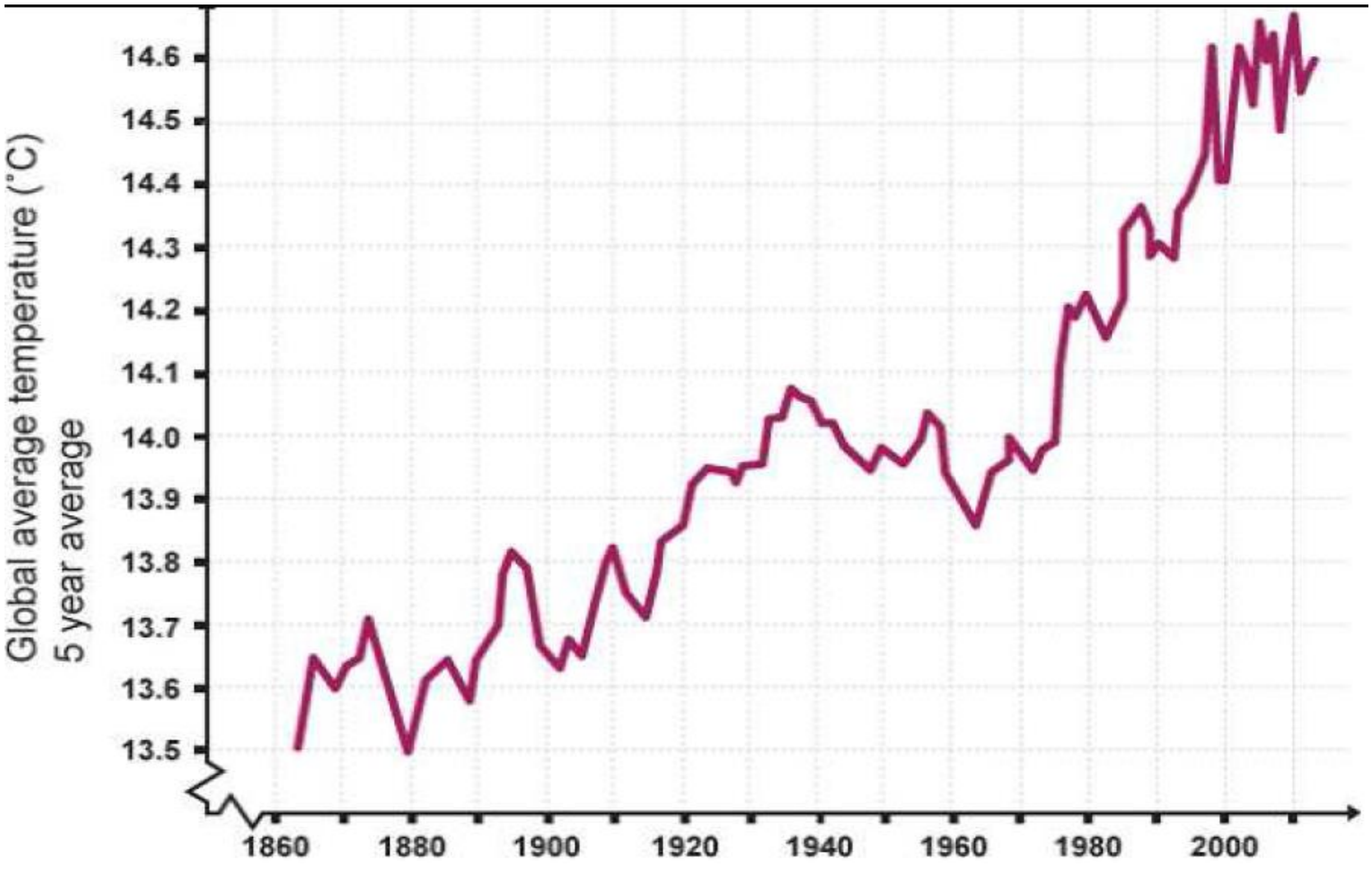
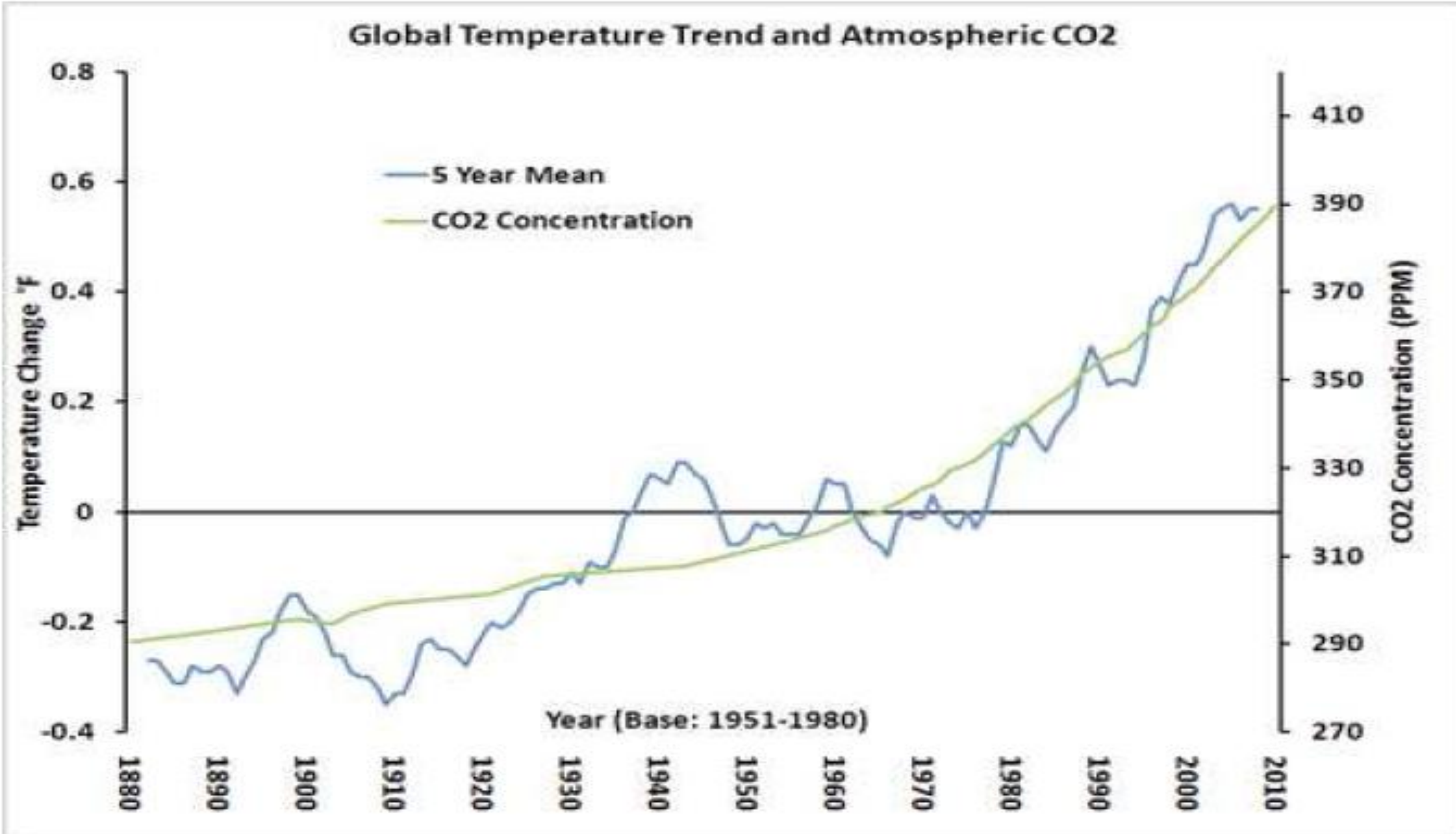
Problem definition

- Global warming and climate changes have become serious threats for human societies.

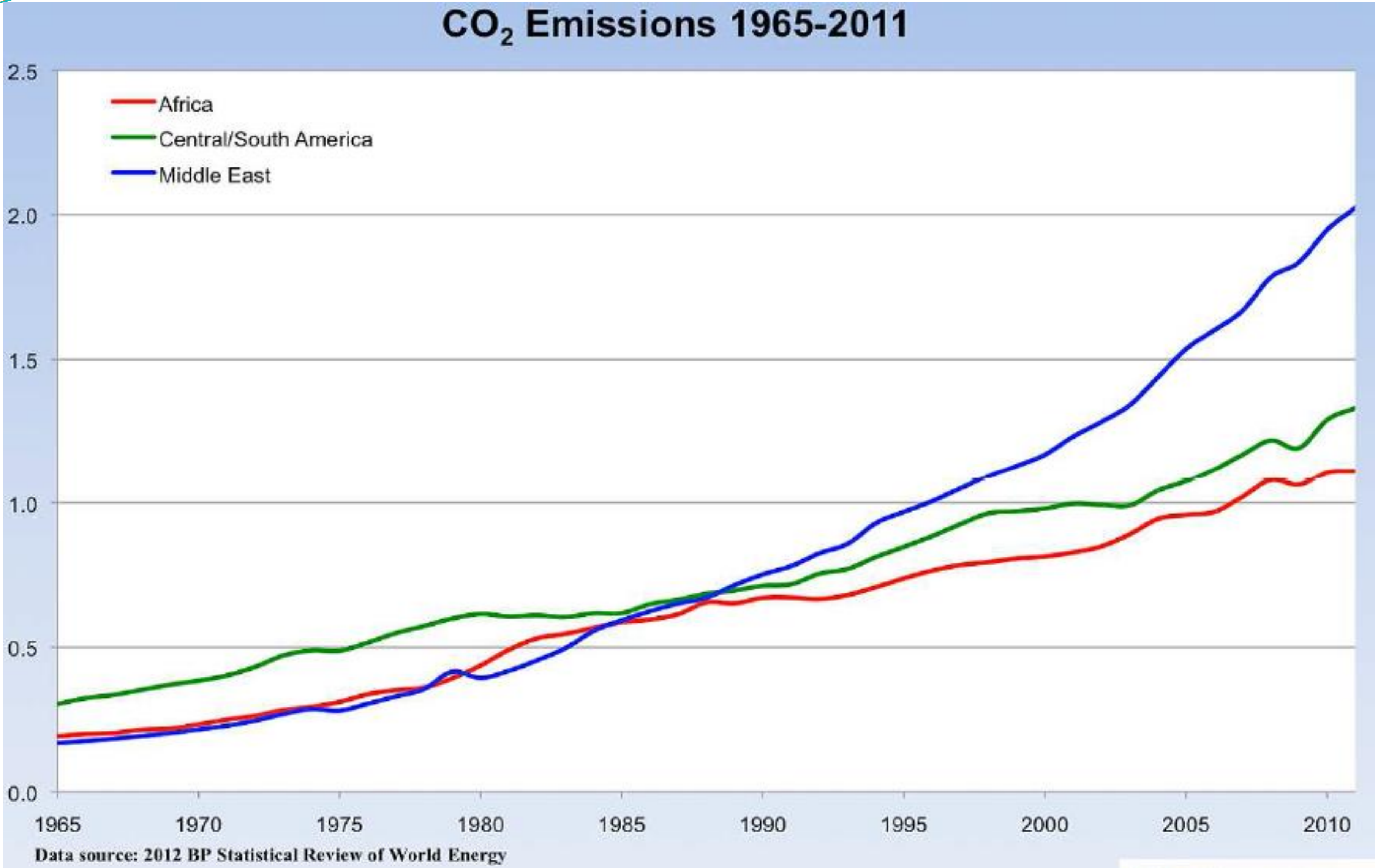




CO2 emissions brings about as much as 58.8% of total greenhouse gas emissions (Bacon and Bhattacharya, 2007).

- CO_2 concentration in the atmosphere has increased from 280 parts per million (ppm) to more than 393 ppm since preindustrial years (Bacon and Bhattacharya, 2007).

- The atmosphere may contain up to 570 ppm CO_2 and causing arise in global temperature of around 1.9°C and an increase in mean sea level of 3.8 m by the year 2100 (Stewart & Hessami, 2005).


CO2 Emissions 1965-2011
Africa
Central/South America
Middle East
2.5
2.0
1.5
1.0
0.5
0.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Data source: 2012 BP Statistical Review of World Energy

Iran is the greatest emitter of CO_2 among the Middle Eastern countries.

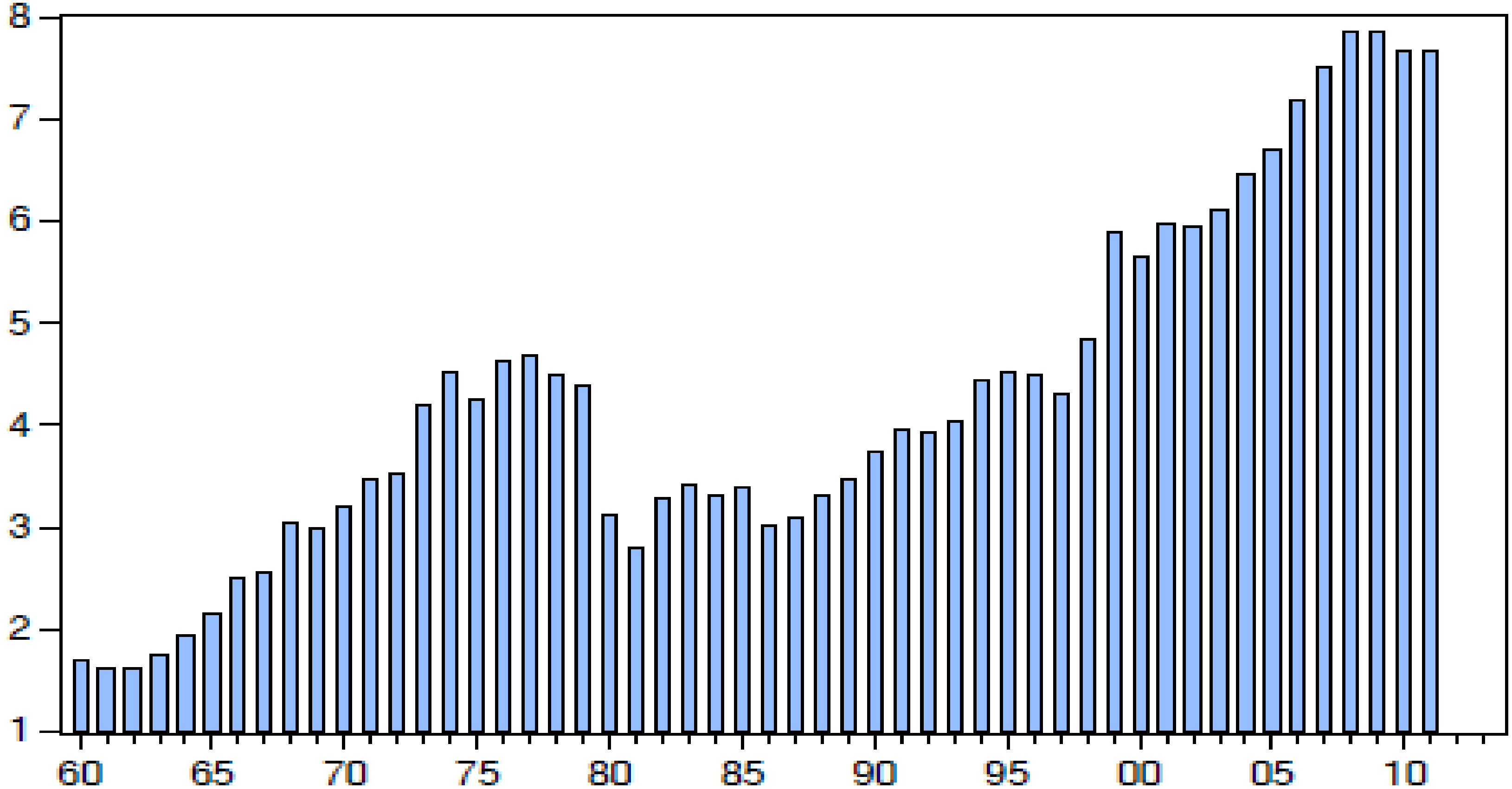


Fig.1. Time series plot of Iran's CO2 emissions (metric tones per capita)

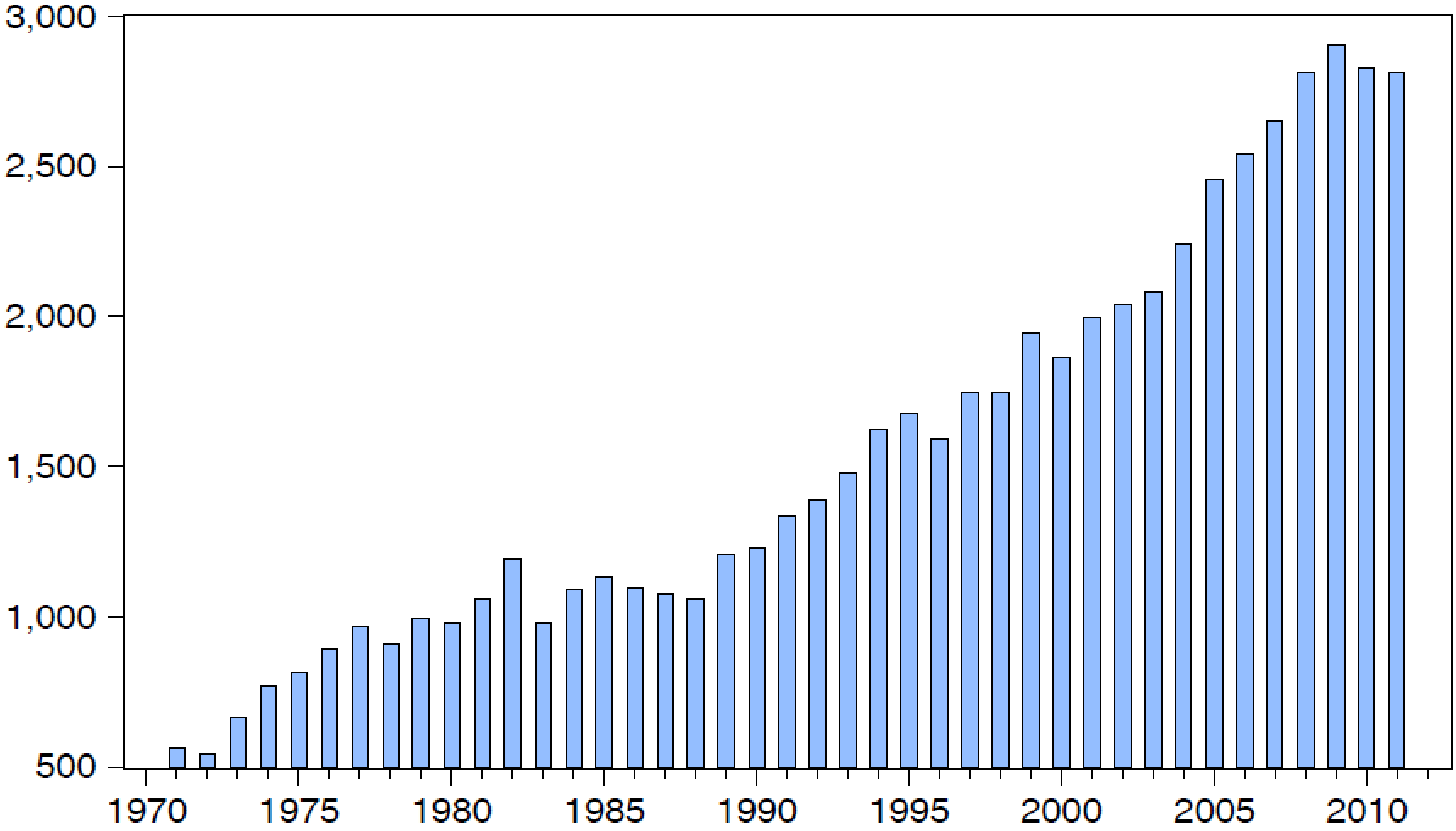
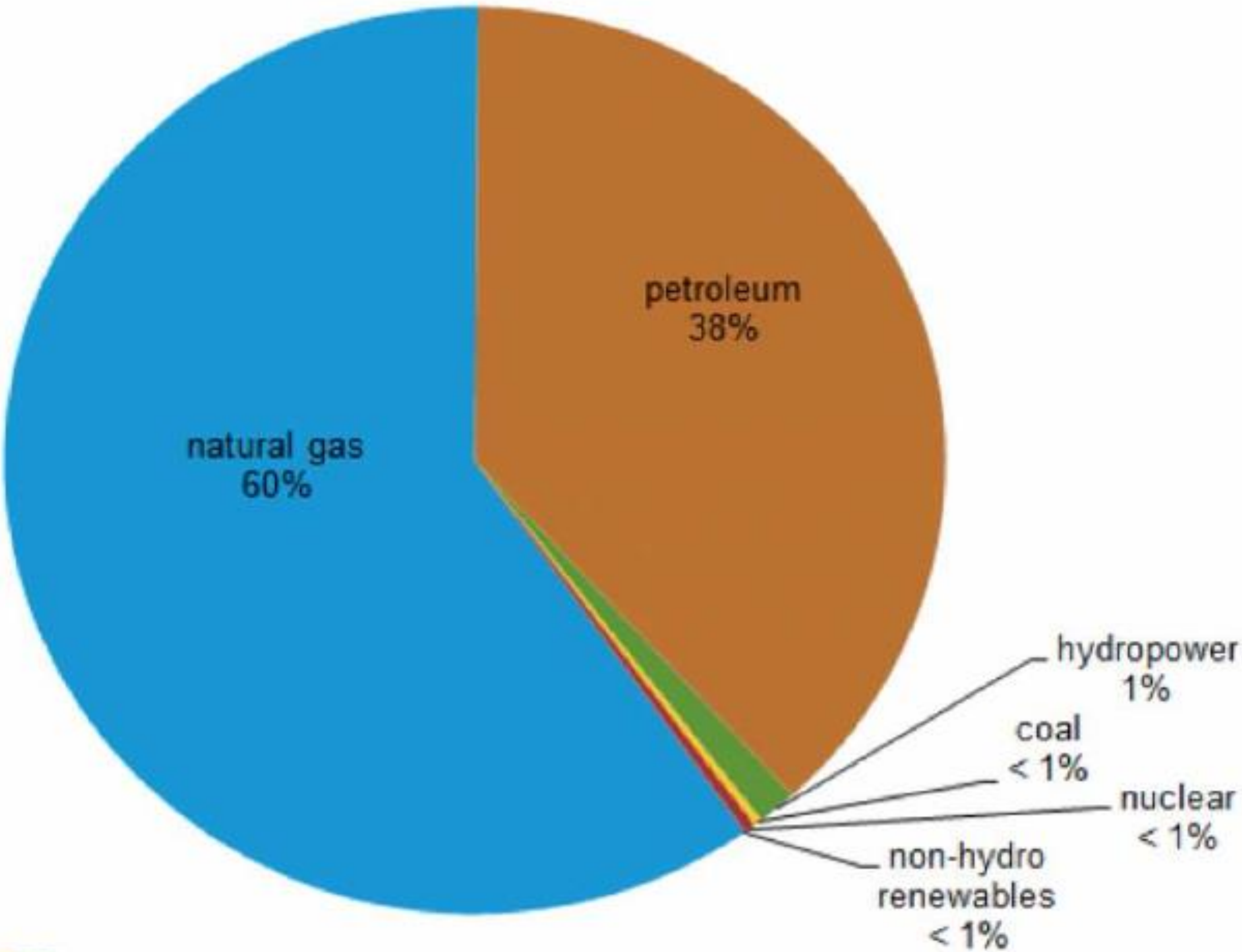


Fig.2. Time series plot of Iran's energy consumption (kg of oil equivalent per capita)

Iran's total primary energy consumption, share by fuel 2013



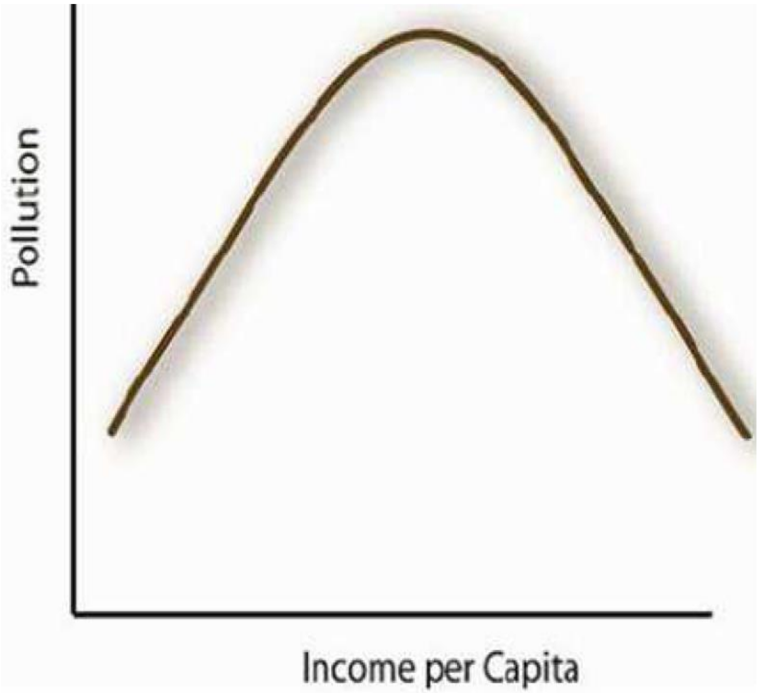
Note: Chart does not include traditional biomass and waste, such as burning firewood and waste
Source: BP Statistical Review of World Energy 2014.

Literature Review

Five important research strands:

1) *Relationship between air pollutant indicators and economic growth*

Inverted U-shaped relationship (The environmental Kuznets (1955) curve (EKC))

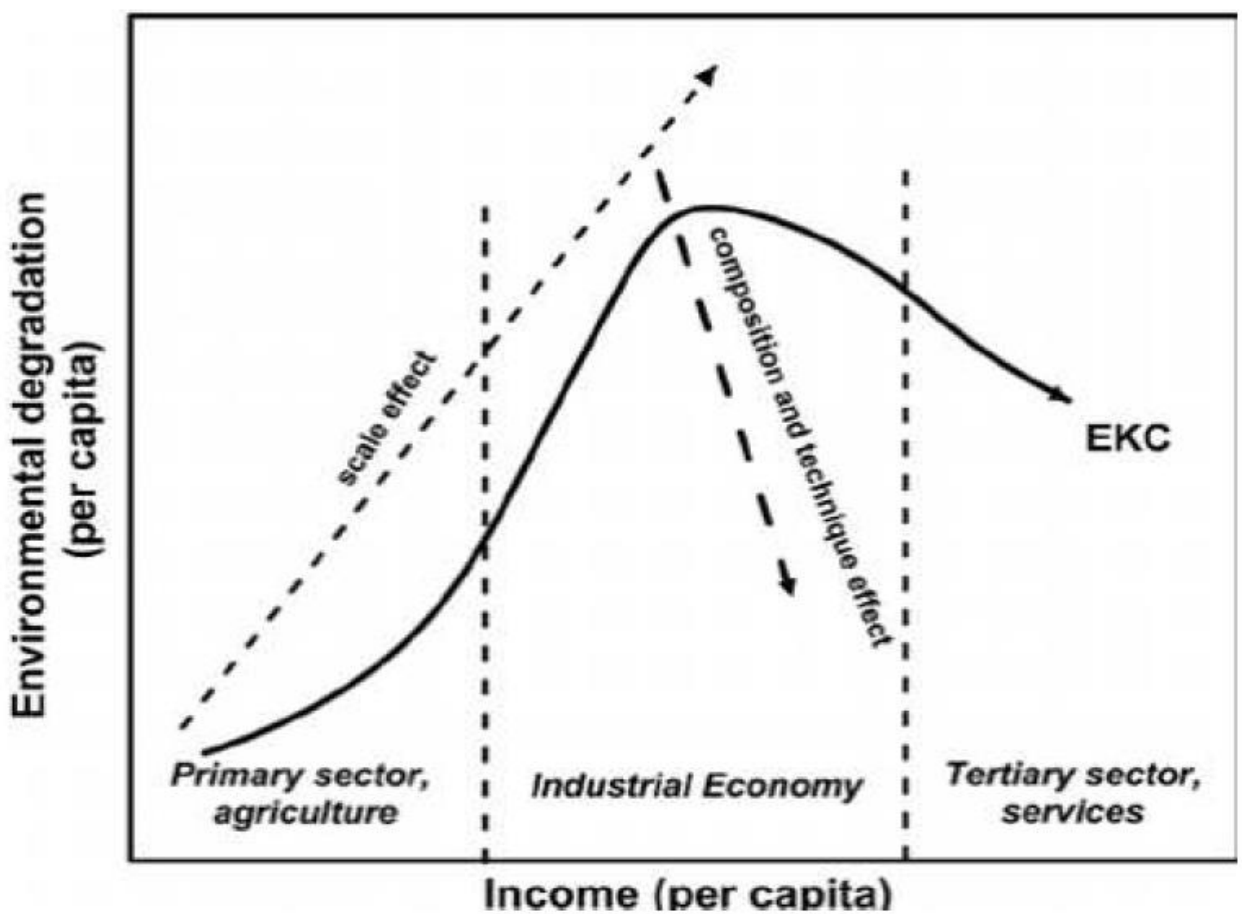


Some Empirical works on ERC

- Grossman and Krueger (1995) ------confirm EKC
- Cole et al. (1997) -----confirm EKC for the case of local pollutants.
- Akbostanci et al. (2009)----find a monotonically increasing relationship.

- Friedl and Getzner's (2003) conclude that both linear and quadratic models are not suitable, but the cubic model can represent it much better.

- Moomaw and Unruh (1997) ----- confirm that the N-shaped curve.



2) *Relationships among CO_2 emissions, income and energy consumption*

- Ang (2007, 2008) finds a unidirectional causality running from economic growth to energy consumption in France and Malaysia.
- Chebbi (2010) shows that energy consumption stimulates economic growth which Granger causes CO_2 emissions in the case of Tunisia.

Chang (2010), Alam et al. (2012), Hossain (2011), Soytas et al (2007)

3) The role of financial development on environmental quality

- Claessens and Feijen (2007), Halicioglu (2009), Tamazian et al, (2009), and Tamazian and Rao (2010) argue that development of financial sector may reduce energy pollutants by providing superior financial services for eco-friendly programs at decreased costs.

- Claessens and Feijen (2007) ----confirm the negative impact of financial development.

- Jalil and Feridun (2010)---- confirm the negative impact.

- Zhang (2011) ---- finds a positive impact.

4) The relationship between international trade and air pollutant indicators

Three types of free trade effects on environment Copeland and Taylor(1994)

- Technology Effect
- Scale effect
- Composition effect

Halicioglu (2009)----- confirm the positive impact of trade openness

Nasir and Rehman (2001)---- confirm the positive impact of trade openness

Shahbaz et al. (2012) ---- finds a negative impact

5) Nation's democracy and environmental quality

Four key reasons why more democratic governments will provide better environmental Payne (1995):

- Accountability
- Information
- Civil society
- International cooperation

Barrett and Graddy (2000)---- Negative impact

Harbaugh et al (2002)----- Negative impact

Farzin and Bond (2006)----- Negative impact

Desai (1998) argues that----- Positive impact

Methodology (VAR , VECM and ARDL?)

Vector Autoregressive (VAR) techniques are useful methods particularly when there is not an adequate theory to determine the specific relation among variables (Sims, 1980).

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \varepsilon_t$$

Vector Error Correction Model (VECM) is restricted form of unrestricted VAR that builds on Johansen's test for cointegration.

Variance decomposition in VAR models attributes the variance of forecast errors in a given variable to self-shocks, as well as those of the other variables in the VAR system (Brown et al., 2004).

Autoregressive distributed lag (ARDL) method is applied to establish cointegration relationships among the variables (Pesaran, Shin, and Smith 2001).

Advantages of ARDL approach

- It can be used where the samples are small (Ghatak and Siddiki, 2001).
- we can apply it irrespective of the regressors' order of integration
- It estimates only a single reduced form equation.
- It makes it possible that different variables have different optimal lags in the estimations.

Two steps in estimating ARD models:

1) Determining the existence of a long-run relationship among the variables.

2) Estimating the long-run coefficients of the ARDL model.

Data description

Our general model (L indicates the logarithmic form of the variable):

$$Lc_t = f(Le_t, Lg_t, Lf_t, Ltr_t, pol_t)$$

- c_t : CO2 emissions per capita
- e_t : energy consumption per capita
- g_t : real GDP per capita
- f_t : real domestic credit to private sector per capita (also M2 per capita)
- tr_t : real trade openness (exports+imports) per capita
- pol_t : index of democracy (Polity2/Vanhanen)

Annual data from 1971 to 2011 are used.

Empirical results

- *Unit root test*

Table 1
ADF and Phillips-Perron unit root tests

Variable	ADF		Phillips-Perron	
	Level	1st diff	Level	1st diff
Lc	-1.25	-5.8**	-1.28	-5.7**
Le	-1.9	-8.06**	-1.41	-7.91**
Ltr	-2.16	-4.06*	-1.93	-4.05*
Lg	-2.42	-3.46*	-2.00	-3.34*
Lf	-2.53	-5.86**	-2.72	-5.91**
Lm	-2.45	-5.87**	-2.44	-5.8**
Van	-2.67	-8.82	-2.57	-8.95**
Pol	-2.07	- 7.16**	-2.09	-7.2**
Critical Value 1%	-3.56	-3.57	-3.56	-3.57
Critical Value 5%	-2.92	-2.92	-2.92	-2.92

**: Null hypothesis rejection at 1%. *: Null hypothesis rejection at 5%.

- *Cointegration test*

Table 2
Johansen cointegration test

Rank	Cointegration Rank test (Maximum eigenvalue)		Cointegration Rank test (Trace)	
	Max-eigen statistic	0.05 critical value	Trace statistic	0.05 critical value
r=0	65.97*	40.07	135.18*	95.75
r≤1	41.61*	33.87	69.21	69.81
r≤2	16.29	27.58	27.59	47.85
r≤3	7.47	21.13	11.3	29.79
r≤4	3.17	14.26	3.83	15.49

*: Denotes rejection of the hypothesis at the 0.05 level.

The number of cointegrating vectors in estimating a VEC model is very important.

↓

We try another approach based on ARDL specification to get more confidence about the number of cointegrating vectors.

$$DLc = \alpha_0 + \sum_{i=1}^{2} \theta_i DLc_{t-i} + \sum_{i=1}^{2} \varepsilon_i DLe_{t-i} + \sum_{i=1}^{2} \rho_i DLtr_{t-i} + \sum_{i=1}^{2} \omega_i DLf_{t-i} \sum_{i=1}^{2} \beta_i DLg_{t-i} + \sum_{i=1}^{2} \gamma_i Dpol_{t-i} + \delta_1 Lc_{i-1} + \delta_2 Le_{i-1} + \delta_3 Ltr_{i-1} + \delta_4 Lf_{i-1} + \delta_5 Lg_{i-1} + \delta_6 pol_{i-1}$$

The null hypothesis is ‘non-existence of the long-run relationship’ defined by

$$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$$

Against

$$H_1: \delta_1 \neq 0, \delta_2 \neq 0, \delta_3 \neq 0, \delta_4 \neq 0, \delta_5 \neq 0, \delta_6 \neq 0$$

Table 3
The results of ARDL cointegration test

Dependent variable	F-statistic	Prob	Existence of long-run relationship
F(Lc/Le,Ltr,Lf,lg,pol)	1.49	0.23	Rejected
F(Le/Lc,Ltr,Lf, Lg, pol)	2.96	0.03	-
F(Ltr/Le,Lc,Lf,Lg, pol)	5.08	0.00	Accepted
F(Lf/Lc,Le,Ltr, Lg, pol)	1.23	0.33	Rejected
F(lg/Lc,Le,Ltr,Lf,pol)	1.22	0.33	Rejected
F(pol/Lc,Le,Ltr,Lf,Lg)	1.87	0.14	Rejected

Significance level	Critical values	
	Lower bounds I(0)	Upper bounds I(1)
1 per cent level	3.51	4.78
5 per cent level	2.64	3.80
10 per cent level	2.26	3.36

	Le	Ltr	Lf	Lg	pol	Lc
Variance decomposition of Le						
1 year	100.00	0.00	0.00	0.00	0.00	0.00
2 years	93.38	2.12	2.31	0.59	1.57	0.01
5 years	86.59	9.69	1.92	0.34	1.4	0.03
10 years	81.45	14.34	2.44	0.26	1.39	0.1
Variance decomposition of Ltr						
1 year	2.41	97.58	0.00	0.00	0.00	0.00
2 years	17.7	76.39	3.62	0.14	0.4	1.73
5 years	15.89	67.88	11.72	0.34	0.44	3.68
10 years	15.81	67.00	12.47	0.34	0.47	3.89
Variance decomposition of Lf						
1 year	0.31	2.45	97.22	0.00	0.00	0.00
2 years	1.60	7.58	90.04	0.12	0.63	0.00
5 years	3.37	10.52	84.84	0.19	0.81	0.25
10 years	3.67	11.35	83.60	0.16	0.88	0.32
Variance decomposition of Lg						
1 year	8.6	27.01	0.11	64.26	0.00	0.00
2 years	21.74	32.78	2.04	42.39	0.34	0.00
5 years	25.76	42.00	7.86	21.91	0.49	1.96
10 years	26.87	45.44	8.64	16.37	0.50	2.15
Variance decomposition of pol						
1 year	0.00	0.51	1.01	2.28	96.18	0.00
2 years	4.55	8.32	0.89	6.31	79.77	0.13
5 years	10.10	24.20	0.95	5.79	58.68	0.26
10 years	13.54	31.81	1.48	4.86	47.83	0.44
Variance decomposition of Lc						
1 year	44.11	0.14	0.03	15.08	7.63	32.99
2 years	50.67	0.19	13.38	14.69	3.82	17.21
5 years	33.58	7.06	43.12	7.02	1.56	7.63
10 years	21.05	22.87	43.54	4.99	1.04	6.48

Short/Long run equations for CO2 emissions based on ARDL approach

Table 5

Results of different models specifications for CO2 emissions in short run and long run

All variables in linear form

Model1: ARDL (1,0,0,0,1)	Results of the diagnostic tests: satisfied					
Variables	intercept	Le	Ltr	Lf	Lg	War80
Long run	pos*	pos	neg	pos	neg	neg**
Short run	pos	pos	neg	pos	pos**	neg**

Model2: ARDL (1,0,0,2,2,1)	Results of the diagnostic tests: satisfied						
Variables	intercept	Le	Ltr	Lf	Lg	war80	Pol
Long run	pos**	pos	neg**	pos**	neg	neg**	pos**
Short run	pos**	pos	neg**	pos	pos**	neg**	neg*

1 variable in quadratic form

Model3: ARDL(2,1,0,2,0,1,1)	Results of the diagnostic tests: satisfied							
Variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Lg)^2$
Long run	pos**	pos	neg**	pos**	pos**	neg**	pos**	pos**
Short run	pos**	pos**	neg**	pos	pos**	neg**	neg	pos**
Model4: ARDL(2,1,0,0,2,1,1)	Results of the diagnostic tests: satisfied							
Variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Ltr)^2$
Long run	pos**	pos	neg**	pos**	Pos**	neg**	pos**	pos**
Short run	pos**	Pos**	neg**	pos	Pos**	neg**	neg	pos**
Model5: ARDL (2,1,0,2,0,1,1)			Results of the diagnostic tests: satisfied					
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Lf)^2$
Long run	pos**	pos	neg	neg**	pos**	neg**	pos**	pos**
Short run	pos**	Pos**	neg	neg**	pos**	neg**	neg	pos**
Model6: ARDL (2,0,0,1,1,0,1)					Results of the diagnostic tests: satisfied			
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Pol)^2$
Long run	pos**	pos	neg*	pos*	neg	neg**	neg	neg
Short run	pos**	pos	neg*	neg	Pos**	neg**	neg	pos

2 variables in quadratic form

Model7: ARDL(2,1,0,0,0,1,0,1)	Results of the diagnostic tests: satisfied								
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Lg)^2$	$(Ltr)^2$
Long run	pos**	pos*	pos*	pos	neg**	neg**	pos**	pos**	neg*
Short run	pos**	pos**	pos**	pos	neg**	neg**	neg*	pos**	neg*
Model 8: ARDL(2,1,0,1,0,2,0,1)	Results of the diagnostic tests: Not satisfied (existence of serial correlation)								
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Lg)^2$	$(Lf)^2$
Long run	pos**	pos	neg	neg	pos	neg**	pos**	neg	pos
Short run	pos**	pos*	neg	neg	pos	neg**	neg	neg	pos
Model9: ARDL(2,1,0,1,0,0,0,1)	Results of the diagnostic tests: satisfied								
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Ltr)^2$	$(Lf)^2$
Long run	pos**	pos*	pos**	neg*	pos**	neg**	pos*	neg**	pos**
Short run	pos**	pos**	pos**	neg**	pos**	neg**	neg*	neg**	pos**

Robustness checks for model 9

Model 10: ARDL(2,0,0,1,0,0,0,1)	Results of the diagnostic tests: satisfied								
variables	intercept	Le	Ltr	Lm2	Lg	war80	pol	$(Ltr)^2$	$(lm2)^2$
Long run	pos**	pos**	pos*	neg*	pos*	neg**	pos*	neg*	pos**
Short run	pos*	pos**	pos**	neg**	pos	neg**	neg*	neg*	pos**
Model 11: ARDL (2,1,1,0,0,0,0,2)	Results of the diagnostic tests: satisfied								
variables	intercept	Le	Ltr	Lf	Lg	war80	van	$(Ltr)^2$	$(Lf)^2$
Long run	pos**	pos	pos*	neg**	pos**	neg**	pos	neg*	pos**
Short run	pos**	pos**	pos*	neg**	pos**	neg**	neg	neg*	pos**

GDP in cubic form

Model 12:	Results of the diagnostic tests: not satisfied (Existence of multicollinear regressors)								
variables	intercept	Le	Ltr	Lf	Lg	war80	pol	$(Lg)^2$	$(Lg)^3$

**: significance at 5%. *: significance at 10%.

The satisfaction of diagnostic tests means that absence of significant autocorrelation or heteroscedasticity based on various test results. Moreover the error term was normally distributed based on the Jarque–Bera test and the power of the model was high given the very high values of the R^2, adjusted R^2 and F value.

Selected model based on different ARDL specifications

Table 6
Results of estimated optimal ARDL model for CO_2 emissions (model 9) based on the Schwarz–Bayesian criterion

ARDL (2,1,0,1,0,0,0,1) based on Schwarz Bayesian Criterion Dependent Variable: Lc			
Regressor	**coefficient**	**T-Ratio**	**prob**
Lc(-1)	0.39	3.76	0.00
Lc(-2)	-0.33	-4.17	0.00
Le	0.48	3.53	0.00
Le(-1)	-0.21	-2.09	0.04
Ltr	2.96	2.21	0.03
$(Ltr)^2$	-0.09	-2.18	0.03
$(Ltr)^2(-1)$	-0.003	-1.85	0.07
Lf	-2.98	-2.82	0.00
$(Lf)^2$	0.07	2.85	0.00
Lg	0.38	3.61	0.00
Pol	-0.005	-1.83	0.07
Pol(-1)	0.01	3.77	0.00
Intercept	0.01	2.6	0.01
War80	-0.44	-7.67	0.00
Significance level of autocorrelation test based on Lagrange multiplier (LM) test			0.18
Ramsey's RESET test based on Lagrange multiplier (LM) test			0.85
Significance level of Jarque-Bera test of normality of the error term			0.76
Significance level of the LM heteroscedasticity test			0.42
R=0.99	Adjusted R=0.98	F-stat=195.41(prob=0.00)	

Table 7
Results of estimated long-run relationship
Derived from the optimal ARDL model for CO2 emissions (model 9)

Regressor	coefficient	T-Ratio	prob
Dependent variable Lc			
Le	0.28	1.86	0.07
Ltr	3.16	2.12	0.04
$(Ltr)^2$	-0.1	-2.15	0.04
Lf	-3.18	-2.7	0.01
$(Lf)^2$	0.08	2.73	0.01
Lg	0.4	3.92	0.00
Pol	0.005	2.49	0.02
Intercept	0.01	2.88	0.00
War80	-0.47	-7.12	0.00

$$\left(\frac{\partial Lc}{\partial Ltr}\right)_{long-run} = 0 \Rightarrow Ltr = 14.44 \Rightarrow tr = \frac{(real\ imports + real\ exports)}{poulation}$$

$$= 1867292\ Rials$$

- This figure is smaller than the amount of trade openness per capita of Iran in recent years and it is also smaller than the average amount of trade openness over the period of our study which is equal to 2559551 Rials.

$$\left(\frac{\partial Lc}{\partial Lf}\right)_{long-run} = 0 \Rightarrow Lf = 18.7 \Rightarrow f$$

$$= \frac{(real\ domestic\ credit\ to\ private\ sector)}{poulation} = 1322299\ Rials$$

This figure is bigger than the amount of real domestic credit to private sector per capita of Iran in recent years and it is also bigger than its average over the period of our study which is equal to 1161244 Rials.

Table 8

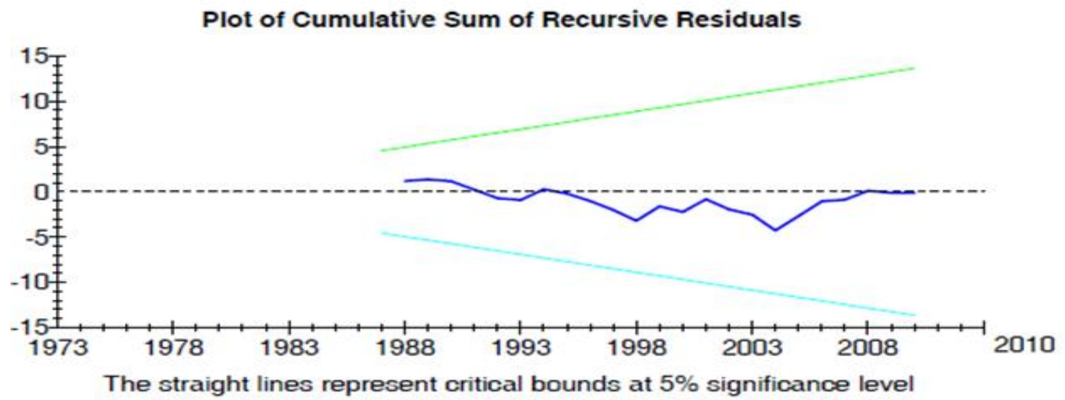
Error Correction Representation for the selected ARDL-Model (9)

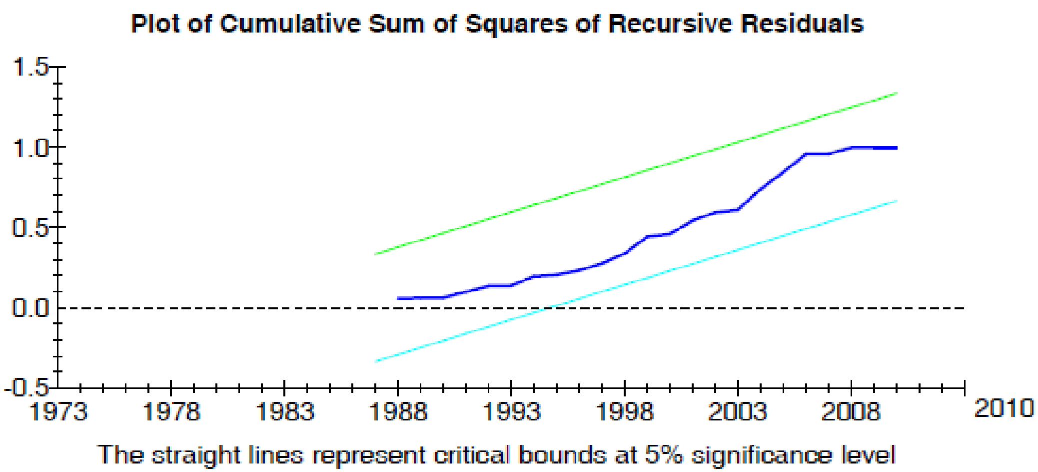
ARDL (2,1,0,1,0,0,0,1) based on Schwarz Bayesian Criterion Dependent Variable: dLc			
Variables	**Coefficients**	**t-Values**	**Prob-Values**
dLc(1)	0.33	4.17	0.00
dLe	0.48	3.53	0.00
dLtr	2.96	2.21	0.03
$d(Ltr)^2$	-0.09	-2.18	0.03
dLf	-2.98	-2.82	0.00
$d(Lf)^2$	0.07	2.85	0.00
dLg	0.38	3.61	0.00
dpol	-0.005	-1.83	0.07
d(intercept)	0.014	2.60	0.01
dwar80	-0.44	-7.67	0.00
ecm(-1)	-0.93	-9.24	0.00
R^2=0.89		Adjusted R^2=0.84	
Akaike Info. Criterion=87.21		Schwarz Bayesian Criterion= 55.75	
DW-statistic=2.35		F-stat=21.32(prob=0.00)	

The larger the error correction coefficient (in absolute value) the faster will be the economy's return to its equilibrium, after an exogenous shock (Dizaji, 2012).

A highly significant error correction term is further proof of the existence of a stable long-term relationship (Bannerjee et al (1998)).

Plots of CUSUM and CUSUMQ statistics for coefficients Stability Tests





Thank you for your attention