Economics Bulletin

Volume 35, Issue 2

Is there a causal relationship between unemployment and informal economy in Tunisia: evidence from linear and non-linear Granger causality

Sami Saafi
EAS – Faculty of Economic Sciences and Management of Mahdia, University of Monastir

Meriem Haj mohamed
EAS, FSEG Mahdia, University of Monastir Tunisia

Abdeljelil Farhat
EAS, FSEG Mahdia, University of Monastir Tunisia

Abstract

This study investigates the dynamic relationship between informal economy and unemployment in Tunisia during the period of 1980–2009. Two different methodologies have been employed to test the Granger non-causality: the linear causality approach of Toda– Yamamoto (1995) and the non-linear causality method of Kyrtsou-Labys (2006). Both tests have yielded a strong evidence for unidirectional causality running from the unemployment to the informal economy. The empirical results show that high levels of unemployment lead to enhanced economic activities in the informal sector. The policy implication is that any measures aiming at a reduction of the informal economy without tackling the principal problem of unemployment would be counterproductive.

he authors wish to thank warmly two anonymous referees for valuable comments to an earlier version of this paper. The usual disclaimer applies and views are the sole responsibility of the authors.

Citation: Sami Saafi and Meriem Haj mohamed and Abdeljelil Farhat, (2015) "Is there a causal relationship between unemployment and informal economy in Tunisia: evidence from linear and non-linear Granger causality", *Economics Bulletin*, Volume 35, Issue 2, pages 1191-1204

Contact: Sami Saafi - samisaafi@yahoo.fr, Meriem Haj mohamed - meriem.hjmed@yahoo.fr, Abdeljelil Farhat - abdeljelil.farhat@fsegma.rnu.tn.

Submitted: April 22, 2014. **Published:** May 14, 2015.

1. Introduction

Since the adoption of the International Monetary Fund's structural adjustment program in 1986, Tunisia has achieved persistently macroeconomic performance. Since that date, the country's GDP has recorded an average growth rate of around 5% per annum. Nonetheless, the unemployment rate is unusually high in Tunisia with an average level of 14%, making it among the highest in the world. Indeed, according to the 2011 ILO annual report on employment trends, the average world unemployment rate is 6.2%, while in Tunisia it is 13%. Compared to unemployment rates in different regions, only the North Africa and the Middle East region report similar or higher rates. In particular, Tunisia's unemployment rate increases with higher education levels and is highest for those with university degrees. In 2010, the unemployment rate for university graduates was above 20 percent and above 30 percent for the young university graduates (Boughzala, 2013).

To cope with this situation, the Tunisian government has implemented active policies designed to help young graduates to integrate into the labour market, and spends on average about 0.8% of GDP per annum on active employment policies, which is comparable to the European Union's average budget for the same purpose (Bou Abid and Drine, 2013; Haouas et al., 2012). With regard to Tunisia's labour regulations, there has been some attempt to achieve greater flexibility in the labor regulations through the revisions of the Labor Code in 1994, and again in 1996. One of the main objectives of these reforms has been to reduce the cost of hiring new employees and, as a result, increase the demand for labour. However, despite all these reforms and incentives, the unemployment rate remains high. Clearly, as noticed by Gouider (2013), the high level of unemployment was as one of the main driver of the social protests that occurred in Tunisia in mid-December 2010 and which led to the ousting of former President Ben Ali on 14 January 2011.

As far as the Tunisian labor market is concerned, it is widely acknowledged that the causes of rampant unemployment are multifaceted. Indeed, as emphasized recently by a number of authors (e.g., Bou Abid and Drine, 2013; Boughzala, 2013; Gouider, 2013), the persistently high rate of unemployment is the result of not only excess labour supply but is also related to a mismatch between the needed and the available job skills. Add to this, several empirical studies suggest the existence of a number of underlying rigidities in the Tunisian labour market which hinder the reallocation process. For instance, the World Bank (2004a) and Boughzala (2004) argue that the rigidity of the regulation regarding the termination of work contracts often represents a serious constraint to business environment (World Bank, 2004a; Boughzala, 2004). A study conducted by the World Bank (2004b) reveals also that the public wage policies generate a bias in favor of the public sector, which can ultimately reduce private employment. This finding is supported by the 2010 Global competitiveness report. Tunisia is indeed ranked 115th out of 183 countries in the flexibility of wage determination.

It is, however, worth to note that very little attention has been devoted to possible interactions between unemployment and the informal economy[1]. Surprisingly, to our knowledge, only one notable study by Boughzala and Kouki (2003) has investigated the nexus between

[1] A common definition of the informal or shadow economy are market-oriented production activities that are hidden from state authority to avoid, payment of income, value added, or other taxes, payment of social security contributions, having to meet certain legal labor market standards, such as minimum wages, maximum working hours, safety standards; and complying with certain administrative procedures, such as completing statistical questionnaires or other administrative forms (Schneider et al., 2010).

unemployment and informal economy in Tunisia. Using a dynamic general equilibrium model, Boughzala and Kouki (2003) conclude that the presence of a larger informal sector leads to a more persistent unemployment. Another interesting result in their study is that an exogenous increase of the wage rate paid by the informal sector would lower the unemployment rate significantly.

There is, as yet, no comprehensive study on the causal relationship between unemployment and informal economy in Tunisia. This is a significant gap in the literature as the size of the informal sector in the country accounts for more than 36% of the size of the economy (Elgin and Oztunali, 2012). The scarcity of studies on this subject dedicated to developing countries and, in particular, to Tunisia is widely attributed to the lack of long-term data-series on informal economy. However, our guess is that such studies could potentially help to explain the high and persistent unemployment in Tunisia. More importantly, a better understanding of the relationship between unemployment and informal economy provides important information for implementing relevant labour market policies.

The nexus between unemployment and informal economy remains one of the most important issues in the economic literature and met with renewed interest in recent years mainly for countries suffering from unemployment problems and large informal economy. Theoretically, however, the nature of this relationship remains controversial. (see Tanzi, 1999; Giles and Tedds, 2002; Dell'Anno et al., 2007). As Tanzi (1999, p. 347) points out, "the current literature does not cast much light on these relationships even though the existence of large underground activities would imply that one should look more deeply at what is happening in the labour market". In this sense, one cannot tell much about the informal economy-unemployment nexus before conducting any empirical analysis. This theoretical ambiguity have motivated some authors to empirically investigate the mentioned relationship. The empirical evidence, though limited, is in favor of the positive causal relationship between unemployment and informal economy. For example, Boeri and Garibaldi (2002) found a positive relationship between unemployment rate and informal economy across 20 Italian regions over five years (1995-1999). As for the Unites States (US) case, Dobre et al. (2010) found a strong evidence of Granger causality from unemployment rate to informal economy. Related papers by Alexandru et al. (2010) and Alexandru and Dobre (2012) focused on the two-way linkage between unemployment and informal economy in the US over the period 1980-2009. The results were found to be cointegrated and indicated the existence of a uni-directional causality that runs from unemployment rate to informal economy. In a more recent study, Alexandru and Dobre (2013) examined the cointegration and causality between unemployment and informal economy for Romania. By using data covering the period 2000Q1-2010Q2, cointegration was established between the two variables. To accomplish the above results, the authors also carried out causality tests and found evidence of a unidirectional causality running from unemployment to informal economy. This finding is subsequently confirmed by Alexandru (2014).

As the above-related literature review indicates, an overwhelming majority of previous studies that explicitly test for causality between unemployment and informal economy rely exclusively on traditional linear Granger causality tests. However, it should be noted that one of the shortcoming of such analysis, is that researchers often neglect the possible nonlinear relation between these variables. This is because the traditional Granger causality test is unable to explore nonlinear causal relations among variables (see, for instance, Baek and Brock; 1992, Hiemstra and Jones, 1994). For this reason, conventional Granger causality tests might overlook a significant nonlinear relation between unemployment and informal economy. Hence, in this paper, we use both linear and nonlinear causality tests to investigate the short-run causal relationships between unemployment and informal economy. In addition to linear linkages, the variables of interest may

have nonlinear linkages. This is due to growing empirical evidence that suggests nonlinearities in unemployment rate time series (see, e.g. Rothman, 1991; Rothman, 1998; Skalin and Terasvirta, 2002; Caporale and Gil Alanal, 2007). These nonlinearities are normally attributed to the presence of asymmetric adjustment costs of labour, such as hiring and firing costs (Caporale and Gil Alanal, 2007). Another potential source of nonlinearity in the unemployment-informal economy nexus is the presence of structural breaks caused by significant economic and political events (economic crisis, structural adjustment, tax and welfare reforms, reallocation shocks, and so forth). As Ajmi et al. (2013) noted, it is a well known fact that the repeated occurrences of such events ultimately cause regime-switching behavior, asymmetry and leverage effects in time series variables. In particular, as a developing economy, Tunisia is undergoing continuous structural reforms and policy changes that might generate a nonlinear interdependence between unemployment and informal economy.

Testing for asymmetry in the unemployment-informal economy linkage is of paramount importance for at least two main reasons. First, model misspecification issues, such as the assumption of a linear relationship between unemployment and informal economy, may lead to biased inferences and hence misleading results. Indeed, if the unemployment-informal economy relationship is actually nonlinear, then the existing evidence indicating causal link running from unemployment to informal economy, which were based on linear models, may need to be revisited, as they could be erroneous and misleading. Second, a thorough understanding of the time-series properties of the variables of interest is of ultimate importance for policy makers and economic agents. For instance, knowledge about the extent of asymmetry in the unemployment-informal economy linkage could be useful for both structural policies (eg, labour market reforms, tax reforms) and stabilisation policies (eg, appropriate monetary policy responses).

The main goal of the current study, then, will be trying to further investigate the nature and the direction of the unemployment-informal economy causality in Tunisia over the period of 1980-2008. For this purpose, both linear and nonlinear Granger causality methods are employed here. We indeed make use of two different types of Granger non-causality tests: the linear Granger causality test in the sense of Toda and Yamamoto (1995) and the nonlinear causality test proposed by Kyrtsou and Labys (2006). In this respect, this paper adds to the literature on the unemployment-informal economy nexus by modeling the potential nonlinearities in the dynamic relationship between unemployment and informal economy. A deeper understanding of this causal asymmetric link is potentially useful to policy makers, as it helps better characterize labor market dynamics and accurately forecast future levels of unemployment and informal economy, which are critical inputs to their own policy decisions.

More specifically, this article contributes to the related literature along several dimensions. On the methodological side, it is the first attempt to apply both the nonlinear and linear frameworks for examining the causal relationship between between unemployment and informal economy. As far as the authors are aware, this is the first study on this topic using the nonlinear causality test of Kyrtsou and Labys (2006) based on the bivariate noisy Mackey-Glass process. The most important feature of the non-linear Mackey-Glass terms is that they enable to filter more difficult dependent dynamics in a time series (Kyrtsou and Labys, 2006). Because of this advantage, it has been widely used in the literature (for instance, Kyrtsou and Labys, 2006; Hristu Varsekelis and Kyrtsou, 2008; Kumar, 2009; Kumar and Thenmozhi, 2012 and Ajmi et al., 2013). On the empirical side, Tunisia appears to be an interesting case study as it is one among the developing countries with high rates of unemployment and large informal sectors. Given the current debate on the Tunisian labor market among economists and policymakers and the possible implication of informal economy on its dynamics, a better understanding of the relationship

between unemployment and informal economy is of great relevance to policy making. Conclusions for Tunisia may also be relevant for a large number of countries with similar labour market characteristics and similar magnitude of shadow activities.

2. Data and preliminary analysis

The annual data used in this study cover the period from 1980 to 2008. Following Dobre et al. (2010) and Alexandru (2014), the variables used in the model are: the size of the informal economy expressed as % of official GDP, s_t, and registered unemployment rate, u_t. To estimate the size of the informal sector, as in Elgin (2012), Elgin and Uras (2013), and Goel and Saunoris (2014), we use panel estimates provided by Elgin and Oztunali (2012), which use the two-sector dynamic general equilibrium model[2]. As noted by Elgin (2012), this data is actually the largest set on informal economy, particularly with its times-series dimension. The data on unemployment rate are sourced from the National Institute of Statistics (INS).

Table 1 reports the summary statistics of the variables used in the empirical investigation. To begin, the average size of the informal economy, as a percent of official GDP is 36.79 percent during the period under consideration, with a standard deviation of 0.8069, a maximum size of 38.95 percent, and a minimum of 35.27 percent. The average unemployment rate is 14.35 percent, with a standard deviation of 1.6540, a maximum unemployment rate of 16.98 percent, and a minimum of 11.10 percent. The Ljung-Box statistics with time lags of 5 and 10 periods show that significant linear and nonlinear dependencies exist in both variables. The evolution of the two series, size of the informal economy and unemployment rate, appears in Fig. 1 showing a close co-movement between the two series. However, the plots also suggest that the association between unemployment and informal economy may have altered over time. It can be clearly seen from Fig. 1, that both series are characterized by at least one shift in the slope/intercept of the trend function.

[2] For a review of methods usually applied to estimate the size of the informal economy, see Schneider and Enste (2000), Schneider (2005), Schneider (2007), Schneider et al. (2010), and Elgin and Oztunali (2012).

Table 1. Descriptive statistics of examined variables

	Size of the informal economy		Unemployment rate	
Mean	36.79		14.35	
Std. Dev.	0.8609		1.6540	
Max.	38.95		16.98	
Min.	35.27		11.10	
Skewness	0.3070		-0.4617	
Kurtosis	0.0399		-1.1790	
Jarque-Bera	0.5885		2.4689	
Ljung-Box Q(5)	33.5399	(2.94e-06)	52.0722	(5.21e-10)
Ljung-Box Q(10)	36.4181	(7.13e-05)	63.8966	(6.58e-10)
Ljung-Box Q^2(5)	32,9323	(-3,88e-06)	53.346	(-2.09e-10)
Ljung-Box Q^2(10)	35,8096	(-9,08e-05)	66,2253	(-2.36e-10)

Notes: Numbers in parentheses indicate the p-value for Ljung-Box test.

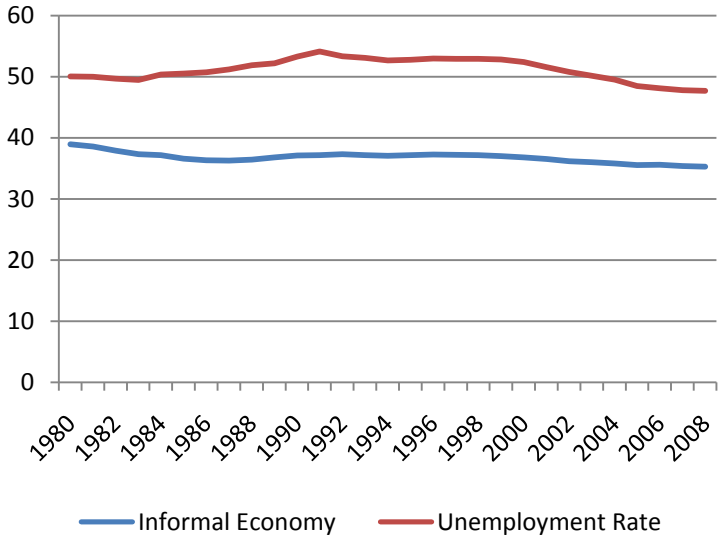

Fig. 1. Evolution of of the informal economy and unemployment rate in Tunisian economy, 1980–2008**.**

3. Methodology

In this section, we present the methodology adopted to investigate the linear and nonlinear causal relationships between unemployment and informal economy in Tunisia. In the first sub-section, we briefly introduce the linear Granger causality test in the since of Toda and Yamamoto (1995), while in the second sub-section we present in detail the nonlinear Granger causality test of Kyrtsou and Labys (2006).

3.1 Toda-Yamamoto linear Granger causality approach

Since the seminal work by Granger (1969), causality test has seen many extensions (for instance, Sims (1990), Toda and Phillips (1993), Toda and Yamamoto (1995), Dolado and Lütkepohl (1996). Among those, the Toda- Yamamoto causality test has received a great deal of attention in recent years. One of its benefits is that avoids the problems associated with the ordinary Granger causality test by ignoring any possible non-stationary or cointegration between series when testing for causality. Toda and Yamamoto (1995) have shown that the conventional F-statistic used to test for Granger causality may not be valid as the test does not have a standard distribution when the time series data are integrated or cointegrated. Instead, they have proposed an interesting yet simple procedure requiring the estimation of an augmented VAR irrespective of whether the time series is integrated or cointegrated.

In accordance with that approach, the unemployment-informal economy model is represented with the following VAR system:

$$s_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} s_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} s_{t-j} + \sum_{i=1}^{k} \gamma_{1i} u_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{2j} u_{t-j} + \varepsilon_{1t} \quad (1)$$

$$u_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} u_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} u_{t-j} + \sum_{i=1}^{k} \emptyset_{1i} s_{t-i} + \sum_{j=k+1}^{k+d_{max}} \emptyset_{2j} s_{t-j} + \varepsilon_{2t} \quad (2)$$

where, (s_t) and (u_t) are the size of informal economy (as a percentage of GDP) and the unemployment rate, respectively. ε_{1t} and ε_{2t} are error terms and that are assumed to be white noise with zero mean, constant variance and no autocorrelation. From (1) Granger causality from u_t to s_t implies $\gamma_{1i} \neq 0 \forall i$ similarly in (2) s_t Granger causes u_t if $\emptyset_{1i} \neq 0 \forall i$ The test statistic, called Modified Wald Statistic (MWALD), is asymptotically distributed as a χ^2 with k degrees of freedom.

3.2. Kyrtsou-Labys nonlinear granger causality approach

One of the commonly criticisms of the linear Granger causality test, described above, that it does not account for nonlinear causal relationships among the variables. To overcome these weaknesses, various nonparametric causality tests have been developed in the literature. The earliest test is the one suggested in Baek and Brock (1992) which is based on the correlation integral, a measure of spatial dependence across time, and is applied to the residuals of linear Granger causality models.

One drawback of this test is that it depends on the asumption that the variables are mutually independent and identically distributed. This is relaxed in the paper by Hiemstra and Jones (1994). They develop a modified test statistic for the nonlinear causality, which allows each series to exhibit short-term temporal dependence. In order to detect nonlinear causal relations, the modified Baek and Brock's test is applied to the residual series from a VAR model and not to the initial stationary variables as input in the model. However, as Kyrtsou and Labys (2006) argue, linear filtering of data using VAR methodology before the application of the Hiemstra and Jones test of nonlinear Granger causality can lead to serious distortions. As an alternative, Kyrtsou and Labys (2006) propose a new test statistic that overcomes these limitations.

To define nonlinear Granger causality, Kyrtsou and Labys (2006) propose a bivariate noisy Mackey-Glass model. Its general form is as follows:

$$s_t = \alpha_{11}\frac{s_{t-\tau_1}}{1+s_{t-\tau_1}^{c_1}} - \beta_{11}s_{t-1} + \alpha_{12}\frac{u_{t-\tau_2}}{1+u_{t-1}^{c_2}} - \beta_{12}u_{t-\tau_2} + \xi_{1,t}$$

$$u_t = \alpha_{21}\frac{s_{t-\tau_1}}{1+s_{t-\tau_1}^{c_1}} - \beta_{21}s_{t-1} - \alpha_{22}\frac{u_{t-\tau_2}}{1+u_{t-1}^{c_2}} - \beta_{22}u_{t-\tau_2} + \xi_{2,t} \quad (3)$$

where $\xi_{1,t}$ and $\xi_{2,t}$: N(0,1),$t = \tau, \dots, N$ $\tau = \max(\tau_1, \tau_2)$. β_{ij} and α_{ij} indicate the nonlinear and linear effects of the independent variables on the dependent variable, respectively. τ_i is the integer delays, and c_i is the constants which can be chosen via prior selection. In this study, following the Kyrtsou and Labys's suggestion, the best delays (lags), τ_1 and τ_2 are selected on the basis of likelihood ratio tests and the Schwarz criterion. The Kyrtsou and Labys's causality test is similar to the linear Granger causality test, except that the models fitted to the series are M-G processes. This test is performed by estimating the M-G model parameters under no constraint with ordinary least squares. To test reverse causality (i.e. from u to s), another M-G model is estimated under the constraint $\alpha_{12} = 0$ that reflects our null hypothesis. Let $\hat{\vartheta}$ and $\hat{v}$ the residuals obtained by the unconstrained and constrained best-fit M-G model, respectively. Thus, the corresponding sums of residual squares can be written as $S_u = \sum_{t-1}^{T}\widehat{\vartheta^2}$ and $S_c = \sum_{t-1}^{T}\widehat{v^2}$ Let $n_u = 4$ is the number of free parameters in the M-G model and on the other side $n_c = 1$ is the number of parameters required to be zero when estimating the restricted model. Obviously, the test statistic satisfies the following:

$$S_F = \frac{(S_c - S_u)/n_c}{S_u/(T - n_u - 1)} : F(n_c, T - n_u - 1), \quad (4)$$

where S_F is the test statistic.

4. Empirical results

Prior to carrying out the Toda and Yamamoto (1995) approach, unit root tests are required to obtain the maximal integration order (d_{max}) of variables under consideration. In this paper, we performed three standard unit root tests on each of two series: the Dickey and Fuller (1979) (ADF), the Phillips and Perron (1988) (PP), and the Kwiatkowski et al. (1992) (KPSS) tests. The unit root test results, presented in Table 2, show that the two variables are non-stationary at their levels but stationary at their first differences, being integrated of order one, I(1).

Table 2. Unit root test results

	ADF		PP		KPSS	
	s_t	u_t	s_t	u_t	s_t	u_t
Levels	-0.682	-0.05	0.666	0.934	0.126	0.260
Δ	-2.598**	-2.050**	-2.251**	-2.716***	0.172**	0.072***

*** and ** denote rejection of the null hypothesis at the 1% and 5% respectively.

To ascertain the order of integration, the Zivot and Andrews (1992) (ZA) unit root test allowing for an endogenous structural break was also conducted. The use of this test is entirely justified by the potential of structural change in the unemployment rate series and in the level of the informal economy over the study period which is characterized by several episodes of crises and important terrorist and geopolitical events. As shown in Table 3, the ZA test results support the hypothesis that the two variables used in the analysis are integrated of I(1) at 5% critical level, and thus the maximum order of integration for the variables in the system is one (i.e., $d_{max} = 1$).

Furthermore, for Tunisia, structural break about informal economy appears to occur at the end of the 1980s, corresponding to the start period of economic liberalization within the context of structural adjustment, instigated by international financial institutions (International Monetary Fund, World Bank, etc.). More to the point, from the mid-1980s to the end of 1990s, Tunisia, as other countries, has experienced several crises, which are the stock market crash in 1987, the Mexican currency crisis in 1994 and the Asian currency crises in July, 1997. For unemployment, however, break occurs during the 2000s, which coincides with the period in which there was two important events: the terrorist attack of September 11, 2001 and the global financial crisis sparked by the US subprime market failures in mid-2007. Such events could lead to important changes in the underlying relationships between the two considered variables.

Table 3. Results of the ZA Unit root tests with a structural break

	Levels		First differences	
Variable	$t_{\hat{\alpha}}(\hat{\lambda}_{inf})$	Year of break	$t_{\hat{\alpha}}(\hat{\lambda}_{inf})$	Year of break
s_t	-3.472	1988	-4.58*	1985
u_t	-2.727	1983	-4.937**	1990

** and * denote rejection of the null hypothesis at the 5% and 10% respectively.

It is also well known that the Toda–Yamamoto testing method is very sensitive to the number of lags included in the regression. Thus, prior to causality analysis, it is customary to select the appropriate lag length for the model. In this study, we determined the lag length (k) using four lag selection information criteria often employed in the literature, namely the Aikaike Information Criterion (AIC) (Akaike, 1973), Schwarz Information Criterion (SIC) (Schwarz, 1978), Final Prediction Error (FPE) (Akaike, 1969) and Hannan Quinn (HQ) (Hannan and Quinn, 1978) information criterion. As shown in Table 4, the obtained results indicate that the appropriate lag length is estimated as 1 (k=1).

Table 4. Lag Length Selection

	1	2	3	4	5
AIC(n)	-6.53e + 01*	-6.42e+01	-6.38e+01	-6.37e+01	-6.39e+01
HQ(n)	-6.52e + 01*	-6.39e+01	-6.34e+01	-6.32e+01	-6.33e+01
SC(n)	-6.48e + 01*	-6.32e+01	-6.23e+01	-6.18e+01	-6.16e+01
FPE(n)	3.992e -29*	1.283e-28	2.214e-28	2.935e-28	3.336e-28

* indicates lag order selected by the criterion

The results of the linear Granger causality test based on Toda and Yamamoto (1995) are reported in Table 5. The estimated χ^2 statistics for Granger causality indicate that at 5% significance level, there is a unidirectional causality running from unemployment to informal economy. This indicates that high levels of unemployment lead to high levels of informal economy.

Table 5. Toda-Yamamoto Tests of Granger Causality

Null Hypothesis	W_{χ_2}	p-values	Decision
H_0 s_t does not Granger cause u_t	4.8	0.093*	Reject H_0
H_0 u_t does not Granger cause s_t	8.0	0.019*	Reject H_0

** and * denote rejection of the null hypothesis at the 5% and 10% respectively.

As outlined in the introduction, there are several reasons to expect nonlinearities in the relationship between unemployment and informal economy. In such a case inference from causality tests based on a linear VAR model may be inaccurate and misleading. Thus, the BDS nonlinearity test developed by Brock et al. (1987) was applied to determine whether the data are characterized by nonlinearities or not. The results reveal that, irrespective of the implemented dimension, the null hypothesis of linearity should be rejected at the 1 percent level of significance for both unemployment and informal economy. Such a finding implies that, instead of the standard Granger causality test, the nonlinear Granger causality test would appear to be more appropriate.

Table 6. Results of BDS test

Length in S.D. (σ2)	Embedding dimension (m)	s_t		u_t	
		W statistic	P-value	W statistic	P-value
0.5	2	12.167	2.2e-16	8.8557	2.2e-16
	3	14.498	2.2e-16	13.502	2.2e-16
	4	20.259	2.2e-16	19.301	2.2e-16
	5	29.972	2.2e-16	35.629	2.2e-16
1					
	2	8.075	6.75e-16	10.923	2.2e-16
	3	8.041	8.89e-16	11.924	2.2e-16
	4	7.887	3.07e-15	15.057	2.2e-16
	5	8.047	8.43e-16	21.243	2.2e-16
1.5					
	2	7.016	2.27e-12	11.123	2.2e-16
	3	6.422	1.34e-10	12.521	2.2e-16
	4	5.858	4.67e-09	14.408	2.2e-16
	5	5.318	1.04e-07	17.687	2.2e-16
2					
	2	19.395	2.2e-16	10.376	2.2e-16
	3	17.887	2.2e-16	10.755	2.2e-16
	4	16.535	2.2e-16	11.135	2.2e-16
	5	15.034	2.2e-16	11.901	2.2e-16

Given the potential existence of a nonlinear relationship between unemployment and informal economy in Tunisia, the nonlinear Granger causality test in the sense of Kyrtsou and Labys (2006) were additionally performed to examine the relationship between the variables of interest. Table 7 reports the empirical results from the Kyrtsou-Labys test. As can be learned from the significance of the p-values of the computed *SF*-statistic, the nonlinear Granger causality tests provide evidence supporting a unidirectional causality running from unemployment to informal economy. This finding is consistent with the result of linear Granger causality test.

Table 7. Results of nonlinear Granger causality test

Null Hypothesis	S_F	P_{value}	Decision
H_0 s_t does not Granger cause u_t	2.18	0.149	Do not reject H_0
H_0 u_t does not Granger cause s_t	14.1	0.00065^{***}	Reject H_0

*** denote rejection of the null hypothesis at the 1%

We used $\tau_1 = \tau_2 = 8$ and $c_1 = c = 4$

5. Policy implications and conclusions

In this paper, we have made an attempt to examine the causal relationship between unemployment and shadow economy in Tunisia during the period of 1980-2008 using parametric and non-parametric techniques. Different from previous studies, we have made use of two recent econometric procedures which are the linear causality approach of Toda and Yamamoto (1995) and the non-linear causality method of Kyrtsou and Labys (2006). Both tests have yielded a strong evidence for unidirectional causality running from unemployment to informal economy in accordance with that found by Dobre et al. (2010) and Alexandru and Dobre (2013) and Alexandru (2014). This implies that a faster rate of unemployment promotes a higher share of the informal economy in total GDP.

In terms of policy implications, our empirical results suggest that any measures aiming at a reduction of the informal economy without tackling the principal problem of unemployment would be counterproductive. In agreement with Schneider et al. (2010), we believe that an interdisciplinary approach seems to be necessary for a more comprehensive analysis to learning more about why people work in the shadow economy and what effect it has on the official economy. Noteworthy is that, the nonlinear dependence between informal economy and unemployment identified in our analysis implies that a shock to unemployment does not necessarily affect informal sector in expected manners, and hence, policy makers should carefully take into consideration the complex structure of the variables in forming relevant policies.

Our findings for Tunisia may be relevant for a large number of countries that have similar level and patterns of unemployment and informal economy. Nevertheless, more individual country studies are needed to obtain true insight on the relationship between informal economy and unemployment since causality between the two variables is also country-specific. That is to say, further investigation is required to determine whether it is different national and institutional conditions affects to our results.

The authors believe this research serves as an initial step to completely disclose causal linkages between unemployment and informal economy in Tunisia. Two extensions of the current study are of immediate interest. First, the bivariate framework used here may be subject to the problem of potential omitted variables bias. Thus, this framework can be readily extended to other multivariate modeling frameworks, where unemployment and informal economy are exposed to be determined by other economic factors such as economic growth, tax and social security burdens, quality of state institutions, etc. Such an analysis helps to disentangle the channels through which unemployment affects informal economy (and vice versa). Secondly, even if our testing procedure can detect nonlinear causal dependence with high power, it provides no guidance regarding the source of the nonlinear dependence. Such guidance seems to be an area for potentially fruitful future research.

References

Ajmi, A.N., Montasser, G. El. and Nguyen, D.K. (2013) "Testing the relationships between energy consumption and income in G7 countries with nonlinear causality tests". *Economic Modelling,* 35, 126-133.

Akaike, H. (1969) "Fitting autoregressive models for prediction". *Annals of the Institute of Statistical Mathematics,* 21, 243-247.

Akaike, H. (1973) "Information theory and an extension of the maximum likelihood principle". *Proceedings of the 2nd International Symposium on Information Theory*, B. N. Petrov and F. Csaki (eds.), Akademiai Kiado, Budapest, 267-281.

Alexandru, A. (2014) "Revisiting the relationship between unemployment rates and shadow economy. A Toda-Yamamoto approach for the case of Romania" Procedia Economics and Finance. 10, 227-236 .

Alexandru, A. and Dobre, I. (2013) "The impact of Unemployment Rate on the Size of Romania Shadow Economiy". *Public Finance Review,* Vol 41, 5, 578-607.

Alexandru, A. and Dobre, I. (2012) "The causality relationships between unemployment rate and U.S. shadow economy: A Toda Yamamoto Approach*". Journal of Social and Economic Statistics,* No.1, Vol.1, 21-34.

Alexandru, A., Dobre, I. and Ghinararu, C. (2010) "Revisiting the relationship between Unemployment rate and the size of the shadow economy for United States using Johansen Approach for Cointegration". *Recent Advances in Mathematics and Computers in Business, Economics, Biology and Chemistry,* 199-204.

Baek, E. and Brock, W.(1992) "A general test for non-linear Granger causality: bivariate model". Working paper, Iowa State University and University of Wisconsin, Madison, WI.

Boeri, T. and Garibaldi, P. (2002) "Shadow Activity and Unemployment in a Depressed Labor Market". CEPR Discussion papers, n.3433.

Bou Abid, A. and Drine, I. (2013) "Efficiency frontier and matching process on the labour market: Evidence from Tunisia". *Economic Modelling* 28, 1131-1139.

Boughzala, M. (2013) "Youth employement and economic transition in Tunisia". Global Economy & Development Working Paper 57.

Boughzala M. (2004) "The Labor market in Tunisia. Study on the functioning of the labor markets in the Mediterranean Region and the implications for employment policy and training systems". University of Tunis.

Boughzala, M. and Kouki, M. (2003) "Unemployment Persistence and The Informal Sector". Working Paper 0326.

Brock,W., Dechect,W., Scheinkman, J. (1987) "A test for independence based on the correlation dimension".Working Paper. Department of Economics, University of Wisconsin, Madison.

Caporale, G.M. and Gil-Alanal, A. (2007) "Nonlinearities and Fractional Integration in the US Unemployment Rate". *Oxford Bulletin of Economics and Statistics*, 69, 4, 521-544.

Dell'Anno, R., Miguel, G. and Angel, A. P.(2007) "Shadow economy in three different Mediterranean countries: France, Spain and Greece. A MIMIC approach". *Empirical Economics*, 33, 51-84.

Dickey, D. and Fuller, W. (1979) "Distribution of the estimators for autoregressive time series with a unit root". *Journal of the American Statistical Association*, 74, 427-431.

Dobre, I., Alexandru, A. and Lepas, O. (2010) "The USA Shadow Economy and the unemployment Rate: Granger causality resultss." *Journal of Applied Quantitative Methods.* Vol. 5,

No. 1, 98-104.

Dolado, J.J. and Lütkepohl, H. (1996) "Making Wald test work for cointegrated VAR systems". *Econometric Theory* 15, 369-386.

Elgin, C. (2012) "Unionization and informal economy". *Economics Bulletin*, Vol. 32, no. 03, 2615-2623.

Elgin, C. and Oztunali, O. (2012) "Shadow economies around the world: model based estimates". Working Papers 2012/05, Bogazici University, Department of Economics, Istanbul.

Elgin. C and Uras, B. (2013) "Public debt, sovereign default risk and shadow economy". *Journal of Financial Stability* 9, 628-640.

Giles, D.E.A. and Tedds, L.M. (2002) "Taxes and the Canadian Underground Economy". Canadian Tax Paper No. 106, Canadian Tax Foundation, Toronto/Ontario.

Goel, R.K. and Saunoris J. W. (2014) "Global corruption and the shadow economy: spatial aspects". *Public Choice* 161, 119-139.

Gouider, A. (2013) "The Tunisian labour market after the Arab Spring: trends, prospects and new policies*". International Journal of Management Concepts and Philosophy*, Vol. 7, No. 1, 31-46.

Granger, C.W.J. (1969) "Investigating causal relation by econometric and cross sectional method". *Econometrica*,37,424-438.

Hannan, E.J. and Quinn, B.G. (1978) "The determination of the order of an autoregression". *Journal of Royal Statistical Society*, 41, 190-195.

Haouas, I., Sayre, E. and Yagoubi, M. (2012) "Youth Unemployment in Tunisia: Characteristics and Policy Responses". *Topics in Middle Eastern and African Economies* Vol. 14, 395-415.

Hiemstra, C. and Jones, J.D. (1994) "Testing for linear and nonlinear Granger causality in the stock price volume relation". *Journal of Finance* 49, 1639-1664.

Hristu-Varsekelis, D. and Kyrtsou, C. (2008) "Evidence for Nonlinear Asymmetric Causality in US In ation, Metal, and Stock Returns". *Discrete Dynamics in Nature and Society*, 5 (3), 1-7.

Kumar, M. (2009) "A Bivariate Linear and Nonlinear Causality between Stock Prices and Exchange Rates". *Economics Bulletin*, Vol. 29 No.4, 2884-2895.

Kumar, M. and Thenmozhi, M. (2012) "Causal effect of volume on stock returns and conditional volatility in developed and emerging market". *American Journal of Finance and Accounting*, Vol. 2, No. 4, 346-362.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992) "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root". *Journal of Economics*, 54, 159-178.

Kyrtsou, C. and Labys, W.C. (2006) "Evidence for chaotic dependence between US inflation and commodity prices". *Journal of Macroeconomics* 28, 256-266.

Phillips, P.C.B and Perron, P.(1988) "Testing for unitroot in time series regression". *Biometrica*, 75, 335-346.

Rothman, P. (1991) "Further evidence on the asymmetric behaviour of unemployment rates over the business cycle". *Journal of Macroeconomics*, Vol. 13, 292-298.

Rothman, P.(1998) "Forecasting asymmetric unemployment rates". *Review of Economics and Statistics*, Vol. 80, 164-168.

Schwarz.G. (1978) " Estimating the dimension of a model". *Annals of Statistics*, 6, 461-464.

Schneider, F., Buehn, A. and Montenegro, C. E. (2010) "Shadow Economies all over the

World". World Bank Policy Research Working Paper, 5356.

Schneider, F. (2005) "Shadow Economies Around the World: What do We Really Know?" *European Journal of Political Economy*, 21, 598-642.

Schneider, F. and Enste, D. (2000) "Shadow economies: size, causes, and consequences". *Journal of Economic Literature* 38, 77-114.

Schneider, F. (2007) "Shadow Economies and Corruption All Over the World: New Estimates for 145 Countries". *Economics, the open Access, Open Assessment E-Journal*, No.9.

Sims, C., Stock, J. and Watson, M. (1990) "Inference in linear time series models with unit roots". *Econometrica* 58, 113- 144.

Skalin, J. and Terasvirta, T. (2002) "Modelling asymmetries and moving equilibria in unemployment rates". *Journal of Econometrics*, Vol. 110, 135-165.

Tanzi, V. (1999) "Uses and Abuses of Estimates of the Underground Economy". *The Economic Journal*, 338-340.

Toda, H.Y. and Phillips, P.C.B. (1993) "Vector autoregressions and causality". *Econometrica* 61, 1367- 1393.

Toda, H.Y. and Yamamoto, H. (1995) "Statistical inference in vector autoregressions with possibly integrated processes". *Journal of Econometrics*, Vol. 66, 225-250.

World Bank. (2004a) "République tunisienne - Stratégie d'emploi" . Rapport No. 25456-TUN, Moyen-Orient et Afrique du Nord Secteurs sociaux (MNSHD), Washington DC.

World Bank. (2004b). "Republic of Tunisia. Development Policy Review: Making Deeper Trade Integration Work for growth And Jobs". Report No. 29847-TUN, Social and Economic Development Group Middle East and North Africa Region, Washington DC.

Zivot, E. and Andrews, D. W. K. (1992) "Further Evidence on the Great Crash, the Oil Price Shock, and the Ut Root Hypothesis". *Journal of Business and Economic Statistics*, Vol. 10, No. 3, 251-270.