The relationship between unemployment rate and the size of the shadow economy. The case of United States

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Abstract: The paper aims to investigate the nature of the relationship between unemployment rate(UR) and the size of the U.S.A. shadow economy(SE) measured as % of official GDP for the period 1980-2009, using cointegration and granger causality tests. The size of the shadow economy estimated using the MIMIC model is decreasing over the last two periods, achieving the value of about 7.3% of official GDP at the middle of 2009.
The empirical results point out the existence of a long-run relationship between the variables and a unidirectional causation that runs from unemployment rate to shadow economy. We extend the classical Okun's law, in order to estimate the relationship between growth rate of official economy, unemployment rate and the size of the shadow economy. The results reveal a significant direct relationship between shadow economy and the unemployment rate and an indirect relation between shadow economy and growth of official sector.

Keywords: shadow economy, unemployment rate, MIMIC model, Johansen approach, VECM, Granger causality, Okun law.

1. Introduction

The relationship between the shadow economy and the level of unemployment is one of major interest. People work in the shadow economy because of the increased cost that firms in the formal sector have to pay to hire a worker. The increased cost comes from the tax burden and government regulations on economic activities. In discussing the growth of the shadow economy, the empirical evidence suggests two important factors: (a) reduction in official working hours, (b) the influence of the unemployment rate.
Enste [12] points out that the reduction of the number of working hours below worker's preferences raises the quantity of hours worked in the shadow economy. Early retirement also increases the quantity of hours worked in the shadow economy.

In Italy, Bertola and Garibaldi [1] present the case that an increase in payroll taxation can have effect on the supply of labour and the size of the shadow economy. An increase in tax and social security burdens not only reduces official employment but tends to increase the shadow labour force. This is because an increase in payroll tax can influence the decision to participate in official employment. Also, Boeri and Garibaldi [2] show a strong positive correlation between average unemployment rate and average shadow employment across 20 Italian regions during the period 1995-1999.
The paper analyzes the relationship between SE and UR using Johansen and Granger causality tests. Also, a reexamination of the classical Okun's law is provided in the paper, showing the relationship between unemployment and official economy in the presence of shadow economy.

2. Data and Methodology

2.1. Data issues

The variables used in the estimation are defined in appendix A. The data series are quarterly, seasonally adjusted covering the period 1980:Q1 to 2009:Q2.

The series in levels or differences have been tested for unit roots using the Augmented-Dickey Fuller (ADF) test and PP tests. All the data has been differentiated for the achievement of the stationarity. While all the variables have been identified like integrated on first order, the latent variable is estimated in the same transformation of independent variables (first difference).

2.2 Methodology

The size of the U.S. shadow economy is estimated as % of official GDP using a particular type of structural equations models-MIMIC model.

The MIMIC model- Multiple Indicators and Multiple Causes model (MIMIC model), allows to consider the SE as a "latent" variable linked, on the one hand, to a number of observable indicators (reflecting changes in the size of the SE) and on the other, to a set of observed causal variables, which are regarded as some of the most important determinants of the unreported economic activity [4].

The model is composed by two sorts of equations, the structural one and the measurement equations system. The equation that captures the relationships among the latent variable (η) and the causes (X_q) is named "structural model" and the equations that links indicators (Y_p) with the latent variable (non-observed economy) is called the "measurement model".
A MIMIC model of the hidden economy is formulated mathematically as follows:

$$Y = \lambda\eta + \varepsilon \quad (1)$$

$$\eta = \gamma X + \xi \quad (2)$$

where:
η is the scalar latent variable(the size of shadow economy);
$Y' = (Y_1,....Y_p)$ is the vector of indicators of the latent variable;
$X' = (X_1,...X_q)$ is the vector of causes of η;
$\lambda_{(p\times 1)}$ and $\gamma_{(q\times 1)}$ vectors of parameters;
$\varepsilon_{(p\times 1)}$ and $\xi_{(q\times 1)}$ vectors of scalar random errors;
The $\varepsilon's$ and ξ are assumed to be mutually uncorrelated.
Substituting (2) into (1), the MIMIC model can be written as:

$$\mathrm{Y} = \Pi\mathrm{X} + \mathrm{z} \quad (3)$$

where: $\Pi = \lambda\gamma'$, $z = \lambda\xi + \varepsilon$.

The estimation of (1) and (2) requires a normalization of the parameters in (1), and a convenient way to achieve this is to constrain one element of λ to some pre-assigned value (Giles, Tedds, 2000).

The possible causes of shadow economy considered in the model are: tax burden decomposed into personal current taxes (X_1), taxes on production and imports(X_2), taxes on corporate income(X_3), contributions for government social insurance(X_4) and government unemployment insurance(X_5), unemployment rate(X_6), self-employment in civilian labour force (X_7), government employment in civilian labour force (X_8) called bureaucracy index. The indicator variables incorporated in the model are: real gross domestic product index (Y_1), currency ratio M_1/M_2 (Y_2) and civilian labour force participation rate (Y_3).

The variables used into the estimation of the shadow economy are also quarterly and seasonally adjusted covering the period 1980-2009. All the data has been differentiated for the achievement of the stationarity.

In order to estimate the MIMIC model, by Maximum Likelihood, using the LISREL 8.8 package, we normalized the coefficient of the index of real GDP ($\lambda_1 = -1$) to sufficiently identify the model. This indicates an inverse relationship between the official and shadow economy.

In order to identify the best model, we have started with MIMIC model 8-1-3 and we have removed the variables which have not structural parameters statistically significant.

A detailed description and implementation of the MIMIC model for the USA shadow economy is provided in [10].

After we estimate the size of the shadow economy, we investigate the nature of the relationship between the two variables.

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root Tests are employed to test the integration level and the possible co-integration among the size of the shadow economy estimated using MIMIC model and the unemployment rate ([7], [25]).

After the order of integration is determined, co-integration between the series should be tested to identify any long run relationship. Johansen trace test is used for the co-integration test in this study. Cheung and Lai [3] mention that the trace test is more robust than the maximum eigenvalue test for co integration. The Johansen trace test attempts to determine the number of co-integrating vectors among variables. There should be at least one co-integrating vector for possible co integration.

This procedure [1][20] can be expressed in the following VAR model:

$$X_t = \Pi_1 X_{t-1} + ... + \Pi_K X_{t-K} + \mu + e_t \quad t = 1,..,T \quad (4)$$

where X_t, X_{t-1}, ..., X_{t-K} are vectors of current and lagged values of P variables which are $I(1)$ in the model; $\Pi_1, ..., \Pi_K$ are matrices of coefficients with (PXP) dimensions; μ is an intercept vector[1]; and e_t is a vector of random errors. The number of lagged values, in practice, is determined in such a way that error terms are not significantly auto-correlated.. The rank of Π is the number of co integrating relationship(s) (i.e. r) which is determined by testing whether its Eigen values (λ_i) are statistically different from zero. Johansen and Juselius [16] propose that using the Eigen values of Π ordered from the largest to the smallest is for computation of trace statistics[2]. The trace statistic (λ_{trace}) is computed by the following formula[3]:

$$\lambda_{trace} = -T \sum \ln(1 - \lambda_i) \quad (5)$$

$i = r+1, ..., n-1$ and the hypotheses are :

H_0: r = 0 H_1: r ≥ 1
H_0: r ≤ 1 H_1: r ≥ 2
H_0: r ≤ 2 H_1: r ≥ 3

If the series are I(1) and cointegrated, then Granger Causality tests should be run under VECM framework([20], [21]):

$$\Delta Y_t = C_0 + \sum_{i=1}^{k} \beta_i Y_{t-i} + \sum_{i=1}^{k} \alpha_i X_{t-i} + p_i ECT_{t-1} + u_t \quad (6)$$

$$\Delta X_t = C_0 + \sum_{i=1}^{k} \gamma_i X_{t-i} + \sum_{i=1}^{k} \zeta_i Y_{t-i} + \eta_i ECT_{t-1} + \varepsilon_t \quad (7)$$

Where Y, X are the variables, p_i is the adjustment coefficient while ECT_{t-1} expresses the error correction term. In eq.(6), X Granger causes Y if α_i, p_i are significantly different from zero. In eq.(7) Y Granger causes X if ζ_i, η_i are significantly different from zero. F-test alone is not enough to have causation; t-ratio of ECM term should be also negative and statistically significant together with F value of the model to have causation in the models.

3. Empirical results

3.1. Estimating the size of the shadow economy

In order to estimate the size of the shadow economy, we have identified the best model as MIMIC 4-1-2 with four causal variables (taxes on corporate income, contributions for government social insurance, unemployment rate and self-employment) and two

[1] This procedure is presented in detail in Katircioglu S.T. "Financial development, trade and growth triangle: the case of India", International Journal of Social Economics, Vol. 34 No. 9, 2007, pp. 586-598.

[2] Asymptotic critical values are obtained from Osterwald-Lenum (1992).

[3] At the beginning of the procedure, we test the null hypothesis that there are no co integrating vectors. If it can be rejected, the alternative hypothesis (i.e. $r \leq 1, ..., r \leq n$) are to be tested sequentially. If $r=0$ cannot be rejected in the first place, then there is no co integrating relationship between the variables, and the procedure stops.

indicators (index of real GDP and civilian labour force participation rate).

Taking into account the reference variable ($Y_1, \frac{\text{Re}\,al\,GDP_t}{\text{Re}\,al\,GDP_{1990}}$) the shadow economy is scaled up to a value in 1990, the base year, and we build an average of several estimates from this year for the U.S.A. shadow economy (table 1).

The index of changes of the shadow economy (η) in United States measured as percentage of GDP in the 1990 is linked to the index of changes of real GDP as follow:

Measurement Equation: $$\frac{GDP_t - GDP_{t-1}}{GDP_{1990}} = \frac{\tilde{\eta}_t - \tilde{\eta}_{t-1}}{GDP_{1990}} \quad (8)$$

Table 1: Estimates of the size of U.S.A. shadow economy (1990)

Author	***Method***	***Size of Shadow Economy***
Johnson et. Al(1998)	Currency Demand Approach	13.9%
Lacko(1999)	Physical Input(Electricity)	10.5%
Schneider and Enste(2000)	Currency Demand Approach	7.5%*
Mean 1990		***10.6%***

*means for 1990-1993

The estimates of the structural model are used to obtain an ordinal time series index for latent variable (shadow economy):

Structural Equation:

$$\frac{\Delta\tilde{\eta}_t}{GDP_{1990}} = -0.24\Delta X_{3t} + 3.00\Delta X_{4t} + 1.49\Delta X_{6t} + 1.01\Delta X_{7t} \quad (9)$$

The index is scaled to take up to a value of 10.6% in 1990 and further transformed from changes respect to the GDP in the 1990 to the shadow economy as ratio of current GDP:

$$\frac{\tilde{\eta}_t}{GDP_{1990}} \times \frac{\eta^*_{1990}}{GDP_{1990}} \times \frac{GDP_{1990}}{\tilde{\eta}_{1990}} \times \frac{GDP_{1990}}{GDP_t} = \frac{\hat{\eta}_t}{GDP_t} \quad (10)$$

I. $\frac{\tilde{\eta}_t}{GDP_{1990}}$ is the index of shadow economy calculated by eq.(8);

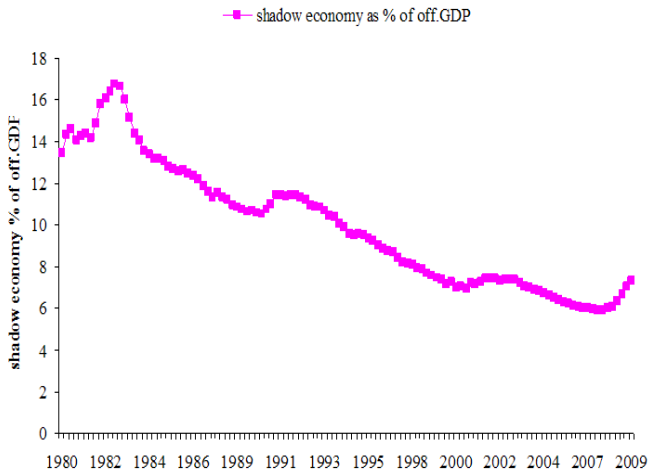
II. $\frac{\eta^*_{1990}}{GDP_{1990}} = 10.6\%$ is the exogenous estimate of shadow economy;

III. $\frac{\tilde{\eta}_{1990}}{GDP_{1990}}$ is the value of index estimated by eq.(8);

IV. $\frac{GDP_{1990}}{GDP_t}$ is to convert the index of changes respect to base year in shadow economy respect to current GDP;

V. $\frac{\hat{\eta}_t}{GDP_t}$ is the estimated shadow economy as a percentage of official GDP.

Fig.1. The size of the shadow economy in U.S. as % of official GDP



The shadow economy measured as percentage of official GDP records the value of 13.41% in the first trimester of 1980 and follows an ascendant trend reaching the value of 16.77% in the last trimester of 1982. At the beginning of 1983, the dimension of USA shadow economy begins to decrease in intensity, recording the average value of 6% of GDP at the end of 2007. For the last two year 2008 and 2009, the size of the unreported economy it increases slowly, achieving the value of 7.3% in the second quarter of 2009.

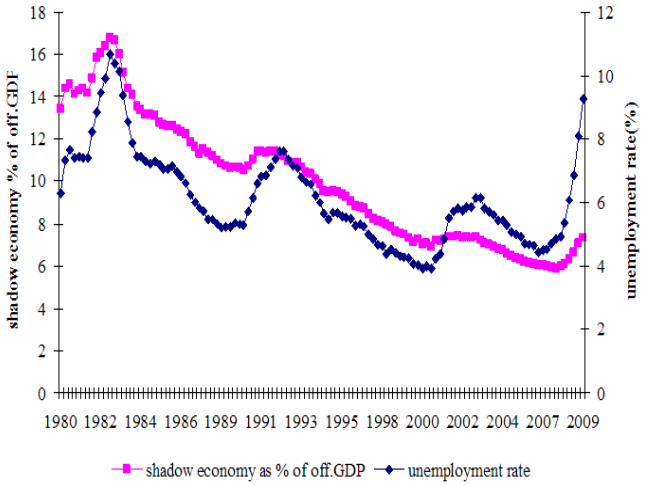
The results are not far from the last empirical studies for USA ([12], [29]).Schneider estimates in his last study, the size of USA shadow economy as % of GDP, at the level of 7.9% in 2005, respectively 8% in 2006.

3.2. There is a link between shadow economy and unemployment rate in the case of United States?

In many empirical studies, is has been found that tax burden is the biggest causes of shadow economy. Also the size of shadow economy is influenced by the level of unemployment. An increase in unemployment rates reduces the proportion of workers employed in the formal sector' this leads to higher labor participation rates in the informal sector.

The graphical evolution of the shadow economy versus unemployment rate reveal the existence of a strong positive relationship between the two variables, quantified by a value of about 0.80 of correlation coefficient.

Fig. 2. Shadow economy vs. Unemployment rate



Giles([13], [14]) state that the effect of unemployment on the shadow economy is ambiguous (i.e. both positive and negative). An increase in the number of unemployed increases the number of people who work in the black economy because they have more time. On the other hand, an increase in unemployment implies a decrease in the shadow economy. This is because the unemployment is negatively related to the growth of the official economy (Okun's law) and the shadow economy tends to rise with the growth of the official economy.

3.2.1. The U.S. shadow economy and unemployment rate: Granger causality results

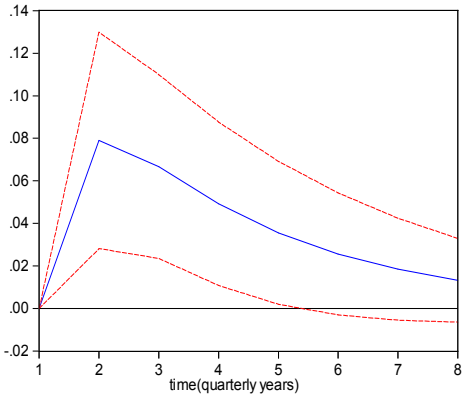
The first step in investigating the nature of the relationship between SE and UR is the estimation of a unrestricted VAR model. The analysis of non-stationarity reveals that the both series are non-stationary and they must be detrended by taking the first differences. According to ADF unit root test, the size of the shadow economy seems to be stationary at level but this is not justified by PP test. The optimal lag length is 1 accordingly with AIC, SC and HQ criterions.

Table 2. ADF and PP Tests for Unit Root

		Shadow Economy(SE)			Unemployment rate(UR)		
		T&C	C	None	T&C	C	None
Level	ADF	-3.09	-1.39	-1.68***	-1.03	-2.14	-0.22
	lag	(3)	(3)	(6)	(1)	(1)	(1)
	PP	-2.26	-0.92	-1.61	-1.41	-1.69	0.03
	lag	(6)	(6)	(6)	(6)	(6)	(7)
First diff.	ADF	-3.43*	-3.39**	-3.33*	-4.40*	-4.17*	-4.17*
	lag	(2)	(2)	(2)	(0)	(0)	(0)
	PP	-6.99*	-6.97*	-6.73*	-4.69*	-4.52*	-4.53*
	lag	(5)	(5)	(6)	(3)	(3)	(3)

Note:
T&C represents the most general model with a drift and trend; C is the model with a drift and without trend; None is the most restricted model without a drift and trend. Numbers in brackets are lag lengths used in ADF test (as determined by SCH set to maximum 12) to remove serial correlation in the residuals. When using PP test, numbers in brackets represent Newey-West Bandwith (as determined by Bartlett-Kernel). Both in ADF and PP tests, unit root tests were performed from the most general to the least specific model by eliminating trend and intercept across the. *, ** and *** denote rejection of the null hypothesis at the 1%, 5% and 10% levels respectively. Tests for unit roots have been carried out in E-VIEWS 6.0.

Fig.3. Response of the shadow economy to a shock in the unemployment rate



A shock in unemployment rate will generate an increase of the shadow economy of about 8% above the baseline, manifested in second quarter, attended by a slow decline towards the baseline. In these circumstances, we can affirm that a rise in the unemployment rate in the official economy will increase the number of people that will work in the shadow economy.

Because the both series are integrated of the same order, I(1) we will apply Johansen and Juselius[16] cointegration approach in order to investigate if there is a long run relationship between the two variables.

Pindyck and Rubinfeld [26] pointed out that it would be best to run the test for a few different lag structures and make sure that the results were not sensitive to the choice of lag length. In order to choose the alternative that we want to test from the five possibilities suggested by Johansen[4], we verify, using ADF test with drift and trend for the both series, if the intercept and the trend coefficient are statistically significant.

In table 3 are presented the results of co-integration tests using Johansen and Juselius approach[16] and confirms that there is a unique co-integration vector(a long run relationship) between the two variables, assuming that we don't have deterministic trend in data.

According to the normalized parameter estimates we can conclude that unemployment rate has a positive and elastic effect on the size of the shadow economy. When unemployment rate grows by 1% the U.S. shadow economy will rise with about 2.34%.

Because a long run equilibrium relationship is found between unemployment rate and the size of the shadow economy, a VECM model is constructed to determine the direction of causality. Table 4 reports the F-statistics and t-statistics for error correction term defined for the null hypothesis of no-causality.

Table 3.Contegration tests using he Johansen (1988) and Johansen and Juselius 1990) approach

Variables	Trace statistic	5% Critical Value[5]	1% Critical Value
Lag 1 UR, SE			
$H_0 : r = 0$	25.41**	12.53	16.31
$H_1 : r \leq 1$	0.70	3.84	6.51
Lag 2 UR, SE			
$H_o : r = 0$	21.00**	12.53	16.31
$H_1 : r \leq 1$	0.14	3.84	6.51
Lag 3 UR, SE			
$H_o : r = 0$	13.31*	12.53	16.31
$H_1 : r \leq 1$	0.04	3.84	6.51
Lag 4 UR, SE			
$H_o : r = 0$	7.42	12.53	16.31
$H_1 : r \leq 1$	0.06	3.84	6.51

Note:
Trace test indicates 1 co integrating equation(s) at both 5% and 1% levels for lag 1 and 2, and 1 cointegrating equation at 5% level. *(**) denotes rejection of the hypothesis at the 5% (1%) level.

Because the t-ratio of ECT is positive and not statistically significant, we can conclude that we don't have any granger causality from SE to UR, but we can say that we have a unidirectional causality from UR to SE (t-ratio of ECT and F-ratio are statistically significant at 1% and 5% levels, but the ECT is not negative).

Table 4.Granger Causality Tests

Null hypothesis		UR does not Granger cause SE	SE does not Granger cause UR
Lag 1	F-stat	22.42*	39.37*
	$t_{ECT_{t-1}}$	2.63**	1.47
Lag 2	F-stat	12.94*	25.96*
	$t_{ECT_{t-1}}$	2.40**	2.062
Lag 3	F-stat	11.14*	19.99*
	$t_{ECT_{t-1}}$	2.50**	1.78

*and ** denote significance for 1% and 5% levels.

[4] M1-no drift/no trend in cointegrating equation or fitted VAR.
M2-drift/no trend in both cointegrating equation, no drift in fitted VAR.
M3-drift/no trend in both cointegrating equation and fitted VAR.
M4-drift and trend in cointegration equation, no trend in fitted VAR.
M5-drift and trend in cointegration equation and fitted VAR.

[5] We have used the critical values of Osterwald-Lenum.

Table 5.Estimation of the Granger Causality Tests within Block Exogeneity Wald Tests

Dependent variable:SE

χ^2

Exclude	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
UR	15.43*	14.30*	11.15**	12.50**	18.22*

Dependent variable: UR

χ^2

Exclude	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
SE	0.06	0.02	0.37	4.48	7.66

* and ** denote significance for 1% and 5% levels.

3.2.2. A re-examination of Okun's law in presence of shadow economy

The Okun's law relates decreases in the unemployment rate to increases in output growth. We want to test if the shadow economy has any significant effect on this empirical evidence. We go on the hypothesis that a lower growth rate of official GDP from potential output is associated with higher deviations of the unemployment rate from its "natural" level. The increase in unemployment leads to an increase in the number of laborers who work in the unofficial labour market.

In fig.1(appendix), we present the significant statistical relationships among growth rate of official GDP, changes in unemployment rate and growth of shadow economy for the case of United States covering the period 1980-2009.

The estimates obtained based on the standard relation given by Okun's law are presented in the following table:

$$g_t^Y = \alpha_0 \Delta u_t + \varepsilon_t \qquad (11)$$

where:

$g_t^Y = (g_t^{off} - \bar{g}^Y_{(80-09)})$ indicates the difference of growth rate of the official gross domestic product (g_t^{off}) from it average calculated over the period 1970 to 2008;

$g_t^\eta = (g_t^{shad} - \bar{g}^\eta_{(80-09)})$ indicates the difference of shadow economy(g_t^{shad}) from it average calculated over the period 1980 to 2009, Δu_t id the first difference of unemployment rate, ε_t are residuals i.i.d.

Table 6. Estimation output of regression: $g_t^Y = \alpha_0 \Delta u_t + \varepsilon_t$

Dependent Variable: G_GROWTH
Method: Least Squares
Date: 07/15/10 Time: 20:20
Sample: 1980Q2 2009Q2
Included observations: 117

	Coefficient	Std. Error	t-Statistic	Prob.
DU	-1.754908	0.166910	-10.51413	0.0000

R-squared	0.487965	Mean dependent var	0.000171
Adjusted R-squared	0.487965	S.D. dependent var	0.852275
S.E. of regression	0.609859	Akaike info criterion	1.857333
Sum squared resid	43.14368	Schwarz criterion	1.880941
Log likelihood	-107.6540	Hannan-Quinn criter.	1.866918
Durbin-Watson stat	1.810181		

The estimates show an inverse relationship between changes in unemployment and the growth rate of official output. Furthermore, we use a modified version of Okun's law by including the shadow economy: $g_t^Y = \alpha_1 \Delta u_t + \beta g_t^\eta + \varepsilon_t$ (12)

Table 7. Estimation output of regression: $g_t^Y = \alpha_1 \Delta u_t + \beta g_t^\eta + \varepsilon_t$

Dependent Variable: G_GROWTH
Method: Least Squares
Date: 07/15/10 Time: 20:23
Sample: 1980Q2 2009Q2
Included observations: 117

	Coefficient	Std. Error	t-Statistic	Prob.
DU	-0.696164	0.279337	-2.492196	0.0141
G_ETA	-1.686008	0.370776	-4.547237	0.0000

R-squared	0.565999	Mean dependent var	0.000171
Adjusted R-squared	0.562225	S.D. dependent var	0.852275
S.E. of regression	0.563904	Akaike info criterion	1.709080
Sum squared resid	36.56854	Schwarz criterion	1.756296
Log likelihood	-97.98115	Hannan-Quinn criter.	1.728249
Durbin-Watson stat	1.508212		

The econometric results reveal that we have a significant negative relationship on the one hand, between the growth rate of official economy and the level of unemployment, that confirm the Okun's law, and on the other hand, between the growth rate of official output and the size of the shadow economy. We deduce therefore, that shadow economy tends to cushion the

effects of changes in unemployment on the official GDP.

In order to investigate the impact of shadow economy on the unemployment rate, we develop a structural relationship, taking into account also the growth rate of official GDP:

$$g_t^{shad} = \gamma g_t^{off} + \lambda \Delta u_t + \varepsilon_t \quad (13)$$

where:

(g_t^{off}) is the first difference of annual growth rate of the official gross domestic product;

g_t^{shad} is the first difference of the shadow economy;

Δu_t is the first difference of unemployment rate; ε_t residuals;

Table 8. Estimation output of regression:

$$g_t^{shad} = c + \gamma g_t^{off} + \lambda \Delta u_t + \varepsilon_t$$

Dependent Variable: G_SHAD
Method: Least Squares
Date: 07/15/10 Time: 20:32
Sample: 1980Q2 2009Q2
Included observations: 117

	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001980	0.019761	0.100205	0.9204
G_OFF	-0.088836	0.019845	-4.476588	0.0000
DU	0.474043	0.050005	9.479919	0.0000

R-squared	0.744924	Mean dependent var	-0.052154
Adjusted R-squared	0.740449	S.D. dependent var	0.255095
S.E. of regression	0.129961	Akaike info criterion	-1.217857
Sum squared resid	1.925446	Schwarz criterion	-1.147032
Log likelihood	74.24465	Hannan-Quinn criter.	-1.189103
F-statistic	166.4625	Durbin-Watson stat	1.345612
Prob(F-statistic)	0.000000		

The parameter γ of the equation shows an inverse relationship between the growth of the official economy (g_t^{off}) and growth of the shadow economy (g_t^{shad}). On the other-hand, the parameter λ shows a direct relationship between changes in unemployment and the growth of the shadow economy.

The coefficients are statistically significant (prob.<5%) and the degree of determination in the model is high, 75% of the variation of shadow economy is explained by the two exogenous variables unemployment rate and growth rate of official GDP.

Our estimations show that the presence of the shadow economy acts as a buffer as it absorbs some of the unemployed workers from the official economy into the shadow economy.

4. Conclusions

The paper has investigated the nature of the relationship between unemployment rate and the size of the U.S.A. shadow economy measured as % of official GDP for the period 1980-2009, using cointegration and granger causality tests. The size of the shadow economy estimated using the MIMIC model is decreasing over the last two periods, achieving the value of about 7.3% of official GDP at the middle of 2009.

The empirical results point out the existence of a long-run relationship between the variables and a unidirectional causation that runs from unemployment rate to shadow economy. We extend the classical Okun's law, in order to estimate the relationship between growth rate of official economy, unemployment rate and the size of the shadow economy.

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*** www.bls.gov , U.S. Department of Labour Statistics
*** Eviews 6.0 software
*** Lisrel 8.8 package

Appendix. Unit-root analysis

The data sources are: Bureau of Economic Analysis (BEA), Bureau of Labor Statistics Data (BLS) and Federal Reserve Banks.

	CAUSES	Source	Unit root analysis		Level				First Difference				
					ADF	lag	PP	lag	ADF	lag	PP	lag	
X_1	Personal current taxes/GDP	BEA	I(1)	T&C	-2.474	4	-2.11	7	-13.83*	0	-13.42*	7	$\Delta(X_1)$
				C	-2.493	4	-2.00	6	-13.79*	0	-13.40*	7	
				None	-0.881	1	-6.761	6	-13.79*	0	-13.40*	7	
X_2	Taxes on production and imports/GDP	BEA	I(1)	T&C	-3.543	0	-3.813	6	-11.24*	0	-11.28*	2	$\Delta(X_2)$
				C	-2.922	0	-3.286	6	-11.27*	0	-11.31*	2	
				None	0.289	0	0.255	5	-11.32*	0	-11.37*	2	
X_3	Taxes on corporate income/GDP	BEA	I(1)	T&C	-4.19*	3	-3.45	6	-10.93*	0	-10.93*	4	$\Delta(X_3)$
				C	-4.14*	3	-3.44	6	-10.98*	0	-10.98*	4	
				None	-1.18	0	-1.13	5	-4.14*	2	-11.01*	4	
X_4	Contributions for government social insurance/GDP	BEA	I(1)	T&C	-2.32	6	-2.01	10	-5.99*	5	-18.57*	8	$\Delta(X_4)$
				C	-2.73	4	-3.40	10	-4.36*	3	-14.03*	9	
				None	0.62	4	1.08	10	-4.35*	3	-13.75*	9	
X_5	Government unemployment insurance	BEA	I(1)	T&C	-2.63	2	-1.76	4	-4.44*	2	-6.49*	3	$\Delta(X_5)$
				C	-3.22	2	-2.07	4	-4.00*	1	-6.36*	3	
				None	-0.94	2	-0.38	4	-4.33*	2	-6.37*	3	
X_6	Unemployment rate	BLS	I(1)	T&C	-1.03	1	-1.41	6	-4.40*	0	-4.69*	3	$\Delta(X_6)$
				C	-2.14	1	-1.69	6	-4.17*	0	-4.52*	3	
				None	-0.22	1	0.03	7	-4.17*	0	-4.53*	3	
X_7	Self-employment/Civilian labour force	BLS	I(1)	T&C	-2.44	0	-2.18	4	-9.68*	1	-12.79*	13	$\Delta(X_7)$
				C	-0.90	0	-0.51	5	-11.03*	0	-11.44*	8	
				None	-0.71	0	-0.91	9	-11.05*	0	-11.41*	8	
X_8	Index of bureaucracy	BLS	I(1)	T&C	-2.69	0	-2.67	3	-12.73*	0	-12.38*	7	$\Delta(X_8)$
				C	-2.88	0	-2.94	3	-12.01*	0	-11.99*	7	
				None	-2.27	0	-2.10	5	-11.37*	0	-11.68*	7	
	INDICATORS												
Y_1	M_1 / M_2	Federal Reserve Banks	I(1)	T&C	-2.12	2	-1.43	8	-3.02	1	-6.59*	7	$\Delta(Y_1)$
				C	-1.69	2	-0.90	8	-3.03*	1	-6.51*	7	
				None	-0.59	2	-0.78	8	-3.02*	1	-6.48*	7	
Y_2	Index of Real GDP[6]	BEA	I(1)	T&C	-1.71	2	-2.35	4	-5.43*	1	-8.71*	4	$\Delta(Y_2)$
				C	1.14	2	2.03	5	-5.26*	1	-8.44*	4	
				None	4.63	2	9.68	5	-2.39*	1	-4.45*	6	

[6] Real Gross Domestic Product, Chained Dollars. Billions of chained (2500) dollars. Seasonally adjusted at annual rates/ $\mathrm{Re}al\ GDP_{1990-Q1}$

Y_3	Civilian labor force participation rate	BLS	I(1)	T&C	-0.47	2	-0.66	1	-10.29*	1	-10.59*	0	$\Delta(Y_3)$
				C	-2.03	0	-2.08	3	-5.98*	2	-10.08*	4	
				None	1.12	0	1.15	4	-5.81*	2	-10.01*	5	

Note:
T&C represents the most general model with a drift and trend; C is the model with a drift and without trend; None is the most restricted model without a drift and trend. Numbers in brackets are lag lengths used in ADF test (as determined by SCH set to maximum 12) to remove serial correlation in the residuals. When using PP test, numbers in brackets represent Newey-West Bandwith (as determined by Bartlett-Kernel). Both in ADF and PP tests, unit root tests were performed from the most general to the least specific model by eliminating trend and intercept across the models (Katircioglu, 2009). *, ** and *** denote rejection of the null hypothesis at the 1%, 5% and 10% levels respectively. Tests for unit roots have been carried out in E-VIEWS 6.0.

Fig.1.Growth of official GDP, Changes in unemployment and Growth of Shadow Economy