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How Reliable are the Estimates of the Underground Economy?*

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Abstract

Economists have proposed several different econometric techniques for measuring the underground economy but these estimates have varied widely and have cast doubts on their credibility and usefulness. This paper describes a dynamic bootstrap routine for constructing confidence intervals for these estimates. This approach avoids the need for subjective opinion on the relative merit of each technique and offers a way to assess the reliability of the various econometric methodologies that have been used.

Keywords: underground economy, bootstrap, currency demand, taxes, welfare benefits.

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1. Introduction

Recently there have been a number of attempts to estimate the size of the underground economy in many countries. These estimates have varied widely even for one country and consequently have cast doubts on their credibility and usefulness. For example, estimates for the United States have varied between a low of 4% (Tanzi, 1983) to a high of 33% of GNP (Feige, 1979). There may be two possible explanations for this. First, the nature of the problem makes it difficult to model and measure such activities, and second, the econometric methodology used may produce inefficiently large estimates because of its sensitivity to small changes in the sampling distribution. The first has been discussed at some length (see Tanzi, 1999 and Thomas, 1999) but the second has not. The objective of this paper is to examine the reliability of one well-known technique for measuring the size of the underground economy (the so-called currency-demand approach) and to use the recent estimate for Australia (see Bajada, 1999) to test its performance and reliability.

As opposed to the most standard econometric analysis, the underground economy literature gives only point estimates not standard errors and this makes it difficult to see how sensitive the econometric methodology is to small changes in the sampling distribution. This paper describes a dynamic bootstrap routine that may also be used to assess the reliability of other econometric methods used to produce estimates of the underground economy elsewhere. If the procedure produces very wide confidence intervals, the econometric methodology is likely to produce unreliable estimates of the size of the underground economy and it's use should be avoided. This technique offers a better way to assess the reliability of such methodologies than simply a subjective view of what is or is not a credible result.

The paper is organised as follows. Section 2 describes Bajada's (1999) methodology for estimating Australia's underground economy. Section 3 describes the dynamic bootstrap technique and in Section 4 are my results. Section 5 concludes.

2. The Underground Economy in Australia

The underground economy consists of unmeasured economic activity that has contributed to value added according to the national accounting convention but is not recorded because of the failure to report income in whole or in part. Activities that are not usually measured by the national accounting convention (e.g. criminal activity) will not form part of the measure of the underground economy.[1] Such studies are important because the existence of a non-negligible underground economy may distort the size of important economic variables, such as the tax base and the growth of GDP, which are often used to gauge the functioning of the economy. Further still, a non-negligible and volatile underground economy may have significant implications for the business cycle (Bajada, 1999). If acted upon, misguided information on the size of the underground economy may lead to inefficient use of public sector resources.

Among the many estimates of the underground economy abroad, Bajada (1999) produced a time series estimate for Australia for the period 1967 to 1996. The estimates are based on an approach that assumes individuals are motivated to avoid the payment of taxes or prevent the loss of any government welfare assistance by expressly requesting cash when receiving

[1] See Feige (1989) for a complete and comprehensive taxonomic framework that distinguishes between various concepts of underground economic activity.

payment so as to minimize their chances of being detected. For this reason Bajada (1999) argues that it makes goods sense to examine the money supply for clues to its size. Using a variant of the monetary approaches of Cagan (1958) and Tanzi (1983), Bajada estimates the size of the Australian underground economy to be approximately 15% of GDP.

Pagan and Volker (1981) estimate money demand for Australia using M1 as the dependent variable and the level of income and the rate of interest as the independent variables which they find to be the most satisfactory explanation for holding money balances. However Bajada (1999) is concerned with estimating the demand for currency and for reasons to be discussed below, he introduces additional regressors to income and interest rates in order to satisfactorily explain holdings of currency. The choice of functional form for the estimated equation (an Error Correction Model - ECM) was based on the Davidson-MacKinnon J-test for model selection – which was found to be consistent with the preferred model specification of Pagan and Volker (1981).

Bajada (1999) estimates the underground economy by measuring the excess sensitivity of taxes (T) and welfare benefits (*Wf*) on currency demand, that is whether changes in T and *Wf* changes real per capita currency holdings (*C*) in addition to the effects on disposable income (*YD*). The demand for currency is also driven by other explanatory variables, namely, (i) the interest rate (*R*); (ii) the rate of inflation (π) - rising rates of inflation, for example, erode the value of money and induce individuals to hold less of it; (iii) private consumption expenditure as a percentage of GDP (*E*) - to capture currency demand arising as a result of spending on goods and services (derived demand) in the legitimate economy; and (iv) technological change (*Tr*).

With the following specification of currency demand:

$$\mathrm{C} = f(YD,\ R,\ \pi,\ E,\ Tr) \tag{1}$$

taxation and welfare benefits affect currency holdings through disposable income, which implies that (1) could alternatively be written as

$$\mathrm{C} = f(Y - T + Wf,\ R,\ \pi,\ E,\ Tr) \tag{2}$$

It is however the excess sensitivity of *T* and *Wf* on currency that is important, so Bajada (1999) estimates currency demand using the following general specification

$$\mathrm{C} = f(Y - T + Wf,\ T,\ Wf,\ R,\ \pi,\ E,\ Tr) \tag{3}$$

The results of this estimation are presented in the Table 1. Most of the t-statistics are significant at the 1% level and the adjusted R^2 is 0.79. The Ramsey (1969) RESET test shows no indication of mis-specification at the 1% level. Furthermore this specification does not exhibit autocorrelated (Durbin-Watson - DW) or heteroscedastic (Breusch and Pagan, 1979) disturbances. Testing for conditional heteroscedasticity using ARCH (see Engle, 1982) the error variances show no evidence of being serially correlated. The calculated τ- statistic from the Augmented Dicker-Fuller equation used to test the existence of a unit root in the residuals, (not reported here) is larger in absolute terms than the critical value (see Phillips and Ouliaris, 1990, p.190), suggesting the variables being co-integrated.

Using an ECM framework, equation (3) is expressed as follows:

$$\Delta \ln(\mathbf{C}_t) = \mathbf{X}\beta + \mathbf{T}\alpha + \mathbf{W}\delta + \varepsilon \tag{4}$$

where

$\mathbf{X} =$ a 119×14 matrix of explanatory variables except taxes and welfare benefits that are included separately, namely intercept, $\Delta \ln(\mathrm{YD})$, $\Delta \ln(\mathrm{E})$, $\Delta \ln(\mathrm{R})$, $\Delta \ln(\pi)$, $\ln(\mathrm{YD}_{t-1})$, $\ln(\mathrm{E}_{t-1})$, $\ln(\pi_{t-1})$, $\ln(\mathrm{R}_{t-1})$, $\mathrm{T}r$, $\ln(\mathrm{C}_{t-1})$ and 3 seasonal dummies . The lag of real currency per capita, $\ln(\mathrm{C}_{t-1})$, is introduced in the ECM to capture the speed of adjustment to fluctuations in currency demand by holders of currency.

$\beta =$ a 14×1 vector of coefficients corresponding to the explanatory variables in **X**;

$\mathbf{T} =$ a 119×2 matrix of two tax variables, namely $\Delta \ln(\mathrm{T})_t$ and $\ln(\mathrm{T})_{t-1}$;

$\alpha =$ a 2×1 vector of coefficients corresponding to the tax variables in T;

$\mathbf{W} =$ a 119×1 vector of $\Delta \ln(\mathrm{W})$;

$\delta =$ the coefficient on $\Delta \ln(\mathrm{W})$;

$\varepsilon =$ stochastic disturbance term.

Solving equation (4) for nominal currency (C_t^*) gives:

$$\mathrm{C}_t^* = \exp\left(\mathrm{X}_t\beta + \mathrm{T}_t\alpha + \mathrm{W}_t\delta + \ln(\mathrm{C}^*)_{t-1} + \Delta \ln(\mathrm{P})_t + \Delta \ln(\mathrm{N})\right) \tag{5}$$

where P_t = GDP implicit price deflator and N_t = population.

Subtracting these excess sensitive components produces an estimate of currency in circulation in the absence of an underground economy that may be expressed as:

$$\mathrm{C}_{wt} = \exp\left(\mathrm{X}_t\beta + \ln(\mathrm{C}^*)_{t-1} + \Delta \ln(\mathrm{P})_t + \Delta \ln(\mathrm{N})\right) \tag{6}$$

Consequently illegal currency in period t is defined as:

$$\begin{aligned} \mathrm{H}_t &= \mathrm{C}_t^* - \mathrm{C}_{wt} \\ &= \exp\left(\mathrm{X}_t\beta + \ln(\mathrm{C}^*)_{t-1} + \Delta \ln(\mathrm{P})_t + \Delta \ln(\mathrm{N})\right) \times \left(\exp(\mathrm{T}_t\alpha + \mathrm{W}_t\delta) - 1\right) \end{aligned} \tag{7}$$

Assuming that the velocity of currency (V) in the underground economy is equal to that in the legitimate economy, Bajada (1999) multiplies the velocity of currency to the volume of illegal currency, given by equation (7), to produce an estimate of the size of the underground economy that may be expressed as

$$\mathrm{UG}_t = \mathrm{V}_t \times \left[\exp\left(\mathrm{X}_t\beta + \ln(\mathrm{C})_{t-1} + \Delta \ln(\mathrm{P})_t + \Delta \ln(\mathrm{N})_t\right) \times \left(\exp(\mathrm{T}_t\alpha + \mathrm{W}_t\delta) - 1\right)\right] \tag{8}$$

where $\mathrm{V}_t = \mathrm{Y}_t^* \div \mathrm{C}_{wt}$ and $\mathrm{Y}^* =$ GDP less consumption of fixed capital less net income paid overseas.

However an interval estimate, in contradistinction with a point estimate given by (8), takes into account the possibility that a sample estimate may differ from its true value because of sampling fluctuations. Since each point estimate, generated by (8), has variability around its mean and subject to sampling fluctuations, we cannot be certain that the unknown mean size of the underground economy is adequately represented by these point estimates. An assessment on the robustness of these estimates can be determined by constructing intervals for the underground economy at each data point. I construct a 95% confidence interval from which we can be 95% confident that the unknown mean size of the underground economy lies between these constructed intervals. To do this one needs the sampling distribution of (8) and this is not known because of its unique calculation. It is possible however to approximate this distribution using a dynamic bootstrap technique.

3. Assessing Point Estimate Reliability – A Confidence Interval Approach

3.1 The Traditional Bootstrap Approach – Coefficient Intervals

The general idea behind the bootstrap technique is as follows (see Veall, 1988; and Horowitz, 1997). Bajada's currency demand equation may be written as:

$$\ln C = \Psi\rho + \varepsilon \tag{9}$$

where Ψ is a $(n \times m)$ matrix of all the explanatory variables and intercept;
ρ is a $(m \times 1)$ vector of all coefficients; and
ε is an $(n \times 1)$ vector of white noise residuals.

The OLS estimated equation is given by

$$\ln(\hat{C}) = \Psi\hat{\rho} + e \tag{10}$$

where $\hat{\rho} = (\Psi'\Psi)^{-1}\Psi'\ln(C)$

The random error terms are assumed to have come from an unknown distribution with a mean of zero and a variance of σ^2. The result yields a vector of estimated residuals (e_1, e_2, ..., e_n). Suppose that F(ε) takes any distribution. These values of the disturbance terms generate a vector of values for $\ln C(\ln C_1, \ln C_2, ..., \ln C_n)$ where

$$\ln C_t = f(\Psi_t;\rho) + \varepsilon_t \tag{11}$$

The distribution will depend on the distribution function of F(ε) but this in unknown since we do not know the distribution of the ε terms. We are therefore prevented from getting a small sampling distribution for both $\hat{\rho}$ and $\ln(\hat{C})$. This can be overcome by using the bootstrap method because it allows the replacement of F(ε) by F(*e*). The estimated residuals then become,

$$e_t = \ln C_t - f(\Psi_t;\hat{\rho}) \tag{12}$$

From this vector of estimated residuals a sample of size *n* is drawn with replacement, so that from this vector of estimated residuals, *n* residuals are randomly selected and a second vector of residuals is created. However each random selection is followed by replacement so that if e_1 is selected, it is replaced and has a probability of being selected again of 1/*n*. This second vector, $\mathbf{e}^*$ of re-sampled residuals, are substituted into equation (9) and a new vector of estimated lnC^1 is generated holding of course the original estimate of ρ constant.

$$\ln C^1 = \Psi\hat{\rho} + e^* \tag{13}$$

The vector $\boldsymbol{\Psi}$ remains unaltered throughout this procedure. Given the newly generated ln(C) we regress $\ln C^1 = \Psi\rho + \varepsilon$ in order to re-estimate ρ. The number of estimates of ρ will equal the number of replications that one performs. The process is repeated a large number of times and an empirical distribution of $\hat{\rho}$ is obtained which will serve as a proxy for the true distribution of $\hat{\rho}$. This distribution can be used to calculate a confidence interval for ρ. Because of the nature of this estimation, we are concerned not with the empirical distribution of the estimated coefficients in the currency demand equation but rather the distribution of (8).

3.2 A Dynamic Bootstrap Approach – Interval Estimates

Consequently the traditional bootstrap routine is modified and the general process of estimating the confidence intervals for the underground economy in Australia for each data point are summarised in the following seven steps.

1. Using the error correction model defined by Bajada (1999) to estimate the size of the underground economy, as

$$\Delta \ln(\mathbf{C}) = \mathbf{X}\beta + \mathbf{T}\alpha + \mathbf{W}\delta + \varepsilon \tag{14}$$

where ε_t is white noise, we estimate equation (14) to obtain the estimates of $\hat{\beta}$, $\hat{\alpha}$, $\hat{\delta}$ and residuals $\hat{\varepsilon}_t$.

2. Sample randomly 119 white noise errors from 119 $\hat{\varepsilon}$ with replacement. Denote these re-sampled errors by $\hat{\hat{\varepsilon}}$.

3. Generate a new set of observations on the dependent variable by

$$\Delta \ln\left(\hat{\hat{C}}_t\right) = X_t\hat{\beta} + T_t\hat{\alpha} + W_t\hat{\delta} + \hat{\hat{\varepsilon}}_t \tag{15}$$

However since $ln(C_{t-1})$ is an independent variable in the regression, for each new set of observations on the dependent variable in (15), we solve for $\ln(C_t)$ (using $\ln(C_1)$ as the first observation) which we use in the next period as $\ln(C_{t-1})$. This dynamic bootstrap ensures consistent estimates of $\Delta \ln\left(\hat{\hat{C}}_t\right)$.

4. Regress $\Delta \ln\left(\hat{\hat{C}}_t\right)$ on X_t, T_t and W_t to obtain a new set of coefficients $\hat{\hat{\beta}}$, $\hat{\hat{\alpha}}$, $\hat{\hat{\delta}}$ and residuals $\hat{\hat{\varepsilon}}$.

5. Obtain the predictor of $\Delta \ln\left(\hat{\hat{C}}_t\right)$ based on these estimates as

$$\Delta \ln\left(\tilde{C}_t\right) = X_t\hat{\hat{\beta}} + T_t\hat{\hat{\alpha}} + W_t\hat{\hat{\delta}} + \hat{\hat{\varepsilon}}_t \tag{16}$$

6. Estimate the volume of illegal currency $\left(\tilde{H}_t\right)$ as the difference between the existing levels of currency holdings $\left(\tilde{C}_t\right)$ and the level estimated in the absence of the excess sensitivity of taxes and welfare benefits, $\left(\tilde{C}_{wt}\right)$.

$$\begin{aligned}\tilde{H}_t &= \tilde{C}_t - \tilde{C}_{wt} \\ &= \exp\left(\Omega_t\right) - \exp\left(\Omega_t - T_t\hat{\hat{\alpha}} - W_t\hat{\hat{\delta}}\right)\end{aligned} \tag{17}$$

where $\Omega_t = ln\left(\tilde{C}_t\right) + ln\left(C_{t-1}\right) + \Delta\, ln\left(P_t\right) + \Delta\, ln\left(N_t\right)$

7. Finally estimate the size of the underground economy by

$$\begin{aligned}U\tilde{G}_t &= \tilde{H}_t \times \tilde{V}_t \\ &= \tilde{V} \times \left[\exp\left(X_t\hat{\hat{\beta}} + \ln(C)_{t-1} + \Delta\ln(P)_t + \Delta\ln(N)_t\right) \times \left(\exp\left(T_t\hat{\hat{\alpha}} + W_t\hat{\hat{\delta}}\right) - 1\right)\right]\end{aligned} \tag{18}$$

Repeating steps (1) to (7), 10,000 times for each quarter generates an empirical distribution of the predictor UG_t. By sorting out the 10,000 replications of UG in ascending order, the 2.5 and 97.5 percentiles form the 95% confidence interval for the point estimates of the underground economy in Australia. The data used in this study is obtained from the sources reported in Bajada's (1999) data appendix.

5. Results

Table 2 reports the lower (2.5 percentile) and upper (97.5 percentile) interval estimates constructed for the underground economy using the dynamic bootstrap procedure outlined in the previous section. The intervals are expressed both as a percentage of GDP [columns 4 and 6] and in millions of dollars, expressed in 1989/90 prices [columns 1 and 3]. The point estimates are given in columns 2 and 5 of the same table. The empirical frequency distribution of the average bootstrapped estimates of the underground economy is given in Figure 1[2]. This distribution appears normal so it is acceptable to take the lower 2.5 percentile and upper 97.5 percentile to construct the intervals. These confidence intervals can be interpreted as follows - we can say that we are 95% confident that the unknown mean size of the underground economy lies between the constructed intervals. For example, in 1967 we can say that we are 95% confident that the unknown population mean size of the underground economy to be between 12.68% and 15.27% of GDP. In Figure 2 we plot the interval estimates as a percentage of GDP for the entire sample period.

The bandwidth of the 95% confidence intervals is slightly below 2.8% of GDP. This result reaffirms the claim by Bajada (1999) that the point estimates of the size of the underground

[2] The single period distributions have very similar skewness and kurtosis as that represented by the average which is plotted in Figure 1.

economy in Australia are relatively robust. It also suggests that the currency-demand approach is not sensitive to small changes in the sampling distribution.

6. Conclusion

The foregoing analysis has sought to demonstrate that the (excess sensitive) currency-demand approach to estimating the size of the underground economy in Australia is quite reliable and is not sensitive to small changes in the sampling distribution. The constructed intervals were found to be quite close to the point estimates previously estimated by Bajada (1999). The bandwidth was estimated to be on average less than 2.8% of GDP. However constructing interval estimates not only substantiates the robustness of the point estimates, it also allow us to say that we are (95%) confident that the unknown mean size of the underground economy lies between these constructed intervals.

This confidence interval approach is directly applicable to existing methodologies used to estimate the size of the underground economy elsewhere and is likely to offer a better way to assess the reliability of the point estimates. It is quite possible that some methodologies that have been used to estimate the underground economy in the United States and elsewhere are unreliable because of the sensitivity to small sampling fluctuations. This would be quite noticeable if the confidence intervals, using this dynamic bootstrap procedure, are found to be very wide.

Table 1 – Estimation Results (1967-1996)

Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
$\ln(T)_{t-1}$	0.061	2.00	$\Delta\ln(T)$	0.183	4.82
$\ln(YD)_{t-1}$	0.066	1.00	$\Delta\ln(YD)$	0.522	7.44
$\ln(E)_{t-1}$	-0.147	2.24	$\Delta\ln(E)$	0.410	5.46
$\ln(R)_{t-1}$	-0.022	2.79	$\Delta\ln(R)$	-0.017	1.17
$\ln(\pi)_{t-1}$	-0.009	2.68	$\Delta\ln(\pi)$	-0.014	3.18
$\ln(W)_{t-1}$	-0.049	2.74	D1[a]	-0.046	4.56
$\ln(C)_{t-1}$	-0.190	4.24	D2[a]	-0.040	4.40
Tr	0.001	1.62	D3[a]	-0.043	3.41
Constant	1.179	1.74			
Dependent variable: $\Delta\ln C_t$ Adjusted R^2 = 0.79 Durbin Watson (DW) = 1.97 LM statistic = 0.179 Breusch-Pagan = 14.07			**Engle (1982) ARCH test** ARCH (1): χ^2 =0.22; ARCH (2): χ^2 =0.80 ARCH (3): χ^2 =0.85; ARCH (4): χ^2 =1.02 **Specification[b]** RESET(2) = 4.10; RESET(3) = 2.48		

Notes: (a) D denotes seasonal dummies; **(b)** RESET (2) includes the squared lagged dependent variable and RESET(3) includes the squared and the cubic lagged dependent variable as additional regressors.

Table 2 - Interval Estimates of the Underground Economy [a]

Date	Lower Interval ($m) (1)	Point Estimate ($m) (2)	Upper Interval ($m) (3)	Lower Interval (% of GDP) (4)	Point Estimate (% of GDP) (5)	Upper Estimate (% of GDP) (6)
1967	20202.13	22620.57	24326.33	12.68	14.19	15.27
1968	21355.34	23758.10	25783.86	12.61	14.03	15.23
1969	23872.07	26242.21	28704.87	13.12	14.42	15.77
1970	25530.48	28168.88	30756.12	13.25	14.62	15.96
1971	26784.98	29621.56	32329.25	13.22	14.63	15.96
1972	27173.56	29978.12	32923.56	12.94	14.28	15.68
1973	29498.44	33036.09	35493.87	13.60	15.23	16.36
1974	31356.91	34900.49	37777.76	14.07	15.66	16.96
1975	31724.84	35105.58	38446.13	13.74	15.20	16.65
1976	34130.68	37366.53	41154.29	14.09	15.43	16.99
1977	34113.42	37622.29	41198.21	14.03	15.47	16.94
1978	34539.72	37506.00	41852.58	13.55	14.71	16.41
1979	35087.96	39341.40	42366.26	13.56	15.21	16.38
1980	36633.87	41043.65	44196.76	13.83	15.49	16.68
1981	39174.62	43326.03	47254.63	14.09	15.58	16.99
1982	38239.14	41875.56	46324.47	13.65	14.95	16.54
1983	37771.30	41384.84	45753.38	13.37	14.65	16.20
1984	41052.84	45842.66	49493.29	13.77	15.38	16.60
1985	43577.76	47855.60	52612.37	13.77	15.13	16.63
1986	44971.74	49378.68	54221.89	13.95	15.31	16.82
1987	46709.10	51425.61	56455.53	13.85	15.25	16.74
1988	48757.77	54023.55	58888.61	13.96	15.47	16.86
1989	50516.77	55655.32	61065.56	13.80	15.20	16.68
1990	49870.23	55771.42	60376.33	13.62	15.23	16.49
1991	49191.33	53938.84	59690.65	13.37	14.66	16.22
1992	49981.90	55399.85	60482.81	13.36	14.81	16.17
1993	52122.18	57587.27	63028.37	13.36	14.76	16.16
1994	55713.09	61891.89	67202.15	13.71	15.23	16.54
1995	58639.28	65085.26	70767.58	13.97	15.51	16.86
Mar 96[(b)]	14765.42	17193.05	17823.60	14.05	16.36	16.96
Jun 96[(b)]	15188.33	16067.88	18331.11	14.16	14.98	17.09

Notes: (a) Based on Dec-31 each year. **(b)** March and June quarters 1996 are quarterly estimates only.

Figure 1 - Empirical Frequency Distribution of Bootstrapped Estimates of the Underground Economy (% of GDP).

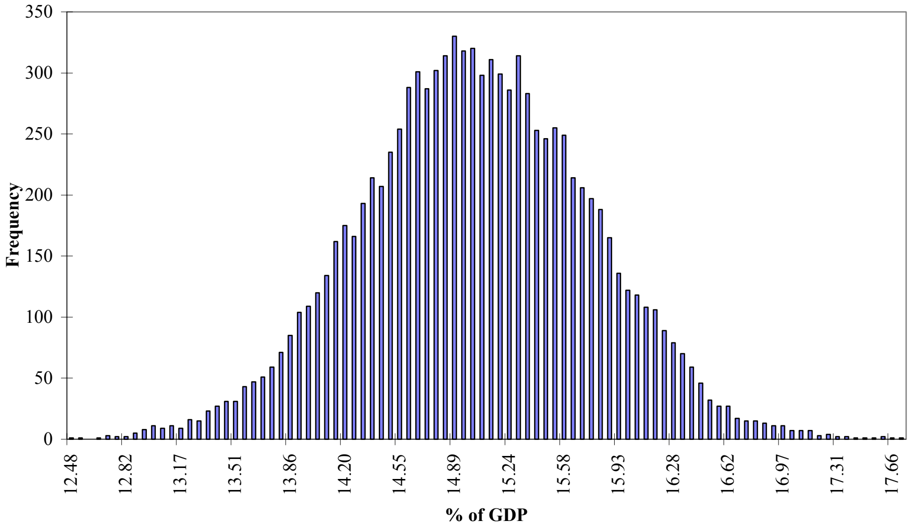
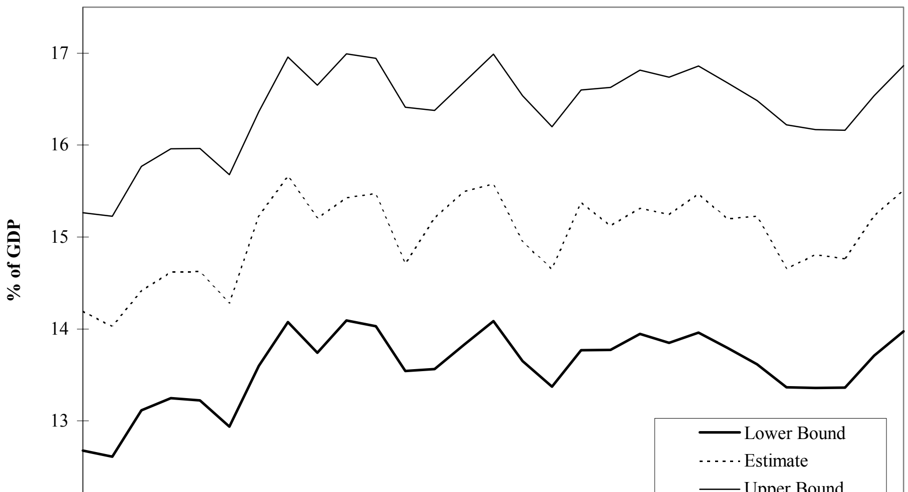


Figure 2 - Upper and Lower Bound Estimates of the Underground Economy- (% of GDP)



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