Causality Between the Measured and Underground Economies in New Zealand

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***Abstract*:** We investigate some characteristics of the underground economy in New Zealand by testing for Granger causality between measured and "hidden" real GDP in that country. We find clear evidence of causality from measured to hidden economic activity, but only weak evidence of causality in the reverse direction. This poses a dilemma for policy-makers who wish to stimulate economic growth and also minimize the size of the "tax-gap".

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I. INTRODUCTION

Potential tax revenue is lost as a result of unmeasured "hidden" economic activity of various forms. The size of the hidden economy varies from country to country, reflecting differences in the tax burden, the sophistication of the regulatory system, success in prosecuting tax offenders, and the degree of tax "morality", *etc*.. It also varies over time, and both Frey and Weck-Hanneman (1984) and Aigner *et al*. (1988) provide useful comparisons of such measures. The former find that for seventeen OECD countries in 1978, the size of the underground economy (relative to official GNP) was 4.1% for Japan, 8.3% for the U. S. A., 13.2% for Sweden, and averaged 8.8%. Studies summarised by Aigner *et al.* give corresponding figures ranging form 4% to 33% for the U. S. A. at this same time. In contrast, the evidence for the U. S. A. in 1970 yields a range, for this ratio, from 2.6% to 11% .

Such measures are of considerable economic and political importance. They have obvious, and potentially sizeable, budgetary implications, as well as implications for the incidence of taxation and income distribution. Following seminal work by Feige (1979,1982) and others, various techniques have been used to try and measure the size of the hidden economy in different countries. Frey and Weck-Hanneman (1984) and Aigner *et al*. (1988) treat the size of the hidden economy as a "latent variable" and use the MIMIC ("Multiple Indicators, Multiple Causes") model of Zellner (1970), Goldberger (1972), Jöreskog and Goldberger (1975) and others, as the basis for their statistical analysis. This model is a member of the LISREL ("Linear Interdependent Structural Relationships") family of models (*e.g.*, Jöreskog and Sörbom (1993)). As part of a major research program being undertaken by the Inland Revenue Department in New Zealand, Giles (1995) has recently used MIMIC modelling, in conjunction with a non-linear structural model for currency demand, to estimate the size of the hidden economy in that country. Here, we use his estimated time-series data to examine the relationship between hidden and measured GDP in New Zealand, by way of formal Granger (1969) causality testing. Giles (1995) paid special attention to the non-stationarity of the data in his models, and this aspect of the econometric analysis is also emphasised here. Indeed, this appears to be the first underground economy study, and the first application of the MIMIC model, to deal with this issue systematically.

II. DATA FEATURES AND STATIONARITY ISSUES

Our measure of the size of the New Zealand hidden economy comes from[1] MIMIC Model 2 reported by Giles (1995). Annual (calendar year) data for this variable and for the corresponding real measured GDP are available for 1968 to 1994 in real 1982/1983 $Millions. The *relative* size of unrecorded economic activity increased from 6.8% of measured real GDP in 1968 to a peak of 11.3% in 1987. It then fell to 8.7% of measured real GDP in 1992 before increasing to 11.3% in 1994. The rapid rise in the relative size of the hidden economy in the early 1970's is consistent with the expansion in real output which took place in New Zealand before the effects of the international oil price shocks. The cyclical movements in the time-path during the mid-1970's to mid-1980's accord with the (less pronounced) pattern in measured output; as do the trough in 1992, and subsequent expansion.

Using the "augmented" Dickey-Fuller (ADF) test (*e.g.*, Dickey and Fuller (1979,1981); Said and Dickey (1984)), we have tested[2] the data for stationarity. For samples of our size, Dods and Giles (1995) show[3] that the default method of choosing the augmentation level, p, in the SHAZAM (1993) package involves minimal size-distortion. To determine whether drift and trend variables should be included in the ADF regression, we follow the strategy suggested by Dolado *et al.* (1990), and also used by Giles *et al.* (1992). To test that the series x_t is integrated of order 1 (*i.e.*, is I(1)), against the alternative that x_t is integrated of order zero (*i.e.*, is I(0), or stationary) the level of augmentation, p, is determined as above, in the context of the following ADF regression model:

$$\Delta \mathbf{x_t} = \alpha + \beta \mathbf{t} + \gamma \mathbf{x_{t-1}} + \theta_1 \Delta \mathbf{x_{t-1}} + \ldots\ldots + \theta_p \Delta \mathbf{x_{t-p}} + \epsilon_t \qquad \textbf{(1)}$$

We then test $H_o : \gamma = 0$ *vs.* $H_A : \gamma < 0$ using the Dickey-Fuller "t" test (denoted "t_{dt}" below) and MacKinnon's (1991) critical values. If H_0 is rejected, we conclude that x_t is stationary, otherwise we test $H_0 : \beta = \gamma = 0$, using the "F-test" (denoted "F_{ut}" below) of Dickey and Fuller (1981). Rejection, leads us to conclude that x_t is I(1), otherwise we remove the trend from the ADF regression and test $H_0 : \gamma = 0$ *vs.* $H_A : \gamma < 0$. The ADF "t-statistic" is denoted "t_d". If we cannot reject H_0, we test $H_0 : \alpha = \gamma = 0$ using the "F-test" (denoted "F_{ud}" below) of Dickey and Fuller (1981). Rejection suggests that x_t is I(1), otherwise we remove the drift, re-estimate, and test $H_0 : \gamma = 0$ *vs.* $H_A : \gamma < 0$. This "t-statistic" is denoted "t" in Table 1. Rejection suggests that x_t is I(0), or stationary, while failing to reject suggests that x_t is I(1).

Table 1. ***ADF unit root test results*** [a]

		T	p	t_{dt}	F_{ut}	t_d	F_{ud}	t	Outcome
					GDP				
H_o :	I(2)	25	0	-2.60	3.80	-2.78	n.a.	n.a.	Reject I(2)
[H_A :	I(1)]								
[H_o :	I(1)]	26	0	-2.09	2.19	-0.49	10.16	n.a.	I(1)
[H_A :	I(0)]								
					H				
H_o :	I(2)	24	1	-2.94	4.72	-3.13	n.a.	n.a.	Reject I(2)
[H_A :	I(1)]								
[H_o :	I(1)]	26	0	-2.78	3.99	-0.68	1.72	1.52	I(1)
[H_A :	I(0)]								

[a] T is the sample size; other notation is defined in the text

As some economic time-series apparently are integrated of order 2 (or I(2)), we test I(3) against I(2) (applying the above analysis to the doubly-first-differenced data), then if we reject I(3) we test I(2) against I(1) (using the first-differences of the data), and we finally test I(1) against I(0), if necessary (following Dickey and Pantula (1987)). We see from Table 1 that both (measured) GDP and "hidden" output (H) are I(1). The results of testing I(3) against I(2) are omitted to conserve space.

III. COINTEGRATION AND GRANGER CAUSALITY

As both series are I(1) it is interesting to ask if they are cointegrated (Engle and Granger (1987)). The results in Table 2 indicate cointegration, and hence the existence of a long-run equilibrating relationship between measured and "hidden" real economic activity in New Zealand. Any divergence between the time-paths of these variables arising from an exogenous "shock" will not be sustained in the long-run, and there must also exist Granger causality of some form between GDP and H. Accordingly, we have used a two-equation Vector Autoregressive (VAR) model, and some recent results of Toda and Yamamoto (1995) to identify the direction(s) of this causality.

Table 2. ***ADF cointegration test results***

Dependent Variable	No Trend[a]			Trend[a]		
	T	p	t	T	p	t
GDP	26	0	-4.14	25	1	-3.77
H	26	0	-4.45	25	1	-4.90
			(-3.58)			(-4.18)
			[-3.21]			[-3.79]

[a] "No Trend" and "Trend" refer to the cointegrating regression. In each case the Dickey-Fuller regression has no drift and no trend. 5% and 10% critical values (from MacKinnon (1991)) appear in parentheses and brackets respectively below the "t-statistics"

We might take account of the cointegration between GDP and H when testing for causality, but there are good reasons not to, and instead to fit a standard VAR model in the *levels* of GDP and H, even though they are each non-stationary. We want to minimize the risks associated with possibly wrongly identifying the orders of integration of the series, or the presence of cointegration, and minimize the distortion of the tests' sizes and powers as a result of pre-testing. Toda and Yamamoto (1995) show that the *standard* asymptotic theory for causality testing holds if we proceed as follows. The lags in the VAR equations are chosen by minimizing Akaike's "final prediction error" (FPE) (*e.g.*, Hsiao (1979) and Giles *et al*. (1991)). The results appear in Table 3. Then we add extra lags of the variables, equal in number to the maximum suspected order of integration - here, this means *one more* lag of each variable in each equation. We use a standard Wald test to see if the coefficients of the lagged H variables (*excluding the extra one*) are jointly zero in the GDP equation; and a standard Wald test to see if the coefficients of the lagged GDP variables (*excluding the extra one*) are jointly zero in the H equation. In each case, the Wald statistic will be asymptotically Chi Square, with degrees of freedom equal to the number of "zero restrictions", *despite the fact that GDP and H are I(1), and irrespective of whether or not they are cointegrated.*

Table 3. ***FPE values for VAR lags*** [a]

			Own Lags		
Dep. Var.	**0**	**1**	**2**	**3**	**4**
GDP	22.6	0.606 [b]	0.647	0.733	0.805
H	0.546	0.116 [b]	0.140	0.153	0.172
		Other variable lags (in addition to optimal own lags)			
GDP	0.606	0.697	0.533 [b]	0.549	0.634

H	0.116	0.087	0.079[b]	0.090	0.099

[a] all entries should be multiplied by 10^6

[b] optimal lag length on basis of FPE

In the final model (Table 4) the GDP equation includes two own lags, and three lags of H; and the H equation includes two own lags and three of GDP. The two-equation were jointly estimated as a "Seemingly Unrelated Regression Equations" (SURE) model by Maximum Likelihood, because the Breusch-Pagan Lagrange Multiplier test (LM=4.53) and the Likelihood Ratio test (LRT=5.28) for a diagonal error covariance matrix for the system *reject* the null hypothesis[4]. Various diagnostic tests, suitably modified to allow for their application in the context of a jointly-estimated system[5], suggest that the model is well specified. The Wald tests in Table 4 are for *non-causality*. We see there is strong evidence of *causality* from GDP to H. (We clearly *reject non-causality* in this direction.) There is only very mild evidence[6] that the causality is bi-directional. (We *reject* the *absence* of causality from H to GDP at the 10% or 5% significance levels, but not at the 1% level.)

Table 4. VAR results and causality tests, based on system estimation [a]

Equation	**Wald** (χ^2_2)	**JB** (χ^2_2)	**LM1** (χ^2_1)	**LM2** (χ^2_1)	**LM3** (χ^2_1)	**LM4** (χ^2_1)	**R2** (χ^2_1)	**R3** (χ^2_2)	**R4** (χ^2_3)
GDP	7.18	0.05	0.36	1.05	0.01	2.18	0.95	0.75	0.70
	(0.03)	(0.98)	(0.55)	(0.31)	(0.92)	(0.14)	(0.33)	(0.68)	(0.87)
H	17.37	0.73	0.24	0.12	0.41	0.33	0.22	2.46	2.52
	(0.00)	(0.69)	(0.62)	(0.27)	(0.52)	(0.57)	(0.64)	(0.29)	(0.48)

[a] asymptotic p-values appear in parentheses below the test statistic values

As the Toda-Yamamoto-Wald test may suffer from size-distortion and low power with our small sample, we have performed a small "bootstrap" simulation experiment to investigate its performance[7]. Using 10,000 bootstrap replications we have computed the *exact* p-values for the Wald test values of 7.18 and 17.37 in Table 4 to be 4.94% and 0.37% respectively. Exact critical values and the corresponding exact powers of the test appear in Table 5, where we see that with a significance level of 5% to 10% the Toda-Yamamoto-Wald test for causality has very good power for our data and model. This supports our conclusions regarding the existence and direction of Granger causality.

Table 5. Bootstrap simulations for the (Wald) causality tests [a]

	Exact Critical Values			**Exact Powers (%)**		
Equation	**1%**	**5%**	**10%**	**1%**	**5%**	**10%**
GDP	12.746	7.197	5.210	52.21	80.29	88.89
H	13.159	7.505	5.450	54.40	82.67	91.13

[a] based on 10,000 replications and the dynamic SURE model specification determined in Table 3

V. CONCLUSIONS

We have used new data for the historical time-path of the size of the "hidden" economy in New Zealand, to investigate the causal relationship between such activity and measured real GDP in that country. Our analysis emphasises the use of recent developments in testing for Granger causality between non-stationary time-series, and diagnostic testing. Our finding of causality from measured GDP to "hidden" GDP poses a dilemma for policy-makers: their attempts to stimulate (measured) growth will also promote underground activity and increase foregone tax revenue (although not necessarily in percentage terms). The causal association we have found in this study, including the mild evidence of bi-directional causality, is consistent with a situation where individuals and firms engaged in "underground" economic activity are also part of the "regular" economy, in general. This is very plausible in the New Zealand context. Related work in progress analyzes the size and composition of the "tax-gap" arising from the presence of a "hidden" economy in that country.

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FOOTNOTES

1. Giles (1995) shows that the time-path of the New Zealand hidden economy is very robust to the specification of the MIMIC model that is used for estimation purposes.
2. All of the computations reported in this paper were undertaken with SHAZAM (1993). The MIMIC model used to generate the Hidden Economy series was estimated with the LISREL package (Jöreskog and Sörbom (1993)).
3. This approach has also been used by Giles *et al.* (1992), Giles (1994) and Mandeno and Giles (1995), for example.
4. Each statistic is asymptotically Chi Square with one degree of freedom in the present context.
5. JB denotes the Jarque-Bera normality test; LM1 to LM4 are Lagrange Multiplier tests for serial independence against *simple* AR or MA alternatives; R2 to R4 are asymptotic Wald versions of Ramsey's RESET test, using two to four powers of the predicted dependent variable in their construction. All of these have only asymptotic validity here, as lagged dependent variables appear as regressors.
6. The FPE values in Table 3 *decline* when the optimal number of lags of the second variable are added to the optimal number of lags of the dependent variable, in *both* cases. This suggests informally that there may be bi-directional causality between GDP and H.
7. This appears to be the first such finite-sample analysis of the Toda-Yamamoto testing principle, which is justified by those authors on asymptotic grounds, and the present author is in the process of conducting a more detailed such analysis of this test.