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A fuzzy logic approach to modeling the underground economy in Taiwan

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Abstract

The size of the 'underground economy' (UE) is valuable information in the formulation of macroeconomic and fiscal policy. This study applies fuzzy set theory and fuzzy logic to model Taiwan's UE over the period from 1960 to 2003. Two major factors affecting the size of the UE, the effective tax rate and the degree of government regulation, are used. The size of Taiwan's UE is scaled and compared with those of other models. Although our approach yields different estimates, similar patterns and leading are exhibited throughout the period. The advantage of applying fuzzy logic is twofold. First, it can avoid the complex calculations in conventional econometric models. Second, fuzzy rules with linguistic terms are easy for human to understand.

Keywords: Underground economy; Fuzzy set theory; Fuzzy logic; Effective tax rate; Government regulation

1. Introduction

As the size of an underground economy (UE) expands, the tax gap will increase more rapidly. An UE imposes a burden on the economy, and results in tax distortions and the erroneous measurement of macroeconomic variables. Government policies based on these macroeconomic variables are then less likely to succeed.

Among the factors that affect the UE, the tax burden and government regulation are considered to be two of the major ones.[1] Aigner et al. [5] were of the opinion that government regulation has a strong impact on the UE. Johnson et al. [6,7] also believed that government regulation is the key factor in measuring the UE. Giles

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[1]Other factors include the unemployment rate in relation to the underground economy [1], the corruption of government in relation to the underground economy in Tanzi [2], the share of the economy accounted for by small companies and self-employed people compared with the underground economy in Bordignon and Zanardi [3], and crime rates compared with the underground economy in Eilat and Zinnes [4].

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and Tedds [1] empirically confirmed that government regulation is positively correlated with the UE. Fugazza and Jacques [8] used a continuous time matching model and showed that the size of the UE would expand when the tax rate and the degree of government regulation increase. Ihrig and Moe [9] found that both the tax rate and the government's regulatory policies could affect the size of the UE. Furthermore, they also found that the tax rate had a stronger impact than the government's regulatory policies. Therefore, they suggested that the decrease in the tax rate integrated with the enhancement of government regulation and punishments in the form of fines would reduce the size of the UE.

Dai (2004) applied Joreskog and Goldberger (1975)'s MIMIC (multiple indicators and multiple causes) model to estimate the size of the UE in Taiwan. Hu [10] used the currency-ratio model to re-estimate the size of the UE in Taiwan. He found that the size of Taiwan's UE ranged from 12% to 38% of GDP.

The Taiwan government's budget deficit has recently grown more rapidly. The Taiwan government is facing a tremendous challenge balancing government expenditure. Understanding the size of the UE in Taiwan may help the government in establishing a proper tax system. By avoiding the need for rigid mathematical modeling and distribution assumptions, this study uses fuzzy set theory [11] and fuzzy logic [12] to estimate the size of Taiwan's UE over the period from 1960 to 2003. To this end, two major factors affecting the size of the UE, namely, the effective tax rate (TR) and the degree of government regulation, are used. The size of the Taiwan UE obtained here is compared with the results of other models. The methodology is presented in Section 2, Section 3 reports the empirical results and their implications, and Section 4 concludes the paper.

2. Methodology

Much of the empirical analysis in economics and finance [13–17] uses fuzzy set theory and fuzzy logic models. In contrast to the conventional parameter method, fuzzy logic avoids the need for rigid mathematical modeling and the distribution assumption. Fuzzy logic translates natural language descriptions of decision policies into an algorithm using a mathematical model. Such a model consists of fuzzification, inference, and defuzzication [18]. The methodology of fuzzy set theory and fuzzy logic is described as follows:

2.1. Fuzzification

Two major factors affecting the size of the UE, TR and the proxy for government regulation (REG), are used. TR is equal to the ratio of tax revenue to GDP. We use the ratio of government consumption expenditure to GDP as the proxy for government regulation. The relevant data are retrieved from the TEDC Taiwan Economic Statistical Databank System. First, we set up the membership functions for the two factors. In fuzzy logic, both factors can be described using linguistic terms, such as Very Low (VL), Low (L), Normal (N), High (H), and Very High (VH). Meanwhile, the linguistic terms for UE are Very Small (VS), Small (S), Average (A), Big (B), and Very Big (VB). All these terms are summarized in Table 1. Each linguistic term is associated with membership functions. The peak of the N (degree of membership of N, where $\mu(x) = 1.0$) is calculated by using the moving average of the past consecutive years. We then calculate the peaks of the remaining linguistic terms by adding or subtracting one or two standard deviations (SD) as in Fig. 1.

Table 1
Linguistic terms

TR: Tax burden				
Very Low(VL)	Low(L)	Normal(N)	High(H)	Very High(VH)
$-2SD$	$-1SD$	*Mean*	$+1SD$	$+2SD$
REG: Proxy for government regulation				
Very Low(VL)	Low(L)	Normal(N)	High(H)	Very High(VH)
$-2SD$	$-1SD$	*Mean*	$+1SD$	$+2SD$
UE: Underground economy				
Very Small(VS)	Small(S)	Average(A)	Big(B)	Very Big(VB)