C:\Documents and Settings\Roberto\Desktop \Complexity and MIMIC\final revised_may 2007\finale revised paper\latex inviato finale\sv-layout-contrib11-e.dot

A Complex Approach to Estimate Shadow Economy: The Structural Equation Modelling

Roberto Dell'Anno* and Friedrich Schneider**
*Department of Economics, Mathematics and Statistics, University of Foggia, Largo Papa Giovanni Paolo II, 71100 Foggia, ITALY, e-mail: r.dellanno@unifg.it (corresponding author).

**Department of Economics, Johannes Kepler University Linz, A-4040 Linz-Auhof, AUSTRIA, Phone: +43-732-2468-8210, Fax: -8209, e-mail: friedrich.schneider@jku.at, http://www.econ.jku.at/Schneider

Abstract

May 28, 2007

This paper deals with the empirical research strategies/possibilities of complex economic systems. On the one side economics theory is more and more opening to the ones of social sciences; on the other side, the empirical procedures used are much less often to adapt empirical methods of other social disciplines. Hence an opening towards social sciences can help the economic profession to develop more efficient and broader empirical methodologies to empirically analyse complex phenomenon of an economic system like the shadow economy. We review the literature and estimation procedure on one special case of structural equation modelling, the Multiple Indicators and Multiple Causes (MIMIC) model.

This bearing in mind the lack of other reliable methods, we conclude that the (DY-) MIMIC approach is one of the best approaches to analyse the shadow economy, and is a good example of the advantages derived by an open-mindedness and multidisciplinary approach desirable for the economic research.

Keywords: Complexity, shadow economy, MIMIC model, structural equation modelling, interdisciplinary approach.

JEL-Code: C12, C51, E26.

"...conventional economics ... remains fixated on the view that economics is the physics of society. In other words, most of the profession behaves as if there were a single universally valid view of the world that needs only to be applied."
Paul Ormerod

1. Introduction

This article develops some ideas of the application of the "complexity" approach in economics. The complexity approach criticizes the scientific method by distrusting sample reductionism and proposes a multidisciplinary approach. Hence, it abolishes old paradigms by arguing to build up another one with the endowment of greater realism. We argue that one should promote the sharing of knowledge and/or methodologies among disciplines and, for economics, limiting the "autistic" (or autarchy) process, which is critically discussed in economics already. Remembering Keynes's (1936, p. viii) words, the problem for economics seems to be not so much to develop new ideas but to have the difficulties of "escaping from old ideas" and from "habitual modes of thought and expression".

An increasing body of literature[1], known as "complexity approach" in economics has pointed out that economic data provide little evidence of either linear or simple dynamic relations and/or of lasting convergence to stationarity or (regular) cyclical behaviour. In contrast the result in empirical economic research quite often is that the economic processes emerge from complex interactions that constitute evolutionary or complex non-linear processes inside an economy. Although, the fundamental role of these characteristics of an economic system came from its founders (e.g. Marshall, Keynes, Hayek and Simon) it has been increasingly neglected by neoclassical analysis. This approach in mainstream economics began to slide away starting in the 1940's due to the influence of major new players in our economics profession, such as Samuelson and Hicks, who demonstrated the natural complementarity between technical virtuosity and rationality assumptions (Laibson and Zeckhauser,1998).

Among the plausible reasons of a disconnection between theoretical research and practical applied economic research is the fascination of a formalised or mathematized approach (like in natural sciences) in mainstream economics. The analytical-formal method became progressively one of the primary tools to demonstrate the scientific rigor of the economic analysis. The consequence has been to lead the economists to dodge the question about the relationship between "real world" and "economists's planet". Neoclassical economists inconsistently defend their scientific approach against this criticism. On one side, in fact, they defend their own models as a necessary simplification of the real world, but on the other side, they accept to pay the price for the negation of the complexity of the economic system due to an enormous mathematical complication. Reminding Rabin's (2002, p.673) sarcasm: "*Economists cannot really*

[1]See e.g. Durlauf (2005), Rosser (1999, 2004), Velupillai (2005), Albin and Duncan (1998), Arthur et al. (1997), Day (1994).

claim (with a straight collective face) to be very "complexity-averse". Look at our journals. [...] Economists do not shy away from complicated models nearly as much as some claim when embroiled in the midst of abstract methodological debates. It is odd on the one hand to be told during such debates that economists must forego behavioral realism for the sake of keeping our models simple – when on the other hand we are holding a copy of Econometrica".

Given the barriers to communicate across traditional disciplines in social sciences, considerable effort has been made to build a bridge between research in economics and other social sciences. There are two bridges between these disciplines, one built around experimental methods and the other around theoretical modelling known as behavioural economics.

In this paper we propose an additional "bridge" between quantitative methods for social research, (e.g. psychometric, marketing, education) and economics. In the following, we suggest, that the "Structural Equation Modelling" (SEM), which is extensively used in social science, can take into account an unobserved variable, and can be considered as helpful methodology for economic research. In particular, our analysis concentrates on one special specification of the SEM approach: the Multiple Indicators Multiple Causes (MIMIC) model, which is quite often applied to estimate the Shadow Economy[2].

The great flexibility of the structural equation model are the following points:

1. it can model the relationships among observed and (unobserved) latent variables,

2. the opportunity to set up a structural theory including also non-linear as well as feedback loops among the variables,

3. the chance to estimate cyclical or asymmetric interaction effects among the variables and,

4. finally, the dynamic specifications of the statistical model, lead us to consider SEM as an interesting statistical tool to take into account the difficulties of complexity approach in economic research.

In general all estimates of shadow economy are "vulnerable" and no one can really claim to be confident of the full reliability of his/her estimates. As specialists in this field know quite well, estimating shadow economy is an exercise that quite often does not allow to apply well-defined methods and commonly accepted assumptions.

Hence, our main objective of this paper is twofold: (i) to summarize MIMIC procedure for estimation of the underground economy and (ii) to review its advantages and disadvantages.

For this purpose, we provide an example of the best practices in SEM modelling in applied economics.

[2]Compare Bajada and Schneider (2005), Dell'Anno (2007), Dell'Anno and Schneider (2003, 2006), Giles (1995, 1999), Giles and Tedds (2002), and Schneider and Enste (2000).

The rest of the paper is organized as follows. Section 2 deals with the basic concepts of the complexity approach relevant for our current analysis estimating the size and development of the shadow economy. Section 3 describes the SEM approach in detail as well the MIMIC method. Section 4 illustrates the limits, advantages and disadvantages of this methodology. The last section concludes.

2. Complexity and Economics

The first question that comes up when dealing with the complexity approach is about its definition. As reported by Horgan (1997), Seth Lloyd of MIT compiles a list of more than forty different ways in which the term is used in scientific discourse. The definition of "complexity" is problematic also for the double meaning that the term complex means. First "complex" in its common meaning is synonymous for the terms complicated, twisted, difficult, etc. Secondly, "complex" in a technical scientific sense is a deeper concept. Rather than trying to define what complexity is, Corning (1998) states it would be more useful to identify the properties that are commonly associated with the term. He suggest that "*complexity often (not always) implies the following attributes: (1) a complex phenomenon consists of many parts (or items, or units, or individuals); (2) there are many relationships/interactions among the parts; and (3) the parts produce combined effects (synergies) that are not easily predicted and may often be novel, unexpected, even surprising*" Corning (1998, p. 200). In this sense, Complex describes something that is not decomposable, not explicable without a lose of the essence. Therefore, complex means not only a complicated structure, it means that a complex system is something that cannot be simplified by analysing separately its single components. The whole structure possesses characteristics that the single parts do not have.

Up to nowadays, most of the existing research on economic complexity has been theoretical. According to Durlauf (2005) this is not surprising, since a first goal of research on economic complexity has been the determination of the ways in which complex systems represent an extension/or alternative to standard economic theory. In our paper, an attempt is made to reduce this gap by promoting SEM strategies in empirical economic research to demonstrate that in this area too, the economic system is a complex one.

When an economic system is recognized as "complex", we should analyze it with an interdisciplinary approach. One way of interdisciplinarity is the use of methods from one discipline to another. It allows to develop deeper understandings of specific systems, such interdisciplinary approach should help elucidate the general structure and behaviour of complex (economic) systems. In this sense SEM, by modelling the general structure of system, makes easier to understand how a complex system works.

Now the interesting point is how to link this kind of modelling of causal dynamics either in terms of reciprocal causality or of recursive causality with the processes of economic interaction at the micro- and macro- level. In our opinion, if interactions among economic variables are considered as essential aspects to understand the economic phenomenon then, SEM could become an important

role for future empirical research. Using SEM to model the interaction of an economic system, in fact is able to take into account some features (e.g. non-linear relationships, reciprocal causality) essential for understanding complex economic structures. In this sense, SEM could be one of the best methods to model complex economic interactions.

3. The Structural Equation Approach for Shadow Economy Research

3.1 General Remarks about the SEM

The SEM procedure includes unobservable variable(s) identified as latent ones, which can be defined or described by observed variables. Cooley (1978) argues that SEM allows to establish a theoretical model in order to determine the degree to which the explanatory variables are related to the unobservable variable. Hence, SEM is a generalization of many familiar techniques such as regression, path analysis, discriminant analysis, canonical correlation, confirmatory factor analysis, etc. All these methods can be treated as special cases of SEM, and several authors give the SEM approach a high value. For Stevens (1996, p. 415) SEM is *"one of the most important advances in quantitative methodology in many years"*. Also Capraro et al. (2002, p.10) argue "*SEM subsumes all other parametric statistical analyses it provides some interesting options for the researcher*". It has been also termed "*the single most important contribution of statistics to the social and behavioural sciences during the past twenty years*" (Lomax, 1989, p. 171).

The statistical idea behind SEM is to compare a sample covariance matrix with the parametric structure imposed on it by a hypothesized model[3]. From the original application of the SEM approach nowadays this type of research is extended too already. For instance Cziraky (2004b) develops a generalisation of the classical LISREL model in order to come to dynamic autoregressive distributed lag (ADL) models.[4]

One should remember that an exploratory factor analysis is a technique used to discover underlying latent factors which can become important elements of the theory behind SEM, while SEM is an applied method to test the consistency of a "structural" theory through data. In this sense it is a largely "confirmatory", rather than "exploratory" technique. In fact in confirmatory factor analysis the theory is tested by examining the consistency of actual data with the hypothesized relationships among all of the unobserved (latent) factors and the observed (measured) variables.

In general, such a confirmatory factor analysis has two goals: (i) to estimate the parameters (coefficients, variances, etc.) and (ii) to assess the fit of the model. Applying this to the shadow economy research these two goals mean

[3]Estimation of a Structural equations model with latent variables can be done by means of a computer program for the analysis of covariance structures, such a LISREL (Linear Structural Relations). A useful overview of the LISREL software package in an economics journal is Cziraky (2004a).

[4]For an overview about SEM literature is widespread, among these: Hayduk (1987), Bollen (1989), Hoyle (1995), Maruyama (1997), Byrne (1998), Muthen (2002), Cziraky (2005).

(i) to measure the relationships of a set of observed causes and indicators with shadow economy (latent variable), and (ii) to test if the researcher's theory or the derived hypotheses as whole fit the used data.

Investigating the size and development of the shadow economy the (DY)MIMIC analysis is often used but provides only relative estimates, hence not ones of the absolute size of shadow economy. Hence, this method requires information about an additional procedure so called benchmarking or calibration procedure in order to calculate the values of the absolute size of the shadow economy. Currently, the chosen calibration procedure is one of the most controversial issues when using and evaluating the (DY)MIMIC estimations of the shadow economy.

Compared with the regression and the factor analysis, SEM is a rarely used method by the economists. In our view, this is caused by an under-evaluation of SEM capabilities with respect to its potential contribution for the economic research. In the following, we consider exclusively the SEM applications to estimate shadow economy, and in this context, a particular model specification is utilized: the Multiple Indicators Multiple Causes model.[5]

The applications of MIMIC (or Model) approach for statistical estimation of the size of the shadow economy are growing. One of the earliest was Frey and Weck-Hannemann (1984), followed by other economists, who used this approach to estimate the size of the shadow economy: Loayza (1996), for Latin American countries, Giles (1995, 1999) for New Zealand, Giles and Tedds (2002) for Canada, Dell'Anno (2003) for Italy, Dell'Anno and Schneider (2003) for OECD countries, Cziraky and Gillman (2003) for Romania, Croatia and Bulgaria, Bajada and Schneider (2005) for Asia-pacific countries, Schneider (2005) for 110 countries all over the world, Chaudhuri et al. (2006) for India, Dell'Anno et al. (2007) for France, Greece and Spain, Dell'Anno (2007) for Portugal, Dell'Anno and Solomon (2007) for the USA.

3.2 The MIMIC Estimation Procedure

How does the MIMIC procedure work? Using the standard LISREL notation of Joreskog and Sorbom (1993), equation 1 is a measurement equation where η_t (unobserved or latent) variable determines $y' = (y_1, y_2, \ldots, y_d)'$ column vector of indicators subject to a random error term ε_t. η_t is an unobserved or latent and is a scalar. Following Dell'Anno and Solomon (2007), Λ is a $(d \times 1)$ column vector of parameters that relates y_t to η_t:

$$y_t = \lambda \eta_t + \varepsilon_t. \quad (1)$$

Equation 2 is a structural equation which shows that the unobserved variable η_t is determined by x_t set of exogenous causes $(x_1, x_2, \ldots, x_c)$ and ζ_t a structural disturbance error term. γ is a $(1 \times c)$ vector of structural parameters:

$$\eta_t = \gamma x_t + \zeta_t. \quad (2)$$

[5]Seminal studies using the MIMIC model include Zellner (1970), Hauser and Goldberger (1971), Jreskog and Goldberger (1975), Aigner et al. (1984); in the context of time series applications with MIMIC models Watson and Engle (1983).

Without loss of generality, all variables are taken to have zero means. In equations (1) and (2) it is assumed that: the elements of ζ_t and ε_t are normal, independent and identically distributed[6]; the variance of the structural disturbance term ζ_t is Ψ and the covariance matrix of the measurement errors is a diagonal covariance matrix[7] Θ_ε. Substituting equation 1 and 2 yields a reduced form equation which expresses a relationship between the observed variables x_t and y_t. This is shown in equation 3:

$$y_t = \Pi' x_t + z_t, \quad (3)$$

where: $\Pi = \lambda\gamma'$ is a $c \times d$ reduced form coefficients matrix and has rank one expressed in terms of c and d elements of λ and γ; $z_t = \lambda\zeta_t + \varepsilon_t$ is a reduced form disturbance vector; z has an $d \times d$ reduced form covariance matrix (ω) given by:

$$\omega = \lambda\varphi\lambda' + \Theta_\varepsilon \quad (4)$$

where: $\varphi = var(\lambda)$ and Θ_ε =the reduced-form covariance matrix of the measurement errors.

For the SEM nomenclature, the equations system with the relationships between the latent variable η_t(shadow economy) and the causes x_t is called the "structural model" (eq. 2); the links among indicators y_t and underground economy is called the "measurement model" (eq. 3).

The reduced form of the equation matrix has two restrictions: (i) the $c \times d$coefficient matrix Π which has rank one, and (ii) Θ_ε which is the sum of a rank one matrix and a diagonal $d \times d$ matrix. The necessary condition for identification is that the number of structural parameters should be equal to the number of reduced form parameters. From equations 1 and 2 our structural model has c elements in γ, an element in the variance of ζ_t, $\frac{c(c+1)}{2}$ elements in the variance of x_t and d elements contained in λ and in the variance of ε_t. From equation 3 and 4, the reduced form model contains cdelements in Π, $\frac{d(d+1)}{2}$ elements in Θ_ε and $\frac{c(c+1)}{2}$ elements contained in the variance of x_t. An observation of the reduced form parameters shows that unique solutions to the structural parameters λ and γ cannot be obtained from the reduced form model. This is because altering the scale of η yields an infinite number of solutions to λ and γ from the same reduced form solution. This inability to obtain unique solutions toλ and γ causes an identification problem which can be resolved by fixing the scale of the unobserved variable. This is the sufficient condition for identification which can be achieved by setting one of the coefficients in the

[6]The assumption on independence between structural disturbance ζ_t , and measurement errors the measurement errors ε_t could be considered as too restrictive, when mainly using economic dataset and, consequently, espoused to question the validity of this approach. Hayduk (1987, p. 193) explains it "...is purely a matter of arbitrary convention" for SEM analysis. Dell'Anno (2003) in the context MIMIC model presents a re-parameterization of the MIMIC able to test the assumption on independence between structural disturbance ζ_t , and measurement errors ε_t .

[7]In the standard MIMIC model the measurement errors are assumed to be independent of each other, but this restriction could be relaxed (Stapleton, 1978, p. 53).

column matrix λ to a constant. An alternative is to fix the variance of the unobserved variable η to 1 but the former is more convenient for economic interpretation.

3.3 Application of the MIMIC Procedure

In a first step the researcher has to translate his/her theory into a structural model. In a second step it is necessary to fix one coefficient to the value one in order to give the latent variable an interpretable scale. If the researcher has set up his/her model and fixed the one coefficient to one, in a third step the estimation method has to be chosen. The Maximum Likelihood Estimation (MLE procedure) is the most widely used in SEM. It assumes multivariate normal data and a reasonable sample size[8]. If the data are continuous but not normally distributed, an alternative method is an asymptotically distribution free estimation procedure, which in LISREL is known as WLS (weighted least squares).

All goodness-of-fit measures are a function of sample size and degrees of freedom. Most of these take into account not only the fit of the model but also the model complexity. On the one side, if we have a very large sample, the statistical test will almost certainly be significant with respect to the degrees of freedom. On the other side, if we have small samples the model is very likely to be accepted even if the fit is poor. This is particular important in the analysis of shadow economy, since usually both the data availability is poor and the model complexity is high. When the model fit is not adequate, it has become common practice to modify the model, by deleting non-significant parameters in order to improve the fit and select the most suitable model specification.

4. Advantages and disadvantages of the MIMIC estimates of Shadow Economy

It is widely accepted by most scholars, who estimate the size and development of the shadow economy, that such an empirical exercise is a "minefield" regardless which method is used. In evaluating the estimations of the shadow economy, we should keep in mind, that already Schneider (1997) and Schneider and Enste (2000) warned that there is no best or commonly accepted method. Each approach has its strengths and weaknesses and can provide specific insights and results. Although from the first use the MIMIC approach has been "accompanied" by strong criticisms[9], in the last 10 years it is increasingly used for estimation of the shadow economy[10].

[8] There are several rules of thumb about the sample size in the literature (Garson, 2005): the sample size should be at least contain 50 observations or have more than 8 times observations then the number of independent variables in the model. Another one, based on Stevens (1996), is to have at least 15 observations per measured variable or indicator. Bentler and Chou (1987) recommend at least 5 observations per parameter estimate (including error terms as well as path coefficients). If possible, the researcher should go beyond these minimum sample size recommendations particularly when the data are not normally distributed or are incomplete.

[9] Compare e.g. the criticism by Helberger and Knepel (1988) with respect to the pioneering work of Frey and Weck-Hannemann, 1984.

[10] Compare the studies quoted on section 3.1.

The MIMIC approach offers several advantages in comparison with the other statistical methods to estimate shadow economy. According to Giles and Tedds (2002), MIMIC provides a wider approach than most other competing methods, since it allows one to take multiple indicator variables and multiple causal variables into consideration at the same time. Moreover, it is quite flexible, allowing one to vary the choice of causal and indicator variables according to the particular features of the economy under study, the period in question, and the availability of data. Again, following Giles and Tedds (2002), the MIMIC model leads to a formal estimation and to testing procedures, such as those based on the method of MLE. These procedures are well known and are generally "optimal", if the sample is sufficiently large.

A further advantage of MIMIC approach has been stressed by Schneider and Enste (2000). They emphasize that the MIMIC approach leads to some progress in the estimation techniques of underground economy, because this methodology allows a wide flexibility in its application, therefore it is potentially superior over all other the estimation methods. Compared with other methods Cassar (2001) argues that MIMIC does not need restrictive assumptions to operate (with exception of the calibrating process). Also, Thomas (1992) argues that the only real constraint of this approach is not in its conceptual structure but the choice of variables.

Of course this method has its disadvantages or limitations, which are identified in the literature. We will discuss the six most important ones, which deal with the model implementations, the sample used, and the reliability of MIMIC estimates:

(1) When estimating the shadow economy using the MIMIC model approach the most common objection concerns the meaning of the latent variable (Helberger and Knepel, 1988; Giles and Tedds, 2002; Smith, 2002; Hill, 2002; Dell'Anno, 2003), because the MIMIC approach is largely a confirmatory rather than exploratory technique. This means a researcher is more likely to determine whether a certain model is valid, rather to "find" a suitable model. Therefore, it is possible that the theoretical construct "shadow economy" could include other potential definitions, (i.e. traditional crime activities, do-it-yourself, etc.). This criticism which is probably the most common in literature, remains difficult to overcome as it goes back to the theoretical assumptions behind the choice of variables and empirical limitation on the availability of data.

(2) Another objection is expressed by Helberger and Knepel (1988). They argue that the MIMIC estimations lead to an instable estimated coefficients with respect to changes the sample size and with respect to alternative model specifications. As Dell'Anno (2003) shows, instability disappears asymptotically as the sample size grows large and if data is stationary and normally distributed.

However, Schneider and Enste (2000) argue that it is difficult to undertake this estimation procedure using a pure time-series data, and to get reliable data on variables other than taxes.

Dell'Anno (2003) points out additional objections: (i) to calculate the confidence intervals associated with estimates of the latent variable, (ii) to test the hypothesis of independence between structural and measurement errors, (iii) to

identify exhaustively the properties of the residuals, and (iv) to apply the SEM approach to small sample sizes and time series analysis. We believe that these cited weaknesses are the main limitations of this approach.

(3) In the SEM analysis, the researcher has to solve or overcome at least two important trade-offs: the first one is the increasing complexity of the model and the decreasing degrees of freedom[11]; the second one is the increasing number of variables and the increasing sample size. Which combination is the best equilibrium to proceed here, it is an open question.

(4) A further criticism is pointed out by Dell'Anno (2003). When using the MIMIC-approach he finds that there is a frequent possibility of the MIMIC approach to encounter an indefinite covariance matrix in the estimation procedure. According to Bollen and Long (1993) this problem arises when the data contains too little information, like small sample size, to few indicator variables, small factor loadings, missing values, etc. Unfortunately, these are obstacles quite usual when one uses this kind of estimation application in economics.

(5) Another criticism about the reliability of the MIMIC estimates of shadow economy is related to the benchmark method (Breusch, 2005a, 2005b). This criticism has its origin in the complications researchers face, when he wants to convert the index of shadow economy (estimated by MIMIC model) into cardinal values. This is not an easy task, as the latent variable and its unit measure are not observed. The model provides just a set of estimated coefficients from which one can calculate an index which shows the dynamics of the unobserved factor.

Such a calibration – regardless which methodology is used - requires experimentation, and a comparison of the calibrated values in a wide academic debate, although at this stage of research on the MIMIC approach, it is not clear which benchmark method is the best or most reliable one. In which way to proceed here is still problematically and unexplored hence every suggestion about this aspect of technique is welcome.

In the following, we summarize four different benchmarking strategies which have been recently applied to convert the index of the shadow economy into absolute values. We use the following symbols:

$\left(\frac{\eta}{GDP}\right)_t^{ordinal}$ is the value of the index of the shadow economy as ratio of official GDP estimated at time t by using structural equation (eq. 2); $\overline{\mathrm{T}}$ is the subscript to indicate the base-period. The base-period $\overline{\mathrm{T}}$ is the time in which there is the exogenous estimate of the shadow economy;

$\left(\frac{\eta}{GDP}\right)_{\overline{T}}^{*}$is the shadow economy as percentage of official GDP estimated by an auxiliary method at the base-period $\overline{\mathrm{T}}$;

$\hat{\gamma}^{'}$ is the vector (of dimension q) of structural coefficients estimated by MIMIC model; x_t is the vector of the q-causes observed at time t;

GDP is the real official Gross Domestic Product. It is hypothesized that the GDP is the reference indicator.

The first benchmarking/calibration procedure is one applied by Giles and Tedds (2002):

[11] A sufficient number of degrees of freedom is need to test if the proposed model specification is confirmed by data.

$$\left(\frac{\eta}{GDP}\right)_t^{final} = \mu \left(\frac{\eta}{GDP}\right)_t^{ordinal}, \quad (5)$$

where$\mu = \left(\frac{\eta}{GDP}\right)_{\overline{T}}^{*} \Big/ \left(\frac{\eta}{GDP}\right)_{\overline{T}}^{ordinal}$ is a constant. It is multiplied for the index estimated by equation (2) in order to satisfy the condition that the shadow economy as percentage of official GDP at the base-period is equal to the value obtained from the external source.

The second one is proposed by Dell'Anno and Schneider (2003). They estimate the index of Shadow Economy $\left(\eta_t^{ordinal}\right)$ by the following structural equation: $\Delta\eta_t^{ordinal} = \hat{\gamma}^{'}\Delta x_t$.

The calibration consists to apply an additive constant (τ). It is chosen in order to satisfy the usual condition that the shadow economy as percentage of official GDP at the base-period is equal to the value obtained from the external source: $\left(\frac{\eta}{GDP}\right)_{\bar{T}}^{*} = \frac{\eta_{\bar{T}}^{ordinal}+\tau}{GDP_{\bar{T}}} = \frac{\eta_0^{ordinal}+\tau+\hat{\gamma}'(x_{\bar{T}}-x_0)}{GDP_{\bar{T}}}$. By defining $\tilde{\tau} = \left(\tau + \eta_0^{ordinal}\right)$, the absolute values of Shadow economy are calculated with:

$$\eta_t = \tilde{\tau} + \hat{\gamma}'\left(x_t - x_0\right) \quad (6)$$

The third benchmarking/calibration strategy applied by Bajada and Schneider (2005) is:

$$g_t^{final} = g_{\overline{T}}^{*} + \hat{\gamma}'\Delta x_t, \quad (7)$$

where $g_{\bar{T}}^{*}$ is chosen in order to satisfy the condition $g_{\overline{T}}^{final} = g_{\overline{T}}^{*} + \hat{\gamma}^{'}\Delta x_{\bar{T}}$. g_t^{final} indicates the growth rate of shadow economy and $g_{\overline{T}}^{final}$ is equal to the growth rate of shadow economy estimated in the base-period by an auxiliary method.

Finally, Dell'Anno (2007) proposes a fourth benchmarking procedure. It requires a transformation of the indicator chosen as reference variable (GDP_t) from absolute values to an index of ($GDP_t/GDP_{\overline{T}}$). According with identification rule ($\lambda_1 = -1$) the index of the shadow economy as a percentage of GDP in the base-period is linked to the chain index of real GDP as follow:

$$\text{Measurement equation: } \frac{GDP_t - GDP_{t-1}}{GDP_{\overline{T}}} = -\frac{\hat{\eta}_t - \hat{\eta}_{t-1}}{GDP_{\overline{T}}}. \quad (8)$$

The estimates of structural model are used to obtain an ordinal time series index for the latent variable[12].

$$\text{Structural Equation: } \frac{\hat{\eta}_t}{GDP_{\overline{T}}} = \hat{\gamma}^{'}x_t. \quad (9)$$

[12]This procedure is valid whether observed causes are stationary or they are all differenced to same degree. In fact, to calculate the levels of the latent variable multiplying the structural coefficients for raw (unfiltered) data, it is equivalent to compute the changes in the index by multiplying coefficients for the differenced causes and then to integrate them.

The index is scaled to take up to a value of μ and further transformed to the shadow economy as ratio of current GDP. These operations are shown in the following benchmarking equation[13]:

$$\frac{\hat{\eta}_t}{GDP_{\overline{T}}}\left[\frac{\eta^*_{\overline{T}}}{GDP_{\overline{T}}}\frac{GDP_{\overline{T}}}{\hat{\eta}_{\overline{T}}}\right]\frac{GDP_{\overline{T}}}{GDP_t}=\frac{\eta_t}{GDP_t}. \quad (10)$$

Where:

(a) $(\hat{\eta}_t/GDP_{\overline{T}})$is the index calculated by eq.(9);

(b) $\left(\eta^*_{\overline{T}}/GDP_{\overline{T}}=\mu\right)$is the exogenous estimate of shadow economy at the base-period $\overline{\mathrm{T}}$;

(c) $(\hat{\eta}_{\overline{T}}/GDP_{\overline{T}})$ is the value of index estimated by eq. (9) at the base-period;

(d) $(GDP_{\overline{T}}/GDP_t)$is able to convert the index of shadow economy as changes respect to base-period in shadow economy respect to current GDP;

(e) (η_t/GDP_t) is the estimated shadow economy as a percentage of GDP at the time t.

The multiplication of (b) and (c) fulfills the constraint that estimated shadow economy divided to GDP at the reference-period is equal to (μ) and the last part of LHS in eq. (10) converts the index of changes respect to the base-period into a ratio between shadow economy and current GDP. As Dell'anno and Schneider (2006) argue this method shares the proportional properties of Giles and Tedds's (2002) benchmarking strategy. It attempts to overcome the Breusch's (2005b) criticism to assign the monetary unit of measure from the reference indicator to the latent variable.

Finally, we argue that standardization of any methodology requires experimentation, comparisons and a wide academic debate, although, at this stage of research on the MIMIC approach, it is not clear which benchmark method is the best or most reliable one. In which way to proceed here is still problematically and unexplored hence further research is necessary about this aspect of technique.

(6) The last criticism about MIMIC estimates refers to the methodological side and, according with aims of this paper, may be the most relevant. Breusch (2005b) argues that the statistical properties/nature of MIMIC approach is unsuitable for economic questions/problems because this approach was designed to psychometric application and "*to measuring intelligence seems far removed from estimating the underground economy*". Dealing with this critique, the main problem of the MIMIC approach lies in the strong difference between economic and psychological variables. Although, we agree that it is (still) problematical to apply this methodology to an economic dataset and to specify a macroeconomic model through the MIMIC framework, it doesn't mean to abandon this approach. At the contrary, following an interdisciplinary approach to economics, the marked criticism should be considered as incentives for further (economic)

[13]The form of equation 10 is equivalent of $\eta_t=\hat{\eta}_t\left(\eta^*_{\overline{T}}\big/\hat{\eta}_{\overline{T}}\right)$. It is preferable the eq. 10 as benchmark formula because the external value of Shadow Economy (μ) is usually expressed as ratio of GDP. Then, although it seems a more complicated formula, it is easier to apply as benchmark method.

research in this field rather than to suggest not to use this method because of the difficulties in the implementation of the MIMIC method.

5. Conclusions

This paper deals with the empirical research strategies/possibilities of economic systems, especially if one assumes that the economic system is a complex one. According with Durlauf (2005) the empirical side of the literature on economic complexity is growing, but it still suffers from serious weaknesses, which it is not surprising given the difficulties of e.g. estimating the size and development of a shadow economy. According our view, we argue that one can overcome these problems when it one uses multidisciplinary methods.

First, we realize that while economics theory is increasingly opening to the social sciences (e.g. behavioural economics, experimental economics), the methods used in empirical research seem to be stiffer to share/use methods of other social disciplines (e.g. psychometrics, marketing, educations, social research, etc.). Hence opening towards social sciences can help the economic profession to develop some adequate empirical methodology to analyse complex phenomenon of an economic system like the shadow economy.

Second, we formulate two principles in line with such a methodology: The first principle is that one should not only study the object but also analyze the process; the second one is that we have to consider a method that takes into consideration the relationships, i.e. direct, indirect and cyclical effects among observed and unobserved economic variables. In our view, these two principles can be found in Structural Equation Modelling.

The advice to use more methods of other disciplines is not new one. Unfortunately it seems discouraging to observe that, after more than thirty years, Goldberger's (1972, p.999) advice on "*...numerous incentives for econometricians to break through those fences which still separate the social sciences.*" is still largely unheard! We consider that the best way to support interdisciplinary approach in empirical economics is by showing examples of this kind of application. In this sense, we present the method of structural equation modelling. It is an appropriate econometric tool to study a complex phenomenon like the shadow economy. In particular, we review the literature and estimation procedure on one special case of structural equation modelling, the Multiple Indicators and Multiple Causes (MIMIC) model.

Third, according to Popper's thought, the growth of human knowledge gains from problems and from attempts to solve them. These attempts require the formulation of theories which must go beyond existing knowledge and therefore require creatively and imagination. In the shadow economy research, where the estimation step is particularly challenging, researchers are forced to use of "imagination" because existing estimation procedures are not convincing and complications are still numerous. We admit that only a few hypotheses are commonly accepted in this filed, one of those is that the underground economy is a very controversial issue and extremely difficult to measure. Notwithstanding economists cannot surrender in the light of such difficulties.

Fourth, we showed that several criticisms are misguided, while others effectively highlight weaknesses of MIMIC approach. The latter, in our opinion should be considered mainly due to the fact that we are still in an "initial stage of research" in this field. The main difficulties go back to the properties of SEM that is designed to use as a quantitative method in the social sciences. This means that is quite difficult to implement a time series analysis with this method and there are no specific guidelines to convert the index provided by MIMIC method into real figures.

In our opinion the most attractive and important arguments of criticisms are related to the process of benchmarking (i.e. calculating the absolute values of the shadow economy) and the (potential) questionability of the economic hypotheses behind the MIMIC specification. Further attempts to adapt this procedure for econometric analysis of an economic problem are certainly necessary.

Fifth, in applied economies for an evaluation of MIMIC approach if is important to remember that, to measure the shadow economy, is just one important aspect for a more general economic analysis, because economists are often more interested to understand the economic phenomenon of "shadow activities" rather then to just measure them. In fact, for policy makers and (macro-) economists it is much more attractive to be aware which are the main causes for the dynamics of the shadow economy compared with a detailed knowledge of the size of the shadow economy over time. This bearing in mind, the lack of other reliable methods, and the additional information provided by Model approach lead us to the conclusion that the (DY-) MIMIC approach is a very useful tool for our economic profession, e.g. to analyse the shadow economy.

Sixth, with respect to the suggestion of some authors (e.g. Breusch, 2005b) to abandon Model approach for shadow economy estimation, we argue this is not a good advice. In our view, not using the MIMIC model at this stage of the empirical research in economics is not only premature, but the contrary, we believe that further research and a greater opening among disciplines could provide constructive comments to overcome the difficulties of the MIMIC approach.

Finally, we conclude that considering the current state of art, the MIMIC model is still one of the best approaches to this purpose, and provide a meaningful example of the advantages derived by an open-minded and multidisciplinary approach desirable for the economic research.

References

Aigner D. J., Hsiao C., Kapteyn A., Wansbeek T., (1984). Latent variable models in econometrics. In: Griliches, Z., Intriligator, M.D., (Eds) *Handbook of Econometrics*, vol. 2, North-Holland, Amsterdam, pp. 1321–1393.

Albin P. S., Duncan K. F., (1998). *Barriers and Bounds to Rationality: Essays on Economic Complexity and Dynamics in Interacting Systems.* Princeton: Princeton University Press.

Arthur W. B., Durlauf S. N., Lane D. A. (Eds.) (1997). *The Economy as an Evolving Complex System II.* Reading: Addison-Wesley.

Bajada C., Schneider F., (2005). The Shadow Economies of the Asia-Pacific, *Pacific Economic Review* 10(3), 379-401.

Bentler P. M., Chou C. P., (1987). Practical issues in structural modeling. *Sociological Methods and Research* 16(1), 78-117

Bollen K. A., (1989). *Structural equations with latent variables*, New York: John Wiley & Sons.

Bollen K. A., Long J. S., (1993). *Testing structural equation models.* Beverly Hills, CA: Sage.

Breusch T., (2005a). The Canadian Underground Economy: An Examination of Giles and Tedds, *Canadian Tax Journal* 53(2), 367-391.

Breusch T., (2005b). Estimating the underground economy using MIMIC models, *working paper*, Canberra, Australia (http://econwpa.wustl.edu/eps/em/papers/0507/0507003.pdf)

Byrne B. M., (1998). Structural equation modeling with LISREL, PRELIS, and SIMPLIS. In: Mahwah, N. J. (Eds.) *Multivariate applications book series.* Lawrence Erlbaum Associates.

Capraro R. M., Kulm G., Capraro M. M., (2002). Investigating the Complexity of Middle Grade Students' Understandings of Mathematical Constructs: An Example from Graphic Representation. Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 1-5, 2002). Downloadable from ERIC - the Education Resources Information Center.

Cassar A., (2001). An index of the underground economy in Malta. *Bank of Valletta Review* 23, 44-62.

Chatterjee S., Chaudhuri K., Schneider F., (2003). The Size and Development of the Indian Shadow Economy and a Comparison with other 18 Asian countries: An Empirical Investigation, Discussion Paper, 2003-02, Johanes Kepler University of Linz, Department of Economics, Austria.

Cooley W. W., (1978). Explanatory observational studies. *Educational Researcher* 7, 9-15.

Corning P.A., (1998). Complexity Is Just a Word!, *Technological Forecasting and Social Change* 59, 197-200.

Cziraky D., (2004a). LISREL 8.54: A program for structural equation modelling with latent variables. *Journal of Applied Econometrics* 19, 135-141.

Cziraky D., (2004b). Estimation of dynamic structural equation models with latent variables. *Advances in Methodology and Statistics* 1(1), 185-204.

Cziraky, D. (2005). A unifying statistical framework for dynamic structural equation models with latent variables. (http://stats.lse.ac.uk/ciraki/framework.pdf).

Cziraky D., Gillman M., (2003). Inflation-growth causality with a latent underground economy model. Research Report, WIIW/GDN-SEE, research field II Enterprise Development, Informal Economy and Labour Markets. Vienna: The Vienna Institute for International Economic Studies (www.wiiw.ac.at/balkan/files/GDN_EnterpriseLabourInformal_InflationGrowthUnderground.pdf).

Day R. H., (1994). *Complex Economic Dynamics, Volume I: An Introduction to Dynamical Systems and Market Mechanisms.* Cambridge: MIT Press.

Dell'Anno R., (2003). Estimating the Shadow Economy in Italy: a Structural Equation Approach, Working paper 2003-7, Department of Economics, University of Aarhus, DK.

Dell'Anno R., (2007). The Shadow Economy in Portugal: an analysis with the MIMIC approach, *Forthcoming Journal of Applied Economics.*

Dell'Anno R., Gomez-Antonio M., Alanon Pardo A., (2007). Shadow Economy in three different Mediterranean Countries: France, Spain and Greece. A MIMIC Approach, *Forthcoming Empirical Economics.*

Dell'Anno R., Schneider F., (2003). The Shadow Economy of Italy and other OECD Countries: What do we know? *Journal of Public Finance and Public Choice/Economia delle scelte pubbliche* 21(2/3), 97–120.

Dell'Anno R., Schneider F., (2006). Estimating the underground economy: a response to T. Breusch's critique, Discussion Paper, 2006-07, Johanes Kepler University of Linz, Department of Economics, Austria.

Dell'Anno R., Solomon H. O., (2007). Shadow Economy and unemployment rate in U.S.A. Is there a structural relationship? An empirical analysis, *Forthcoming Applied Economics.*

Durlauf S. N., (2005). Complexity and Empirical Economics. *The Economic Journal* 115, 225-243.

Frey B. S., Weck-Hannemann H., (1984). The Hidden Economy as an 'Unobservable' Variable. *European Economic Review* 26, 33-53.

Garson D. G., (2005). Statnotes: An online textbook. (http://www2.chass.ncsu.edu/garson/pa765 /structur.htm).

Giles D. E. A., (1995). Measuring the size of the hidden economy and the tax gap in New Zealand: an econometric analysis, Working Paper on Monitoring the Health of the Tax System n.5a, Inland Revenue Department, Wellington, New Zealand.

Giles D.E.A., (1999). Measuring the hidden Economy: Implications for Econometric Modeling. *The Economic Journal* 109(46), 370–380.

Giles D.E.A., Tedds L. M., (2002). *Taxes and the Canadian Underground Economy*, Canadian Tax Foundation: Toronto.

Goldberger A. S., (1972). Structural equation methods in the social sciences. *Econometrica* 40(6), 979–1001.

Hauser R. M., Goldberger A. S., (1971). The treatment of Unobservable variable in path analysis. In: Costner, H.L., (Eds.), *Sociological Methodology.* Jossey-Bass, San Francisco, pp. 81–177.

Hayduk L. A., (1987). *Structural equation modelling with LISREL. Essential and advances.* The Johns Hopkins University Press. London.

Helberger C., Knepel H., (1988). How Big is the Shadow Economy? A Re-Analysis of the Unobserved-Variable Approach of B.S. Frey and H.Weck-Hannemann. *European Economic Review* 32, 965-976.

Hill R., (2002). The Underground Economy in Canada: Boom or Bust?. *Canadian Tax Journal* 50(5), 1641-1654.

Horgan J., (1997). T*he End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age*, paperback edition. New York: Broadway Books.

Hoyle R. H., (Eds.) (1995). *Structural Equation Modeling: Concepts, Issues, and Applications.* Thousand Oaks, CA: Sage.

Jaccard J., Wan C. K., (1996). *LISREL approaches to interaction effects in multiple regression.* Thousand Oaks, CA: Sage Publications.

Joreskog K.G., Goldberger A. S., (1975). Estimation of a model with multiple indicators and multiple causes of a single latent variable. *Journal of the American Statistical Association* 70, 631-639.

Joreskog K.G., Sorbom D., (1993). *LISREL 8, User's Reference Guide.* Chicago: Scientific Software International.

Keynes J. M., (1936). *General theory of employment, interest and money.* London:Macmillan.

Laibson D. I., Zeckhauser R., (1998). Amos Tversky and the Ascent of Behavioral Economics, *Journal of Risk and Uncertainty* 16, 7-47.

Loayza N. V., (1996). The Economics of the Informal Sector: A Simple Model and Some Empirical Evidence from Latin America, *Carnegie-Rochester Conference Series on Public Policy* 45, 129–162.

Lomax R., (1989). Covariance structure analysis: Extensions and developments. In: Thompson, B. (Eds.), *Advances in social science methodology.* vol. 1. Greenwich, CT: JAI Press, pp. 170-204

Maruyama G. M., (1997). *Basic of Structural Equation Modeling.* SAGE Publications, Inc. Thousand Oaks, California.

Muthen B. O., (2002). Beyond SEM: general latent variable modeling. *Behaviormetrika* 29(1), 81-117.

Rabin M., (2002). A perspective on psychology and Economics. *European Economic Review* 46, 657-85.

Rosser J. B. Jr., (1999). On the complexities of complex economic dynamics. *Journal of Economic Perspectives* 12(4), 169-192.

Rosser J. B. Jr., (2004). Epistemological implications of economic complexity. *Annals of the Japan Association for Philosophy of Science* 13, 45-57.

Schneider F., (1997). The shadow economies of Western Europe'. *Economic Affairs* 17, 42–48.

Schneider F., (2005). Shadow Economies around the World: What do we really know. *European Journal of Political Economy* 21(3), 598-642.

Schneider F., Enste D. H., (2000). Shadow Economies: Size, Causes, and Consequences. *Journal of Economic Literature* 38(1), 77-114

Smith R. S., (2002). The Underground Economy: Guidance for Policy Makers?. *Canadian Tax Journal* 50(5), 1655-1661.

Stapleton D. C., (1978). Analyzing political participation data with a MIMIC Model. *Sociological Methodology* 15, 52-74.

Stevens J., (1996). *Applied multivariate statistics for the social sciences* (3rd ed.). Lawrence Erlbaum Associates, Inc., USA.

Thomas J., (1992). *Informal economic activity.* LSE, Handbooks in Economics, London, Harvester Wheatsheaf.

Velupillai K. V., (Eds.) (2005). *Computability, Complexity and Constructivity in Economic Analysis.* Blackwell. Victoria, Australia.

Watson M. W., Engle R. F., (1983). An alternative Algorithms for the estimation of Dynamic Factor, MIMIC and Varying Coefficient Regression models. *Journal of Econometrics* 23, 385–400.

Zellner A., (1970). Estimation of regression relationships containing unobservable variables. *International Economic Review* 11, 441–454.