Persistence of suicides in G20 countries: SPSM approach to three generations of unit root tests

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PERSISTENCE OF SUICIDES IN G20 COUNTRIES: SPSM APPROACH TO THREE GENERATIONS OF UNIT ROOT TESTS

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ABSTRACT: Suicides represent an encompassing measure of psychological well-being, emotional stability as well as life satisfaction and have been recently identified by the World Health Organization (WHO) as a major global health concern. The G20 countries represent the powerhouse of global economic governance and hence possess the ability to influence the direction of global suicide rates. In applying the sequential panel selection method (SPSM) to three generations of unit root testing procedures, the study investigates whether G20 countries should be concerned with possible persistence within suicide rates. The results obtained from all three generation of tests provide rigid evidence of persistence within the suicides for most member states of the G20 countries hence supporting the current strategic agenda pushed by the WHO in reducing suicides to a target rate of 10 percent. In addition, we further propose that such strategies should emulate from within G20 countries and spread globally thereafter.

Keywords: Suicides; sequential panel selection method (SPSM); nonlinear unit root tests; Fourier form unit root tests; G20 countries

JEL Classification Code: C22; C32; C51; C52; I12

1 INTRODUCTION

According to World Health Organisation (WHO) Mortality Database, suicides are classified as one of the leading causes of death worldwide and claims almost a million lives every year. It is thus risen as an important public health problem and a source of concern for public health management in both the developed and developing countries. Suicides as an extreme form of mortality encompasses a broad base of psychological factors such as mental health, life satisfaction and happiness (Daly et al., 2013) and has a profound effect not only on the public health but also on social and economic spheres. Moreover, death caused by suicide, besides the emotional and psychological effects on the community, also results in a loss of potential labour force participation (United Nations, 2017). In 2013, the World Health Organization (WHO) launched its "*Mental Health Plan*" in which member states have committed themselves to reducing global suicides by 10 percent by 2020. In 2014, the WHO released its first suicide-focused report titled "*Preventing Suicides: A global imperative*", in which it is recommended that member states adopt and implement national strategies aimed at combating and preventing suicides (WHO, 2014).

Considering the overriding importance of suicides on a global platform, it is curious to know as to why very little is known and researched about suicides in the empirical economic literature. This is, firstly, because, initially, the psychological aspect of human behaviour were earlier thought to be unnecessary towards economic analysis since such measures were not backed by observable data (Case and Deaton, 2013). Secondly, in many countries suicides are considered a 'taboo' topic, hence the collection of adequate data on suicide statistics becomes problematic. A contributing factor to this relates to media reporting on suicides which have been shown to influence suicide behaviour as 'careless' media reporting triggers imitation behaviour amongst vulnerable citizens (Chu et al., 2018). Thirdly, studies on suicides have been dominated within the fields of psychological sciences which primarily depend on longitudinal analytical techniques. It is only more recent that academics have considered the use of adequate time series analysis (see Platt (1984), Platt et al. (1992) and Phiri and Mukuku (2017) for a comprehensive review of the empirical literature).

A policy question which demands empirical attention is whether policymakers are currently in control prevailing levels of suicides globally? Currently, a majority of the economic literature have examined the relationship between suicides and other economic factors such as income (Brainerd, 2001; Neumayer, 2003; Chuang and Huang, 2003) unemployment (Andres, 2005; Dahlberg and Lunding, 2005; Phiri and Mukuku, 2017); divorce (Chuang and Huang, 2003; Neumayer, 2003; Andres, 2005). Some other studies have even designed the so-called "natural rate of suicides", a concept which assumes that the suicides could never be zero regardless of how ideal socio-economic conditions are (Yang and Lester (1991, 2009), Viren (1999) and Andres and Halicioglu (2011)). Nevertheless, these studies do not address the issue of whether suicides will converge back to their 'natural rate' in the face of exogenous shocks to the time series. This is certainly of concern following the global disturbances recently experienced between 2007 and 2010 (i.e. US sub-prime crisis of 2007, global recession period of 2009 and the Euro debt crisis of 2010) which have reportedly believed to have significantly increased global levels of suicides (Chang et al., 2013). In the advent of these global shocks, it is important to know whether suicides will revert back to their natural equilibrium or will they continue in disequilibrium until they reach a 'new equilibrium level'.

As inferred in the earlier works of Nelson and Plosser (1982) and Campbell and Mankiw (1987), the aforementioned concerns can be addressed by examining the stationarity properties of the time series and such an empirical exercise bears specific significance to policymakers from a modelling and forecasting perspective. To the best of our knowledge, only Chang et al. (2017) and Chen et al. (2018) have previously attempted to address this policy concern of 'persistence in suicide rates' using appropriate time series econometric techniques albeit restricted towards the US and OECD countries, respectively. Our paper extends on these previous works by examining whether suicides are persistent in G20 countries which encompasses of a wider range of industrialized and emerging economies whose data is easily/readily accessible from recent WHO statistics (WHO, 2017). Methodologically, we apply the sequential panel selection method (SPSM) of Chortareas and Kapetanois (2009) which we apply to three generations of unit root testing procedures.

The remainder of our paper is structured as follows. Section 2 presents the theoretical framework for the paper whereas the methodology is outlined in section 3 of the paper. Section 4 of the paper gives a brief overview of suicides in G20 countries. The empirical results are presented in section 5 whereas the study is concluded in section 6 in the form policy implications and recommendations for future research.

2 THEORETICAL FRAMEWORK

Models of suicide within the academic realm have become increasingly sophisticated since the seminal contribution of Durkheim (1987) which is widely recognized as the earliest comprehensive sociological theory of suicide. In Durkheim's model suicides are primarily driven by two psychological factors, namely, excess 'social integration' and 'social regulation'. Durkheim's argument is that since both economic prosperity and depression result in less social integration and regulation, then suicides will rise during these two extreme periods when compared to periods of normal economic circumstances and hence, suicides are generally consider a 'societal problem'.

Nevertheless, in the early post Great Depression period of the late 1930's and early 1940's, researchers began to think of suicides in socio-economic spheres. Henry and Shorts (1954) proposed a countercyclical theory based on a 'frustration-aggression' approach in which suicides rise during recession and fall during economic booms, with the correlation between suicides and the business cycle being more prominent for 'upper-class citizens'. Similarly, Ginsberg (1966) develops a procyclical theory which states that suicide arise from the dissatisfaction of individuals. This is directly related to the discrepancy between the actual reward of an individual and his/her level of aspiration. Ginsberg (1966) argues that as the economy expands, the prosperous economic environment pushes aspirations up to a rate faster than the rewards and this resulting disparity motivates suicide.

In the mid-1970's, Hamermesh and Soss (1974) provided the first real attempt at using dynamic economic theory at explaining suicides as a individuals decision. In particular, the authors use the following 'neo-classical type', utility maximizing framework in which the utility function for the average individual in a group of people with permanent income *YP*:

$$U_m=U[C(m,YP) - K(m)] > 0, \tag{1}$$

Where *m* represents his age and *K* represents a technological relation describing the cost each period of maintaining himself alive at some minimum level of subsistence. If this is the utility of the average individual age *m* with permanent income *YP*, then the present value of his expected life-time utility at age *a* is represented by the following equation:

$$Z(a, YP) = \int_{\alpha}^{\omega} e^{-r(m-a)} U_m P(m) \qquad \partial Z/\partial YP > 0,\ \partial Z/\partial a < 0 \tag{2}$$

Where r is the private discount rate, ω is the highest attainable age, and *P(m)* is the probability of survival to age *m* given survival to age *a*. In defining $b_i \sim N(0, \sigma^2)$ as an individual's preference for living or distaste for committing suicide, then the hypothesis of committing suicides can be given as

$$Z_i(a,YP) + b_i = 0 \tag{3}$$

Where equation (3) assumes that that an individual commits suicide if when the total discounted lifetime utility remaining reaches zero. Notably, whilst the model presented by Hamemesh and Soss (1974) can address certain question such as the impact of age and income on suicides, it, however, fails to appropriately address other 'supply-side' policy-related issues such as how changes in the availability of different suicide methods can affect the agent's choice of when and whether to commit suicide.

The demand and supply model presented by Yeh and Lester (1987) more appropriately addresses these issues. In their model, the demand-side is characterized by a positive relationship between the perceived benefits of suicides such as alleviation of suffering and the probability of committing suicide.

$$p_t^d = \alpha_0 + \alpha_1 E(s_t) \qquad \alpha_1 > 0 \qquad (4)$$

On the other hand, the supply-side is characterized by a negative relationship between the perceived costs of suicides such as painfulness of committing suicide and the probability of committing suicide i.e.

$$p_t^s = \beta_0 + \beta_1 E(s_t) \qquad \beta_1 < 0 \qquad (5)$$

By setting $p_t^d = p_t^s$, the equilibrium suicide rate can be expressed as:

$$s_t^* = \pi_0 + \pi_1 E(s_t) \qquad (6)$$

Where $\pi_0 = (\alpha_0 + \beta_0)/ \beta_1$, $\pi_1 = \alpha_1/ \beta_1$, $E(s_t) = v_0 + v_1 s_{t-1} + \ldots + v_q s_{t-q}$ and e_t is an error term which soak up any shocks influencing demand-side and supply-side determinants of suicide. In further denoting $\pi_0^* = \pi_0 + v_0$ and $\pi_j^* = \pi_j v_j$, for j = 1, 2, 3,…, q, the equilibrium suicide rate (s_t^*) can be derived as:

$$s_t^* = \pi_0^* + \pi_1^* s_{t-1} + \pi_2^* s_{t-2} + \ldots + \pi_q^* s_{t-q} + e_t \qquad (7)$$

Note that equation (7) bears much structural resemblance to a standard unit root test regression and it is on this foundation that we build our empirical framework.

3 METHODOLOGY

3.1 SPSM approach

When it comes to the testing of unit roots within a time series, the power properties of panel-based unit root testing procedures are well acknowledged within academic circles, and yet simultaneously, a number of concerns arise in particularly dealing with 'homogeneity of results' produced by panel tests (Maddala and Wu, 1999). The SPSM was developed by Chortareas and Kapetanois (2009) as an alternative to conventional panel unit root tests which fail to appropriately deal with the problem of heterogeneities existing with panel series. The authors propose a procedure in which panel unit root testing procedures are performed sequentially on a reducing panel set of data, and in each sequence the individual series with the highest rejection of a unit root is removed from the panel, before the panel is estimated again. The main end of this procedure is a segregation of the stationary from the nonstationary series, by taking advantage of power properties provided by panel unit root tests.

In order to econometrically carry out this procedure, we assume that we have a panel series of suicides, $S_i = (s_{ji},\ldots,s_{jm})$, which produces a set of individual based unit root tests statistics, $t_i = (t_{j1},\ldots,t_{jm})$, where $i = \{j_1,\ldots j_{m'}\}$, for some M<N. By defining $i = i^{-j} \cup i^{j}$, such that $i^{j} = \{j\}$ $i^{1,N} = \{1,\ldots,N\}$ our objective is to estimate a binary object, ϑ_j, which takes the value 1 if the series is stationary and the value 0 if the panel series is a unit root. We thereafter implement the following 3-step algorithm to separate the stationary from the unit root processes.

- Step 1: Initially set j=1 and $i_j=\{1,\ldots,N\}$
- Step 2: Perform a decision rule in which a panel unit root tests statistic is computed over y_i and we set $\vartheta i_j = (0,\ldots,0)$ if panel statistic fails to reject the unit root hypothesis

whereas we set $\vartheta i_j = 1$. Only if the later condition holds to we proceed to step 3 otherwise we stop the procedure.

- Step 3: Set $i_{j+1} = i_j^{-l}$, where l is the index of the individual series which produces the highest rejection of the unit root hypothesis (i.e. produces the lowest test statistic). Thereafter make j=j+1 and go return to step 2 and repeat the procedure.

In order to effectively carry out the SPSM approach it is imperative that one uses a combination of the individual based unit root tests and panel-based unit root tests. The following sub-sections present these 'individual-panel' corresponding pairs of unit root testing procedures for first, second and third generation unit root testing procedures.

3.2 First generation unit root tests

The first generation of unit roots can be traced to the seminal contribution of Dickey and Fuller (1979), who specify the following autoregressive (AR) time series, y_t,:

$$y_t = \rho y_{t-1} + e_t , \qquad t = 1,2,\ldots,T \text{ and } e_t \sim N(0, \sigma^2) \qquad (8)$$

Dickey and Fuller (1979) suggest that the time series, y_t converges to a I(0), stationary process as $t \to\infty$ under the conditions $\rho < 1$ whereas if $\rho =1$, then the series evolves as a random walk with a variance which grows exponentially as $t \to\infty$. A more generalized form of regression (8), for the case of suicide time series (s_t), is the following Augmented Dickey Fuller (ADF) regression:

$$\Delta sr_t = \alpha_i + \beta_i sr_t + \sum_{j=1}^{p} \lambda_j \Delta sr_{t-j} + e \qquad (9)$$

Where $\Delta sr_t = sr_t - sr_{t-1}$, $\alpha_i = (1 - \rho)$, and $\sum_{j=1}^{p} \lambda_j \Delta sr_{t-j}$ is a truncated lag intended/designed to soak up any excess serial correlation. The DF test statistic used to test the unit root null hypothesis (i.e. H_0: $\beta_i = 0$) against the stationarity alternative (i.e. H_1: $\beta_i < 0$) is the t-ratio of the β_i coefficient i.e.

$$T = \frac{\Delta y M y_{-1}}{\sqrt{\sigma^2 y'_{-1_{-1}} M y_{-1})}} \tag{10}$$

Where $M = I_T - \tau_T(\tau'_T, \tau_T)^{-1}\tau'_T$ and $\sigma^2 = \Delta y_i M_{xi} \Delta y_i/(T\text{-}1)$. The critical values used to evaluate the computed test statistic are reported in McKinnon (1994). Nevertheless, many authors have argued that the Dickey-Fuller testing procedure lacks power in distinguishing unit root processes from stationary properties and that using panel data unit root tests is one way of increasing the power of unit root testing procedures (Maddala and Wu, 1999). Levin et al. (2002) (LLC hereafter) suggest that following panel unit root testing regression:

$$\Delta sr_{i,t} = \alpha_{mi} d_{mi,t} + \beta_i sr_{i,t-1} + \sum_{j=1}^{p} \lambda_{ij} \Delta sr_{i,t-j} + e_{it} \qquad \text{for } i=1,\ldots,N;\ t=1,\ldots,T \tag{11}$$

Where d_{mi} is contains deterministic terms. LLC suggest three step procedure to perform the panel unit root test. i) Firstly, perform individual ADF test regressions to determine the optimal lag (p). Then run two auxiliary regressions, by regressing $\Delta y_{i,t}$ and $y_{i,t-1}$ against $\Delta y_{i,t-j}$ ($j = 1,\ldots,p$) and generate residual terms e_{it} and v_{it-1}, respectively and normalize these errors ii) Secondly, regress e_{it} on v_{it}, (i.e. $e_{i,t} = \rho_i v_{i,t-1} + u_{i,t}$) and then formulate the unit root null hypothesis is tested as H_0: $\beta_1 = \beta_2 = \ldots = \beta_N = \beta = 0$ which is tested against the stationary alternative of H_1: $\beta_1 = \beta_2 = \ldots = \beta_N = \beta < 0$. iii) Lastly, estimate the ratio of the long-run to short-run standard deviations which will be used to adjust the mean of the t-statistic use to test the null versus alternative hypothesis. A well-recognized limitation of LLC test is that β is the same for all i. To circumvent this, Im et al. (2003) (IPS hereafter) propose a more general alternative hypothesis in which H_1: $\beta_i < 0$, $i,\ldots,N_1$; $\beta_i = 0$, $i = N+1,\ldots,N$. As opposed to pooling the data, IPS estimate separate unit root tests for the N cross sections and then compute the panel test statistic as:

$t_{N,T} = \frac{1}{N}\sum_{i=1}^{N} t_{i,L}$ (12)

Where $\sqrt{N}\frac{t_{N,T}-\mu}{\sigma}$. The test statistic is then standardized and IPS demonstrate has better performance than the LLC test when N and T are small.

3.3 Second generation unit root tests

Dissatisfied with the power properties and time series assumptions presented by the first-generation unit root tests, the second generation unit root tests primarily dismissed the notion of linearity within time series variables in which nonlinearity may be mistaken for unit root behaviour. The most comprehensive nonlinear unit root testing procedure is outlined in Kapetanois et al. (2003) (KSS hereafter), who particularly specifies the following ESTAR unit root test regression:

$\Delta y_t = \gamma_i y_{t-1}\,[1\text{-}\exp(-\Phi y_{t-1}^{2})] + \sum_{j=1}^{p} \rho_i \Delta y_{t-i} + e_t$ (13)

From equation (12) testing the unit root null hypothesis can be achieved by imposing, $\Phi = 0$, and yet given the presence of nuisance parameters under the null hypothesis, it is more feasible to test for unit roots after applying a first order Taylor approximation, resulting in the following auxiliary regression:

$\Delta y_t = \mu_t + \delta_i y_{t-1}^{3} + \sum_{j=1}^{p} \rho_j \Delta y_{t-j} + e_t$ (14)

And henceforth the null hypothesis of a unit root is formally tested as H_0: $\delta_i = 0$ against the ESTAR stationary alternative of a stationary process H_1: $\delta_i < 0$, using the following test statistic:

$t_{kss} = \frac{\sum_{t=1}^{T} y_{t-1}^{3}\,\Delta y_t}{\sqrt{\widehat{\sigma^2}\sum_{t=1}^{T} y_{t-1}^{6}}}$ (15)

The obtained t_{kss} statistic is then compared against the corresponding critical values which are tabulated in Kapetanois et al. (2003). Ucar and Omay (2009) (OU hereafter) expanded the KSS testing procedure into a panel framework based on the procedure of IPS. Their baseline panel ESTAR (PESTAR) testing regression is given as:

$$\Delta y_{i,t} = \mu_{i,t} + \delta_i y_{i,t-1}^3 + \sum_{j=1}^{p} \rho_{i,j} \Delta y_{i,t-j} + e_{it} \tag{16}$$

Where the panel unit root test statistic used to test the unit root hypothesis (i.e. H_0: $\delta_i = 0$) against the nonlinear stationary alternative (i.e. H_1: $\delta_i < 0$,), is computed as the invariant average statistic of the individual KSS statistics for each series i.e.

$$t_{NL} = \frac{1}{N} \sum_{i=1}^{N} t_{i,NL} \tag{17}$$

UO propose the following five-step sieve-bootstrap algorithm to compute the panel unit root tests statistic:

i) Estimate univariate KSS regression (as in equation (13) for each of the individual countries with the optimal lag of each individual regression being determined by the Schwartz criterion.
ii) We then estimate and generate a series of bootstrapped errors (i.e. $e_{i,t} = \Delta y_{i,t} - \mu_{i,} - \sum_{j=1}^{p} \rho_{i,j} \Delta y_{i,t-j}$) which are then centred as; $e_{i,t} = e_{i,t} - (T - p - 2)^{-1} \sum_{t=p+2}^{T} e_t$.
iii) We then developing a N by T matrix for the entire panel, we then produce a series of bootstrapped error terms $e_{i,t}^*$, from which derive bootstrapped series of $\Delta y_{i,t}^*$ as:

$$\Delta y_{i,t}^* = \mu_{i,} + \sum_{j=1}^{p} \rho_{i,j} \Delta y_{i,t-j}^* + e_{i,t}^* \tag{18}$$

iv) And then we generate our bootstrapped sample series of $y^*_{i,t}$ from the partial sums i.e. $\Delta y^*_{i,t}$ (i.e. $y^*_{i,t} = \sum_{j=1}^{t} \Delta y^*_{i,j}$).

v) Finally, we derive the bootstrap p-values for the t^*_{NL} statistic which are computed by running the following nonlinear regression:

$$\Delta y^*_{i,t} = \mu_{i,t} + \gamma_i(\Delta y^*_{i,t-1})^3 + \sum_{j=1}^{p} \alpha_{ij}\Delta y^*_{i,t-1} + v_{it} \tag{19}$$

3.4 Third generation unit root tests

The third-generation unit root tests are the flexible Fourier form (FFF) type tests introduced into econometric paradigm in the seminal of Becker et al. (2006) and more recently popularized in the paper by Enders and Lee (2012). The idea behind these FFF-type tests is that a sequence of smooth structural breaks using the low frequency components of a Fourier approximation (Becker et al., 2006). These tests are seen as an improvement over other structural-break unit root tests such as Perron (1989), Zivot and Andrew (1992) and Lee and Strazicich (2004, 2013), which determine structural breaks either exogenously or endogenous, the FFF function itself is not periodic such that the Fourier approximation can still capture the shape of unknown structural shifts in a time series. The general flexible Fourier function can be specified as follows:

$$d(t) = \beta_0 + \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi Kt}{T}\right) + \sum_{k=1}^{n} b_k \cos\left(\frac{2\pi Kt}{T}\right),\ n \leq T/2 \tag{20}$$

Where n is the number of cumulative frequency components, a and b measure the amplitude and displacement of the sinusoidal and K is the singular approximated frequency selected for the approximation. Becker et al. (2006) and Enders and Lee (2012) suggest the restriction of n=1 (i.e. single frequency components) to circumvent over-fitting problems as well as to ensure that the evolution of the nonlinear trend is gradual over time. The resulting low frequency component can mimic structural changes which are characterized by spectral density functions which tend towards a zero frequency. In placing the restricting n=1 in equation (17) and substituting the resulting regression into (13) results in the following FFF-augmented KSS 'individual' unit root testing regression:

$$\Delta y_t = \delta_i y_{t-1}^3 + \sum_{j=1}^{p} \rho_j \Delta y_{t-j} + a_i \sin\left(\frac{2\pi K t}{T}\right) + b_i cos(\frac{2\pi K t}{T}) + v_t, \tag{21}$$

Whilst substituting into equation (14) results in the following FFF-augmented OU 'panel' unit root testing regression:

$$\Delta y_{i,t} = \mu_{i,t} + \delta_i y_{i,t-1}^3 + \sum_{j=1}^{p} \rho_{i,j} \Delta y_{i,t-j} + a_i \sin\left(\frac{2\pi K t}{T}\right) + b_i cos(\frac{2\pi K t}{T}) + v_t \tag{22}$$

Where t = 1,2,…,T and v_t is a $N(0, \sigma^2)$ process. Following recommendations of Enders and Lee (2012) we perform a grid search for optimal values of frequency, K, and lag length, j, which is obtained by selecting the estimated regression which produces the lowest sum of squared residuals (SSR).

4 DATA AND PRELIMINARY OVERVIEW OF SUICIDE TRENDS IN G20 COUNTRIES: 1991-2016

Our empirical data consists of the individual member states of the G20 countries (minus the European Union) which is collected from the Institute of Health Metrics and Evaluation (IHME), Global Burden of Disease database and is available on an annual basis from 1990 to 2016. The data is reported as suicides per 100,000 people and Table 1 presented the descriptive statistics of each of the countries. In examining the overall global trends in suicide mortality rate, our empirical data suggests that on average, approximately 830,883 people die annually from suicide worldwide from 1990 – 2016. This corresponds to an age-standardised suicide mortality rate of about 14.3 per 100 000 people over the period. In 2016, approximate 817 147 people died from suicide worldwide compared to 766 043 in 1990. This reflects an age-standardised suicide mortality rate of about 11.2 per 100 000 people in 2016.

A cursory look at the trends in the time series data for G20 countries indicates that the prevalence of suicide mortality varies considerably across countries and over time. We particularly note that the highest suicide averages are found in 4 out of the 5 members of the BRICS alliance of countries (Russia (38.23), India (20.12), China (16.11), South Africa (17.91)) as well as for Japan (18.46) and Korea (22.00) which are East Asian economies. On the other hand, lower, single digit suicide averages are more prominent within Saudi Arabia (3.03) as a "Middle-East" representative; the three 'G20 members' of the MINT group of emerging economies (Mexico (5.18), Indonesia (3.90) and Turkey (3.93)); the South American countries of Brazil (6.71) as well as for Italy (6.67) and the UK (8.72). Finally, intermediate, double digit averages of suicide rates are found in the remaining economies which are largely G7 and Latin American countries (Argentina (11.69), Australia, (11.79), Canada (12.00), US (12.31), Germany (12.70), France (18.91)). Note that these observations are somewhat contrary to conventional academic wisdom which speculates on suicide mortality being more prevalence in emerging and less developed countries than in developed countries due to the socioeconomic and behavioural factors, limited access to mental health care and shortage of behavioural health care providers (Moneim et al. (2011); Kumar et al. (2013); Kegler et al. (2017)).

Table 1: Descriptive statistics

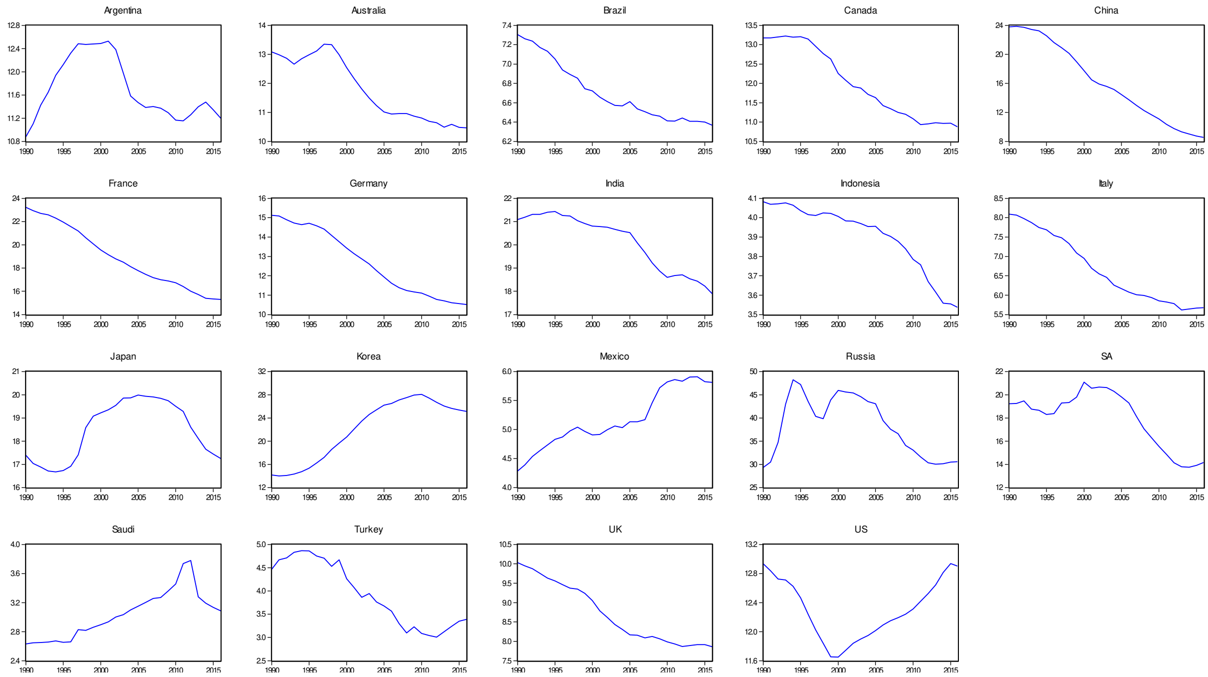
country	Mean	Maximum	Minimum	Standard Deviation.	j-b (p-value)
Argentina	11.69	12.53	10.88	0.53	2.74 (0.25)
Australia	11.79	13.35	10.47	1.08	3.30 (0.19)
Brazil	6.71	7.30	6.37	0.31	3.15 (0.21)
Canada	12.00	13.22	10.87	0.91	2.98 (0.23)
China	16.11	23.87	8.54	5.25	0.12 (1.59)
France	18.91	23.21	15.31	2.65	0.24 (1.67)
Germany	12.70	15.13	10.52	1.68	2.84 (0.24)
India	20.12	21.43	17.90	1.19	3.28 (0.19)
Indonesia	3.90	4.08	3.54	0.18	4.46 (0.11)
Italy	6.67	8.09	5.62	0.88	2.83 (0.24)
Japan	18.46	19.98	16.67	1.25	3.09 (0.21)
Mexico	5.18	5.91	4.29	0.50	1.45 (0.48)
Korea	22.00	28.07	14.00	5.22	3.19 (0.20)
Russia	38.23	48.22	29.30	6.46	2.68 (0.26)
Saudi Arabia	3.03	3.78	2.63	0.33	1.56 (0.46)
South Africa	17.94	21.08	13.74	2.44	3.06 (0.22)
Turkey	3.93	4.87	3.01	0.69	2.87 (0.24)
UK	8.72	10.03	7.86	0.77	3.01 (0.22)
US	12.31	12.94	11.65	0.42	1.81 (0.40)

Notes: Authors own computation. j-b statistic indicates that all series are normally distributed.

Figure 1 depicts the evolution of suicide mortality rate per 100 000 people for period 1990 – 2016 among the G20 members. While most countries do not exhibit clear trends, it is evident that suicide mortality rate has progressively declined over time except for the Republic of Korea and to some extent the Kingdom of Saudi Arabia and the United States. However, there are two noticeable trends in suicide mortality over the periods. First, there were spikes in suicide mortality in a number of countries such as Argentina, Australia, Japan, Republic of Korea, Russia, Saudi Arabia, South Africa, Turkey and the United States) around

1997 – 2000. This period coincides with the periods of economic crises such as the Asian currency crisis of 1997, the Russian default crisis of 1998, and Turkish crisis of 2000 (Asongu, 2012). Another notable trend was around the global financial crisis of 2007/08 in which countries such as Mexico, Republic of Korea, Saudi Arabia and Turkey experienced increase in suicide mortality over this period. These represent important structural break points which need to be accounted for in our empirical analysis.

Figure 1: Suicide mortality rate per 100 000 people, 1990 – 2016



Data source: IHME, Global Burden of Disease

5 EMPIRICAL RESUTLS

5.1 First generation unit root test results

Table 2 presents the results of the SPSM approach applied to the cluster of first generation unit root tests, with Panel A reporting the results of the procedure performed on the pairs of unit root tests with a drift and Panel B showing the results for the procedure performed on pairs of unit roots performed with both a drift and trend. To carry out the procedure, we firstly compute the individual ADF test statistics for each of the time series and report the results in a sequential format, with the series with the highest rejection or lowest test statistic being reported first (in our case is Korea when the tests are performed with a drift and Argentina when the tests are performed with both drift and trend) followed by the series with the second highest rejection 'test statistic' (which is now Brazil for the drift models and Russia for the drift and tend model) and so forth.

We then perform the panel unit root tests (LLC and IPS tests) in a similar sequential fashion, with the first panel test statistic computed for the entire panel, then the second panel statistic computed for the panel with the individual series yielding the highest rejection being removed from the panel, then the third panel statistic is computed for the panel with the individual series yielding the highest and second highest rejection rates being removed from the panel, and this procedure is carried out in this fashion of a consecutively reducing panel until we have segregated the stationary from the non-stationary panel. The optimal lag for each of the performed tests is determined by the minimization of the modified AIC as suggested by Ng and Perron (1996, 2001). The results show some discrepancies in results obtained. For instance, when the procedure is carried out with a drift, the LLC statistic identifies 6 stationary processes (i.e. Korea, Brazil, Japan, china, US and France) whereas the IPS statistics find no stationary series. On the other hand, when the procedure is carried out with a drift inclusive of a trend, none of the individual or panel statistics identified any stationary processes. Nevertheless, we cannot consider these results as conclusive since they ignore important nonlinearities and structural breaks found in the data. We address these concerns in the following sub-sections.

Table 2: SPSM applied to first generation unit root tests

	intercept				Intercept and trend			
sequence	Minimum ADF stat	series	LLC stat	IPS stat	Minimum ADF stat	series	LLC stat	IPS stat
1	-3.22** [1]	Korea	-4.25*** (0.00)	1.01 (0.84)	-2.96 [0]	Argentina	2.67 (0.99)	4.65 (0.99)
2	-2.81* [0]	Brazil	-3.32*** (0.00)	1.46 (0.93)	-2.89 [0]	Russia	3.10 (0.99)	4.98 (0.99)
3	-2.23 [1]	Japan	-2.83*** (0.00)	1.82 (0.97)	-2.29 [0]	India	2.68 (0.99)	5.06 (0.99)
4	-1.95 [1]	China	-2.72*** (0.00)	2.06 (0.98)	-1.87 [2]	US	2.91 (0.99)	5.24 (0.99)
5	-1.83 [2]	US	-1.83** (0.03)	2.32 (0.98)	-1.54 [1]	South Africa	3.73 (0.99)	5.37 (0.99)
6	-1.70 [1]	France	-1.79** (0.03)	2.51 (0.99)	-1.52 [0]	Turkey	3.73 (0.99)	5.21 (0.99)
7	-1.69 [4]	Italy	-0.87 (0.19)	2.65 (0.99)	-1.45 [0]	Mexico	-3.65 (0.99)	5.19 (0.99)
8	-1.62 [1]	Germany	-0.33 (0.37)	2.89 (0.99)	-1.38 [1]	Germany	5.73 (0.99)	5.15 (0.99)
9	-1.61 [1]	UK	-0.04 (0.48)	2.76 (0.99)	-1.17 [0]	Australia	3.22 (0.99)	5.20 (0.99)
10	-1.40 [0]	Mexico	0.92 (0.82)	2.92 (0.99)	-1.12 [2]	China	3.52 (0.99)	5.68 (0.99)
11	-1.22 [2]	Argentina	1.02 (0.85)	2.86 (0.99)	-1.07 [0]	Canada	2.99 (0.99)	5.65 (0.99)
12	-0.85 [2]	Russia	0.94 (0.83)	2.96 (0.99)	-1.05 [0]	Saudi Arabia	2.79 (0.99)	5.53 (0.99)
13	-1.04 [1]	Australia	0.76 (0.78)	2.93 (0.99)	-0.94 [3]	Japan	2.58 (0.99)	5.40 (0.99)
14	-0.65 [1]	South Africa	1.03 (0.85)	3.04 (0.99)	-0.66 [0]	Brazil	1.99 (0.99)	4.50 (0.99)
15	-0.55 [0]	Turkey	0.97 (0.83)	2.91 (0.99)	-0.44 [0]	Indonesia	1.96 (0.99)	4.13 (0.99)
16	-0.51 [4]	Saudi Arabia	0.98 (0.84)	2.71 (0.99)	0.05 [3]	France	1.71 (0.99)	3.60 (0.99)
17	-0.35 [0]	Canada	0.84 (0.80)	2.70 (0.99)	0.45 [0]	UK	1.00 (0.99)	2.87 (0.99)
18	0.27 [2]	Indonesia	1.75 (0.96)	2.71 (0.99)	0.78 [0]	Italy	0.77 (0.99)	2.67 (0.99)
19	0.39 [1]	India	1.19 (0.88)	2.05 (0.99)	1.50 [0]	Korea	-0.02 (0.49)	0.34 (0.63)

Notes: "***", "**", "*" represents the 1%, 5% and 10% critical levels, respectively.

5.2 Second generation unit root test results

Table 3 presents the results of the SPSM approach applied to our second-generation unit root tests of KSS (2003) and Omay and Ucar (2009). As before we begin the process by computing the individual KSS statistic for each of the individual series, which are reported in sequence of lowest statistic (highest rejection) to the highest test statistics (lowest rejection).

The sequences as well as the estimated values of these individual statistics are found in the first three columns of Table 3. Thereafter, we apply the OU sieve bootstrap procedure in order to compute the corresponding OU panel statistic, firstly for the entire panel, and then on a reducing panel set in which individual series with the highest rejection are sequentially removed until we effectively segregate the stationary from the non-stationary panel. These panel unit root statistics are reported in the fourth column of Table 3 whilst the bootstrap p-values and the associate optimal lags lengths are found in the fifth and sixth columns of Table 3, respectively.

After completing the procedure, we find the panel of stationary time series for 11 of the G20 countries (the United Kingdom, Brazil, Indonesia, France, Italy, China, Australia, Canada, Germany, Russia and India) whereas the remaining countries (Turkey, South Africa, Korea, Argentina, Japan, the United States, Saudi Arabia and Mexico) exhibit non-stationary behaviour. Interestingly enough, the stationary panel consists of 6 advanced and 5 emerging economies of the G20 panel whereas the non-stationary panel primarily consists of emerging non-G7 member states. We also note that these results can also be compared to those obtained in the previous study of Chang et al. (2017) who use a similar SPSM framework applied to a sample of 23 OECD countries of which 6 of these countries (The United Kingdom, France, Italy, Canada, Japan and the United States) belong to our panel of G20 countries. However, in differing from Chang et al. (2017) who find unit root behaviour for all these ‘commonly sampled’ economies, our current findings point to stationarity in 5 out of the 6 of these countries.

Table 3: SPSM approach to second generation unit root tests

sequence	series	Min. KSS	OU statistic	p-value	lag
1	UK	-6.89	-2.19**	0.02	0
2	Brazil	-5.65	-2.18**	0.02	0
3	Indonesia	-4.14	-2.17*	0.03	0
4	France	-3.62	-2.14*	0.04	3
5	Italy	-3.30	-2.09*	0.04	1
6	China	-2.79	-1.92*	0.06	1
7	Australia	-2.28	-1.91*	0.06	4
8	Canada	-2.05	-1.86*	0.06	2
9	Germany	-1.76	-1.79*	0.08	6
10	Russia	-1.75	-1.78*	0.08	4
11	India	-1.72	-1.68*	0.09	1
12	Turkey	-1.43	-1.64	0.10	0
13	South Africa	-1.09	-1.61	0.10	1
14	Korea	-0.97	-1.61	0.11	1
15	Argentina	-0.68	-1.55	0.12	2
16	Japan	-0.24	-1.26	0.21	1
17	US	-0.15	-0.71	0.48	2
18	Saudi Arabia	0.15	-0.26	0.79	0
19	Mexico	0.92	-0.21	0.78	1

Notes: "***", "**", "*" represents the 1%, 5% and 10% critical levels, respectively. p-values for OU statistic generated through a bootstrap of 10,000 replications.

5.3 Third generation unit root test results

Table 4 presents the results for the results for the SPSM applied to the third generation unit root testing procedure. These tests vary from the first and second generation tests, by including a flexible Fourier approximation to the unit root tests which by design are intended to capture a series of unobserved, smooth structural breaks and have been demonstrated to be more powerful than other structural breaks or nonlinear unit root tests (Becker et al. (2006) and Enders and Lee (2012)). Recall, that the procedure is cried by firstly estimating individual KSS-FFF test statistics for the individual countries and then these test statistics are arranged in order of lowest to the highest values. The results of this exercise are reported in the first three columns of Table 4. Thereafter the OU bootstrap procedure is carried out as previously, firstly for the whole panel, then on a reducing panel in which the KSS-FFF statistic with the highest rejection is sequentially removed in each stage of the estimation process.

The obtained panel statistics are found in the fourth column of Table 4 and the bootstrap p-values are given in the fifth column of the same table, whereas the findings of the grid search to identify the optimal frequency component, k*, and lag length, are reported in columns 6 and 7 of Table 4, respectively. In a nutshell, our results point to a stationary of panel of countries inclusive of Brazil, Russia, Japan, Canada and China, whilst the non-stationary panel consists of Argentina, the United States, South Africa, Saudi Arabia, Australia, Indonesia, Turkey, France, Korea, India, Italy, Mexico, the United Kingdom and Germany. Notice that the stationary panel is smaller than that obtained for the KSS test performed without a FFF approximation, and this panel consists of 3 of the BRICS member states and two G7 member states. Further note that these findings are now more similar to those of Chang et al. (2017), who also find that by including a FFF approximation in the testing procedure, most industrialized countries fall under the non-stationary panel of suicides. Overall, these findings highlight the importance of accounting for both nonlinearities and smooth structural breaks in distinguishing stationary from non-stationary series when checking the integration properties of suicides.

Table 4: SPSM approach to second generation unit root tests

sequence	series	Min. KSS	OU statistic	p-value	K*	Lag
1	Brazil	-4.61	-2.05*	0.04	1	5
2	Russia	-4.19	-2.01*	0.04	1	6
3	Japan	-4.18	-1.98*	0.05	5	6
4	Canada	-3.40	-1.93*	0.05	5	6
5	China	-3.01	-1.87*	0.06	5	6
6	Argentina	-2.93	-1.51	0.13	5	5
7	US	-2.42	-1.36	0.18	5	6
8	South Africa	-2.39	-1.32	0.19	5	6
9	Saudi Arabia	-1.80	-1.29	0.19	5	6
10	Australia	-1.59	-1.28	0.20	5	5
11	Indonesia	-1.55	-126	0.21	5	6
12	Turkey	-1.33	-1.26	0.21	5	6
13	France	-1.17	-1.25	0.21	5	5
14	Korea	-1.08	-1.23	0.22	5	6
15	India	-0.22	-1.22	0.22	5	6
16	Italy	0.29	-1.21	0.23	5	6
17	Mexico	0.38	-0.90	0.37	5	6
18	UK	1.71	-0.73	0.46	5	6
19	Germany	2.72	-0.68	0.51	5	6

Notes: "***", "**", "*" represents the 1%, 5% and 10% critical levels, respectively. p-values for OU statistic generated through a bootstrap of 10,000 replications.

6 CONCLUSION

Primarily motivated by the lack of empirical evidence due to the novelty of the field in research study, we have investigated the possibility of persistence in suicides in G20 countries. We consider this research worthwhile since suicides have been recently identified by the World Health Organization (WHO) as one of the leading causes of mortalities globally. The selection of the G20 countries as a case study is important since these countries are currently the centre of global economic dominance and hence the potential influence of these countries in reducing global suicides cannot be overlooked or taken for granted. Previous studies have examined possible persistence in suicides for the US and OECD countries hence lacking global outlook on the subject matter. Our sample covers a period of 1996 to 2017 since this is the longest and most consistent data collectively available for empirical use from various databases. Empirically we rely on the SPSM approach of Chortareas and Kapetanois (2009) which we apply to three generations of unit root tests (those being the i) conventional unit root tests ii nonlinear unit root tests iii) FFF-based nonlinear unit root tests). After controlling for nonlinearities and smooth structural breaks in the data, we find that only Brazil, Russia, Japan, Canada and China have stationary suicides whilst we fail to find any convincing evidence of stationarity amongst the remaining countries, which comprises mainly of industrialized, G20 member states.

There are some important policy implications which can be gathered from our findings. For starters, we concur with the World Organization and particularly advise that G20 countries should move toward adoption of formal national suicide prevention strategies which are tailored according to each of the members social, religious and economic standards. Other non-G20 countries could then ‘copy’ the strategies implemented by G20 countries by identifying with member states which best correspond with their social, economic, religious and regional standings. Such proposed suicide prevention strategies should primarily emulate from health and social ministries within each economy and should then be spread across different sectors of the economy, primarily the health care sector, business sector, education sector (primary, secondary and tertiary levels of education) as well within local communities. As detailed in the “*Mental Health Plan*” report of the World Health Organization (2013) prevention strategies could include surveillance measures, means restrictions, media guidelines, stigma reduction as well as public awareness and training.

From an empirical standpoint, a comprehensive system of adequate data collection should be put into place by G20 as well non-G20 member states which can provide a rich source of suicide numbers across the different sexes, races, age groups, religious backgrounds and other relevant socio-demographic factors. This would require more rigid data-collecting institutional structures dedicated towards collecting and processing such time series which would in turn naturally enrich the future academic path of research on suicides as well as forecasting practices not only for G20 countries but other less researched recognized economies in less developed regions of the world. However, with the currently available data, one possible avenue for the near-future research would be to extend upon the current knowledge on the so-called "natural-rate of suicides" literature which can be perceived as a natural extension of the knowledge gained from investigating the persistence of suicides.

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