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Abstract: The Kingdom of Swaziland is a small, open economy which is heavily dependent on trade activity with neighboring and other industrialized countries. This study implements the recently-developed fractional frequency flexible Fourier form (FFFFF) unit root to examine the income convergence hypothesis for a dataset of per capita income differences between Swaziland and 5 of her main trading partners over a period of 1950 to 2016. With the exception of Japan, the empirical evidence indicates non-convergence of Swaziland towards her main trading partners.

Keywords: Income convergence; fractional frequency flexible Fourier form (FFFFF) unit root test; Swaziland.

JEL classification codes: C21; C22; E23.

1. Introduction

The income convergence hypothesis, which postulates that countries with lower initial income levels will exhibit 'catch-up' effects towards income levels of more advanced countries, remains at the heart of Neoclassical growth theory (Baumol (1986), Barro and Sala-i-Martin (1992), Mankiw et al. (1992)). Endogenous growth theorists (Rommer, 1986, 1990) challenged the notion of income convergence by undermining the relevance of initial conditions and insinuating the possibility of multiple equilibriums. The empirical debate on the convergence hypothesis is no less inconclusive. Initially, convergence effects were confirmed by a negative and statistically significant estimate on the initial per income variable found in a growth regression exemplified in Barro (1991). This approach was criticized by Friedman (1992) and Quah (1993) (i.e. Gallons fallacy) which led to Quah, (1993), Bernard and Durlauf (1996) and Evans and Karras (1998) suggesting a new measure of 'convergence', that being the stationarity of income disparities amongst a group of countries. Needless to say, much criticism has also been placed on conventional unit root testing practices in distinguishing between a unit root and a close-to-unit root process and these criticisms range from the failure to account for structural breaks in the series, to the failure to account for underlying asymmetries in the data generating process. Consequentially, econometricians are continuously tasking themselves with devising newer and more powerful unit root testing procedures.

Recently, Enders and Lee (2012) and Rodrigues and Taylor (2012) have demonstrated that unit root tests estimated with an integer flexibly Fourier form (IFFF) approximation tend to more efficiently capture nonlinearities and unobserved smooth structural breaks and additionally avoids inherent econometric issues such as selection of break dates as well as type (smooth or instantaneous) of structural break. And even more recently, Omay (2015) argues that the power of flexible Fourier based unit root tests can be enhanced by approximating the Fourier frequency form with smaller increments as opposed to integer valued frequencies. Omay (2015) ultimately demonstrates that the resulting fractional frequency flexible Fourier form (FFFFF) unit root test outperforms the conventional IFFF type tests in small smaller samples. In our article, we use the FFFFF unit root test to examine whether real per capita GDP

Kingdom of Swaziland, as a small, middle-income open African monarchy, will converge towards the income of her main trading partners. We particularly test a hypothesis put forward by Ben-David (2006) which speculates that developing countries with increased reliance on openness and trade should, via the factor price equalization theorem, act as a catalyst for equalization of income towards that of more developed trading partners. We thus consider this empirical exercise an important one for the Swazi Kingdom which derives a majority of government income through trade activity and this, in turn, is used to finance the public wage bill as well as to ensure the provision of basic human needs through service delivery. With virtually no existing empirical evidence testing this assumption for Swaziland, we fill an important gap in the literature.

The remainder of the study is organized as follows. The next section presents our methodological framework of the study; section 3 presents the data as well as the empirical results whilst the study is concluded in section 5 of the paper.

2. Methodology

Quah, (1993), Bernard and Durlauf (1996), Evans and Karras (1998) and Ben-David (2006) propose a test of convergence hypothesis, in which deviations of the natural logarithm of real per capita GDP (i.e. $y_{1,t+i}$, $y_{2,t+i}$,….,$y_{N,t+i}$) from their trading partner's per capita averages $\bar{y}_t$ can be expected to approach constant values as i approaches infinity, such that:

$$\lim_{i\to\infty} E_t(y_{n,t+i} - \bar{y}_{t+i}) = \mu_n \qquad (1)$$

Note that equation (1) can only hold if $y_{n,t+i} - \bar{y}_{t+i}$ is a stationary, I(0) process, otherwise there is absence of convergence effects if $y_{n,t+i} - \bar{y}_{t+i}$ is found to be integrated of order I(1) or higher. Alternatively (1) can be represented by the following Dickey-Fuller (DF) type regression:

$$z_t = d(t) + \psi z_{t-1} + \gamma t + e_t \quad (2)$$

Where d(t) is a deterministic function of t, $e_t \sim N(0, \sigma^2)$ and the initial value of y_t, y_0, is assumed to be fixed. In circumstances where d(t) is known, the direct test for a unit root (i.e. $\psi = 1$) becomes problematic if d(t) is misspecified. To circumvent this, Enders and Lee (2012) and Rodrigues and Taylor (2012) propose the approximation of d(t) using the following Fourier function:

$$d(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_k \sin(2\pi kt/T) + \sum_{k=1}^{n} \alpha_k \cos(2\pi kt/T);\ n \leq T/2 \quad (3)$$

Where n represents the number of cumulative frequencies contained in the approximation, k represents a particular frequency and T is the number of observations and n is the number of cumulative frequencies. In the absence of a nonlinear trend, the condition $\alpha_K = \beta_K = 0$ holds such that regression (3) is reduced to standard DF test. To circumvent problems of degrees of freedom and over-fitting, Enders and Lee (2012) and Rodrigues and Taylor (2012) suggest the use of small values of n which also ensures gradual evolution of the nonlinear trend. Moreover, the literature also advises on specifying k=1 which leads to a good approximation to a model with structural changes (Enders and Lee, 2012). Omay (2015) and Omay et al. (2017) more recently recommend using fractional frequency instead of integer values of k which are incorporated through the following unit root test regression:

$$\Delta z_t = \rho z_{t-1} + c_0 + c_1 t + c_3 \sin(2\pi k^{fr} t/T) + c_4 \cos(2\pi k^{fr} t/T) \quad (4)$$

Where k^{fr} is a fractional frequency. Omay (2015) and Omay et al. (2017) suggest applying grid search for the fractional frequencies between the intervals $0.1 \leq k^{fr} \leq 2$, with increments of 0.1 for the selected frequencies and obtaining $k = k^{fr*}$ that minimizes the SSR of regression (4). Omay (2015) tabulates the relevant critical values for a range of fractional increments.

3. Data and Results

The empirical data used for our analysis comprises of differences of logged per capita GDP between Swaziland and her top 5 trading partners, namely, South Africa (RSA), The US, the EU-28, Japan and China. Collectively, these countries account for approximately 97 percent of Kingdom's trade activity. The source of our raw time series data is the most recently up-dated dataset of Maddison (2013), which as far as we are concerned, has the longest available time series data on per capita GDP for the countries considered in our investigation. For consistency sake, the data is collected from 1950 to 2016 and as can be observed from the summary statistics reported in Table 1, all trade partners have on average, larger per capita GDP levels than Swaziland with the sole exception of China. We also report evidence of a non-normal distribution for all series except per capita GDP differences with Japan where the J-B statistics fails to reject the null hypothesis of a normal, bell-shaped distribution. These latter statistics further raise our curiosity for unobserved structural breaks existing in the data.

Table 2 presents our empirical unit root test results and for comparative sake we also report the findings from conventional DF test statistic (i.e. k=0) performed inclusive of both a drift and trend. As can be observed, the preliminary DF tests statistics fail to provide any evidence for convergence between Swaziland and all her main trading partners. However, when accounting for unobserved structural breaks in the series the estimated IFFF test statistic of Enders and Lee (2012) detects relatively weak evidence of convergence effects (10% rejection of the unit root hypothesis) between Swaziland and Japan whilst the test statistics obtained for the remaining series continue to indicate unit root behavior. Note that the optimal frequency for all performed IFFF tests is k=1 which complies with predictions from previous literature.

Following Omay (2015) and Omay et al. (2017) we run fractional increments over the range $0.1 \leq k \leq 2$ and based on our findings we then proceed to run smaller fractional increments of .01 and then .001. We particularly implement Davies (1987) grid search method to obtain the minimum RSS for each of these fractional increments. This time around, the produced FFFFF test statistics obtained from each of the optimal fractional increments strongly rejects

the unit root hypothesis at a 5 percent critical level for the income differences between Swaziland and Japan whereas the remainder of the series retain their status quo of non-convergence effects.

Table 1: Descriptive statistics

series	sd_rsa	sd_us	sd_eu	sd_rsa	sd-china
Mean	-0.97	-2.31	-1.73	-1.75	0.26
Std. dev.	0.64	0.45	0.39	0.22	0.39
Jarque-bera	5.98	5.52	5.10	4.10	4.91
Probability	0.05	0.06	0.08	0.13	0.08
Observations	67	67	67	67	67

Table 2: Unit root test results

series		DF	IFFF	FFFFF			
sd_rsa	k	0	1	1	1.1	1.09	1.087
	t-stat	**-0.88**	**-2.55**	**-2.55**	**-2.56**	**-2.57**	**-2.57**
sd_us	k	0	1	1	0.8	0.79	0.788
	t-stat	**-1.68**	**-3.19**	**-3.19**	**-3.22**	**-3.23**	**-3.23**
sd_eu	k	0	1	1	1.3	1.27	1.268
	t-stat	**-1.25**	**-2.75**	**-2.75**	**-2.78**	**-2.80**	**-2.80**
sd_japan	k	0	1	1	1.8	1.73	1.725
	t-stat	**-2.78**	**-3.40***	**-3.40***	**-3.71****	**-3.73****	**-3.73****
sd_china	k	0	1	1	0.1	0.01	0.001
	t-stat	**-0.32**	**-2.27**	**-2.27**	**-2.92**	**-2.92**	**-2.93**

Notes: “***”, “**”, ”*” are 1%, 5% and 10% critical levels, respectively.

4. Conclusion

Our study provides a brief contribution to convergence literature, this time focusing on whether the Kingdom of Swaziland, as a small, open African economy converges towards the

per capita GDP of her main trading partners. To this end we rely on the recently-introduced FFFFF unit root test of Omay (2015) using data spanning from 1950 to 2016. Whereas the standard DF unit root tests fail to establish any evidence of convergence effects, in applying the more powerful IFFF and FFFFF unit root tests, we find evidence of convergence effects between Swaziland and Japan but not for other trading partners (South Africa, the US, the EU and China). We note that the statistics obtained from the more powerful FFFFF type tests provides a higher rejection of non-convergence effects between Swaziland and Japan.

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