

## **The Feldstein-Horioka Puzzle in South Africa: A Fractional Cointegration Approach\***

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### **Abstract**

The Feldstein-Horioka puzzle (FH), that is the strong correlation between saving and investment in a world where obstacles to capital mobility are limited, has been studied extensively since it was exposed in 1980. Even though the theoretical and empirical literature has examined many of its potential causes, the puzzle persists. This paper aims at shedding further light on the issue by investigating the relationship between saving and investment in South Africa since 1946 using fractional integration and cointegration techniques to account for high persistence in the series. We find evidence of fractional cointegration between saving and investment, indicating some degree of persistence in the gap between the two variables. We also find a structural break in saving and investment ratios to GDP around 1980, which roughly coincides with the start of a financial deregulation process in South Africa. While fractional cointegration holds before the break, it does not thereafter. In other words, while the FH puzzle is observed before the start of financial deregulation, it subsequently disappears. This suggests financial deregulation may have loosened the link between saving and investment.

JEL Codes: C22, C32, E21, E22, F41.

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\* The views expressed in this paper are those of the authors and do not necessarily reflect those of the Organisation for Economic Co-operation and Development (OECD) or the governments of its member countries.

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## 1. Introduction

Since the seminal article of Feldstein and Horioka (1980), a vast literature has tested cointegration between saving and investment over various country and time samples, using a wide variety of econometric techniques (for literature reviews, see Coakley *et al.*, 1998 and Apergis and Tsoumas, 2009). Beyond the intellectual challenge posed by one of the six major puzzles in international economics (Obstfeld and Rogoff, 2000), the Feldstein-Horioka (hereafter FH) puzzle has major policy implications, including on the opportunity of encouraging saving and investment, the incidence of taxes and the effectiveness of fiscal and monetary policy. Feldstein and Horioka estimated the following relationship in a cross section of 21 OECD countries over the period 1960-74:

$$(I/Y)_i = \alpha + \beta (S/Y)_i \quad i= 1, \dots, n,$$

where  $(I/Y)_i$  and  $(S/Y)_i$  are respectively the ratios of gross domestic investment and gross domestic saving to GDP in country  $i$ .

They found  $\beta$  close to one, implying that domestic investment was closely linked to domestic saving. They interpreted this result as evidence that international mobility of capital was low. Subsequent research focussed on two questions: first, how robust was the result that  $\beta$  was close to one? Second, does  $\beta$  close to one imply low international capital mobility?

The FH puzzle has proved robust acrosss OECD countries, although the association between saving and investment seems to have declined somewhat over time (Obstfeld and Rogoff, 2000; Apergis and Tsoumas, 2009). The increase in global current account imbalances since the mid-1990s, partly related to the rise of the BRICS (Brazil, Russia, India, China and South Africa) suggests a loosening of the link between domestic saving and investment, at least in some countries. Nevertheless, the empirical evidence broadly supports the persistence of the FH puzzle in OECD countries. In contrast, the literature points to low correlations between investment and

saving in developing economies (Kasuga, 2004; Sinha and Sinha, 2004). There are, however, exceptions. Narayan (2005) finds high correlation in China over the period 1952-1998, which is consistent with limited capital mobility, at least prior to 1994. Ang (2009) finds fairly strong correlation in India over the period 1950-2005, when controlling for the degree of financial liberalization. Gomes *et al.* (2008), using the Kalman filter, show that  $\beta$  has varied significantly over the period 1950-2000 in Argentina, Brazil and Chile, but find high correlation on average, especially in Brazil where the average  $\beta$  is close to one. Moving to transition economies, Petreska and Mojsoska-Blazevski (2013) find support for the existence of the FH puzzle in South-East Europe, Central and Eastern Europe and the Commonwealth of Independent States, albeit with  $\beta$  generally lower than one and slow adjustment to equilibrium.

While the literature provides ample evidence in favour of the existence of the FH puzzle, its interpretation as evidence of low capital mobility is controversial. From a theoretical point of view, it has been demonstrated that a high correlation between investment and saving is not incompatible with perfect capital mobility (Murphy, 1984; Baxter and Crucini, 1993; Tesar, 1991; Barro *et al.*, 1995). Moreover, the empirical finding of lower investment-saving correlations in most developing countries than in the OECD is hardly compatible with an interpretation purely based on the degree of capital mobility, which is higher among OECD countries than in most of the developing world. Kasuga (2004) shows that low correlations between investment and saving in developing countries can be related to the under-development of their financial systems. This could also explain the seemingly paradoxical finding by Ang (2009) that financial liberalization in India reinforced the link between domestic saving and investment, as the impact of greater capital mobility may have been offset by higher efficiency of the financial system in channelling saving to domestic investment.

A number of more general factors have been put forward to explain the FH puzzle. The investment-saving correlation seems to be positively related to the size of the country. This may result from the impact changes in saving and investment in big countries have on the world interest rate. An increase in saving in a big country would lower the world interest rate, which would in turn increase investment. On the contrary, an increase in saving in a small country has no impact on the world interest rate (Murphy, 1984; Baxter and Crucini, 1993). An alternative explanation is that larger countries offer more opportunities to match savings with investment projects and hence are less dependent on international capital flows (Harberger, 1980). Hence, the FH puzzle may to some extent result from a big-country bias. Saving and investment could also be subject to common shocks, which would induce correlation. However, empirical support for this hypothesis is weak, even though Giannone and Lenza (2008) find that general equilibrium effects can partly rationalize the high correlation between investment and saving in OECD countries when heterogenous country responses to global shocks are taken into account. Finally, the FH puzzle could result from a solvency constraint. The gap between saving and investment is the current account balance. As countries cannot run current account deficits forever, the solvency constraint will tend to equalise domestic saving and investment in the long term, irrespective of the degree of capital mobility (Coakley *et al.*, 1996).

Our paper adds to the literature by investigating the FH puzzle in South Africa in a fractional integration and cointegration framework. South Africa is an interesting case for several reasons. First, it is one of today's most dynamic emerging economies and is well integrated in the global economy. Second, the analysis can be performed over an extended time span, as reliable time series for saving and investment go back to 1946. Third, South Africa has had a well-developed financial system for a long time and its financial deregulation process started in the early 1980s, earlier than in most other major emerging economies. Thus, it is unlikely that a low

correlation between investment and saving could be driven by financial system inefficiencies in channeling saving to investment domestically. The 1946-2013 sample covers more than three decades both before and after the start of financial deregulation, allowing meaningful comparisons between sub-periods. Finally, compared to other BRICS, South Africa is relatively small, making it less prone to the potential big-country bias.

Fractional integration and cointegration techniques are particularly relevant for studying the FH puzzle, as they allow accounting for high persistence in economic processes. Fractional cointegration, that is a long run relationship with slow adjustment to equilibrium, which can be considered as a weak form of the FH puzzle, is compatible with the solvency constraint hypothesis. Mobile capital would fill gaps between investment and saving, but the solvency constraint would impose a correlation between investment and saving in the long term, as countries cannot run current account deficits forever. Fractional integration and cointegration techniques have been applied to many economic issues, including exchange rates behaviour (Baillie and Bollerslev, 1994; Nielsen, 2004; Caporale and Gil-Alana, 2013), purchasing power parities (Cheung and Lai, 1993; Masih and Masih, 1995; Holmes, 2002; Cuestas and Gil-Alana, 2009), stock markets volatility (Nielsen, 2007; Gil-Alana *et al.*, 2014) and oil price persistence (Gil-Alana and Gupta, 2014). However applications to the FH puzzle are scarce. Cooray and Felmingham (2008) find fractional cointegration between saving and investment in Australia over the period 1959Q3-2005Q4. Cooray and Sinha (2007) find fractional cointegration in 12 African countries, including South Africa, out of a sample of 20 starting between the late 1940s and the mid-1960s depending on the country and ending in the early 2000s.

We find fractional cointegration between the two series over the full sample, which implies a long-term relationship, but slow adjustment to equilibrium. However, we also find evidence of a break in both the investment and saving ratios to GDP (though it is more remarkable in the case of

S/GDP than for I/GDP), which coincides with the start of a financial deregulation episode in South Africa (Odhiambo, 2006; Singleton and Verhoef, 2010). While fractional cointegration holds before the break, it is no longer the case afterwards. In other words, while the FH puzzle is observed in a weak form before the start of financial deregulation, it subsequently disappears. This suggests that financial deregulation has loosened the financial constraint on investment. We also test for non-linearity in the investment and saving ratios to GDP and find some evidence of nonlinear trends for the S/GDP series, but not for I/GDP. As the non-linear regression model suggests that over the 1980-2013 period, S/Y is I(0) while I/Y is I(1), we use the autoregressive distributed lag (ARDL) methodology to test for cointegration. The results confirm the absence of cointegration over this period.

The paper is structured as follows. Section 2 describes the data and displays the results. Section 3 carries out robustness analysis allowing for non-linearity and structural breaks. Section 4 concludes.

**[Insert Figure 1 about here]**

## **2. Data and Results**

The data used in this work correspond to the ratios of gross domestic saving and gross domestic investment to GDP at annual frequency covering the period of 1946-2013, with the start and end-points of the sample being purely driven by data availability.<sup>1</sup> The data is sourced from the online data service of the South African Reserve Bank.<sup>2</sup>

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<sup>1</sup>It must be pointed out that quarterly data on these two variables are also available, starting at 1960:Q1. However, we chose to use annual data, as it allows us to cover a longer time span.

<sup>2</sup>Available at: [www.resbank.co.za](http://www.resbank.co.za).

As mentioned in Section 1 we conduct the analysis of the FH puzzle by using fractional integration and cointegration methods. In the first step, we examine the statistical properties of the individual series<sup>3</sup> by means of estimating the fractional differencing parameter  $d$  in the following model,

$$y_t = \beta_0 + \beta_1 t + x_t, \quad (1 - L)^d x_t = u_t, \quad t = 1, 2, \dots \quad (1)$$

where  $y_t$  is each of the two observed time series (S/GDP and I/GDP),  $\beta_0$  and  $\beta_1$  are the coefficients corresponding to the intercept and a linear time trend respectively, and the detrended series  $x_t$  is supposed to be  $I(d)$ , with the  $d$ -differenced process  $u_t$  assumed first to be a white noise process, though we also admit the possibility of a weakly autocorrelated process. In the latter case, we use a non-parametric approximation due to Bloomfield (1973) that approximates ARMA structures with a reduced number of parameters.<sup>4</sup>

**[Insert Tables 1 and 2 about here]**

Table 1 displays the estimates of  $d$  using a parametric Whittle approach in the frequency domain (Dahlhaus, 1989). We present the estimates of  $d$  along with the corresponding 95% confidence intervals, for the three standard cases of no regressors in (1) (i.e.,  $\beta_0 = \beta_1 = 0$  a priori), an intercept (i.e.,  $\beta_0$  unknown and  $\beta_1 = 0$  a priori) and an intercept with a linear trend (i.e.,  $\beta_0$  and

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<sup>3</sup>As is standard practice in time-series econometrics, we also analyzed the integration properties of the two series using various unit root tests, starting with the standard linear tests: Augmented Dickey Fuller (ADF, 1979), GLS-detrended Dickey-Fuller (Elliot, Rothenberg, and Stock, 1996), Phillips-Perron (Phillips and Perron, 1988), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992), Ng and Perron (NP, 2001), and the recently developed test of Müller and Watson (2008) for low-frequency data. Then we conducted four unit root tests with one (Zivot and Andrews, 1992), two (Lumsdaine and Papell, 1997 and Lee and Strazicich, 2003), and an unknown (Enders and Lee, 2012) number of structural breaks. Also, the Leybourne *et al.*, (2007) unit root test of change in persistence was used. Further, we also carried out two non-linear unit root tests proposed by Kapetanios, Shin and Shell (KSS, 2003), and Sollis (2009). Finally, we also combined the KSS test with the Enders and Lee (2012) tests to accommodate for non-linearity due to regime switching and structural breaks. The results were found to be inconsistent, with degrees of integration changing across the type of unit root tests. Due to the lack of robustness amongst the various unit root tests and the fact that unit root tests have low power when a series is characterized by a fractional integration process (Ben Nasr *et al.*, 2014), we decided to use tests of fractional integration to determine whether a series is stationary or not. The results of the various unit root tests conducted are, however, available upon request from the authors.

<sup>4</sup>See Gil-Alana (2004) for approximations of ARMA structures with the model of Bloomfield (1973) in the context of fractional integration

$\beta_1$  unknown). The results clearly indicate that S/GDP is I(1) for the two types of errors and the three modeling assumptions since the I(1) hypothesis cannot be rejected in any single case. For I/GDP, the same evidence is obtained with white noise errors. However, with autocorrelated disturbances, I(1) is only found if no deterministic terms are included; otherwise, with an intercept and/or a linear time trend, the estimated value of  $d$  is smaller than 1 and about 0.45. Due to this disparity in the results for the I/GDP series, we also conduct a semiparametric Whittle method estimation (Robinson, 1995) where no functional form is imposed on the error term. Using this approach, in Table 2, the evidence of I(1) behavior is supported in all cases, i.e. across the different bandwidth numbers examined and for the two variables.<sup>5</sup>

Next we focus on the multivariate approach, testing the existence of a long run equilibrium relationship among the two variables. Here we use techniques based on fractional cointegration. As a preliminary step, we conduct a test about the homogeneity condition in the orders of integration of the two series. This is a necessary condition for cointegration in the bivariate representation of the two series. The results, based on an adaptation of Robinson and Yajima's (2002) approach, though not reported, strongly support the hypothesis of equal orders of integration in the two series.

Based on the fact that the two parent series seem to be nonstationary I(1), the OLS regression of one of the variables over the other is supposed to be consistent even in the context of cointegration. Therefore, we focus in what follows on the estimation of the degree of integration in the errors of the potential cointegrating relationship. These errors are displayed in Figure 2 and they do present a stationary appearance.

**[Insert Figure 2 and Tables 3 and 4 about here]**

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<sup>5</sup> Based on the nonstationary nature of the series, the analysis of fractional integration is conducted on the first differenced data, adding then 1 to the estimated values of  $d$ .

Table 3 presents the estimates of  $d$  on the estimated errors for three different types of disturbances and again for the three cases of no regressors, an intercept, and an intercept with a linear time trend. It is observed that the unit root null cannot be rejected under the assumption of white noise errors; however, allowing autocorrelated disturbances, the estimated value of  $d$  is much lower, 0.31 with Bloomfield-type errors and 0.39 with AR(1), and the  $I(1)$  hypothesis is decisively rejected in favour of mean reversion, and thus, supporting the evidence of cointegration among the two variables. Performing the Whittle local semiparametric estimate of Robinson (1995), which is also valid in the context of cointegration, the results again support the hypothesis of cointegration at least for some bandwidth numbers, including  $m = (T)^{0.5}$  widely used in other empirical applications.

### **3. Additional issues**

There are two issues that many authors argue might be intimately related with fractional integration. One is the presence of non-linear trends and the other is the existence of structural breaks (e.g. Cheung, 1993; Diebold and Inoue, 2001; Giraitis *et al.*, 2001; Mikosch and Starica, 2004; Granger and Hyung, 2004). Starting with the non-linear issue, some papers show that non-linear transformations of fractionally integrated processes will have a lower memory than the original series (Dittmann and Granger, 2002; Avarucci and Marinucci, 2007), while others have tried to introduce stochastic non-linear structures in  $I(d)$  contexts (Caporale and Gil-Alana, 2007). In this paper we will employ a recent development suggested by Cuestas and Gil-Alana (2012) that uses fractional integration with non-linear deterministic trends and thus can accommodate the presence of breaks and other abrupt changes in the data.

With respect to the structural breaks, some authors claim that fractional integration may be a spurious phenomenon caused by the existence of breaks that have not been taken into account in

the data. For example, Lobato and Savin (1998) argue that structural breaks may be responsible for the long memory in return volatility processes, and several test statistics have been proposed in recent years to test for fractional integration versus structural breaks (e.g. Beran and Terrin, 1996; Bos et al., 2001; Ohanissian et al., 2008). Also in the I(d) context, many authors consider the possibility of mean shifts and split deterministic terms (Hidalgo and Robinson, 1996; Kuan and Hsu, 1998; Kramer and Sibbertsen, 2002) but they impose the same degree of integration across regimes. In this section we will implement a procedure developed by Gil-Alana (2008) in the context of fractional integration with structural breaks at unknown periods of time, allowing for different degrees of integration across subsamples.

We start by performing Cuestas and Gil-Alana's (2009) approach of fractional integration with non-linear deterministic trends. We consider the following model,

$$y_t = \sum_{i=0}^m \theta_i P_{iT}(t) + x_t, \quad (1 - L)^d x_t = u_t, \quad (2)$$

where  $P_{i,T}(t)$  are the Chebyshev time polynomials, defined by:

$$P_{0,T}(t) = 1, \\ P_{i,T}(t) = \sqrt{2} \cos(i\pi(t-0.5)/T), \quad t = 1, 2, \dots, T; \quad i = 1, 2, \dots \quad (3)$$

In this context,  $m$  indicates the order of the Chebyshev polynomial: if  $m = 0$  the model contains an intercept, if  $m = 1$  it adds a linear trend, and if  $m > 1$  the model becomes non-linear, and the higher  $m$  is the less linear the approximated deterministic component becomes.<sup>6</sup>

**[Insert Tables 5 and 6 about here]**

Table 5 displays the d-coefficient estimates and their 95% confidence bands for different degrees of linear ( $m = 1$ ) and non-linear ( $m = 2, 3$ ) behavior. Table 6 displays the estimated

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<sup>6</sup> See Hamming (1973) and Smyth (1998) for a detailed description of these polynomials.

coefficients for the Chebyshev polynomials in each case. A strong non-linear trend is observed for the S/GDP series, with a significant reduction in its degree of integration, which is now 0.44 (with  $m = 3$ ) and significantly smaller than 1. On the other hand we do not observe any evidence of non-linearity for the I/GDP series and the unit root null cannot be rejected for this series.

**[Insert Table 7 about here]**

Table 7 displays the results of the Gil-Alana's (2008) approach testing fractional integration with structural breaks. A single break is clearly identified in the two series, in 1980 for S/GDP and one year earlier for I/GDP, and this evidence of a structural break is stronger in case of the S/GDP series, at least in relation with the degree of integration observed in the sub-samples. Thus, for S/GDP, we see that the I(1) hypothesis cannot be rejected before the break date, and this hypothesis is decisively rejected in favour of mean reversion ( $d < 1$ ) since 1980. In general, we observe a reduction of the order of integration after the break for the three cases presented. This might explain the non-linearity observed in Tables 5 and 6 in this series. For I/GDP the I(1) hypothesis cannot be rejected in any case in the first subsample and in the second subsample if no deterministic terms are included; however, a value significantly higher than 1 is obtained with an intercept and/or a linear trend. Allowing for autocorrelated errors the results are substantially the same.

Given the above results, we now re-test for cointegration using fractional cointegration methods for the sub-sample 1946-1979, as both series are identified to be I(1). These results are reported in Table 8, showing the estimated values of  $d$  in the cointegrating regression errors. We observe that if the errors are white noise the unit root null hypothesis cannot be rejected, suggesting that the two series do not cointegrate; however, under autocorrelated errors, which seems to be more plausible, according to the structure of the error term, the estimated value of  $d$  is slightly negative and the I(0) hypothesis cannot be rejected, suggesting the existence of

cointegration even in the standard case with integer degrees of differentiation.<sup>7</sup> Thus, the evidence of cointegration found in the results reported in Tables 3 and 4 and referring to the whole sample size are clearly due to the data corresponding to the first sub-sample and ending in 1979.

**[Insert Table 8 about here]**

But since the saving-GDP ratio is I(0) over 1980-2013, we use the autoregressive distributed lag (ARDL) model, also popularly called the bounds testing methodology of Pesaran and Shin (1999) and Pesaran *et al.* (2001), given that it is the only known approach that allows testing for cointegration with a mixture of I(0) and I(1) data.

The ARDL approach to estimate the long-run cointegrating relationship between the saving-GDP and investment to GDP ratios involves first estimating a model with the variables in first differences (equation 4) and subsequently, computing a *F*-statistic test to determine if additional lags of the two ratios in levels result in significant coefficients (equation 5).

$$\Delta \left( \frac{I}{Y} \right)_t = \mu + \sum_{k=1}^n \beta_k \Delta \left( \frac{I}{Y} \right)_{t-k} + \sum_{k=1}^n c_k \Delta \left( \frac{S}{Y} \right)_{t-k} \quad (4)$$

$$\Delta \left( \frac{I}{Y} \right)_t = \mu + \sum_{k=1}^n \beta_k \Delta \left( \frac{I}{Y} \right)_{t-k} + \sum_{k=1}^n c_k \Delta \left( \frac{S}{Y} \right)_{t-k} + \delta_1 \left( \frac{I}{Y} \right)_{t-1} + \delta_2 \left( \frac{S}{Y} \right)_{t-1} \quad (5)$$

where  $\Delta$  denotes the first difference operator,  $I/Y$  and  $S/Y$  the investment to GDP and saving to GDP ratios,  $B_k$  and  $C_k$  are the coefficients of lagged  $\Delta(I/Y)$  and  $\Delta(S/Y)$  to be estimated. The null hypothesis for the *F*-statistic is  $\delta_1 = \delta_2 = 0$  (i.e., no long-run relationship or no co-integration).

The distribution of the *F*-statistic is non-standard and hence the critical values have to be calculated. Pesaran *et al.* (2001) and Narayan (2005) both develop two bounds of critical values where the upper bound applies when all variables are integrated of order 1 and the lower bound when all of them are stationary. If the *F*-statistic for a particular level of significance lies between

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<sup>7</sup> Note that the wide confidence intervals are a consequence of the small sample sizes used for the analysis in this subsample.

the lower and upper bounds, then conclusive inference cannot be made. If the test statistic is higher than the upper bound, the null hypothesis of no cointegration is rejected.

In order to estimate the above equations, the appropriate lag length has to be decided. To do so, a simple vector autoregressive (VAR) model of  $\Delta(I/Y)$  and  $\Delta(S/Y)$  is estimated. From there, a suite of criteria, such as the Akaike Information Criterion (AIC), the Schwarz Information Criterion (SIC), the Hannan-Quinn (HQ) and the Final Prediction Error (FPE), are applied to determine the lag order in the test equation. These criteria unanimously select a lag-length of 1.

**[Insert Table 9 about here]**

Table 9 presents the results of the ARDL model. Panel A reports the critical values of Pesaran *et al.* (2001) and Narayan (2005). Both papers generated critical values for specific non-standard  $F$ -distribution, with Pesaran *et al.* (2001) generating them using samples of between 500 and 1000 observations. Narayan (2005), on the other side, argues that Pesaran's critical values might not be appropriate for smaller samples. Therefore, he regenerated critical values using samples of 30 to 80 observations. Given our sample size, the critical values generated by Narayan (2005) are the most appropriate. But, for the sake of comparability, we also report the critical values of Pesaran *et al.* (2001), which, are, understandably, less stringent. Panel B of Table 9, in turn, reports the  $F$ -statistics for not only the sub-sample of our concern (1980-2013), but also the full-sample 1946-2013 (68 observations) and 1946-1979 (34 observations). While no evidence of cointegration is observed for the two sub-samples, the null of no-cointegration is rejected for the full-sample. The latter result is consistent with the evidence of cointegration found with tests of fractional cointegration.<sup>8</sup> So, for our sample of concern (1980-2013), the ARDL test indicates that there is no long-run relationship between the investment-GDP and saving-GDP ratios.

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<sup>8</sup> The long-run coefficient for the full-sample (1946-2013), given by  $(-\delta_2/\delta_1)$  is found to be 0.548 and is significant at conventional levels of significance. This value is quite comparable to the full-sample OLS estimate of  $\beta$ , found to be

## 5. Conclusion

In this paper, we have investigated the FH puzzle in South Africa over the period 1946-2013 using fractional integration and cointegration techniques to account for high persistence in saving and investment ratios to GDP. We found evidence of fractional cointegration between saving and investment ratios to GDP over the whole sample. We also found a structural break in both series around 1980, which roughly coincides with the start of a financial deregulation process in South Africa. While fractional cointegration holds before the break, it does not thereafter. In other words, while the FH puzzle is observed in a weak form before the start of financial deregulation, but it subsequently disappears. The result is confirmed when allowing for non-linearity and testing for cointegration using an ARDL model. This suggests financial deregulation may have loosened the link between saving and investment in South Africa.

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0.48, based on fractional cointegration estimation. While the estimate of  $\beta$  for 1946-1979 was found to be 0.22. Both these estimates of are significant at the 5% level.

## References

Ang, J.2009. The Saving-Investment Dynamics and Financial Sector Reforms in India.*MPRA Paper* 14498, University Library of Munich, Germany.

Apergis, N. and Tsoumas, C. 2009. A survey of the Feldstein-Horioka puzzle: What has been done and where we stand.*Research in Economics*, Elsevier, vol. 63(2), pages 64-76.

Avarucci, M., and Marinucci, D. 2007, Polynomial cointegration between stationary processes with long memory, *Journal of Time Series Analysis* 28, 923-942.

Baillie, R.T. and Bollerslev, T. 1994, Cointegration, fractional cointegration and exchange rate dynamics, *Journal of Finance* 69, 2, 737-745.

Barro, R.J., Mankiw, N.G. and Sala-I-Martin, X. 1995. Capital Mobility in Neoclassical Models of Growth. *The American Economic Review*, Vol. 85, No. 1 (Mar., 1995), pp. 103-115.

Baxter, M. and Crucini, M.J. 1993. Explaining Saving-Investment Correlations. *The American Economic Review*, Vol. 83, No. 3 (Jun., 1993), pp. 416-436.

Ben Nasr, A., Ajmi, A.N., & Gupta, R. 2014. Modeling the volatility of the Dow Jones Islamic market world index using a fractionally integrated time varying GARCH (FITVGARCH) model, *Applied Financial Economics*, 24, 993-1004.

Beran, J. and Terrin, N.1996. Testing for a change of the long memory parameter.*Biometrika*, 83(3), 627-638.

Bloomfield, P.1973. An exponential model in the spectrum of a scalar time series, *Biometrika* 60, 217-226.

Bos, C., Franses, P.H. and Ooms, M.2001. Inflation, forecast intervals and long memory regression models, *International Journal of Forecasting* 18, 243-264.

Caporale, G.M. and Gil-Alana, L.A.2007. Non-linearities and fractional integration in the US unemployment rate, *Oxford Bulletin of Economics and Statistics* 69, 4, 544-608.

Caporale, G.M. and Gil-Alana, L.A.2013. Long memory and fractional integration in high frequency data on the US dollar/British pound spot exchange rate.*International Review of Financial Analysis*, Elsevier, vol. 29(C), pages 1-9.

Cheung, Y.W.1993. Tests for fractional integration. A Monte Carlo investigation. *Journal of Time Series Analysis* 14:331-345.

Cheung, Y.W. and Lai, K.S. 1993. A fractional cointegration analysis of the Purchasing Power Parity, *Journal of Business and Economic Statistics* 11, 1, 103-112.

- Coakley, J., Kulasi, F. and Smith, R. 1996. Current Account Solvency and the Feldstein-Horioka Puzzle. *The Economic Journal*, Vol. 106, No. 436 (May, 1996), pp. 620-627.
- Coakley, J., Kulasi, F. and Smith, R. 1998. The Feldstein-Horioka Puzzle and Capital Mobility: A Review. *International Journal of Finance and Economics*, 3: 169–188.
- Cooray, A.V. and Felmingham, B. 2008. Are Australia's savings and investment fractionally cointegrated? *International Journal of Applied Economics*, 5(1), 2008, 48-53.
- Cooray, A. and Sinha, D. 2007. The Feldstein–Horioka model re-visited for African countries, *Applied Economics*, 39:12, 1501-1510.
- Cuestas, J.C. and Gil-Alana, L.A. 2009. Further evidence on the PPP analysis of the Australian dollar: Non-linearities, fractional integration and structural changes. *Economic Modelling*, Elsevier, vol. 26(6), 1184-1192.
- Cuestas, J.C. and Gil-Alana, L.A. 2012. A Non-Linear Approach with Long Range Dependence Based on Chebyshev Polynomials, *Working Papers 2012-013*, The University of Sheffield, Department of Economics.
- Dahlhaus, R. (1989)., Efficient parameter estimation for self-similar process, *Annals of Statistics* 17, 1749-1766.
- Dickey, D.A. and Fuller, W.A. 1979. Distribution of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association* 74, 427–431.
- Diebold, F.X. and Inoue, A. 2001. Long memory and regime switching, *Journal of Econometrics* 105, 131-159.
- Dittmann, I. and Granger, C.W.J. 2002, Properties of nonlinear transformations of fractionally integrated processes, *Journal of Econometrics* 110, 113.133.
- Elliott, G., Rothenberg, T.J. and Stock, J.H. 1996. Efficient tests for an autoregressive unit root, *Econometrica* 64, 813–836.
- Enders, W. and Lee, J. 2012. A Unit Root Test Using a Fourier Series to Approximate Smooth Breaks. *Oxford Bulletin of Economics and Statistics*, Volume 74, Issue 4, pages 574–599.
- Feldstein, M. and Horioka, C. 1980. Domestic savings and international capital flows. *Economic Journal*, 90, 314–329.
- Giannone, D. and Lenza, M. 2008. The Feldstein-Horioka Fact. *European Central Bank Working Paper*, No. 873.
- Gil-Alana, L.A. 2004. The use of the Bloomfield model as an approximation to ARMA processes in the context of fractional integration, *Mathematical and Computer Modelling* 39, 429-436.

Gil-Alana, L.A. 2008, Fractional integration and structural breaks at unknown periods of time, *Journal of Time Series Analysis* 29, 163-185.

Gil-Alana, L.A. and Gupta, R. 2014. Persistence and cycles in historical oil price data. *Energy Economics*, Elsevier, vol. 45(C), pages 511-516.

Gil-Alana, L.A., Shittu, O.I. and Yaya, O.S. 2014. On the persistence and volatility in European, American and Asian stocks bull and bear markets. *Journal of International Money and Finance*, Elsevier, vol. 40(C), pages 149-162.

Giraitis, L., Kokoszka, P. and Leipus, R. 2001. Testing for long memory in the presence of a general trend. *Journal of Applied Probability* 38, 1033-1054.

Gomes, F.A.R., Borges Ferreira, A.H. and de Jesus Filho, J. 2008. The Feldstein–Horioka puzzle in South American countries: a time-varying approach, *Applied Economics Letters*, 15:11, 859-863.

Granger, C.W.J. and Hyung, N. 2004. Occasional structural breaks and long memory with an application to the S&P 500 absolute stock returns, *Journal of Empirical Finance* 11, 399-421.

Hamming, R. W. 1973. *Numerical Methods for Scientists and Engineers*, Dover.

Harberger, A.C. 1980. Vignettes on the World Capital Market. *The American Economic Review*, Vol. 70, No. 2, Papers and Proceedings of the Ninety-Second Annual Meeting of the American Economic Association (May, 1980), pp. 331-337.

Hidalgo, J. and Robinson, P. 1996. Testing for structural change in along-memory environment. *Journal of Econometrics*, 70, 59-174.

Holmes, M.J. 2002. Purchasing Power Parity and the Fractional Integration of the Real Exchange Rate: New Evidence for Less Developed Countries, *Journal of Economic Development* 27, 1, 125-135.

Kapetanios, G., Shin, Y. and Snell, A. 2003. Testing for a unit root in the nonlinear STAR framework, *Journal of Econometrics*, 112, 359-379.

Kasuga, H. 2004. Saving-investment correlations in developing countries. *Economics Letters* 83, 371-376.

Krämer, W. and Sibbertsen, P. 2002. Testing for structural changes in the presence of long memory. *International Journal of Business and Economics*, 1, 235-242.

Kuan, C. M. and Hsu, C.-C. 1998. Change-point estimation of fractionally integrated processes. *Journal of Time Series Analysis*, 19, 693-708.

- Kwiatkowski, D., Phillips, P. C. B., Schmidt, P. and Shin, Y.1992. Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics*, 54, 159-178.
- Lee, J. and Strazicich, M. C. 2003.Minimum Lagrange multiplier unit root test with two structural breaks, *Review of Economics and Statistics*, 85(4), 1082-1089.
- Leybourne, S., Kim, T. H. and Taylor, A. M. 2007.Detecting multiple changes in persistence. *Studies in Nonlinear Dynamics & Econometrics*, 11(3).
- Lumsdaine, R. and Papell, D. 1997. Multiple trend breaks and the unit root hypothesis, *Review of Economics and Statistics*, 79, 212-218.
- Masih, R. and Masih, A.M.M. 1995. A fractional cointegration approach to empirical tests of PPP: New evidence and methodological implications from an application to the Taiwan/US dollar relationship, *Review of World Economics* 131, 4, 673-694.
- Mikosch T and Starica, C.2004. Nonstationarities in financial time series, the long range dependence and the IGARCH effects. *Review of Economics and Statistics* 86, 378-390.
- Müller, U. K. and Watson, M. W. 2008. Testing Models of Low-Frequency Variability. *Econometrica*, 76(5), 979-1016.
- Murphy, R.G. 1984. Capital Mobility and the Relationship between Saving and Investment Rates in OECD Countries, *Journal of International Money and Finance* (1984), 3, 327-342.
- Narayan, P.K. 2005. The saving and investment nexus for China: evidence from cointegration tests. *Applied Economics*, 37: 17, 1979-1990.
- Nielsen, M.O. 2004. Optimal Residual-Based Tests for Fractional Cointegration and Exchange Rate Dynamics, *Journal of Business and Economic Statistics* 22, 331-345.
- Nielsen, M.O. 2007. Local Whittle analysis of stationary fractional cointegration and the implied realized volatility, *Journal of Business and Economic Statistics* 25, 427-446.
- Ng, S. and Perron, P. 2001. Lag length selection and the construction of unit root tests with good size and power, *Econometrica* 69, 1519–1554.
- Obstfeld, M., and Rogoff, K. 2000. The six major puzzle in international economics: is there a common cause? *NBER Working Paper*, No. 7777.
- Odhiambo, N.M. 2006. Financial Liberalisation and Savings in South Africa: An Empirical Analysis, *African Review of Money Finance and Banking*, (2006), pp. 61-74.
- Ohanissian, A., Russell, J.R. and Tsay, R.S. 2008. True or spurious long memory?A new test. *Journal of Business & Economic Statistics*, 26(2), 161-175.

Pesaran, M.H. and Shin, Y. 1999. An autoregressive distributed lag modelling approach to cointegration analysis. Chapter 11 in S. Strom (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*. Cambridge University Press, Cambridge.

Pesaran, M.H., Shin, Y. and Smith, R.J. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16, 289 of 1

Petreska, D. and Mojsoska-Blazevski, N. 2013. The Feldstein-Horioka Puzzle and Transition Economies. *Economic Annals*, Volume LVIII, No. 197, pp. 23-45.

Phillips, P. C. and Perron, P. 1988. Testing for a unit root in time series regression, *Biometrika*, 75(2), 335-346.

Robinson, P.M. and Yajima, Y. 2002. Determination of cointegrating rank in fractional systems, *Journal of Econometrics* 106, 217-241.

Singleton, J. and Verhoef, G. 2010. Regulation, deregulation, and internationalisation in South African and New Zealand banking. *Business History*, 52:4, 536-563.

Sinha, T. and Sinha, D. 2004. The mother of all puzzles would not go away. *Economic Letters*, 82, pp. 259-267.

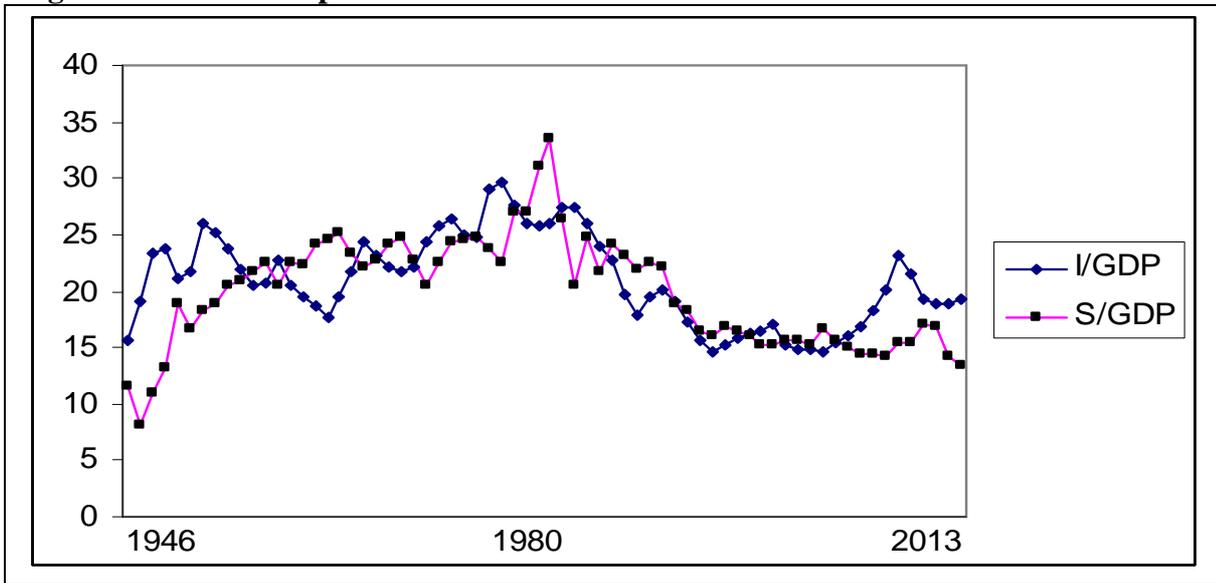
Smyth, G.K. 1998. *Polynomial Approximation*, John Wiley & Sons, Ltd, Chichester.

Sollis, R. 2009. A simple unit root test against asymmetric STAR nonlinearity with an application to real exchange rates in Nordic countries. *Economic modelling*, 26(1), 118-125.

Tesar, L.L. 1991. Saving, investment and international capital flows. *Journal of International Economics* 31, 55-78.

Zivot, E., and Andrews, D. W. K. 1992. Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis, *Journal of Business and Economic Statistics*, 10(10), 251-270.

**Figure 1: Time series plots**



**Table 1: Estimates of d and 95% confidence bands**

i) White noise disturbances			
	No regressors	An intercept	A linear time trend
S / GDP	<b>0.89 (0.79, 1.04)</b>	<b>0.89 (0.76, 1.08)</b>	<b>0.89 (0.76, 1.08)</b>
I / GDP	<b>1.18 (1.00, 1.48)</b>	<b>1.18 (0.92, 1.69)</b>	<b>1.18 (0.92, 1.67)</b>
ii) Autocorrelated disturbances			
	No regressors	An intercept	A linear time trend
S / GDP	<b>0.98 (0.80, 1.22)</b>	<b>0.79 (0.57, 1.06)</b>	<b>0.80 (0.59, 1.05)</b>
I / GDP	<b>0.86 (0.62, 1.21)</b>	0.45 (0.25, 0.75)	0.44 (0.18, 0.74)

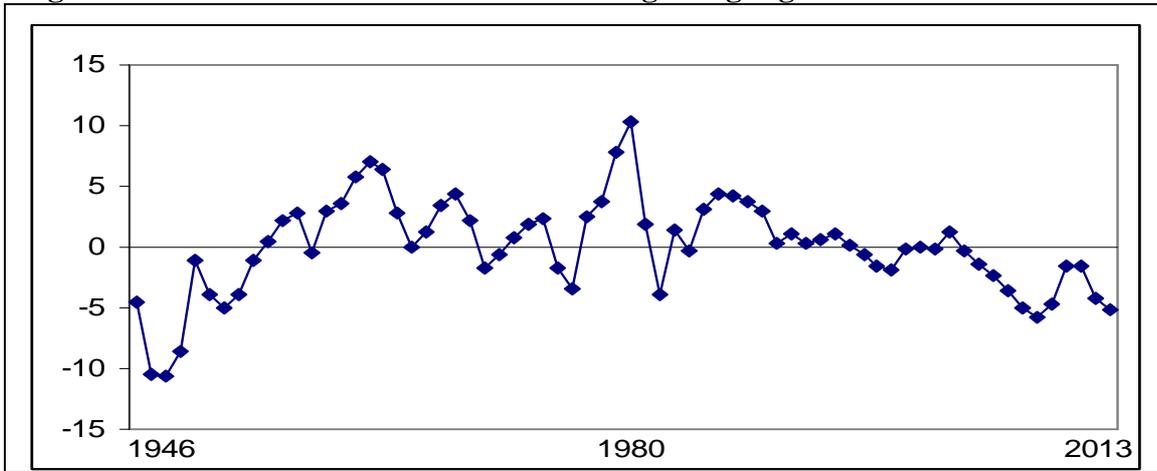
In bold, statistical evidence of unit roots at the 5% level.

**Table 2: Estimates of d using a semiparametric Whittle method**

	5	6	7	8	9	10	15
S / GDP	1.401	<b>1.215</b>	<b>1.047</b>	<b>1.011</b>	<b>0.882</b>	<b>0.943</b>	<b>0.852</b>
I / GDP	<b>1.331</b>	<b>1.225</b>	<b>1.299</b>	<b>0.958</b>	<b>1.038</b>	<b>1.072</b>	<b>0.857</b>
Lower 95%	0.632	0.664	0.689	0.709	0.723	0.739	0.787
Upper 95%	1.367	1.335	1.310	1.290	1.274	1.260	1.212

In bold, statistical evidence of unit roots at the 5% level.

**Figure 2: Estimated residuals from the cointegrating regression**



**Table 3: Estimates of d and 95% confidence bands on the estimated errors**

	No regressors	An intercept	A linear time trend
White noise	0.85 (0.62, 1.26)	<b>0.77 (0.58, 1.15)</b>	0.77 (0.59, 1.15)
Bloomfield	0.30 (0.09, 0.60)	<b>0.31 (0.09, 0.62)</b>	0.34 (0.09, 0.63)
AR(1)	0.39 (0.15, 0.61)	<b>0.38 (0.17, 0.60)</b>	0.39 (0.17, 0.61)

In bold, the selected models according to the deterministic terms.

**Table 4: Estimates of d using a semiparametric method in the estimated residuals**

	5	6	7	<b>8</b>	9	10
Residuals	0.865	0.949	0.881	<b>0.590</b>	0.554	0.613

In bold, the estimated value of d corresponding to the bandwidth number  $(T)^{0.5}$ .

**Table 5: Estimates of d in a non-linear regression model**

	m = 1 (linear)	m = 2 (non-linear)	m = 3 (non-linear)
S / GDP	0.59 (0.43, 0.60)	0.49 (0.40, 0.58)	0.44 (0.34, 0.56)
I / GDP	0.95 (0.88, 1.03)	0.95 (0.88, 1.04)	0.88 (0.78, 0.98)

In parentheses, the 95% confidence intervals of the differencing parameters.

**Table 6: Estimates coefficients in the non-linear models**

i) m = 3				
	$\theta_0$	$\theta_1$	$\theta_2$	$\theta_3$
S / GDP	<b>18.005 (6.12)</b>	1.090 (0.65)	<b>-3.811 (-3.28)</b>	<b>-1.527 (1.71)</b>
I / GDP	14.675 (1.23)	2.728 (0.37)	-1.544 (-0.49)	-0.956 (-0.58)
i) m = 2				
S / GDP	<b>16.348 (4.242)</b>	0.715 (0.325)	<b>-3.803 (-2.63)</b>	xxx
I / GDP	12.899 (1.13)	3.021 (0.41)	-1.553 (-0.49)	xxx
i) m = 1				
S / GDP	<b>10.319 (1.94)</b>	1.003 (0.28)	xxx	xxx
I / GDP	10.383 (0.92)	3.182 (0.40)	xxx	xxx

In parentheses, t-values.

**Table 7: Estimates based on the existence of breaks assuming white noise errors**

i) S / GDP			
	No regressors	An intercept	A linear time trend
[1946 - 1979]	0.94 (0.72, 1.19)	0.52 (0.29, 1.17)	0.81 (0.56, 1.15)
[1980 - 2013]	0.72 (0.54, 0.96)	0.50 (0.39, 0.64)	0.51 (0.34, 0.76)
ii) I / GDP			
	No regressors	An intercept	A linear time trend
[1946 - 1978]	1.05 (0.78, 1.49)	0.87 (0.39, 1.86)	0.91 (0.44, 1.77)
[1979 - 2013]	0.97 (0.71, 1.37)	1.36 (1.02, 2.03)	1.35 (1.01, 2.08)

**Table 8: Estimates of d and 95% confidence bands on the estimated errors (1946-1979)**

	No regressors	An intercept	A linear time trend
White noise	0.72 (0.42, 1.36)	<b>0.90 (0.42, 1.61)</b>	0.89 (0.42, 1.60)
Bloomfield	-0.19 (-0.61, 0.26)	<b>-0.15 (-0.71, 0.16)</b>	-0.15 (-0.70, 0.17)
AR(1)	-0.16 (-0.59, 0.31)	<b>-0.17 (-0.74, 0.34)</b>	-0.19 (-0.77, 0.34)

In bold, the selected models according to the deterministic terms.

**Table 9: Autoregressive distributed lag (ARDL) model results**

Panel A: Critical values according to Pesaran et al. (2001) and Narayan (2005)						
	1%		5%		10%	
Critical	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Pesaran et al.	6.840	7.840	4.940	5.730	4.040	4.780
Narayan	7.095	8.260	5.060	5.930	4.135	4.895
Panel B: Results of ARDL tests for the existence of a long run relationship						
1946 – 2013	4.930*					
1946 – 1979	2.944					
1980 - 2013	3.708					

Note: \*, \*\*, \*\*\* denotes that the null can be rejected at 10%, 5% and 1% levels of significance respectively.