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In Search of Equilibrium: Estimating Equilibrium Real Exchange Rates in Sub-Saharan African Countries

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In Search of Equilibrium: Estimating Equilibrium Real Exchange Rates in Sub-Saharan African Countries

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Abstract

This paper presents a methodology to estimate equilibrium real exchange rates (ERER) for Sub-Saharan African (SSA) countries using both single-country and panel estimation techniques. The limited data set hinders single-country estimation for most countries in the sample, but panel estimates are statistically and economically significant, and generally robust to different estimation techniques. The results replicate well the historical experience for a number of countries in the sample. Panel techniques can also be used to derive out of sample estimates for countries with a more limited data set.

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I. Introduction

A significant development challenge facing Sub-Saharan African (SSA) countries is determining, and achieving, an exchange rate that balances a country's external competitiveness[2] against its macroeconomic stability. The resulting equilibrium real exchange rate (ERER)—a rate that is consistent with an economy's medium-term fundamentals and macroeconomic stability—can therefore be a key indicator for macroeconomic policy.

In its Medium-Term Strategy, the Fund has renewed its efforts to refine its analysis of ERERs in its surveillance of macroeconomic policies in member countries.[3] While most ERER research focuses on advanced and emerging economies, there has been relatively few studies estimating ERERs in low-income countries, mostly owing to lack of reliable data. This paper attempts to fill that gap by deriving a methodology to estimate the ERER for 39 SSA countries using both single-country and panel-data estimation techniques.

The paper finds that the results are less reliable when it comes to single-country estimations—with the exception of a few countries. However, panel estimation techniques provide statistically significant results for oil-importing and, to a lesser extent, for oil-exporting countries. Panel estimation techniques also permit the derivation of the ERER for countries like Eritrea, where the sample period is limited to 14 annual observations.

The paper is organized as follows: Section II provides a description of the theoretical background on the determinants of the equilibrium real exchange rates. Section III applies this approach to SSA countries. Section IV discusses data issues and econometric methodology. Section V and VI describe the empirical evidence from single-country and panel estimations, respectively. Section VII presents an extension of panel estimation for countries with limited data, like Eritrea. Section VIII presents the conclusions.

II. Theoretical Background on Determinants of the ERER in Low-Income Countries

In the extensive theoretical and empirical research on the determination of ERERs, two main approaches have emerged: (i) the "macroeconomic balance" approach (MB), pioneered by John Williamson (1994), and (ii) the "behavioral equilibrium exchange rate" (BEER)

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[2] Competitiveness is defined according to the OECD (1992) definition: "the degree to which a country can, under free trade and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the long term." For further discussion of defining competitiveness, see also Boltho (1996). The real exchange rate is defined in this paper as the nominal effective exchange rate deflated by the consumer price inflation differential between the home country and trading partners.

[3] See IMF (2006a).

approach, including the seminal work by Edwards (1989). While there are advantages and disadvantages to either approach, this paper focuses exclusively on the BEER approach.[4]

The MB approach is based on econometric estimates of the impact of a set of fundamental variables on the external current account. Equilibrium in this framework is defined as the level of current account ("current account norm") that would be consistent with the levels of these fundamentals projected over the medium term. In advanced economies, for example, current account norms are often related to, among other factors, the achievement of potential output. They are then translated into the level of real exchange rate that would bring about the required adjustment in the current account to reach its norm. Such translation requires the estimation of relatively stable trade elasticities—an avenue that has provided some useful results so far in the empirical literature for low-income countries.[5]

The alternative BEER approach directly estimates the structural relationship between economic fundamentals and the ERER. In the seminal work by Edwards (1989, 1994), the ERER is defined as the relative price of tradables to nontradables that, all else equal, results in the simultaneous attainment of internal and external equilibrium. Internal equilibrium is defined in the model as the clearing of all nontradable markets (static equilibrium). External equilibrium is attained when the net present value of future current accounts is nonnegative, given the level of exogenous long-run capital inflows (dynamic equilibrium). These two equilibrium conditions identify a unique ERER,[6] which can be estimated empirically on the basis of the following reduced form equation:

$$\log(e_t) = \gamma_0 + \sum_{j=1}^{r} \gamma_j \log(FUND_{jt}) + (1-\theta)\log(e_{t-1}) - \sum_{k=1}^{s} \lambda_k (Z_{kt} - Z_{kt}^*) + v_t \qquad (1)$$

where all variables are in logarithms, e_t is the real exchange rate, $\{FUND_{it}\}$ is a set of fundamental variables, $\{Z_{kt}\}$ is a set of policy variables (which may deviate from the variables that are consistent with the medium-term equilibrium Z_{kt}^*), and v_t is an error term. This is a dynamic autoregressive function that requires the use of time-series estimation techniques .[7] The rest of this paper uses this reduced form equation to derive an ERER for SSA countries.

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[4] A third approach, the external sustainability approach, has recently been proposed (see Lane and Milesi-Ferretti (2006)), and has not yet found its way in the empirical literature for low-income countries. In addition, Johnson, Ostry, and Subramanian (2006) have shown that analyzing cross-sectional price levels, based on the Balassa-Samuelson principle over long horizons, can also yield a useful tool for estimating misalignments in low-income countries.

[5] Empirical applications of the MB approach include Debelle and Faruquee (1995), Isard and Faruqee (1998), and Chinn and Prasad (2003). Khan and Ostry (1991) provide panel data estimates of the elasticities of terms-of-trade shocks and changes in commercial policies to the ERER in a static model.

[6] A formal summary of the model is available in Edwards (1994).

[7] The optimal number of lagged terms for the explanatory variables can be determined through econometric techniques, allowing for possibly richer short-run dynamic behavior than predicted by the original Edwards (1994) model.

The question at the heart of our analysis is what set of fundamentals is relevant for determining the ERER of low-income African countries. While most estimations of currency misalignments in low-income, emerging, and advanced economies are similar, low-income African countries have several unique features that affect the choice of fundamentals. First, capital markets are less advanced, and cross-border capital flows tend to be limited or heavily restricted. Hence, unlike in the case of emerging and advanced economies, the real interest rate differential is unlikely to play a significant role. Second, low-income countries tend to be heavily indebted, with debt service and/or official grants constituting a sizable fraction of GDP. Both debt service and official grants are likely to have an impact on the real exchange rate determination, as they impact the underlying foreign exchange rate flows that determine the ERER. Third, because low-income SSA countries tend to be commodity exporters with only a small share of manufacturing exports, world prices of certain commodities are likely to affect both the external current account and the equilibrium real exchange rate.

Most of the literature has focused on the set of fundamental variables that determine the ERER. Drawing on existing theoretical models (Edwards 1989, 1994; and Hinkle and Montiel 1999), Box 1 lists the likely determinants of ERER in low-income SSA countries and briefly highlights how each may impact the ERER.

III. Empirical Applications to Low-Income Countries

Although empirical applications of Edwards' model and subsequent revisions to developing countries have yielded generally meaningful results, relatively few papers have applied the model to SSA countries. Notable exceptions are Edwards and Ostry (1990, 1992), Ostry (1988) and Ostry and Reinhart (1992). Hinkle and Montiel (1999) provide an overall overview of estimating equilibrium real exchange rates in developing countries. For the specific case of SSA, Ghura and Greenes (1993) present panel estimation for 33 SSA countries. They find that high levels of misalignment between the real exchange rate and the ERER are associated with periods of macroeconomic instability, while lower levels of misalignment correspond to better economic performance. The results of Elbadawy (1994), who applies a simplified framework of Edwards' model to Chile, Ghana, and India, reveals a similar association between misaligned real and equilibrium exchange rates and weak economic performance. More recent research on growth accelerations (Haussman et al., 2005) shows that a real exchange rate overvaluation appears to be one factor that makes it difficult to sustain growth spurts.

Box 1: ERER Determinants for Developing Countries

- The external ***terms of trade*** (*tot*), defined as the ratio of the price of a country's exports over the price of its imports. Most African countries mainly export primary commodities, such as oil, lumber, metals, and diamonds, and/or agricultural products (e.g., coffee and cocoa). The price for these primary commodities is determined in world commodity markets and subject to significant volatility affecting the terms of trade. An improvement in the terms of trade will positively affect the trade balance, and thus lead the ERER to appreciate.

- **Productivity** relative to foreign trading partners, proxied by total factor productivity (tfp), where available, or relative per capita real gdp (*gdp*). Developments in relative productivity capture well-known Balassa-Samuelson effects. Countries with higher productivity growth in the tradables sector (where such growth tends to concentrate) can sustain an ERER appreciation without losing competitiveness.

- **Government consumption** as a share of GDP relative to that of foreign trading partners (*gov*). An increase in government consumption biased toward nontradables creates higher demand for nontradables (relative to the tradable sector). This greater demand boosts the relative prices of nontradable goods, causing the equilibrium real exchange rate to appreciate. However, if the increase in overall government consumption is biased toward the tradable sector, an increase in spending will cause the ERER to depreciate.

- The severity of trade restrictions, proxied by **openness to trade** (*open*). Openness to trade is defined as the sum of exports plus imports as a share of GDP. Protection of domestically produced goods via restrictions on cross-border trade (e.g. import tariffs and nontariff barriers) leads to higher domestic prices and thus ERER appreciation. Consequently, lifting existing trade restrictions (proxied by an increase in openness to trade) should cause the ERER to depreciate.

- The ratio of **investments** to GDP (*invs*) relative to that of foreign trading partners. Investments in low- and middle-income countries have high import content and thus a direct negative impact on the trade balance. Because this variable may also capture technological progress, its overall impact on the ERER is ambiguous.

- **Debt service** as a share of exports (*ds*). An increase in debt service payments leads the external balance to deteriorate; thus, subsequent price adjustments should restore equilibrium. Higher debt service payments should therefore cause the ERER to depreciate.

Box 1 (concluded): ERER Determinants for Developing Countries

- **Net foreign assets** as a share of GDP (*nfa*), a proxy for the country's net external position. An increase in capital inflows from abroad implies higher demand for domestic currency, thus causing the ERER to appreciate.

The following variables, which are not included in the empirical estimations owing to data limitations, could also have a significant impact on the real exchange rate in developing countries:

- **Aid flows** as a share of exports. Similar to debt service payments, aid flows can represent a significant fraction of GDP in low-income countries. An increase in aid flows improves the external balance and thus causes the ERER to appreciate.

- **Controls over capital flows**. Similarly to tightening restrictions on the movement of goods across borders, easing controls on capital flows could impact the ERER. The direction of this impact depends on (i) how much the real interest rate in the domestic economy differs with those of its foreign trading partners and (ii) the country's risk profile.

- **Fiscal and monetary policy**. In Edwards' model, both fiscal and monetary policies affect the real exchange rate. However, it is not clear whether changes in macroeconomic policies have a long-run impact on the ERER.

The increased focus on exchange rate assessments in Fund surveillance has led to a number of empirical studies, including for some African countries. For example, according to Mongardini (1998), debt relief significantly affected Egypt's equilibrium real exchange rate in the first half of the 1990s. Cerra and Saxena (2000) show that India's current account deficit and investor confidence played a key role in the 1991 currency crisis. For SSA countries, Mathisen (2003) finds that Malawi's ERER was positively related to the terms of trade, government spending (excluding wages and salaries), per capita GDP growth, and investment. In addition, misalignments between the real exchange rate and the ERER were relatively short lived (11 months). A more recent paper by Saadi-Sedik and Petri (2006) shows the importance of official external grants in the determination of the ERER for Jordan. The paper also stresses the sensitivity of the misalignment results to smoothing techniques, which introduce an element of potential bias in interpreting the results. The authors therefore argue that less smoothing is preferable in developing countries.

The estimation of ERERs has more recently found its way into the Fund's operational work. For example, estimates of the U.S. ERER, recently published in the 2006 Article IV staff report for the United States, showed a significant misalignment between the U.S. dollar and the ERER. In SSA countries, according to a recent selected issues paper for the Central African Economic and Monetary Union (CEMAC) (IMF 2005), the real effective exchange rate for the region is broadly in line with its ERER. In addition, the CEMAC paper finds relatively slow mean reversion (a half life of nine years), suggesting there are rigidities in relative prices. For the West African Economic and Monetary Union (WAEMU), a more recent selected issues paper (IMF 2006) finds that the ERER misalignment for the region is marginal and the set of fundamentals different from the CEMAC region. Finally, a paper by Abdih and Tsangarides (2006) summarizes these findings by showing that mean reversion to equilibrium is twice as fast in West African Monetary Union (WAEMU) than in CEMAC, while both regions were broadly in line with their ERERs in 2005. The paper also identifies differences between CEMAC and WAEMU long-run elasticities, which can be extended to imply differences in the fundamentals' marginal impacts between oil (CEMAC) and non-oil (WAEMU) producers (see below).

IV. Data Issues and Econometric Methodology

Limited data availability hinders the estimation of the ERER in SSA countries. Reliable data are available only since 1980 for a subset of countries. Eritrea, Liberia, Lesotho, Sao Tomé and Principe, and Zimbabwe are excluded from the analysis. Botswana and South Africa are also excluded because of the predominance of capital flows in determining the ERER. That leaves 39 SSA countries with yearly data spanning the 1980–2005 period (though not all the variables in Box 1 are available for each country or for the entire period).[8] The econometric methodology for the single-country estimations is summarized in Box 2. Following the recommendation in Saadi-Sedik and Petri (2006), the fundamentals are not smoothed to avoid influencing the misalignment results in an arbitrary fashion.

One additional complication in the determination of a meaningful measure of misalignment could arise from abrupt changes in the real exchange rate associated with trade liberalization, the lifting of capital controls, or the elimination of multiple exchange rate practices. The use of an HP filter on the RER data for the 39 SSA countries in the sample suggests that abrupt changes were mostly associated with changes in the exchange rate regime (e.g., the 1994 CFA devaluation) or large shocks to the economy (e.g., the famine in Ethiopia in 1984), which can be accounted for in the econometric estimations below. Trade liberalization is also captured through the explanatory variable on trade openness, which turns out to be highly significant in virtually all regressions.

V. Estimation Results: Single-Country Approach

Following the methodology described above, the estimation results are derived using the model that best fits the data. Every possible combination of four variables is estimated for each country in the sample, yielding 70 possible specifications for countries for which all eight fundamental determinants are available. For each specification, the optimal lag structure is also determined through a search procedure. The models are then ranked according to the following criteria:

[8] The constructions of variables and data sources are described in Table A1 in the Appendix. Table A2 provides details on data availability.

Box 2. Econometric Methodology for Single-Country Estimations

The relatively short sample period (only 26 yearly observations) presents serious challenges to estimating the ERER using single-country estimation techniques. First, equation (1) cannot be reliably estimated with all eight potential ERER determinants defined in Box 1. Data limitations impose, at most, four dependent variables for reliable statistical inference.[9] Thus, the traditional approach of using a general-to-specific estimation strategy cannot be applied here.

Second, the short sample period makes the variables' order of integration uncertain, as it is well known that unit root tests for short samples perform very poorly. Typical econometric techniques (such as Johansen's cointegration tests) require knowing whether or not the variables are stationary and are thus subject to the above-mentioned uncertainty.

To address these challenges, the following econometric methodology is used in this paper. First, to estimate the long-run relationship between the fundamental determinants and the real exchange rate, we follow the bound-testing approach developed by Pesaran, Shin, and Smith (2001). This methodology, which tests for a long-run relationship between the real exchange rate (e_t) and fundamentals ($FUND_{it}$) in equation (1), is independent of whether the variables are stationary, integrated of order one, or a mixture of the two. Furthermore, small-sample performance of the bound-testing approach has been shown to be superior to the conventional Johansen cointegration test.

Second, we use an Autoregressive Distributed Lag Modeling approach (ARDL) pioneered by Pesaran and Shin (1999). The ARDL has superior small sample performance and provides a correct inference regardless of the variables' order of integration. Mongardini (1998) uses a similar modeling strategy for the estimation of currency misalignment. Other estimation techniques (Johanssen's cointegration test and vector error-correction model) are then used as robustness checks.

1. bound test of the level relationship (modified F-test) between the ERER and the fundamentals;

2. the number of statistically significant long-run elasticities at a 5 percent significance level; and

3. the number of correct signs of the coefficient, as predicted by the Edwards model.

[9] This problem is common in the ERER literature, especially for developing and transition economies.

Based on these rankings, only a few single-country estimation results pass all three tests (Table 1).[10] These results suggest that single-country ERER estimations are unlikely to yield robust estimates of exchange rate misalignments for SSA countries in the given sample. More specifically:

- Only 11 out of the 39 sample countries have a combination of fundamental determinants that pass all three criteria.

- In 3 of the 11 countries, the estimation results do not provide a single model that is economically and statistically significant; as many as 3 potential models may fit for these countries. Further economic analysis based on other empirical evidence would be required to determine which one of these models is the relevant one for the estimation of the ERER.

- Even for the eight countries with a unique preferred combination of fundamentals, the estimations are generally sensitive to time-period selection and variable specification. For example, the preferred model for Ethiopia using data for 1980–2005 is[11]

$$ERER_{ETH} = \underset{(8.4)}{45\%} \cdot tot + \underset{(5.3)}{56\%} \cdot gov - \underset{(-7.9)}{107\%} \cdot inv - \underset{(-3.8)}{29.7\%} \cdot ds + const \quad (2)$$

  After expanding the sample by two years (i.e., starting in 1978) and replacing the *gdp* variable with a better proxy for the Balassa-Samuelson effect—relative total factor productivity (*tfp*)—the model with the best fit (according to the criteria described above) becomes:

$$ERER_{ETH} = \underset{(2.3)}{26\%} \cdot tot - \underset{(-3.2)}{45\%} \cdot opn + \underset{(4.4)}{102\%} \cdot tfp + \underset{(2.9)}{55.6\%} \cdot gov + const \quad (3)$$

[10] The authors have developed an econometric template to estimate single-country equations for the operational work of the Fund in SSA countries, based on the methodology discussed in this paper. A copy of the econometric template is available on request from the authors.

[11] The equation shows only the long-run impact of the fundamentals on ERER. The full ARDL model is available upon request from the authors. Numbers in parenthesis are *t*-statistics. All variables are in logarithms.

Table 1: Single-Country Estimations: Model Selection

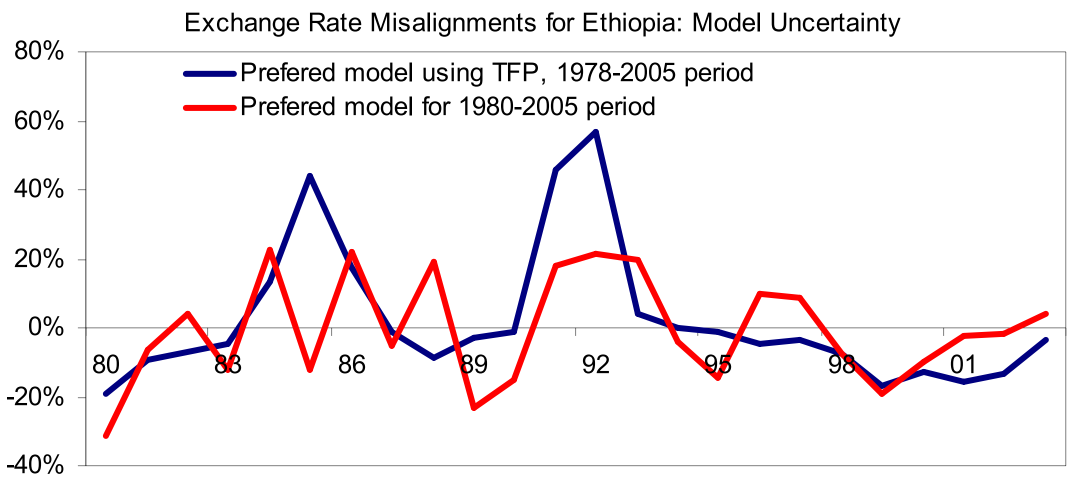
	# of fundamentals	# of models investigated	# of models passing LR relationship test (bound F-test)[1]	(share)	of which # of models with all implied L-R elasticities statistically significant[2]	of which: # of models with correct signs of LR elasticities.
Angola	7	35	11	31.4%	2	1
Benin	7	35	3	8.6%	0	0
Burkina Faso	8	70	10	14.3%	0	0
Burundi	8	70	2	2.9%	0	0
Cameroon	8	70	20	28.6%	3	1
Cape Verde	7	35	17	48.6%	2	0
Central African	7	35	3	8.6%	1	0
Chad	7	35	6	17.1%	0	0
Comoros	5	5	3	60.0%	0	0
Congo, Dem. Rep.	6	15	6	40.0%	2	1
Congo, Republic of	8	70	13	18.6%	3	1
Côte d'Ivoire	7	35	26	74.3%	1	1
Djibouti	5	5	2	40.0%	0	0
Equatorial Guinea	6	15	0	0.0%	0	0
Ethiopia	8	70	35	50.0%	1	1
Gabon	8	70	1	1.4%	0	0
Gambia, The	8	70	12	17.1%	0	0
Ghana	7	35	12	34.3%	0	0
Guinea	8	70	26	37.1%	3	3
Guinea-Bissau	7	35	0	0.0%	0	0
Kenya	8	70	31	44.3%	2	1
Madagascar	8	70	10	14.3%	0	0
Malawi	8	70	19	27.1%	1	1
Mali	8	70	3	4.3%	0	0
Mauritius	8	70	22	31.4%	0	0
Mozambique	7	35	8	22.9%	1	0
Namibia	7	35	1	2.9%	0	0
Niger	7	35	10	28.6%	0	0
Nigeria	8	70	11	15.7%	1	0
Rwanda	7	35	8	22.9%	1	0
Senegal	8	70	47	67.1%	1	0
Seychelles	8	70	10	14.3%	0	0
Sierra Leone	8	70	10	14.3%	0	0
Sudan	6	15	5	33.3%	0	0
Swaziland	7	35	17	48.6%	0	0
Tanzania	8	70	25	35.7%	0	0
Togo	8	70	51	72.9%	3	3
Uganda	6	15	14	93.3%	0	0
Zambia	8	70	42	60.0%	3	3
Average:		49	14	30.4%	0.8	0.4

[1]F-test refers to bound testing approach to the analysis of level relationship developed by Pesaran, Shin and Smith (2001).
[2]Long-run elasticities were derived from more parsimonious ARDL specification. All combinations of lags up to 2 for real exchange rate and up to 1 for each explanatory variable were estimated and the best model according to the Schwartz-Bayesian criterion was chosen. About 92,400 different regressions were computed in the estimation stage alone.

The estimated exchange rate misalignments based on models (2) and (3) are plotted in Figure 1.[12] While both predict a similar alignment of the RER to its equilibrium level in 2003, the two models have a fundamental difference, a finding that demonstrates the model's uncertainty and highlights the sensitivity of the results to the selected sample. While using the longest possible time period is ideal, the historical data before 1980 contain large measurement errors, and the comparability of earlier data and more recent data is questionable.

These caveats notwithstanding, most estimations that pass the above criteria show similar characteristics. Indeed, for most, three variables—terms of trade (*tot*), productivity (*tfp*), and openness *(open*)—are significant consistently throughout different model specifications. In certain cases, government consumption (*gov*) is also significant. This findings points to commonalities that could be exploited to improve the robustness of the estimation using panel techniques.

Figure 1. Exchange Rate Misalignments for Ethiopia



To conclude, single-country estimations for SSA countries are not likely to provide robust evidence to determine exchange rate misalignments. More thorough empirical investigation and robustness analysis could yield promising results for some countries;[13] however, the uncertainty associated with data limitations is, in general, substantial. Moreover, though a longer time period would yield more observations, the use of pre-1980 data, which are of questionable quality, would likely distort the regression results.

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[12] Results are shown only up to 2003, as further analysis is needed to identify more recent levels of misalignment.

[13] For example in the case of Ethiopia, model (1) appears to be quite robust to the selection of different estimators (fully modified OLS and dynamic OLS), and the Johansen cointegration tests confirm existence of unique cointegrating vector at a 1 percent significance level. For more details on the analysis of Ethiopia's real exchange rate, see Chudik and Gilmour (2007).

VI. Estimation Results: Panel Evidence

Panel estimations can circumvent the limitations of single-country estimations by exploiting the commonalities across countries. For SSA countries, for example, heavy reliance on commodity exports implies a similarly strong long-run relationship between the terms of trade and the equilibrium real exchange rate across countries. We therefore pool countries, assuming that the long-run elasticities are homogenous, while allowing short-run dynamics to differ across countries. The assumption that countries have homogenous long-run elasticities is then tested to see if pooling is statistically sound. The drawback of panel techniques is that country-specific idiosyncrasies may be lost, even if the homogeneity test is not rejected. Box 3 describes the econometric methodology for the panel estimations.

Box 3. Econometric Methodology for Panel Estimation

The first step in the panel approach is to conduct unit root tests to determine the order of integration. For the SSA sample, the results in the Appendix (Table A3) suggest that all variables can be treated as integrated of order 1. Some uncertainty also surrounds the order of integration of relative government consumption; only two of the six panel unit root tests argue in favor of nonstationarity.

Second, three different econometric techniques are used to estimate the panel's long-run elasticities: (1) the Pooled Mean Group (PMG) estimator proposed by Pesaran, Shin, and Smith (1999); (2) the Fully-Modified OLS (FMOLS) estimator proposed by Pedroni (2000); and the Panel Dynamic OLS (PDOLS) estimator by Mark and Sul (2003). The PMG, which is based on the ARDL approach, is a maximum likelihood estimation technique, while FMOLS and PDOLS are based on a modified least squares. These panel estimation techniques also treat heterogeneous short-run dynamics differently. There is currently no paper available studying intensively and conclusively the small-sample properties of these estimators, but in a time series context, the Monte Carlo simulation by Pesaran and Shin (1997) suggests that the small-sample properties of the ARDL outperform those of the FMOLS procedure, a finding that is likely to be reinforced in a panel framework. The treatment of short-run dynamics in the DOLS estimation technique suggests that DOLS is not likely to perform well in panels with short time periods. In addition, following Pedroni (2000), four cointegration tests (panel PP and ADF tests, and group PP and ADF tests) are conducted to check for a long-run relationship between the ERER and the fundamentals.

Finally, we test the homogeneity assumption underlying the data pooling. The Hausman (1978) test compares pooled mean group estimates with mean group estimates. If the null hypothesis is rejected, one can infer that the panel is too heterogeneous to be pooled. On the other hand, if the Hausman test is not rejected, the countries in the panel are homogenous enough from a statistical perspective to assume common long-run elasticities.

A. Estimation Results

The selection of the proper set of fundamentals poses the same problem as in single-country estimations. Owing to the short time period, no more than four to five explanatory variables can be used for reliable inference. In view of the above results, and considering the nature of SSA economies, the following three fundamentals are always included in the regressions: terms of trade, openness, and productivity (proxied here by real per capita GDP relative to foreign trading partners). Regarding the remaining five fundamentals, all possible sets of explanatory variables consisting of four (*tot*, *opn*, *gdp* plus one remaining variable) and five (*tot*, *opn*, *gdp* plus two remaining variables) fundamentals were constructed, and the corresponding models were estimated. In all cases, only balance panels—i.e., panels in which all country data series had the same starting and ending periods—were used to estimate the cointegrating vector under the three estimation techniques.[14]

The assumption of homogeneity of all long-run relationships is found to be violated in the panel that includes all countries with available data.[15] As an example, the estimation results for the panel featuring *tot*, *opn*, *gdp,* and *gov* as explanatory variables (36 countries have available data) are presented in Table A5 in the Appendix. The Hausman test strongly rejects long-run homogeneity, implying that the 39 SSA countries are too heterogeneous to be pooled. This result likely reflects the fact that ERERs in oil importing countries would respond differently to oil price shocks than would those in oil producing countries. It therefore seems reasonable to split the panel into two subgroups: 32 oil-importing countries and 7 oil producing countries (Angola, Cameroon, Republic of Congo, Côte d'Ivoire, Equatorial Guinea, Gabon, and Nigeria).[16]

Estimation Results for Oil-Importing Countries

The panel of oil-importing countries shows enough similar characteristics to warrant pooling. The Hausman test for the long-run homogeneity is generally not rejected, and panel cointegration tests generally confirm the existence of a cointegrating vector (Table A5 in Appendix). In addition, the models with four and five explanatory variables commonly have at least three statistically significant nonstationary regressors. Panel cointegration tests alone provide only weak guidance for model selection.[17]

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[14] The PDOLS estimation procedure by Mark and Sul (2003) does not allow for unbalanced panels. Furthermore, the inclusion of countries with data for a very short time frame does not necessarily improve the PMG estimates.

[15] In most cases, the Hausman test rejects the null of homogeneity.

[16] Chad and Sudan are included in the group of non-oil exporters, as they only recently started to export oil. Côte d'Ivoire is included as an oil exporter, reflecting its large oil refinery, as well as its relatively small oil production since the 1980s.

[17] Half-life statistics corresponding to the average speed of mean reversion of real exchange rates is 3.2 years. If only *gdp* is included as an explanatory variable, the half-life of misalignments drops to 2.8 years, and 16 of the countries remain above the 3.2-year benchmark.

Models with Four Fundamental Determinants

The panel evidence confirms the significance of a similar set of fundamental determinants as in the single-country estimations. The ranking of the estimation results for models with four explanatory variables suggests the following preferred combination of fundamentals: *tot*, *opn*, *gdp,* and *gov*. This combination yields statistically significant estimates of a cointegrating vector for both PMG and FMOLS estimators (Table 2). The signs for the long-run coefficients are in line with theory, and the Hausman test does not reject the assumption of long-run homogeneity. Not surprisingly, the PDOLS estimator does not perform very well; however, the magnitude and signs of the PDOLS coefficients are broadly in line with the PMG and FMOLS estimations. The half-life corresponding to the average speed of the mean reversion to the estimated equilibrium declines further, to 2.2 years.

Table 2: Estimates of Cointegrating Vector for Balanced Panel of Non-Oil Exporting Countries

					Including incidental trends:	
		PMG	FMOLS	PDOLS	PMG	PDOLS
Tot		0.186	0.138	0.154	0.264	0.145
	t-ratio	6.2	2.7	0.5	6.9	1.3
Open		-0.473	-0.421	-0.496	-0.54	-0.488
	t-ratio	-11.4	-15.8	-1.9	-15.0	-4.4
Gdp		1.047	0.531	0.368	0.604	0.291
	t-ratio	18.3	7.8	1.3	6.4	1.8
Gov		0.277	0.0704	0.058	0.298	0.028
	t-ratio	5.4	4.2	0.2	6.5	0.2
Hausman test:		2.32			3.73	
p-value		0.68			0.44	

Sample: 1980-2005 Number of Countries: 28 728 observation per variable

Notes: PMG refers to pooled mean group estimator developed by Pesaran, Shin and Smith (1999). FMOLS refers to the fully modified OLS estimator by Pedroni (2000) and PDOLS refers to the panel dynamic OLS estimator by Mark and Sul (2002).

As an additional robustness check, we re-estimate the model to include incidental trends (i.e., heterogeneous linear trends). The findings are encouraging: the estimated long-run elasticities are still significant and close to the original PMG estimates with one exception (*gdp's* elasticity drops from 1.05 to 0.60). The heterogeneous country-specific trend can also serve as a crude proxy for potentially omitted variables.

The estimated long-run elasticities are broadly in line with the literature summarized in Hinkle and Montiel (1999). Gilles and Yehoue (2005) employ similar dynamic panel estimation techniques in a sample of 64 countries. In their sub-sample of 28 low-income countries, the estimated elasticities are in the range of 0.05 to 0.27 for terms of trade, -0.71 to -0.23 for openness, 0.12 to 0.34 for productivity proxied by GNP per worker, and government consumption is found to be significant only in one model with the corresponding elasticity of 0.10. Interestingly, estimates of the long-run impact of the fundamentals on ERER for low-income countries are not that much different from advanced and transition economies. Kim and Korhonen (2005) use data from 29 middle and high-income countries spanning 25 years, and estimate long-run elasticities in the range of (0.41, 0.82) for real GDP per capita, (0.07,0.44) for government consumption and (-0.82, -0.36) for openness.[18]

The panel estimates also confirm the well-known result that changes in productivity have the largest impact on the ERER (Table 3). On average, SSA countries experienced an ERER depreciation of 2.5 percent over the sample period (1980-2005). Changes in productivity (GDP) contributed 61 percent of this equilibrium depreciation, followed by trade liberalization (Open) with 18 percent, changes in terms of trade (ToT) with 13 percent, and changes in government consumption with 8 percent.

Table 3: Average Annual Change in ERER and Contributions from Fundamentals

		Contribution to average annual equilibrium RER appreciation (in percentage points)[19]:			
Average realized annual RER appreciation	Average annual estimated equilibrium RER appreciation	ToT	Open	GDP	Gov
-2.2%	-2.5%	-0.32	-0.44	-1.54	-0.21
		Average observed annual change in:			
		ToT	Open	GDP	Gov
		-1.7%	0.9%	-1.5%	-0.7%

Notes: Period 1980-2005, 28 oil importing countries. PMG estimates of long-run elasticities are used.

Models with Five Fundamentals

There is a trade-off between having a more parsimonious specification—which risks omitting important variables—and a larger set of fundamentals—which risks producing a more imprecise estimation. Pedroni's panel cointegration tests does not resolve this problem, as the results appear to be biased toward selecting fewer explanatory variables in the samples with a short time dimension.

[18] The fourth explanatory variable utilized by Kim and Korhonen (2005) is investments represented by the share of gross fixed capital formation as a percentage of GDP. Corresponding estimated long-run elasticity lies in the range (0.09, 0.17)

[19] The contribution of a fundamental variable to the average change in the ERER is calculated by multiplying the average of the observed change in the fundamental variable by its corresponding long-run elasticity. For instance, in the case of terms of trade (ToT), the average 1.7 percent deterioration in ToT is multiplied by the corresponding long-run elasticity of 0.186 (PMG estimate from Table 2), which yields a 0.32 percentage points contribution to average ERER depreciation of 2.5 percent. The ToT therefore explains 13 percent of the average ERER depreciation. The sum of the contributions from all the fundamental variables equals the average ERER depreciation.

The preferred five-variable model features *tot*, *opn*, *gdp*, *gov,* and *ds*. Only 19 countries have available data. Again, only the estimates using the PMG and FMOLS methodology are statistically significant (Table 4). The signs of the coefficients are in line with theory, and the Hausman test does not reject the long-run homogeneity at a 5 percent confidence level. The estimated long-run impact of these fundamentals is also robust to specifications that include incidental trends (Table 4). As suggested by comparing Tables 2 and 4, estimated long-run elasticities for *tot*, *opn*, *gdp,* and *gov* are similar, suggesting an underlying relationship that is robust to different model specifications. The largest difference is for the long-run impact of government consumption, where the elasticity increased from 28 percent to 53 percent.

Table 4: Estimates of Cointegrating Vector: Preferred Five-Variable Model

					Including incidental trends:	
		PMG	FMOLS	PDOLS	PMG	PDOLS
Tot		0.258	0.137	0.060	0.401	0.067
	t-ratio	5.5	5.1	1.4	9.6	1.4
Opn		-0.456	-0.488	-0.686	-0.587	-0.679
	t-ratio	-7.4	-13.2	-8.9	-15.4	-8.9
Gdp		0.986	0.355	0.412	0.441	0.376
	t-ratio	10.4	4.3	7.2	4.4	6.2
Gov		0.535	0.108	0.189	0.027	0.163
	t-ratio	7.7	4.1	1.9	5.2	1.6
Ds		-0.328	-0.22	-0.526	-0.311	-0.512
	t-ratio	-4.6	-4.4	-7.9	-7.5	-7.0
Hausman test:		9.2			6.27	
p-value		0.11			0.28	

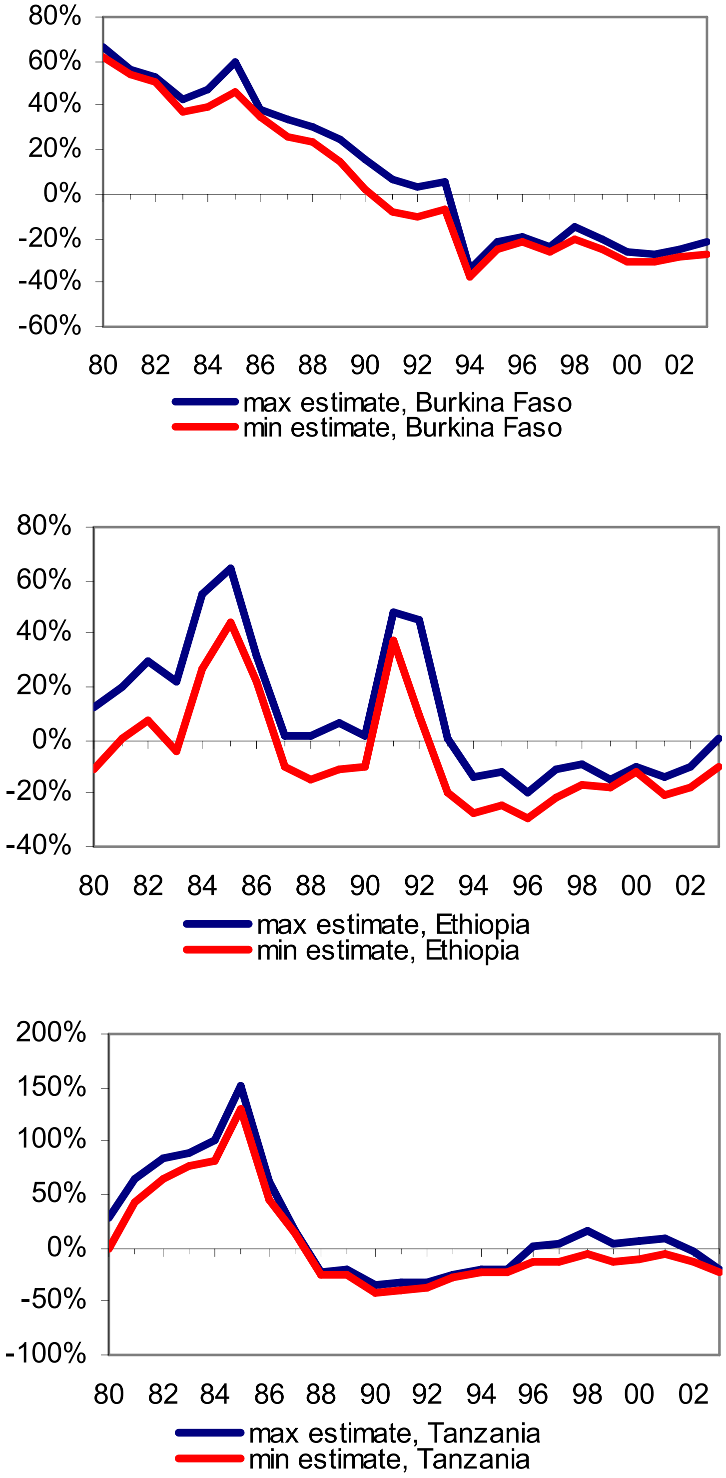
Sample: 1980-2005 Number of Countries[20]: 19 494 Observation per variable

Notes: PMG refers to pooled mean group estimator developed by Pesaran, Shin and Smith (1999). FMOLS refers to the fully modified OLS estimator by Pedroni (2000). PDOLS refers to the panel dynamic OLS estimator by Mark and Sul (2002).

The minimum and maximum estimates of RER misalignments across all specifications in Table 2 (models with 4 fundamentals) and Table 4 (five fundamentals) are plotted in Figures 2 and 3 for three countries in the sample, namely Burkina Faso, Ethiopia, and Tanzania. Further analysis on the rest of the sample is required before a meaningful statement on their ERER misalignment can be made.

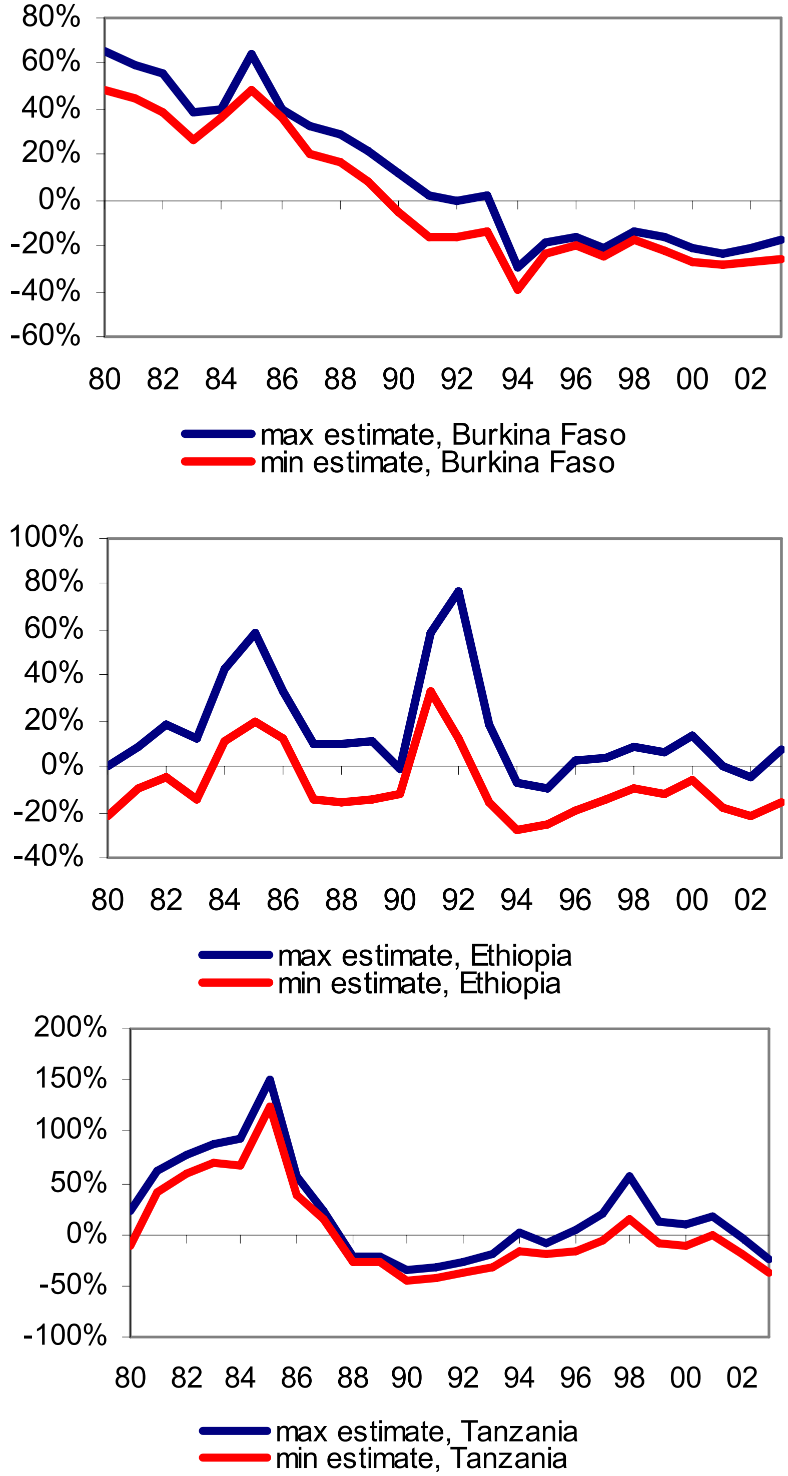
[20] Countries that have enough data are: Burkina Faso, Burundi, Ethiopia, The Gambia, Guinea, Guinea-Bissau, Kenya, Madagascar, Malawi, Mali, Mauritius, Namibia, Senegal, Seychelles, Sierra Leone, Tanzania, Togo, Zambia, and Mozambique.

Figure 2: Exchange Rate Misalignments for A Sample of Non-Oil Exporting Countries (4 variables)[21]



[21] The minimum and the maximum estimates of RER misalignments are constructed from models presented in Table 4.

Figure 3. Exchange Rate Misalignments for A Sample of Non-Oil Exporting Countries (5 variables)[22]



[22] The minimum and the maximum estimates of RER misalignments are constructed from models presented in Table 4.

The econometric results above capture some interesting historical features that give credence to the results, although they would need to be followed up with country-specific models to draw more definite conclusions:[23]

- For Burkina Faso, the policy of structural reforms adopted since the mid 1980s in the context of CFA monetary union led to an appreciation of the ERER, which in turn helped realign the RER to its equilibrium level by the early 1990s. The 1994 CFAF devaluation resulted in an undervaluation that has broadly persisted until 2003. More qualitative assessments by Fund staff concur with the undervaluation immediately following the 1994 devaluation, but suggest a broadly adequately valued level for Burkina Faso's real exchange rate in more recent years. The difference could be partly due to an inadequate intercept for Burkina Faso resulting from the panel estimation, which could bias the results towards an undervaluation. This would also be consistent with the generally accepted assessment that Burkina Faso's real exchange rate was still overvalued in 1994. A Burkina Faso specific analysis would thus be a useful area for further research.

- For Ethiopia, the two peaks in the RER overvaluation reflect the economic collapse associated with the famine of 1984-85 and the end of the Derg regime in 1991, while the official exchange rate had been held fixed to the U.S. dollar during the period 1973-92. The subsequent nominal devaluation of the birr and structural reforms to move to a market-oriented economy led to an undervaluation of the RER exchange that persisted up to 2003.

- For Tanzania, the economic adjustment program started in 1986 to dismantle socialist economic controls, devalue the Tanzanian shilling, and encourage more active participation of the private sector in the economy. This led to a gradual convergence of the RER to its equilibrium level in the second half of the 1980s. The RER has been fluctuating around its equilibrium level since the early 1990s.

Estimation Results for Oil Exporters

Estimations for the panel of oil exporting countries yields somewhat less reliable results because only 7 of the 39 countries are oil exporters. The short period and group dimensions also preclude the use of models with more than four explanatory variables. The panel cointegration tests cannot confirm the existence of a cointegrating relationship between the ERER and any combination of four fundamentals (Table 2A). Furthermore, many of the Hausman test results suggest that the panel may be too heterogeneous to justify pooling the data.

However, the inclusion of the real price of oil (deflated by US CPI) as a fundamental determinant minimizes some of these analytical limitations. In view of the different shares of oil production in GDP, the long-run elasticity coefficient is allowed to vary across countries (an assumption that can only be estimated using the PMG methodology). Therefore, the long-

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[23] For this reason, the results are shown only up to 2003.

run impact of oil prices is allowed to be country specific, while the elasticities on *tot*, *open,* and *gdp* are restricted to be homogenous over the long run. The cointegration tests confirm the existence of a long-run cointegrating vector, and the Hausman test does not reject the homogeneity assumption with the heterogeneous elasticity on oil.

The results of the estimation show limited robustness (Table 5). In the more parsimonious specification (with a maximum of one lag[24]), *tot*, *opn,* and *gdp* are significant, and the signs are in line with theory. The negative sign on the elasticity on the real price of oil for Cameroon and Congo reflects only the implied decomposition of the *tot* into oil- and non-oil exports. The overall impact for both countries of higher oil prices in real terms is still positive, given the weight of oil in the terms of trade. However, a richer lag structure seems to have a nonnegligible impact on the country-specific long-run elasticity of the real oil price in the case of Equatorial Guinea and Gabon. Thus, we conclude that, while the panel results are subject to less uncertainty than the single-country estimations, the results for oil exporting countries are not very robust, reflecting this group's small size and the panel's limited time dimensions.

Table 5: Estimates of Long-Run Elasticities for Oil Exporters

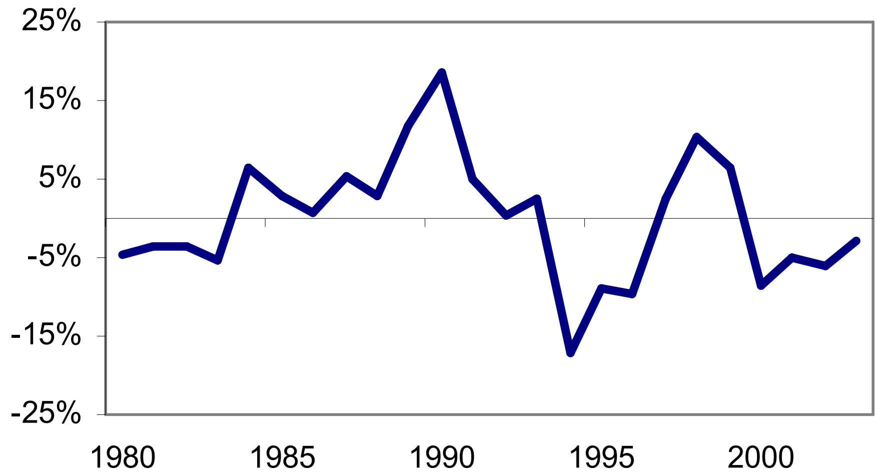
		PMG (max 1 lag)	PMG (1 lag)
Tot		0.23	0.247
	t-ratio	2.7	2.3
Opn		-0.207	-0.24
	t-ratio	-2.7	-2.4
Gdp		0.189	0.15
	t-ratio	2.5	1.4
Hausman test:		5.95	
p-value		0.11	
Country-Specific Long-Run Elasticity of Real Oil Price			
Angola		1.08	1.27
Cameroon		-0.08	-0.06
Congo, Republic of		-0.10	-0.14
Côte d'Ivoire		0.027	0.017
Equatorial Guinea		2.23	1.06
Gabon		0.60	-1.24
Nigeria		1.25	1.04
Sample: 1980-2005			
182 Observation per variable			
Number of Countries: 7			

Notes: PMG refers to Pooled Mean Group Estimator developed by Pesaran, Shin and Smith (1999).

[24] Selected by the Schwartz-Bayesian criterion.

The estimated misalignment for the Republic of Congo is shown in Figure 4 as an example.[25] The results show the gradual overvaluation of the real exchange rate brought about by the unsustainable fiscal policy of the 1980s. The abandonment of social planning in the early 1990s and the CFAF devaluation led to a significant undervaluation by 1994, which was partly reversed by 1997 through the negative effects on economic activity of the civil wars in 1993-97. Economic recovery, together with relatively prudent macroeconomic policies has led to broad convergence back to the ERER in recent years.

Figure 4. Exchange Rate Misalignment for the Republic of Congo



VII. Application for Countries with Limited Data: Out-of-Sample Estimation of Eritrea's ERER

The panel estimation techniques used here can be extended to derive estimates of the ERER for countries with limited data availability (Kim and Korhonen 2005). This extension involves assuming the same long-run elasticities as estimated in the panel and deriving a constant (γ_0) in equation (1) above from an estimated relationship between the panel's constant and average per capita GDP.

This extension is particularly useful for Eritrea, for which data are available starting only in 1992 (as it gained independence in 1991). Although excluded from the above estimations, Eritrea and other non-oil exporting SSA countries have similar economic characteristics, suggesting that the same long-run elasticities estimated in the panel can be applied to Eritrea. For the purpose of this exercise, we use the estimated elasticities from the model with four fundamentals (*tot, gdp, open, gov*) derived through the PMG methodology.

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[25] Min-max error bands cannot be constructed for the panel of oil producers, because there is only one statistically significant model of ERER. Again, results are shown only up to 2003.

The challenge is to determine the constant (γ_0) to derive the ERER for Eritrea. Using the panel data for the 39 countries, we estimate the following cross-sectional regression using a standard ordinary least squares technique:

$$\gamma_0 = 0.7965 - \underset{(12.0)}{0.00047}\, Y_i^{PPP} \tag{4}$$

which has an adjusted R^2 of 85 percent and a t-ratio on the coefficient for average GDP per capita (measured in U.S. dollars in purchasing power parity) of 12. The results suggest a very strong linear relationship (Figure 5). The resulting ERER for Eritrea suggests a significant overvaluation starting in 2000 (Figure 6).

Figure 5. Estimated Relationship between Constant and Average GDP per Capita in Panel

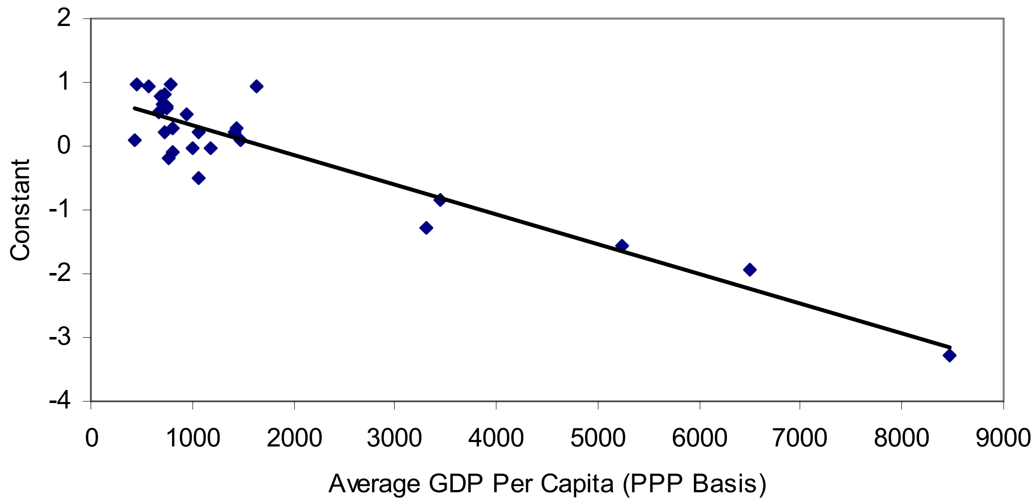
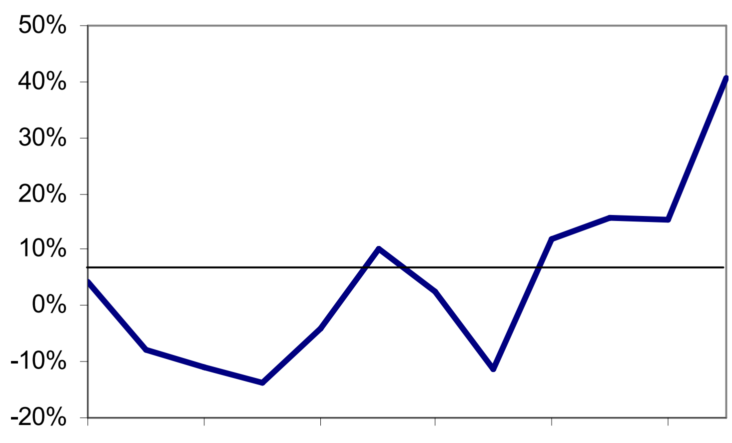


Figure 6. Estimated ERER Misalignment for Eritrea[26]



[26] Again, results are shown only up to 2003.

VIII. Conclusions

This paper provides a methodology to estimate the ERERs for SSA countries. Drawing on Edwards' (1989) seminal model, it derives a reduced-form equation and a set of fundamental ERER determinants. Owing to SSA countries' limited data availability, after deriving single-country estimations, we employ panel estimation techniques that assume the cointegrating (long-run) relationship between the ERER and its fundamental determinants is the same across SSA countries. This assumption is found to be valid for non-oil exporters and, to a lesser extent, for oil exporters (though it is rejected for the panel of 39 countries).

Appendix

Table A1: Construction of Variables

Variable	Logarithmic transformation	Description
rer	yes	Real Effective Exchange Rate (Consumer Price Index based). Data constructed from IMF EER facility. WEO data were used where full history was not available from EER facility.
tot	yes	Terms of trade: Ratio of Export and Import deflators. Source: WEO
open	yes	Openness to trade: Exports plus imports as a share of GDP. Source: WEO
gdp	yes	Real gross domestic product relative to weighted average of trading partners. Source: WEO
gov	yes	Government consumption as a share of GDP. Variable constructed relative to the weighted average of foreign trading partners. Source: WEO.
inv	yes	Investments as a share of GDP. Variable constructed relative to the weighted average of foreign trading partners. Source: WEO.
nfa	no	Net foreign assets as a share of GDP. Source: IMF IFS and WEO.
ds	no	Total debt service (interest and amortization paid) as a share of exports. Source: WEO.

Notes: WEO stands for World Economic Outlook database (summer 2006 version).
IMF IFS is International Financial Statistics published by IMF.

Table A2. Data Availability

		Sample: 1980-2005	rer	tot	open	gdp	gov	inv	nfa	fisc	ds
CFA Franc Zone	CEMAC	Cameroon	yes	yes	yes	yes	yes	yes	yes	yes	yes
		Chad	yes	yes	yes	yes	yes	yes	yes	yes	95-2005
		Congo, Republic of	yes	yes	yes	yes	yes	yes	yes	yes	yes
		Central African Rep.	yes	yes	yes	yes	yes	yes	yes	yes	85-2005
		Equatorial Guinea	yes	yes	yes	yes	yes	yes	85 -2005	yes	81-2005
		Gabon	yes	yes	yes	yes	yes	yes	yes	yes	yes
	WAEMU	Benin	yes	yes	yes	yes	yes	yes	yes	yes	93-2005
		Burkina Faso	yes	yes	yes	yes	yes	yes	yes	yes	yes**
		Côte d'Ivoire	yes	yes	yes	yes	yes	yes	yes	yes	no
		Guinea-Bissau	yes	yes	yes	yes	yes	yes	86 -2005	yes	yes**
		Mali	yes	yes	yes	yes	yes	yes	yes	yes	yes
ECOWAS		Niger	yes	yes	yes	yes	yes	yes	yes	yes	94-2005
		Senegal	yes	yes	yes	yes	yes	yes	yes	yes	yes**
		Togo	yes	yes	yes	yes	yes	yes	yes	yes	yes
	WAMZ	Gambia, The	yes	yes	yes	yes	yes	yes	yes	yes	yes
		Ghana	yes	yes	yes	yes	yes	yes	91 - 2005	yes	83-2005
		Guinea	yes	yes	yes	yes	yes	yes	yes	yes	yes**
		Nigeria	yes	yes	yes	yes	yes	yes	yes	yes	yes
		Sierra Leone	yes	yes	yes	yes	yes	yes	yes	yes	yes**
		Cape Verde	yes	yes	yes	yes	yes	yes	yes	yes	89-2005
		Liberia*	-	-	-	-	-	-	-	-	-

Notes: (*) Liberia has vare limited availability of data due to the civil war. Liberia does not feature in unbalanced panel estimations.
(**) Data were adjusted for outliers.

Sources: WEO, IFS and IMF staff estimates.

Table A2 (Concluded). Data Availability

Group	Sample: 1980-2005	rer	tot	open	gdp	gov	inv	nfa	fisc	ds
COMESA	Djibouti	yes	yes	90 - 2005	yes	yes	yes	84 - 2005	yes	90-2005
COMESA	Egypt *	-	-	-	-	-	-	-	-	-
COMESA	Ethiopia	yes	yes	yes	yes	yes	yes	yes	yes	yes**
COMESA	Eritrea	92 - 2005	92 - 2005	92 - 2005	92 - 2005	92 - 2005	92 - 2005	92 - 2005	92 - 2005	94 - 2005
COMESA	Sudan	yes	yes	91 - 2005	yes	yes	yes	yes	yes	91-2005
COMESA	Burundi	yes	yes	yes	yes	yes	yes	yes	yes	yes
COMESA	Rwanda	yes	yes	yes	yes	yes	yes	yes	yes	95-2005
COMESA	Comoros	yes	yes	82 - 2005	yes	yes	yes	82 - 2005	yes	92-2005
COMESA	Malawi	yes	yes	yes	yes	yes	yes	yes	yes	yes
COMESA	Zambia	yes	yes	yes	yes	yes	yes	yes	yes	yes**
COMESA	Zimbabwe (**)	-	-	-	-	-	-	-	-	-
COMESA	Mauritius	yes	yes	yes	yes	yes	yes	yes	yes	yes
COMESA	Seychelles	yes	yes	yes	yes	yes	yes	yes	yes	yes
COMESA	Madagascar	yes	yes	yes	yes	yes	yes	yes	yes	yes**
COMESA	Namibia	yes	yes	yes	yes	yes	yes	90 - 2005	yes	yes
COMESA	Swaziland	yes	yes	yes	yes	yes	yes	yes	yes	92-2005
COMESA	Angola	yes	yes	yes	yes	yes	yes	yes	95 - 2005	yes**
COMESA	Congo, Dem. Rep. of	yes	yes	yes	yes	no, 90 - 200	yes	no	yes	yes**
COMESA / EAC	Kenya	yes	yes	yes	yes	yes	yes	yes	yes	yes
COMESA / EAC	Uganda	yes	yes	yes	yes	yes	yes	80-86, 92-0	yes	91-2005
EAC	Tanzania	yes	yes	yes	yes	yes	yes	yes	yes	yes
	Mozambique	yes	yes	yes	yes	yes	yes	84-2005	yes	yes

Notes: (*) Egypt is excluded from the estimations as it does not belong to the group of low income countries.
(**) Hyperinflation Zimbabwe is excluded form analysis.

Sources WEO, IFS and IMF staff estimates.

Table A3: Single-Country Estimation of Long-Run Elasticities

	tot	**open**	**gdp**	**gov**	**inv**	**nfa**	**fisc**	**ds**
Cameroon	0.231	-0.357		0.266			-0.024	
t-ratio*	4.5	-3.3		2.2			-3.4	
Congo, Republic of			0.595	0.234			0.007	-0.277
t-ratio*			4.8	4.5			4.8	-3.8
Côte d'Ivoire		-0.420		0.469	-0.122	0.016		
t-ratio*		-3.0		5.4	-2.6	3.6		
Togo (model 1)		0.323	0.538			0.006		-0.405
t-ratio*		5.3	11.1			2.7		-2.9
Togo (model 2)		-0.474		1.003	0.244		0.018	
t-ratio*		-2.5		9.1	2.5		2.1	
Togo (model 3)		-0.412	1.094	0.566	0.230			
t-ratio*		-2.2	2.3	2.5	2.5			
Guinea	0.407	-1.045		1.357			0.019	
t-ratio*	3.5	-5.7		10.2			2.1	
Ethiopia	0.451			0.560	-1.065			-0.297
t-ratio*	8.4			5.3	-7.9			-3.8
Malawi		-1.046	0.825		0.277	0.009		
t-ratio*		-8.7	3.6		2.5	2.8		
Zambia (model 1)		-1.499	0.583			0.011	0.023	
t-ratio*		-5.3	4.3			4.9	2.9	
Zambia (model 2)		-1.976	0.448		0.204		0.038	
t-ratio*		-6.4	2.8		2.4		3.7	
Zambia (model 3)	0.684	-1.676			0.415		0.03	
t-ratio*	3.3	-5.4			3.4		4.1	
Angola			2.206	0.679	-0.488		0.024	
t-ratio*			15.1	2.2	-4.8		3.3	
Congo, Dem. Rep. of		-10026	0.706		-0.284		0.043	
t-ratio*		-5.0	5.4		-2.3		4.4	
Kenya	0.236				0.174	0.017		-0.387
t-ratio*	5.0				3.8	5.8		-6.4
Average elasticity:	0.402	-0.873	0.874	0.642	-0.041	0.012	0.020	-0.341

Notes: (*) Standard errors and corresponding t-ratios were not derived according to the asymptotic formula but by means of Bewley's regression. This approach is identical to the delta method. As suggested by Pesaran, Smith, and Shin (1999), standard errors estimated in this way have advantage that they are consistent in both **I**(0) and **I**(1) processes.

Table A4: First generation unit root tests

	RER					
	level		1st difference		2nd difference	
Method**	Statistic	Prob.*	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	-2.67	0.4%	-19.83	0.0%	-41.57	0.0%
Breitung t-stat	0.96	83.2%	-10.41	0.0%	-21.77	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-0.87	19.3%	-17.20	0.0%	-38.40	0.0%
ADF - Fisher Chi-square	90.60	19.6%	443.90	0.0%	959.49	0.0%
PP - Fisher Chi-square	85.32	32.1%	565.89	0.0%	3909.88	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	15.51	0.0%	-0.52	69.7%	1.46	7.2%

	ToT					
	level		1st difference		2nd difference	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t*	0.00	50.1%	-16.98	0.0%	-45.16	0.0%
Breitung t-stat	-0.28	38.8%	-9.03	0.0%	-16.27	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	1.10	86.5%	-13.67	0.0%	-41.37	0.0%
ADF - Fisher Chi-square	65.24	88.4%	396.17	0.0%	1044.38	0.0%
PP - Fisher Chi-square	75.11	63.4%	707.68	0.0%	4657.86	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	15.53	0.0%	1.04	14.8%	2.77	0.3%

Notes: (*) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

(**) See Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Maddala and Wu (1999), Choi (2001) and Hadri (1999) for details.

Table A4 (Continued …): First generation unit root tests

	open					
	level		1st difference		2nd difference	
Method**	Statistic	Prob.*	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	-0.51	30.6%	-17.81	0.0%	-51.11	0.0%
Breitung t-stat	-1.17	12.2%	-9.73	0.0%	-16.85	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-0.92	18.0%	-18.48	0.0%	-48.44	0.0%
ADF - Fisher Chi-square	96.94	9.6%	478.24	0.0%	1165.04	0.0%
PP - Fisher Chi-square	130.46	0.0%	767.24	0.0%	5376.55	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	13.85	0.0%	1.76	3.9%	3.04	0.1%

	GDP					
	level		1st difference		2nd difference	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t*	-4.83	0.0%	-7.67	0.0%	-40.11	0.0%
Breitung t-stat	2.63	99.6%	-5.05	0.0%	-13.96	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-0.09	46.3%	-8.20	0.0%	-37.62	0.0%
ADF - Fisher Chi-square	103.31	4.1%	246.28	0.0%	944.63	0.0%
PP - Fisher Chi-square	148.83	0.0%	477.53	0.0%	2990.64	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	20.87	0.0%	8.02	0.0%	4.09	0.0%

Notes: (*) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

(**) See Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Maddala and Wu (1999), Choi (2001) and Hadri (1999) for details.

Table A4 (Continued …): First generation unit root tests

	gov					
	level		1st difference		2nd difference	
Method**	Statistic	Prob.*	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	-2.03	2.1%	-21.24	0.0%	-45.19	0.0%
Breitung t-stat	-1.46	7.3%	-10.01	0.0%	-18.48	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-2.42	0.8%	-18.50	0.0%	-42.45	0.0%
ADF - Fisher Chi-square	124.06	0.1%	472.61	0.0%	1059.04	0.0%
PP - Fisher Chi-square	152.27	0.0%	648.26	0.0%	3967.66	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	13.85	0.0%	1.89	2.9%	-0.04	51.4%

	inv					
	level		1st difference		2nd difference	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t*	-0.64	26.1%	-21.37	0.0%	-51.20	0.0%
Breitung t-stat	-1.40	8.1%	-11.60	0.0%	-22.50	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-1.00	15.8%	-18.54	0.0%	-48.12	0.0%
ADF - Fisher Chi-square	99.80	6.6%	494.85	0.0%	1201.09	0.0%
PP - Fisher Chi-square	176.86	0.0%	842.79	0.0%	5243.09	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	12.93	0.0%	-1.45	92.6%	-3.59	100.0%

Notes: (*) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

(**) See Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Maddala and Wu (1999), Choi (2001) and Hadri (1999) for details.

Table A4 (Continued …): First generation unit root tests

	NFA					
	level		1st difference		2nd difference	
Method**	Statistic	Prob.*	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t	1.76	96.1%	-15.16	0.0%	-36.97	0.0%
Breitung t-stat	0.08	53.4%	-9.32	0.0%	-14.85	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	2.26	98.8%	-12.53	0.0%	-34.48	0.0%
ADF - Fisher Chi-square	63.84	90.7%	332.42	0.0%	868.90	0.0%
PP - Fisher Chi-square	75.07	63.5%	503.48	0.0%	3042.97	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	8.55	0.0%	8.01	0.0%	14.02	0.0%

	Fisc					
	level		1st difference		2nd difference	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t*	-4.00	0.0%	-27.60	0.0%	-49.76	0.0%
Breitung t-stat	-1.89	2.9%	-12.61	0.0%	-16.39	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-4.49	0.0%	-25.26	0.0%	-47.68	0.0%
ADF - Fisher Chi-square	142.38	0.0%	641.68	0.0%	1187.45	0.0%
PP - Fisher Chi-square	201.16	0.0%	833.65	0.0%	5710.04	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	7.42	0.0%	2.04	2.1%	0.71	23.9%

Notes: (*) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

(**) See Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Maddala and Wu (1999), Choi (2001) and Hadri (1999) for details.

Table A4 (Concluded): First generation unit root tests

	DS					
	level		1st difference		2nd difference	
Method	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Null: Unit root (assumes common unit root process)						
Levin, Lin & Chu t*	0.68	75.3%	-14.01	0.0%	-32.84	0.0%
Breitung t-stat	-0.99	16.2%	-8.33	0.0%	-14.21	0.0%
Null: Unit root (assumes individual unit root process)						
Im, Pesaran and Shin W-stat	-0.34	36.8%	-13.97	0.0%	-32.39	0.0%
ADF - Fisher Chi-square	42.28	29.1%	253.11	0.0%	556.27	0.0%
PP - Fisher Chi-square	70.03	0.1%	388.95	0.0%	2572.62	0.0%
Null: No unit root (assumes common unit root process)						
Hadri Z-stat	4.75	0.0%	1.53	6.3%	-2.24	98.8%

Notes: (*) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

(**) See Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Maddala and Wu (1999), Choi (2001) and Hadri (1999) for details.

Table A5: Example of Cointegrating Vector Estimates for The Balanced Panel of All Countries in The Dataset

		PMG	FMOLS	PDOLS		
Tot		0.166	0.17	0.156	Cointegration tests*	
	t-ratio	5.5	2.6	0.5		
Open		0.235	-0.45	-0.6	panel pp	-3.9
	t-ratio	7.0	-15.4	-1.98	panel adf	-2.4
Gdp		0.36	0.42	0.358		
	t-ratio	8.3	7.9	1.1	group pp	-4.3
gov		-0.09	0.07	0.177	group adf	-2.6
	t-ratio	-1.8	4.02	0.9		
Hausman test:		20.63				
p-value		0.00				

Sample: 1980-2005 Number of Countries: 36 936 Observation per variable

Notes: PMG refers to Pooled Mean Group Estimator of Pesaran, Shin and Smith (1999). FMOLS refers to panel Fully Modified OLS estimator of Pedroni (2000) and PDOLS refers to Panel Dynamic OLS estimator of Mark and Sul (2002). Insignificant estimates of long-run elasticities are in red font.

(*) Rejection of the null of no-cointegration at 5% level is highlighted.

Table A6: Pedroni's ADF and PP Residual Based Cointegration Tests (Balanced Panel of Non-Oil Exporting Countries)

	variables:											
								4-variable combinations				
								tot	tot	tot	tot	tot
							tot	opn	opn	opn	opn	opn
				tot	tot	opn	opn	gdp	gdp	gdp	gdp	gdp
	opn	tot	gdp	opn	gdp	gdp	gdp	gov	inv	nfa	fisc	ds
panel pp	-0.9	-2.7	-2.9	-2.7	-3.8	2.8	-4.2	-3.9	-3.1	-3.9	-3.4	-3.0
panel adf	-0.8	-2.9	-2.6	-1.1	-3.6	-2.7	-3.1	-2.5	-1.6	-2.5	-2.6	-2.1
group pp	-0.5	-2.9	-2.5	-3.1	-3.7	-2.9	-4.7	-4.3	-3.5	-4.6	-3.2	-2.9
group adf	-0.4	-4.3	-2.7	-1.1	-4.3	-2.6	-3.0	-2.4	-1.3	-2.6	-2.2	-1.6

	5-variable combinations									
	tot	tot	tot	tot	tot	tot	tot	tot	tot	tot
	opn	opn	opn	opn	opn	opn	opn	opn	opn	opn
	gdp	gdp	gdp	gdp	gdp	gdp	gdp	gdp	gdp	gdp
	gov	gov	gov	gov	inv	inv	inv	nfa	nfa	fisc
	inv	nfa	fisc	ds	nfa	fisc	ds	fisc	ds	ds
panel pp	-3.1	-3.3	-3.3	-2.1	-2.8	-2.6	-2.5	-2.7	-2.5	-2.1
panel adf	-1.1	-2.0	-2.1	-1.1	-1.5	-1.8	-2.3	-1.7	-0.8	0.3
group pp	-3.4	-3.7	-3.5	-2.0	-3.2	-2.9	-2.8	-3.2	-2.3	-1.5
group adf	-1.0	-1.7	-1.6	-0.6	-1.6	-1.8	-2.2	-1.9	-0.3	0.8

Notes: Rejection of the null of no cointegration at 5% level is highlighted.

Table A7: Pedroni's ADF and PP Residual Based Cointegration Tests: Oil Exporting Countries

	variables:						
	tot opn gdp	tot opn gdp gov	tot opn gdp inv	tot opn gdp nfa	tot opn gdp ds	tot opn gdp fisc	tot opn gdp oil
panel pp	-1.1	-1.6	-0.7	-1.5	-0.9	-1	-2.3
panel adf	-0.9	-0.9	-0.5	-1.3	0.2	-0.7	-2.52
group pp	-0.8	1.1	1.7	1	1.5	1.5	1
group adf	-0.4	-1.7	-0.2	-1	-0.9	-0.6	-2.03

Notes: Rejection of the null of no cointegration at 5% level is highlighted.

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