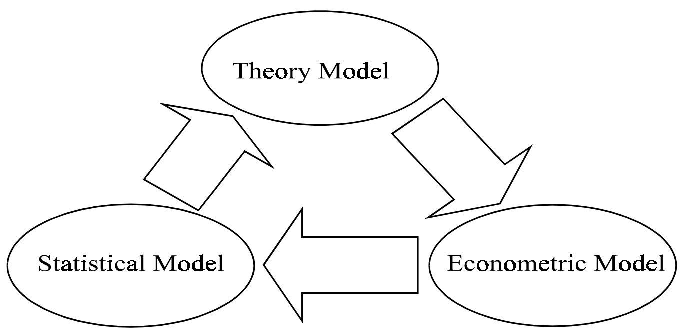
Chapter 1. The Consequences, Identification, and Correction of Statistical Misspecification.

I. Consequences of Statistical Misspecification

The consequence of ignoring statistical misspecification is the possible invalidation of statistical inference, leading to faulty theoretical inference. We must remember that there are three models used to validate a theory: the first is the theoretical model itself, the second is the econometric model that the theory dictates, and third is the statistical model--a set of probabilistic assumptions which capture the relevant features of the data. The goal is to be able to complete a full circle, implying that we can go directly from the resulting statistical model back to the theory.



The Ordinary Least Squares (OLS) estimation is justified via the Gauss-Markov theorem, but only under certain statistical assumptions. Justifying their actions through the use of the Central Limit Theorem (CLT), many economists have a tendency to simply assume-away these criteria. Spanos (1986 and 1999, chapters 9 and 10 respectively) shows that the CLT is today, loosely interpreted. For example, the CLT states that a sequence of random variables with an existing mean and bounded variance, converge to the normal distribution at the limit. These boundedness conditions imply that not any one random variable can dominate the sequence. Hence, in the context of the distribution of the errors, where we have $e = Y - XB$, if there is some unusual characteristic in Y that is not subtracted out by XB, these conditions could be violated and the CLT would not hold.

In light of these problems, in finite samples, we must *test* the assumptions of the Gauss-Markov theorem to guarantee accurate finite sample inference.[1] The Gauss-Markov theorem does not specify a particular distributional assumption, however, implicitly or explicitly, individuals assume normality where $e_t \sim NIID(0, \sigma^2)$.

Spanos (1999) recognized that when viewed in the context of statistical inference, Karl Pearson (1900) unknowingly created a dichotomy between misspecification testing- -testing outside the boundaries of the postulated statistical model- -and Neyman-Pearson (1928 I, II) testing of coefficient significance- -testing within the boundaries of the postulated statistical model. Testing outside the boundaries of the postulated model includes the testing of the error assumptions that can, with high probability, assure that the estimators of the coefficients are unbiased, consistent and efficient. Testing within the boundaries of the postulated model refers to our coefficient estimators having the properties we assume they have based on our model assumptions. Inference can only be drawn about the parameters if these assumptions are valid. Hence, within the set of all possible statistical models, the 'correct' statistical model must first be selected before any inferential testing of parameters can take place. Neyman and Pearson (1928, I) put this interpretation succinctly as follows:

> " . . . it was there supposed that the population Π could be exactly specified, that is to say, we were dealing with a simple hypothesis. We have now another kind of problem in which a theoretical law of frequency of given type, but whose exact form depends upon certain undetermined parameters, is fitted to a series of observations, the value obtained for the parameters depending on the method of fitting."

Shapiro and Wilk (1965) also realized the significance of making sure that a statistical model is correctly specified. They state ". . . many statistical procedures [for example, t-statistics] have been derived based on particular distributional assumptions--especially that of normality."

[1] The theorem is stated mathematically in Appendix K, page 120.

The assumptions implied by Gauss-Markov under the assumption of normality are

$$E(e_t^2) = \sigma^2 \Rightarrow \qquad \text{Homoskedasticity} \qquad (1)$$

$$E(e_t e_s) = 0 \ \text{ for all } \ t \neq s \Rightarrow \qquad \text{Independence} \qquad (2)$$

$$e_t \sim NIID(0, \sigma^2) \Rightarrow \qquad \text{Normality} \qquad (3)$$

and with respect to the statistical parameters of interest, $\theta \equiv (\beta, \sigma^2)$, we have

$$\theta \equiv (\beta, \sigma^2) \Rightarrow \qquad \text{Time and/or Individual invariance} \qquad (4)$$

With respect to (1) and (2), the consequences of heteroskedasticity and serial dependance are that the estimators, and subsequent forecasts, are still unbiased and consistent, but the estimators are no longer efficient.[2] Furthermore, the estimated variance/covariance matrix will be biased and inconsistent invalidating any testing of the parameters of the model in question.

Violation of assumptions (3) and (4) are probably the most serious of all the assumptions. Violation of assumption (4) is obvious in that we assume our parameters are constant over our indices when evaluating the resulting estimates, and if not, neither any statistical nor theoretical inference can be drawn. The consequences of ignoring (3) are not as obvious as the violation of the others. The normality assumption is closely tied with the assumption of our model being linear in our determinants. If the model is linear in its determinants, and homoskedasticity is a valid assumption, relaxing normality might not constitute a "major break from the linear regression framework" (Spanos, 1986, page 447). However, if we are not linear in our determinants, when we assume that we are, our estimators are biased and inconsistant, and moreover, testing and forecasts derived from them are also invalid. Below, I go over the specific procedures for testing these assumptions.[3]

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[2] A simple mathematical derivation of the statistical problems of misspecification is shown in Appendix I, page 113.

[3] The derivation of these test statistics are in Appendix J, page 116.

II. Statistical Testing and Respecification Procedures

In the papers that follow, the results of the misspecification tests of assumptions (1) through (4) are evaluated as a whole and not individually. Testing one assumption at a time, and then 'correcting' the model for that particular problem, can lead the modeler completely astray in terms of finding a statistically adequate model. For example, when errors are a function of nonlinear determinants, a homoskedasticity test may pick this up, hence, we would end up correcting for heteroskedasticity when we should really be correcting for nonlinear determinants (correct functional form), a much more serious problem. Within this package of tests, I have tried to not only implement the most powerful of tests, but complimentary tests as well.

II a. *Testing for Homoskedasticity*

From our specification assumption (1), we must test our model for homoskedasticity, and if there is evidence against this hypothesis after attaining the validity of other all modeling assumptions, correct for the heteroskedasticity by some feasible means that leaves us with valid inference.

Over the years, there have been many suggested methods for testing homoskedasticity. Some of the authors who looked into this misspecification problem are Box and Cox (1964), Goldfeld and Quandt (1965), Griffiths and Surekha (1982), Glesjer (1969), Cook and Weisburg (1983), among others. The primary homoskedasticity testing procedures employed in this paper are the White's test, the Cook-Weisburg (CW) test, and graphical plots of the squared residuals on fitted values of the dependent variable.

The White's test for homoskedasticity (White, 1980), is a useful test in that it does not assume prior knowledge of what may be causing heteroskedasticity, furthermore, this test does not depend on the assumption of normality.[4]

The CW test (Cook and Weisburg, 1983) is based on the score function. Lyon and Tsai (1996) show by Monte Carlo experiments, that the CW score test has consistently high power (against two other score tests and two forms of likelihood ratio tests) for samples as small as 20

[4] This is a large sample Lagrange Multiplier test, but I compliment this with the Cook-Weisburg test seen next which has proven accurate for samples as small as 20 observations.

observations. The third testing procedure used here is simply a graphical plot of the squared residuals on the fitted values of the dependent variable. With this method, we would look for systematic patterns that may indicate a non-constant variance. Given these testing procedures, we can now move to the subject of what to do if heteroskedasticity is found.

Of course, if heteroskedasticity is not found, standard estimation methods produce efficient estimators and tests of hypotheses will still be valid. However, if heteroskedasticity is found after all other assumptions are found valid, I do not focus on its sources, but rather correct for it by using a weight derived from a two-stage estimation procedure of the variance from Harvey-Godfrey (1976, 1978). This procedure is widely known as the Feasible Generalized Least Squares procedure (Harvey, 1976), and is expressed clearly in Ramanathan (1998) and Greene (2000).

II b. *Testing for Linearities*

As we have seen, the result of neglecting to include a non-linear determinant when one is needed is the most serious form of misspecification. The testing procedure used in this paper is the regression specification error test, or RESET, a procedure developed by Ramsey (1969), where one tests

$$H_0: \; E(y_t / X_t = x_t) = x_t B$$

versus

$$H_1: \; E(y_t / X_t = x_t) = h(x_t)$$

and $h(x_t)$ is some non-linear function of x (Spanos, 1986). This test is valuable when the degrees of freedom in a model are limited. Criticisms of this test are that the test does not shed light on the form of misspecification or on what the appropriate functional form of the properly specified model should be (most simply call this test an 'omitted variable' test), however, since this paper views misspecification testing as a battery of testing, the RESET procedure provides ample evidence to the *possibility* that non-linearities exist.

Correcting for non-linearities is a simple procedure--incorporate squares and cross-products of your original independent variables as needed (based on f-tests) until an acceptable test statistic is attained while retaining all other misspecification test statistics.

II c. *Normality Testing*

The assumption of normality is a crucial one for hypothesis testing with finite samples. The normality assumption is inextricably bound with statistical inference and lets us draw inference from the t-test, f-test, and chi-square test with regard to our estimators. Furthermore, the assumption of normality is also critical when testing hypotheses on σ^2. If the conditional distribution of y has mean xB and variance σ^2, then the test statistic

(i) $$\sqrt{T(\hat{s}^2 - \sigma^2)}$$

is asymptotically normally distributed with mean zero and variance

(ii) $$\left(\frac{\mu_4}{\sigma^4} - 1\right)\sigma^4$$

where $\hat{s}^2$ is the OLS estimate of σ^2, and μ_4 is the fourth central moment of the distribution of y conditioned on x. Hence, one can show that when the conditional distribution of y is normal, then $\frac{\mu_4}{\sigma^4} = 3$, which implies that the test statistic, (i), is asymptotically normally distributed with
mean zero and variance $2\sigma^4$ (Spanos, 1986; pg. 450).

To test this hypothesis, I employ four types of normality tests: [a] the Shapiro-Wilk (SW) test (1965), [b] skewness-kurtosis (SK) test suggested by Fisher (1929) and readdressed in Fisher (1930), [c] a graph of the conditional distribution with a normal curve overlay, [d] and a probability plot (P-P plot).

The Shapiro-Wilk (SW) test is not only shown to be invariant to scale and origin,[5] but is also shown to outperform most of seven other normality tests evaluated on thirteen population distributions, and maintains relatively high power with population sizes of less than 20.[6] Shapiro,

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[5] Shapiro and Wilk (1965) prove this for Lemma 1, page 593.

[6] The tests compared were the chi-square, standardized 3rd and 4th moments (a separated skewness-kurtosis test), Kolmogorov-Smirnov, Cramer-Von Mises, a weighted Cramer-Von

Wilk and Chen (1968) show that the SW statistic provides consistently high power for samples of $n = (10,15,20,35,50)$ for nine different statistical tests of normality, including a version of a skewness-kurtosis test used as a complementary procedure in this paper.

The use of both the conditional distribution with the normal curve overlay and the P-P plots are visual, however, they are very helpful in determining what may be causing the non-normality. The graph of the conditional distribution is self explanatory in the sense that comparing a smoothed histogram of the estimated conditional distribution to what the true distribution should be will obviously point out departures from normality, however, the P-P plot may not be as obvious a tool. A P-P plot can provide ". . . visual comparisons of alternative probability models through the display of appropriate reference curves" (see Gan, Koehler and Thompson, 1990). Hence, a probability plot can give us an idea of which distribution we may have in finite samples if the normal is unattainable. However, in this paper, I use it only to check to see if the conditional distribution is normal and do not extend the analysis to other distributions. As stated in D'Agostino and Stephens (1986), "If one is attempting to reach a decision based on visual inspection it is probably easiest to judge if a set of points deviates from a straight line. If the true underlying distribution is normal, for instance, the reference (straight) line results from a transformation of the verticle scale of the empirical cumulative density function graph to a 'scale which will produce exactly a straight line if the hypothesized distribution is plotted on the graph." Hence, the P-P plot is a graphical presentation that is a plot of the inverse of the standard normal cumulative on the horizontal axis and the ordered observations on the vertical axis, where the plot will be a straight line if the underlying distribution is normal (see D'Agostino, Belanger and D'Agostino, Jr, 1990, and Koehler and Thompson, 1991, for further analysis of the usefulness of P-P plots).

The formal and informal tests conducted here as complimentary because as D'Agostino, Belanger and D'Agostino, Jr (1990) point out, the SW test is an omnibus test in that it has good

Mises, and a version of the Kolmogorov-Smirnov test developed by Durbin. The distributions ranged from chi-square with 1 to 10 degrees of freedom, to non-central chi-square, to cauchy, log normal, uniform, logistic, beta, La Place, Poisson, and Binomial. This test actually outperformed in 7 out of the 13 distributions and was within .02 in 2 others.

". . . power properties over a broad range of non-normal distributions." And the SK test has ". . . excellent properties for detecting non-normality associated with skewness and non-normal kurtosis, respectively." Furthermore, the visual testing is a convenient way to graphically support the above statistical testing procedures.

II d. *Testing for Independence*

The method used by most to test for serial correlation in the errors is the Durbin-Watson (DW) test (1950, 1951). This statistic can be approximated by

$$DW \cong 2(1-\rho)$$

where ρ is the coefficient of the correlation between the contemporaneous residual and the lagged residual. In this case, you either accept or reject depending on what predetermined region the statistic lies within. There are two problems with this procedure; first, there exists an area of inconclusiveness where dependence in indeterminant. The second is that even if you do determine that dependence exists, you still must determine the source of the dependence. A much easier and more illuminating way of determining whether dependence exists--include lags of your variables in your regression then drop them through the use of F-type testing until the most parsimonious setup exists where the maintained lags are significant. The argument against this would be that the DW statistic is much easier being that it is pre-programmed into all statistical packages. My answer to this argument would be that the adjustment processes for creating lags are also preprogrammed into all statistical packages, and furthermore, you avoid the inconclusiveness of the DW test.

II e. *Testing for t or me - invariance*

Testing for whether a deterministic trend exists in the data is trivial--simply include a trend and/or a trend squared into your regression and use a F-type test to determine their significance. Testing for homogeneity over individuals is a little more ad hoc in that it is always wise to view a plot first and see if heterogeneity exists, and over which observations.[7] If

[7] Graphical analysis of deterministic trends in panels is difficult because in most cases the time dimension is very short. However, plots are still useful by looking for groups of

heterogeneity is observed it must first be modeled by, say, putting in dummy variables and testing the significance of these variables. I also test this assumption using a method developed by Brown, Durbin and Evans (1975) called a CuSum test for coefficient stability and CuSumSq test for variance stability. This is a recursive testing procedure that is meant to 'study the stability over time of regression relationships.'

The CuSum and CuSumSq tests use a regression technique that starts at a predetermined number of observations, and continues estimating the regression including one additional observation each time, all the time saving the results, until all observations are exhausted. The CuSum and CuSumSq tests test the null hypotheses

$$\begin{array}{l} H_0: B_t = B \\ H_0: \sigma_t = \sigma \end{array} \quad \text{for all } t = 1, 2, 3, \ldots, T.$$

These hypotheses can easily be adapted to panels or cross sections by testing over groups of countries or regions rather than over time.

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observations that appear to be trending up or down, but differentiating between time dependence and time trends is difficult if one should see this pattern.

Chapter 2. A Contribution to the Statistics of Economic Growth

I. Introduction

Since Robert Solow published his seminal paper, *A Contribution to the Theory of Economic Growth* (1956), there have been many articles that have tried to determine whether Solow's theoretical model is supported by cross-country data. Two of the more important papers are Mankiw, Romer and Weil's (MRW), *A Contribution to the Empirics of Economic Growth* (1992), and Nazrul Islam's, *Growth Empirics: A Panel Data Approach* (1995).

Mankiw, Romer and Weil investigate why estimates of the *standard* Solow model over-estimate capital's share of output, while under-estimating rates of convergence. MRW conclude that human capital must be an omitted variable. This is important because we would expect schooling to be correlated with capital and labor, and hence excluding human capital violates the property of orthogonality between the residuals and the regressors. By including schooling in their regressions, they were able to lower the estimates of capital's share of output and increase rates of convergence. On the other hand, Islam argues that it is not the absence of human capital that causes the inconsistencies, but rather they are caused by the failure of MRW's cross-sectional analysis to control for differences in production functions across nations. By including fixed-effects, Islam is able to show that human capital is no longer statistically significant while at the same time, finding rates of convergence and capital's share of output more in line with 'conventional values.'

In this paper, I revisit the evidence attained by these authors. To do this, I test whether the assumption of normal, independent and identically distributed errors is violated, and whether how such violations affect the results attained. What I find is that both MRW and Islam's models are statistically misspecified, particularly MRW's. Furthermore, when respecified to account for problems observed, none of the models coincide with the theoretical Solow model as originally modified by MRW. On the other hand, Islam's respecified models retain their original theoretical specification, and though his estimates change, they do not change as dramatically as the MRW results.

This paper is organized as follows. Section II evaluates MRW's results and compares them with the final results attained from the respecification of the models. Section III uses the same analyses as with MRW to evaluate Islam's work. Section IV is the conclusion.

II. Mankiw, Romer, Weil Paper Results

The purpose of the MRW paper is to explain that while the Solow model (Solow, 1956) correctly predicts the direction of influence that savings and population growth have on GDP, the estimates of these influences are not in line with convention--they are much larger than those assumed from empirical observation. In an attempt to correct for this problem, MRW augment the standard Solow model by including a proxy for human capital. They maintain that since human capital is likely correlated with physical capital and population growth, omission of this variable leads to a violation of the model assumptions that the errors are orthogonal to the independent variables.

II a. *The Theoretical Model (The standard Solow model):*

The theoretical model assumes that saving (s), population growth (n) and technological progress (g) are exogenous. The model assumes a Cobb-Douglas production function with decreasing returns in capital (K) and labor (L), each of which are paid their marginal products. Hence, production at time *t* is given by

$$(1) \qquad Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha} \quad , \qquad 0 < \alpha < 1$$

where Y is output and A is the level of technology. Assuming L and A at time *t* take the form

$$(2) \qquad L(t) = L(0)e^{nt}$$

$$(3) \qquad A(t) = A(0)e^{gt}$$

then, the number of effective units of labor, A(t)L(t), grows at rate n+ g. Further, if we define

$$(4) \qquad k = \frac{K}{AL}$$

$$(5) \qquad y = \frac{Y}{AL}$$

as capital stock and output per unit of effective labor respectively, and defining δ as a fixed depreciation rate, the steady-state capital stock can be defined by

$$(6) \qquad k^* = [s/(n+g+\delta)]^{1/(1-\alpha)}$$

and steady-state output as

$$(7) \qquad y^* = [s/(n+g+\delta)]^{\alpha/(1-\alpha)}$$

Plugging this expression into (5) above, we have

$$(8) \qquad \frac{Y}{L} = A(t)y^* = A(0)e^{gt}y^*$$

Taking natural logs of each side, and evaluating at t = 0, in the steady state we have

$$(9) \qquad \ln\left(\frac{Y}{L}\right) = \ln A(0) + \left(\frac{\alpha}{1-\alpha}\right)\ln s - \left(\frac{\alpha}{1-\alpha}\right)\ln(n+g+\delta)$$

Letting $\ln A(0) = a + e$,[8] we have the final econometric model *without* human capital as

$$(10) \qquad \ln\left(\frac{Y}{L}\right) = a + \left(\frac{\alpha}{1-\alpha}\right)\ln s - \left(\frac{\alpha}{1-\alpha}\right)\ln(n+g+\delta) + e$$

where e is normally distributed with mean zero and constant variance.

Equation (10) above is the primary *levels* regression that MRW estimate. MRW estimate two models. In the first, model (10) is completely unrestricted, while the second restricts the coefficients on saving and population growth to be equal in magnitude but opposite in sign. This restriction comes from the assumption that the production function exhibits constant returns in capital and labor. MRW augment this model by including human capital as shown below.

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[8] This assumption that lnA(0) is constant across countries is the assumption that Islam argues is causing the bias in the estimates, and not the exclusion of schooling from the empirical model.

II b. ***The Theoretical Model (The Augmented Solow model)***

Because of the omitted variable problem mentioned above, MRW augments the traditional Solow setup with human capital. The Cobb-Douglas production function now takes the form

$$(11) \qquad Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta}, \quad \alpha + \beta < 1$$

where H(t) is human capital at time t, and the other variables are as described earlier. If we assume that investment in human capital is s_h and, as before, investment in physical capital is s_k, then physical capital and human capital grow as

$$(12) \qquad \dot{k} = s_k y(t) - (n + g + \delta)k(t)$$
$$\dot{h} = s_h y(t) - (n + g + \delta)h(t)$$

where h=H/AL. Then, steady state physical capital and human capital is

$$(13) \qquad k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)}$$
$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)}$$

Plugging these into the production function above and manipulating this model as we did for the standard Solow model, we have an econometric specification of the form

$$(14) \qquad \ln\left[\frac{Y}{L}\right] = a - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + g + \delta) + \frac{\alpha}{1 - \alpha - \beta} \ln(s_k) + \frac{\beta}{1 - \alpha - \beta} \ln(s_h) + u .$$

where u is normally distributed with mean zero and constant variance. The rate of human capital investment, (s_h) is proxied by the percentage of the working-age population that is in secondary school. MRW test for the sum of the coefficients of capital, schooling, and labor being zero. This tests the assumption of constant returns in physical capital, human capital, and effective labor.

II c. *The Theoretical Model (The Solow Growth model)*

MRW continue their analysis of cross-country determinants of growth in GDP per capita by extending the Solow model to account for speeds of convergence to the steady state. By approximating around the steady state, the speed of convergence is given by

$$\frac{d\ln(y(t))}{dt} = \lambda[\ln(y^*) - \ln(y(t))] \tag{15}$$

with

$$\lambda = (n + g + \delta)(1 - \alpha - \beta) \tag{16}$$

Solving the differential equation in (15), one obtains

$$\begin{aligned}\ln(y(1985)) - \ln(y(1960)) = {} & (1 - e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}\ln(s_k) + (1 - e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}\ln(s_h) \\ & -(1 - e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n + g + \delta) - (1 - e^{-\lambda t})\ln(y(1960)).\end{aligned} \tag{17}$$

where $\ln(y(1985))$ is the natural log of GDP in 1985 and $\ln(y(1960))$ is the natural log of GDP in 1960.

II d. *The Data*

The data used by MRW are from Summers and Heston (1988). The savings variable is proxied by the average share of real investment in real GDP, Y/L is proxied by real GDP in 1985 divided by the working age population, and *n* by the average rate of growth of the working age population. They assume $g + \delta$ is 0.05 and they claim that reasonable changes in this assumption have little effect on the estimates.

There are three samples: (1) a cross-section of 22 OECD countries, (2) a cross-section of 75 "intermediate" countries with populations of less than one million in 1960, and (3) a cross-section of all countries (Non-Oil) that had data available when the paper was written, excluding oil producing countries. This 98 country sample is the most heterogenous of the three samples.[9] Below tables 1 through 3 list the results from the various misspecification tests implemented to

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[9] The MRW results are reproduced in appendix H, page 112.

asses the statistical adequacy of MRW's original models.[10]

II e. *Initial Testing of the Solow Model*

Table 2.1: Misspecification Test Results for MRW--No Schooling, Levels Model

Country Type	Non-Oil		Intermediate		OECD	
Test Type	Unrest	Restricted	Unrest	Restricted	Unrest	Restricted
White's	0.3351	0.2611	0.4981	0.4317	0.2295	0.1383
CW	0.8289	0.7135	0.7715	0.5790	0.1554	0.1023
RESET	0.2202	0.2937	0.3986	0.4492	0.0580	0.0546
Skewness-Kurtosis	0.2276	0.1270	0.0511	**0.0188**	0.1214	0.1095
Shapiro-Wilk	0.2854	0.1370	0.2330	0.0568	**0.0126**	**0.0177**
Cusum	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass
Cusumsq	Pass	Pass	Pass	Pass	Pass	Pass
P-values are shown. Values above 0.05 are interpreted as evidence against the respective null hypothesis.						

Here, we find that the OECD country models passes all misspecification tests except for the Shapiro-Wilk normality test. Looking at pages 72 and 73 in appendix A, we find that the plots of the residuals, the estimated conditional distribution and the P-P plot support the rejection by the SW test, while the bottom four plots indicate that the parameters are stable. Attempts to respecify the model were unsuccessful. Given that we only have 22 observations, I do not try to respecify the OECD models any further.

For the Intermediate country models, the SK test indicates non-normality for the restricted case and questionable normality for the unrestricted case. Looking at the residual plots in the top figures on pages 70 and 71 of Appendix A, we find significant mean heterogeneity that

[10] Here, I show the original testing results for the restricted models, but from this point further, when properly specified, the restriction may not be applicable and hence running regressions with this restriction would be meaningless.

is also being picked up by the slight skewness of the conditional distributions.[11] This evidence leads us to conclude that the model parameters may not be constant over the sample, a contention that is supported by the CuSum tests on pages 82 and 83 of Appendix B. In the plots of the residuals from the models that are not augmented with schooling, the coefficients become unstable at approximately the 18th observation.

Table 2.2: Misspecification Test Results for MRW--With Schooling, Levels Model

Country Type	Non-Oil		Intermediate		OECD	
Test Type	Unrest	Restricted	Unrest	Restricted	Unrest	Restricted
White's	0.4945	0.4920	0.4754	0.3135	0.2638	0.0814
CW	0.5817	0.6720	0.7208	0.5428	0.1643	0.1185
RESET	**0.0007**	**0.0010**	0.3347	0.4241	0.4345	0.4733
Skewness-Kurtosis	0.3538	0.2670	0.2737	0.2577	0.8242	0.8237
Shapiro-Wilk	0.3091	0.1489	0.1066	0.0958	0.6642	0.6674
Cusum	Pass	Pass	Pass	Pass	Pass	Pass
Cusumsq	Pass	Pass	Pass	Pass	Pass	Pass
P-values are shown.						

Before attempting a respecification of the 'standard' Solow model, we examine whether the statistical assumptions underlying the human capital augmented Solow model. Table 2 above summarizes the misspecification results for these models. The inclusion of human capital does slightly change our testing results. Based on the misspecification tests alone, the Intermediate country augmented models (unrestricted and restricted) appear to be statistically adequate (all p-values, including that for the Skewness-Kurtosis test are greater than 0.05). However, the residual plots on pages 74 and 75 of Appendix A provide some evidence of a shifting mean from about the 15th observation to the 44th observation, reflected again in the graph of the conditional distribution where we see a slight skewness to the right. Further concern is justified when

[11] The plots in appendix A are arranged as follows: the top four figures are the original plots prior to respecification, while the bottom four plots are after respecification. In the top left of each four is simply a residual plot that is ordered by region for the Intermediate and Non-Oil country-groups. The top right plot is plotting estimated squared residuals on the ordered predicted values of the dependent variable; the figure on the bottom left is a conditional distribution with a normal curve overlay, and the figure on the bottom right is a normal, P-P plot.

looking at the plots of the CuSum test on page 83 of Appendix B. We see in these plots, that even though the CuSum test passes for both the unrestricted and restricted augmented cases, we find parameter instability after approximately the 15th observation and continuing until the 50th observation. Below, we investigate whether we can capture any of this heterogeneity by respecifying the model.

For the Non-Oil country model, the testing results are less subtle. In table 2, we find evidence of non-linearity even though the CuSum test does not indicate problems (unlike the non-augmented case). As in the Intermediate case, we find slight rightward skewness but the P-P plots provide no evidence against normality (see page 76 of Appendix A). However, we also find evidence of mean heterogeneity in the residual plots starting at approximately the 40th observation, and unstable coefficients in the CuSum plots on page 1 of Appendix B, particularly after the 40th observation, even though the plot stays within the 5% interval over the entire set of observations. Again, we will investigate whether this heterogeneity is significant enough to be modeled in the section below.

Below are the initial testing results for the Solow *growth* model. The misspecification tests performed are the same as in the forms modeling the levels of GDP, however, I only test the unrestricted form, hence, the test statistics for the models that are augmented with schooling are in the right-hand columns while the non-augmented models are in the left-hand columns.

Table 2.3: Misspecification Test Results for MRW-Growth Model

Table 3				
Country Type	Non-Oil (Unrestricted)		Intermediate (Unrestricted)	
Test Type	No School	School	No School	School
White's	0.0858	0.1171	0.3420	0.0718
CW	0.0867	0.2178	0.2700	**0.0110**
RESET	0.6428	0.5047	0.6100	0.3138
Skewness-Kurtosis	0.2459	0.3473	**0.0269**	0.0514
Shapiro-Wilk	0.2717	0.5332	0.0574	0.1306
Cusum	Pass	Pass	Pass	Pass
Cusumsq	**Fail**	**Fail**	**Fail**	**Fail**
P-values are shown.				

The misspecification tests for both the Intermediate and Non-Oil models indicate their models are reasonably specified, with the slight exception of the SK test and the CW test for the intermediate group, and the borderline passing of the White's and CW statistics for the Non-Oil group. However, on pages 77 - 80 in Appendix A, not only do we find mean heterogeneity in the residual plots but we also find possible variance heterogeneity in these same plots. Furthermore, the squared residual plots for the Intermediate country group seems to show possible heteroskedasticity. The CuSumSq plot (pages 85 and 86 of Appendix B) indicate that the possible heterogeneity in the conditional variance depicted by the residual plot is significant. Furthermore, even though the CuSum test does not indicate significant evidence against the null hypothesis that the slope parameters are constant, the plot does indicate some instability around the 40th observation for the Non-Oil case and the 20th observation for the Intermediate case.

Based on the misspecification tests and graphical evidence just summarized, I now attempt to re-specify the MRW models. In general, I proceeded as follows. Initially I attempted to model the mean heterogeneity by adding an intercept shifter (dummy variable) to capture the observed mean shifts. When required, I corrected for possible non-linearities by adding significant second-order terms. Lastly, when needed, I corrected for heteroskedasticity using

Feasible Generalized Least Squares (FGLS). The final respecified attempts are reported below.

II f. *Respecified Estimations for the Levels Models*

Table 2.4: Original and Respecified Estimations for the Levels of GDP, Unrestricted Form

Dependent variable is the natural log of GDP per worker in 1985.								
Variables	Non-Oil (Unrestricted)				Intermediate (Unrestricted)			
	Original (No Sch)	Resp (No Sch)	Original (Sch)	Resp (Sch)	Original (No Sch)	Resp (No Sch)	Original (Sch)	Resp (Sch)
I/GDP	1.424	6.393	0.697	3.921	1.317	1.128	0.700	0.711
	(0.000)	(0.002)	(0.000)	(0.032)	(0.000)	(0.000)	(0.000)	(0.000)
n+g+δ	-1.989	6.635	-1.745	4.193	-2.017	-1.530	-1.499	-1.351
	(0.001)	(0.032)	(0.000)	(0.117)	(0.000)	(0.002)	(0.000)	(0.001)
School			0.654	-0.400			0.731	0.765
			(0.000)	(0.172)			(0.000)	(0.000)
dummy		-0.984		-0.525		-0.694		-0.243
		(0.000)		(0.000)		(0.000)		(0.043)
I/GDP * n+g+δ		-2.732		-1.801				
		(0.009)		(0.047)				
I/GDP * School				0.319				
				(0.005)				

P-values in parentheses.
Sch = Schooling
Resp = Respecified model

Not only does the Non-Oil model have mean heterogeneity as suggested by the CuSum test, there are also non-linearities which are modeled by the inclusion of the interaction of labor and schooling with investment. On the other hand, the Intermediate country model only needed a dummy variable to account for the mean heterogeneity.

We now compare the estimates of our statistically adequate re-specified models to those of MRW to assess the extent to which the conclusions of MRW change. Because each of the MRW models was misspecified from a statistical point of view, we know their conclusions are tenuous at best.

Unfortunately, the need for an interaction term int the Non-Oil, schooling augmented model makes the theoretical interpretation of the model coefficients difficult--recall that the theoretical model is linear in capital, labor and schooling. However, in the case where only intercept shifters were required for statistical adequacy, theoretical interepretation of the coefficients in not compromised, and comparisons between MRW and our respecified models is straight forward.

First, it is interesting to note that the need to include a dummy variable is consistent with Islam's criticisms of MRW. Second, note the difference between the estimates of the non-augmented, Intermediate model before and after respecification. In this case the coefficient for capital decreases by over 14% while the coefficient on labor increases by 24%. For the augmented case we find no real change in the coefficient of capital, but a 13% increase in the coefficient for labor. The third result that should be noted is the difference between the changes in coefficient estimates of the 'Original' models and the changes in the coefficient estimates of the respecified models with and without schooling.

In the original specification of the Intermediate model, we find that when schooling is added to the regression, the coefficient on capital falls by 47%, however, after respecification, the change is only 37%. For the coefficient on labor, the original specification produced an increase of 27% while after respecification, the change was only 12%. Hence, we can conclude that in this Intermediate case, only part of the fall in capital's share of output was due to the inclusion of schooling, the rest was because of model misspecification. Finally, it is of interest to test the theoretical restriction that for the model not augmented with schooling, the coefficients on capital and labor are equal but opposite in sign, and for the schooling augmented case, the coefficients for capital, labor, and schooling sum to zero.

Evaluating these assumptions for the Non-Oil models is irrelevant. This is because these assumptions fall from the derivation of the econometric model directly from theory, and since the theoretical model is no longer a valid model after respecification, the above parameter restrictions cannot be justified. However, these assumptions can be tested with regard to the Intermediate model. What I find is that it is fine to restrict the Intermediate models, surprisingly, however, the P-values estimated by MRW are considerably different from the P-values estimated after respecification. For the non-augmented case, MRW get a P-value of 0.26 while I get 0.46, an increase of 77%. For the augmented case, the restriction that the coefficients to capital, labor and schooling sum to one, MRW get a P-value of 0.89, while I get a P-value of 0.78, a 12% decrease. Since these restrictions for the Intermediate models are justified, I respecify the restricted models below.

Table 2.5: Original and Respecified Estimations for the Levels of GDP, Restricted Form

Dependent variable is the natural log of GDP per worker in 1985.				
Variables	Intermediate (Restricted)			
	Original (No Sch)	Respecify (No Sch)	Original (Sch)	Respecify (Sch)
I/G - (n+g+δ)	1.431 (0.000)	1.189 (0.000)	0.709 (0.000)	0.696 (0.000)
School - (n+g+δ)			0.733 (0.000)	0.759 (0.000)
dummy		-0.707 (0.000)		-0.236 (0.043)
P-values are in parentheses				

In the Intermediate country restricted models, we find no real change in the coefficients for the schooling augmented case, and a 17% drop in the estimate for the coefficient on the difference of physical capital and labor force participation in the non-augmented case.

In summary, all of MRW's models that measure the variation in levels of GDP were misspecified with either mean heterogeneity, or non-linearities. For the Non-Oil country, unrestricted case, the coefficients for both the schooling augmented and non-augmented models are no longer interpretable in the context of the theoretical Solow model because of the inclusion of the interaction terms. On the other hand, the Intermediate country models retained their theoretical interpretation, however, the coefficients changed considerably when shift variables were added to correct for the mean heterogeneity. Next, we take a look at the respecified *growth* models.

The story so far for the models estimating levels of GDP tells us that each non-augmented model was statistically misspecified, and after respecification, the Non-Oil statistical model did not retain the theoretical form of the Solow model because of the inclusion of the interaction between physical capital and labor. On the other hand, the Intermediate statistical model only required the inclusion of a dummy variable to pick up the mean heterogeneity seen in the residual plots, hence, retaining the theoretical form of the Solow model, but not as MRW derived the model. MRW did not allow for heterogeneity in the mean when deriving their econometric setup from the theory.

The augmented models tell a slightly different story because the Intermediate econometric model did pass all formal statistical testing, while the Non-Oil model passed the CuSum test, but not the RESET test (indicating that a non-linearity in the errors may exist). However, even though the CuSum test passed in all cases, there was cause for concern because the plots within the test interval do not paint a picture of parametric stability. This conclusion is further supported by the residual plots. The respecified augmented statistical models, like the non-augmented cases, include interaction terms in physical capital and labor, and physical capital and schooling for the Non-Oil case, and a dummy for both the Intermediate and Non-Oil cases. Again, the Non-Oil models do not retain the theoretical Solow form, while the Intermediate model does retain the theoretical form, just not as MRW derived the econometric model from the theory.

II g. *Respecified Estimations for the Growth Models*

As mentioned earlier, none of the original growth Solow models are well specified statistically. We found some un-modeled heterogeneity in both the Non-Oil and Intermediate country models (parameter instability). In addition, the normality and homoskedasticity assumptions were violated for the Intermediate country models.You will see that correct specification for both the Non-Oil and Intermediate models required dummy variables to account for the mean heterogeneity seen in the residual plots in appendix A (the dummy variables for the Non-Oil case are for observations 1 - 40 and 77 - 98, and for observations 55 - 75 for the Intermediate case), however, the heterogeneity in the variance, represented by the failing of the CuSumSq test, cannot be corrected by a mean-correcting method. Hence, each respecified growth model below was corrected by FGLS where fixed effect dummies were included in the auxiliary regression that estimated the weights for each variable in the model (in both cases the dummy controlled for European countries having a lower variance than the rest of the sample).

Table 2.6: Original and Respecified Estimations for the Growth Models

Dependent variable is the difference of the natural log of GDP in 1985 and the log of GDP in 1960.								
Variables	Non-Oil (Unrestricted)				Intermediate (Unrestricted)			
	Original (No Sch)	Resp (No Sch)	Original (Sch)	Resp (Sch)	Original (No Sch)	Resp(H) (No Sch)	Original (Sch)	Resp(H) (Sch)
GDP60	-0.140	-0.179	-0.288	-0.198	-0.227	-0.135	-0.365	-0.171
	(0.008)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
I/GDP	0.647	0.584	0.523	0.528	0.645	0.638	0.537	0.562
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
n+g+δ	-0.302	0.230	-0.505	-0.313	-0.457	-0.109	-0.545	-0.024
	(0.323)	(0.254)	(0.083)	(0.082)	(0.141)	(0.397)	(0.063)	(0.853)
School			0.231	0.108			0.270	0.172
			(0.000)	(0.077)			(0.001)	(0.023)
dummy1		-0.415		-0.308		-0.231		-0.287
		(0.000)		(0.010)		(0.044)		(0.011)
dummy2		-0.309		-0.286				
		(0.005)		(0.010)				
P-values in parentheses. Sch = Schooling (H) = Heteroskedasticity corrected.								

Table 6 reports the parameter estimates from the original MRW specifications and the respecified models. I find that there are no significant changes in coefficient estimates for the investment ratio from the original specification, however, schooling's impact on growth has reduced significantly after respecification. For the Non-Oil case, the coefficient on schooling fell by over 53% and for the Intermediate case, the coefficient fell by 36%. The most striking results, however, pertains to the coefficients on GDP in 1960. For the respecified models, the addition of the schooling variable implies increased convergence, but not as much as in the original MRW specifications. To see this, note that the decrease in the coefficient on GDP60 when schooling was added to the model was much larger in the MRW models than in the respecified models.

With the exception of the Non-Oil, non-augmented case where the coefficient to GDP in 1960 fell by 28% indicating increased convergence, the coefficient in the Non-Oil, augmented case actually rose from -0.288 to -0.198 (an increase of 32%), which translates to a reduction in the convergence parameter, λ, from 0.014 to 0.009, or by 38%. in the Intermediate, non-augmented case the coefficient rose from -0.227 to -0.135 (an increase of 51%), and in the augmented case the coefficient rose from -0.365 to -0.171 (an increase of 53%). These increases translate into a reduction of λ from 0.01 to 0.006 for the non-augmented case, and from 0.018 to 0.008 for the augmented case, or 40% and 56% reductions respectively. Hence the respecified forms indicate reduced convergence from their respective originally estimated models. This implies that MRW may have gotten over excited about their results with respect to increasing the rates of convergence by adding schooling to the regressions. Next we see if the above respecified models pass our battery of tests we performed earlier.

Table 2.7: Respecified Test Results for MRW, Levels Model

Levels Models	Non-Oil		Intermediate			
Model	Unrestricted		Unrestricted		Restricted	
Test Type	No School	School	No School	School	No School	School
White's	0.3358	0.4286	0.3766	0.7541	0.2325	0.6026
CW	0.9476	0.2567	0.2060	0.5118	0.3046	0.5599
RESET	0.1306	0.2520	0.6369	0.4414	0.6353	0.5698
Skeness-Kurtosis	0.5644	0.9058	0.4427	0.6048	0.5880	0.6239
Shapiro-Wilk	0.7619	0.9836	0.5226	0.6517	0.3831	0.7022
CuSum	Pass	Pass	Pass	Pass	Pass	Pass
CusumSq	Pass	Pass	Pass	Pass	Pass	Pass
P-values are shown.						

We see above that all models are statistically well specified, but do our plots agree with the test statistics? Looking at the bottom set of figures in appendix A, page 67, we see that the residual plots appear homogeneous and homoskedastic, while the conditional distributions no longer appear as skewed as before. With the exception of the Intermediate, unrestricted, non-augmented case, all P-P plots show increased evidence of a normal distribution (the intermediate case just mentioned appears about the same as before the respecification, however, the residual plot has improved greatly). Looking at the figures in appendix C, page 88, we find much more stability in our parameter estimates than before.

Table 2.8: Respecified Test Results for MRW, Growth Model

Growth Models	Non-Oil (Unrestricted)		Intermediate (Unrestricted)	
Test Type	No School	School	No School	School
White's	0.2933	0.2626	0.5321	0.3781
CW	0.9603	0.5836	0.0685	0.1483
RESET	0.8263	0.5744	0.9828	0.6001
Skeness-Kurtosis	0.9557	0.8232	0.1340	0.5531
Shapiro-Wilk	0.9358	0.5766	0.3079	0.6796
CuSum	Pass	Pass	Pass	Pass
CusumSq	Pass	Pass	Pass	Pass
P-values are shown.				

For the growth models, we see that any borderline results shown earlier have improved considerably. We also see a dramatic improvement in the residual and heteroskedasticity plots for the Intermediate and Non-Oil groups in the bottom figures in appendix A (page 67). Furthermore, we see negligible improvement in the conditional distributions, but significant improvement in the P-P plots for the Intermediate cases, and as above for the levels equations, we have greater parameter stability as seen in appendix C in the CuSum and CuSumSq tests. Now the question turns to whether we can continue to justify the restriction that the sum of the coefficients to investment, labor and schooling sum to zero. The p-values resulting from these tests for the Non-Oil and Intermediate cases respectively are 0.0000 and 0.0003, indicating that this restriction does not hold for the respecified forms of these models, and furthermore, assuming constant returns in physical capital, human capital, and labor, is not a valid assumption. On the other hand, MRW's result was 0.40 for the Non-Oil model and 0.42 for the Intermediate model indicating that this is a valid restriction to enforce. So, what have we learned from the statistical critique of this seminal paper?

All of MRW's original models had to be respecified to ensure the model assumptions were reasonably satisfied. In these respecified models, I found that adding schooling to the growth regressions did increase convergence by decreasing the coefficient of GDP in 1960 by 10 and 25% for the Non-Oil and Intermediate cases respectively. This decrease, however, is not as large as MRW find (their coefficients fell by 105 and 61% for the respective models). In the growth case, I also find the restriction that the coefficients to labor, schooling and investment sum to zero does not hold. This is in contrast to MRW and is inconsistent with a constant returns production function. I evaluate and discuss Islam's paper in the next section.

III. Islam Paper Results

The central purpose of Islam's paper is to follow the framework of MRW but to use panel data instead of a simple cross section to allow accountability for differences in aggregate production functions across countries. These phenomena can be accounted for by subtracting out country-specific fixed effects from the models. What Islam finds is that when accounting for fixed effects across panels, the estimated rates of convergence increase and capital's share of output comes more in line with values typically accepted as reasonable *without* the inclusion of human capital.

III a. *The Theoretical and Statistical Models*

As mentioned above, Islam follows MRW in their econometric setup that is derived directly from the standard and augmented Solow models. For the standard case, we have

(1)
$$\ln \hat{y}(t_2) - \ln \hat{y}(t_1) = (1 - e^{-\lambda t}) \frac{\alpha}{1-\alpha} \ln(s) - (1 - e^{-\lambda t}) \frac{\alpha}{1-\alpha} \ln(n + g + \delta) - (1 - e^{-\lambda t}) \ln \hat{y}(t_1)$$

defining $\hat{y}(t) = \frac{Y(t)}{L(t)A(t)e^{gt}}$, hence, $\ln \hat{y}(t) = \ln y(t) - \ln A(0) - gt$ and $y(t)$ is income per capita. After substituting for $\hat{y}(t)$ into equation (1), and after some algebraic manipulation, we have the econometric setup

(2)
$$\ln y(t_2) = (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha}\ln(s) - (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha}\ln(n+g+\delta) + e^{-\lambda\tau}\ln y(t_1) + (1-e^{-\lambda\tau})\ln A(0) + g(t_2 - e^{-\lambda\tau}t_1).$$

For the results that are augmented with human capital, Islam uses a restricted setup based on the theoretical restriction that the coefficients for labor and capital are equal and opposite in sign. The econometric model that Islam uses for the augmented case is:

(3)
$$\ln y(t) = (1-e^{-\lambda t})\frac{\alpha}{1-\alpha}[\ln(s) - \ln(n+g+\delta)] + (1-e^{-\lambda t})\frac{\theta}{1-\alpha}\ln(h^*) + e^{-\lambda t}\ln y(t_1) + (1-e^{-\lambda t})\ln A(0) + g(t_2 - e^{-\lambda t}t_1)$$

where h^* is the steady state level of human capital and θ is the exponent of human capital in the aggregate production function. However, in the updated version of the Penn World Tables that I am using in this paper, we find that the implied restriction on the coefficients of labor and capital in equation (3) is not acceptable.[12] The p-value for this restriction is 0.000 for the Non-Oil and Intermediate countries, indicating that this restriction should not be applied. I show both the restricted and unrestricted results below and for misspecification purposes, work with only the unrestricted results assuming that if Islam were using this version of the PWT data set, he would have also found that the restriction should not be applied.

III b. *The Data*

Like MRW, Islam uses the Summers-Heston (1988) data set for this panel model. I use the same data set, however, I will use the latest version available--the Summers-Heston, Penn World Tables 1995 version.[13] I retain the country grouping of both MRW and Islam of OECD, Intermediate and Non-Oil countries. There are 110, 368, and 475 observations respectively for these groups, however, the schooling variable is not available for the complete sample. For

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[12] This is supported both before and after respecification.

[13] This version of the Penn World Tables will produce results slightly different from those attained from the 1988 version, see Bernanke and Gurkaynak, 2001.

comparative purposes, I restrict my full sample to those observations where schooling *is* available. This reduces the samples to 105, 339, and 410 observations respectively. The reproduced estimates for this reduced sample using a *within* estimation technique are not considerably different from the original Islam results using the 1988 version of the PWT data set and are shown in Appendix G, page 111.[14]

Table 9 reports the results from the same battery of misspecification tests used to examine the MRW models. Two additional tests are added to test whether there is dependence over time and to test for the existence of trends over the added time dimension.

[14] The within estimator used here by Islam theoretically causes a natural non-orthogonality between the lagged dependent variable and the mean of the error over countries, however, to correct for this, we would have to difference over time and instrument the difference lags with the second lag of the dependent variable (see Hsiao, 1986) which causes a change in the model that would be unacceptable for comparison purposes.

III c. *Initial Testing of the Solow Model*

Table 2.9: Misspecification Test Results for Islam-Growth Model without Schooling

Country Type	Non-Oil		Intermediate		OECD	
Test Type	Unrest	Restricted	Unrest	Restricted	Unrest	Restricted
White	**0.0070**	**0.0484**	0.7398	0.8937	0.6673	0.4787
CW	0.1706	0.2687	0.6359	0.8859	0.4035	0.5517
RESET	**0.0107**	**0.0035**	**0.0502**	**0.0063**	0.1772	0.0748
Skewness-Kurtosis	**0.0030**	**0.0104**	**0.0003**	**0.0056**	0.2961	0.7767
Shapiro-Wilk	**0.0001**	**0.0007**	**0.0000**	**0.0001**	0.3583	0.8998
Dependence	0.0776	**0.0179**	0.5848	0.0738	**0.0007**	0.8413
Trend	0.8900	0.5983	0.3350	0.8196	**0.0018**	0.3401
Trend Squared	0.2776	0.1380	0.8764	0.1685	0.0576	0.8879
CuSum	Pass	Pass	Pass	Pass	Pass	Pass
CuSumSq	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass
P-values are in parentheses.						

Table 2.10: Misspecification Test Results for Islam-Growth Model with Schooling

Table 2						
Country Type	Non-Oil		Intermediate		OECD	
Test Type	Unrest	Restricted	Unrest	Restricted	Unrest	Restricted
White	**0.0107**	0.0492	0.7792	0.7032	0.6980	0.6525
CW	0.1804	0.2752	0.7497	0.9214	0.4178	0.5149
RESET	**0.0110**	**0.0034**	**0.0370**	**0.0021**	0.1774	0.0722
Skewness-Kurtosis	**0.0033**	**0.0109**	**0.0002**	**0.0051**	0.2725	0.7128
Shapiro-Wilk	**0.0001**	**0.0007**	**0.0000**	**0.0001**	0.2870	0.9047
Dependence	0.1094	**0.0262**	0.6423	0.0679	**0.0008**	0.8661
Trend	0.8479	0.6175	0.6510	0.1767	**0.0016**	0.3686
Trend Squared	0.3067	0.0980	0.3411	**0.0074**	0.0580	0.8371
CuSum	Pass	Pass	Pass	Pass	Pass	Pass
CuSumSq	**Fail**	**Fail**	**Fail**	**Fail**	Pass	Pass
P-values are in parentheses.						

As shown in tables 9 and 10, none of the models initially specified are statistically adequate. In both tables, we find that with the exception of the OECD country model, the more heterogeneous country models fail linearity and normality[15]. The intermediate group passes homoskedasticity while the Non-Oil group does not. Looking at the top figures in appendix D, page 90, we find that with the exception of slight skewness to the right, the conditional distributions are fairly symmetric but highly leptokurtic. This is also reflected in the P-P plot where the plotted points first rise above and then fall below the normalized line. Furthermore, appendix E tells us that even though it appears as though we have coefficient stability with regard to the CuSum tests, we can not say the same about the conditional variance. We see that

[15] Because we were unable to respecify the MRW OECD models because we only had 22 observations, we have no basis for comparison. Consequently, we proceed no further with this model.

in Appendix E, page 96, the CuSumSq tests obviously fail, indicating that there is heterogeneity in the conditional variance.[16]

In addition to the CuSum and CuSumSq tests, Appendix E presents a recursive squared residual plot for each of the Non-Oil, Intermediate and OECD country models for both the restricted and unrestricted cases. These observations, like MRW, are ordered by region (Africa, Americas, Asia, Europe, and Oceania). The recursive plot is constructed by starting with an initial number of observations, estimating the conditional variance and plotting it, then adding one observation for each additional estimation while plotting the additional estimated variances. We see that the estimated squared residuals for both the Non-Oil and Intermediate countries are highly unstable. The systematic heterogeneity becomes obvious when the regions are delineated. We find very erratic behavior over the African countries with some stabilization for the Americas through Asia, and an obvious downward bias for the regions of Europe and Oceania. Some of this behavior may be because with the smaller sample size, we could expect the conditional variance to be relatively erratic. However, I do not believe this to be the case. This is apparent when viewing the estimated variance of the OECD countries. Here we find that we have very little erratic behavior starting at around 40 observations, whereas in the Non-Oil and Intermediate plots, we find very erratic behavior up until approximately 100 observations. The implication here is that heterogeneity may be so prevalent over the more heterogeneous country groups that many more observations are needed to wash out the erratic effects.

Further inspection of the estimated variance plot does show an obvious downward trend for the Non-Oil sample from approximately 75 observations to the last observation. The Intermediate sample trends down for the first 100 observations, then trends upward until the 240th observation, then trends downward again until the final observation. Even though the OECD plot shows the same behavior initially, we see an obvious flat and stabilizing pattern for about the last 30 observations, or almost one third of the total observations.

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[16] I order the observations in such a way that, considering the Non-Oil sample, the first approximately 120 observations are African countries, the next approximately 130 observations are the Americas, the next approximately 60 observations are Asian countries, the next approximately 80 observations are European countries and the last observations are Oceania countries.

This batch of evidence is a solid foundation from which to conclude that there does exist variance heterogeneity across regions that is significantly more pronounced than in the MRW case. To test this conjecture, I ran a regression of the estimated squared residuals from each the Non-Oil and Intermediate country models on regional dummy variables. The results are below.

Table 2.11: Estimations of Squared Residuals on Regional Dummy Variables

Dependent Variable: Squared Residuals from original regressions		
Variables	Non-Oil	Intermediate
Americas	-0.0006	0.0008
	(0.798)	(0.681)
Oceania	-.0051	-0.0069
	(0.283)	(0.136)
Europe	-0.0074 **	-0.0069 **
	(0.003)	(0.002)
Africa	0.0025 **	0.0018
	(0.009)	(0.462)
Asia (control)	0.0098 **	0.0085 **
	(0.000)	(0.000)
P-values in parentheses ** implies significance at 5%		

Here we see that for the Non-Oil sample, the mean of the variance differs for 3 separate regions and 2 regions for the Intermediate countries with minor support for the Oceania countries.

To correct for these differences in the variance, we use FGLS where the weights are determined from the regressions in Table 11. We then subject these respecified models to our same battery of misspecification tests (see Table 12).[17]

[17] In respecifying these models, 5 outliers were dropped to gain our normality characteristics. Dropping these had little effect primarily because the Non-Oil and Intermediate countries had 410 and 339 observations respectively. No other alterations were performed.

III d. ***Respecified Results***

Table 2.12: Respecified Test Results for Islam, Growth Model

Country Type	Non-Oil		Intermediate	
Test Type	Augmented	Non-Augmented	Augmented	Non-Augmented
White	0.6048	0.6203	0.6042	0.8507
Cook-Weisburg	0.5915	0.9111	0.3655	0.5282
RESET	0.6041	0.9727	0.6346	0.9496
Skewness-Kurtosis	0.4893	0.6850	0.1504	0.2012
Shapiro-Wilk	0.0977	0.1950	0.0678	0.0620
Dependence	0.1608	0.1240	0.2595	0.0997
Trend	0.1339	0.2929	0.8350	0.8646
Trend Squared	0.0600	0.0850	0.2302	0.4376
CuSum	Pass	Pass	Pass	Pass
CuSumSq	Pass	Pass	Pass	Pass
P-values are shown.				

From Table 12, we see that correcting the heterogeneity in the variance greatly increased the p-values from all the misspecification tests and these models appear to be well specified. The bottom figures in Appendix D, page 91, and the figures in appendix F, page 109, reinforce this conclusion. Below, our respecified results are compared to those from the original specification.

Table 2.13: Original and Respecified Estimations for the Non-Oil Countries

Dependent Variable: $lnGDP_{it}$						
	Augmented			Non-Augmented		
Variables	Original	Respec	%-Change	Original	Respec	%-Change
$lnGDP_{i, t-1}$	0.7463	0.7904	+ 6 %	0.7404	0.7767	+ 5 %
	(0.000)	(0.000)		(0.000)	(0.000)	
$ln(s)_{it}$	0.1804	0.2343	+ 30 %	0.1802	0.2330	+ 29 %
	(0.000)	(0.000)		(0.000)	(0.000)	
$ln(n + g + \delta)_{it}$	-0.1074	-0.0755	+ 30 %	-0.1088	-0.0797	+ 27 %
	(0.000)	(0.001)		(0.000)	(0.001)	
$ln(school)_{it}$	-0.0098	-0.0234	- 138 %			
	(0.654)	(0.345)				
P-values in Parentheses. Percentage change here is the change in estimates from the original model to the respecified model.						

Table 2.14: Original and Respecified Estimations for the Intermediate Countries

Dependent Variable: $lnGDP_{it}$						
	Augmented			Non-Augmented		
Variables	Original	Respec	%-Change	Original	Respec	%-Change
$lnGDP_{i, t-1}$	0.7587	0.8106	+ 7 %	0.7743	0.7975	+ 3 %
	(0.000)	(0.000)		(0.000)	(0.000)	
$ln(s)_{it}$	0.2454	0.2953	+ 20 %	0.2478	0.2726	+ 10 %
	(0.000)	(0.000)		(0.000)	(0.000)	
$ln(n + g + \delta)_{it}$	-0.0761	-0.0867	+ 14 %	-0.0759	-0.0624	+ 18 %
	(0.006)	(0.006)		(0.006)	(0.007)	
$ln(school)_{it}$	0.0298	-0.0221	- 174 %			
	(0.338)	(0.562)				
P-values in Parentheses. Percentage change here is the change in estimates from the original model to the respecified model.						

What we see in Tables 13 and 14 is that if we were to estimate the model without worrying about statistical adequacy, our results would have been biased downward (except for the schooling variable coefficient which is biased upward).[18] Furthermore, we see a large change

[18] This bias has not been tested for statistical significance because we are concerned with whether the bias is *economically* significant, not *statistically* significant.

in the coefficient estimate on schooling with a sign change for the Intermediate case, even though in both cases schooling is not significant. Further, my estimates of capital's share of output falls somewhere between MRW's and Islam's, but is closer to Islam's (see Table 15 below).

Table 2.15: Comparisons of Physical Capital's Share of Output

Implied α						
	Islam[19]		My Estimates		MRW[20]	
	W/ School	No School	W/ School	No School	W/ School	No School
Non-Oil	0.415	0.409	0.528	0.511	0.645	0.821
Intermediate	0.505	0.494	0.609	0.573	0.595	0.738

The first thing to note is that, in contrast to MRW, the Islam models (still) indicate no real change in capital's share of output when schooling is added to the model. Further, Islam's results (still) imply a much smaller share of output attributed to capital than MRW in both the augmented and non-augmented models. The results from the respecified model indicate that Islam may not have been completely correct in his conjecture regarding MRW's high capital shares. The respecified model results indicate that, with the exception of the intermediate augmented case, MRW's capital shares are "too" high; allowing for country heterogeneity does lead to more realistic estimates, though these estimates are not as low as those suggested by Islam. Interestingly, the respecified models indicate a larger capital share in output when schooling is added to the model. This directional change is opposite to that found by MRW, and the same as that found by Islam, though the magnitude of Islam's changes were much smaller.

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[19] Keep in mind here that these estimates of capital's share of output are actually estimates of the originally specified form using the PWT, 1995 version.

[20] These estimates of capital's share of output are calculated from MRW's *unconstrained* growth regressions. The results MRW emphasizes are from the *constrained* growth regressions which is not comparable to Islam in the context of this paper.

IV. Conclusion

The results of this paper support Islam's conjecture and findings that the unseemingly high capital output shares were not likely due to the omission of human capital (schooling) as MRW argue. In MRW's case, for 2 of the 8 models explored, it was impossible to review the theoretical implications derived from the Solow model. In the 6 remaining models, the estimates of the coefficients of these models changed at least moderately when correctly specified.

Nazrul Islam concluded that the omitted variable problem as espoused by Mankiw, Romer and Weil is not the cause of the high estimates of capital's share of output. In fact, Islam concludes that these 'high' estimates are because of the inappropriate assumption that the constant (lnA(0)) does not vary by country. Islam allows the constant to vary by country by using a *within* estimator on a panel data set. Although I find some support for this argument, we show here that it may not be the full story.

Using panel data, and a within estimation, Islam obtained estimates more in line with a priori intuition and empirical evidence, however, his models are also statistically misspecified. His models suffered from heterogeneity in the conditional variance. To account for this variance heterogeneity, I use FGLS where our model weights are obtained by regressing the residuals squared on regional dummy variables.

After correcting for the heterogeneity, there is an increase in parameter estimates including estimates of capital's output share (relative to Islam) but the estimates were still smaller than those obtained by MRW. Hence, we can conclude that part of the problem may have been the argument put forth by Islam, but part of the decrease in the estimates was due to statistical misspecification. By using panel data for growth regressions, the theoretical model becomes a valid model in the sense that we can regain our theoretical parameters directly from the statistical model.

To draw a definitive conclusion about the omitted variable problem here would be to put oneself in front of an academic firing squad, however, Islam's intuition does seem to be more in line with statistics than the omitted variable argument posed by MRW.[21]

[21] Unfortunately, it does seem as though the MRW argument is used more often as a justification to include human capital in a model, regardless of whether it is measured in levels.

With regard to the theoretical Solow model being a useful model for 'real' data, as long as we use panel data in the form of Islam, we can retain the pure form of the theoretical model after statistical respecification. This is not the case for cross-section data. On the whole, if only a cross-section is used, and we want to retain the spirit of the Solow framework, we must use somewhat homogeneous country groups which depict stability in incomes across countries.

In this paper, we show how empirical results can change substantially when one worries about whether the statistical assumptions underlying the model seem reasonable for the data at hand. Given that the properties of our estimators and the validity of all inferences drawn from one's models hinge on the appropriateness of these assumptions, it seems prudent to investigate the appropriateness of these model assumptions as closely as possible.

Chapter 3. Politics, Inflation, the Mundell-Tobin Effect, and Growth: A Robust Study of Inflation Rates Below 20%.

I. Introduction

The Mundell-Tobin effect states that an increase in inflation causes an increase in capital investment, and in turn, an increase in growth. In contrast to Mundell (1965) and Tobin (1965), another line of thought argues that high inflation can lead to high inflation variability, and this variability decreases investment and growth.[22] Empirical support for a negative relation between *investment* and inflation can be seen in Greene and Villanueva (1991), Fischer (1993), and Barro (1996).[23] Empirical support for a negative relation between *growth* and inflation can be seen in Barro (1995, 1996), Fischer (1993) and DeGregorio (1993). However, this evidence for a negative relationship between inflation and investment is tenuous. As Temple (2000) observes, the relationship does not hold for countries with low inflation (typically below 15 or 20%), and for higher rates, the correlation is mostly influenced by the existence of a few outliers.

In recent work, authors have argued that the lack of a correlation between inflation and investment in low inflation countries reflects the fact that inflation itself is an endogenous variable. To overcome this problem, one can use instrumental variables for current inflation. One strand of literature tries to instrument inflation with variables such as lagged inflation (Barro; 1995, 1996), central bank independence (Cukeirman et al. 1993), or a limited set of political stability and/or regime characteristics (Barro, 1996; Cukeirman et al., 1993). Using political variables as instruments makes sense if inflation is primarily driven by monetary policy and/or political instability. In this paper I use political variables as instruments for inflation, but extend the list to include a more extensive set of political stability and regime variables gathered from the political science literature.

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[22] Demetriades (1989) cites many authors who have found a positive relation between inflation variability and the level of inflation, while Davis and Kanago (1996) cite many authors who have found support for the negative relation between inflation uncertainty and growth.

[23] Aizenman and Marion (1993) even investigate what they call *inflation surprises* and its negative impact on investment.

I consider a set of 39 political variables as potential instruments on a panel data set spanning at least 10 years. After arriving at a parsimonious model by dropping variables that are found to be insignificant, I typically find that the more democratic the government, the higher is inflation. Stability variables such as riots and coups do not directly add to inflationary pressures, but the number of changes to a democracy from another form of government does add to inflation. I also find that countries with freer trade tend to have higher inflation, and countries with a large number of *effective* lower house parties tend to have lower inflation. I then regress investment on the estimates of inflation attained from the instruments in both a panel and a cross section.

In each regression, I show that politics explains a large portion of inflation, and that this politically influenced inflation explains a large portion of the variation in investment. Furthermore, in the panel model, I find that there exists a positive non-linear relationship between investment and inflation up to approximately 6% inflation. In the cross sectional model, I find a positive non-linear relationship between investment and inflation for rates up to approximately 9%. It is this significant influence of inflation on investment or growth within this *low* range of inflation rates that has not been documented in previous studies. Thus, my results provide evidence that the Mundell-Tobin effect *may* be valid for low inflations.

I briefly extend this analysis of investment to growth by correcting for the possible endogeneity of investment. To instrument for investment I use the predicted values from the investment/inflation regressions in a standard growth regression of the Mankiw, Romer and Weil (1995) form. The results imply that instrumented investment does influence growth in a non-linear fashion over a five year interval in the panel regressions, but does not influence growth over the 10 to 15 year span in the cross section. Thus, it appears that politically driven investment does not influence long run average growth and that treating investment as exogenous in empirical growth models may be problematic by causing biased parameter estimates.

This paper is organized as follows; section II reviews the data. Section III addresses the political influence on inflation and suggests stories for the results that are reasonably consistent with political thinking. Section IV displays plots of estimated inflation on investment and builds a priori reasoning as to what the empirical results should be. In sections V and VI, I estimate both the panel and cross section models respectively, while section VII is the conclusion.

II. The Data

The data used in this study were compiled by Przeworski, Alvarez, Cheibub, and Limongi (PACL) and evaluated in their book *Democracy and Development: Political Institutions and Well-Being in the World, 1950-1990*. There are 6 regime variables , and 33 stability and political transition variables (see appendix L, page 121, for a complete description of these variables). The variable for inflation that I use (CPI) is also in their data set, but is acquired from the IMF (1994, CD-ROM) and is defined as the annual rate of growth of the consumer price index.

PACL's data set covers 135 countries yearly from 1950 to 1990 for some countries, with most covering fewer years. This gives me a highly unbalanced panel with 4,126 observations. I modify the data as follows. First, to eliminate possible dependence in the data, I use 5-year intervals rather than yearly.[24] Second, it seems to make little sense to run regressions with political stability indices that measure such things as riots and coups, or a regular change-over of presidents, where some countries will unduly influence the results if their political variables are allowed to vary over a longer period of time than other countries. To ensure that those countries over a longer time horizon were not dominating the regression results, I limit the data analyzed to 76 countries at five year intervals with all data beginning in 1970 and ending in either 1980 or 1985.[25] Thus, my country panels are at least 3 observations, and most 4 observations long (the average is 3.9 per country).

My investment to GDP ratio, GDP, and population growth variables are constructed from the Summers-Heston data set- -Penn World Tables version 5.6- - and the schooling variables are from the Barro-Lee data set on schooling quality and amounts. The school variables used here are the percentage of the total population (male and female) who have acquired at least secondary schooling (people 25 and older), and the number of years of education in the total

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[24] For completeness, I tested for independence for these 5-year interval data by testing the significance of one 5-year lag and attained a p-value of 0.8352, hence failing to reject the null of independence.

[25] Appendix M, page 127, lists these countries.

population with the same status.[26]

III. Inflation and Politics

Many have tried to overcome the difficulty of dealing with the endogeneity issue when evaluating the impact of inflation on investment and growth. As stated by Barro (1998),

> ". . . an inverse relation between growth and inflation would arise if an exogenous slowing of the growth rate tended to generate higher inflation. This increase in inflation could result if monetary authorities reacted to economic slowdowns with expansionary policies. Moreover, if the path of monetary aggregates did not change, then the equality between money supply and demand at each point in time implies that a reduction in the growth rate of output would tend automatically to raise the inflation rate."

Several ways of correcting for this endogeneity bias include using a measure of central bank independence (the most commonly used determinant of inflation), lagged inflation, institutional factors such as historical or contemporaneous colonial status, whether a country is ruled under a democracy or dictatorship, and political stability indices such as the number of attempted coups or riots, as instruments for inflation. With the exception of lagged inflation, all of the above potential determinants of inflation are political in nature. In the search for determinants of inflation, this seems to be the most logical course to take. Kirshner (2001) states that "all monetary phenomena are fundamentally political." He also states that the most commonly used determinant of inflation–central bank independence(CBI)–"represents a political outcome" that in turn affects growth. It is more likely that CBI is a function of either a regime variable (such as whether a government is ruled under a democracy or a dictatorship), a legislative variable (such as whether a government is a parliamentary democracy or a presidential democracy), or a stability variable (such as the number of times a government head has been overthrown, the number of riots in a country and whether those riots were motivated politically or economically). This view is further supported by Banaian and Luksetich (2001) who state that measures of CBI "may simply be proxies for political and economic freedoms that

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[26] To verify that my data reflects the same characteristics of, say, Barro (1996), in appendix N, page 129, I run a series of regressions and plot the estimated, linear least squares regression line.

are more important checks of political manipulations of the economic system."

It seems that measuring inflation via CBI aggregates the institutional and stability effects, hence, effectively reduces the potential correlation between CBI and economic growth. This may be one reason why most economists find no real correlation between CBI and growth at low levels of inflation. Even though some economists have used other political measures, the set of measures seems to be limited in scope. The political science literature, as Kirshner recognizes, has generated a much more expansive set of these measures that could be utilized in economics.

My argument for using a panel and not a *contemporaneous* cross section to determine estimates of inflation is because political processes take time and for some of the indices there may be little or no contemporaneous variation across countries. I do not use a cross section that is *averaged* over time because most of the political variables are either dummy variables or index variables and the interpretation of the averages of these variables may not make sense.

The first estimate is a general Least Squares with Dummy Variables (LSDV) model where I include all 33 stability and political transition variables, then by a process of elimination based on statistical insignificance, determine the most parsimonious form. I then include each regime variable one at a time, keeping the one that is significant. Taking the model to this parsimonious form mostly due to the fact that leaving in all variables, even if most variables are statistically insignificant, will influence the estimated values of CPI, and hence may artificially influence investment in later regressions. To ensure a statistically adequate model, I end up having to correct for heteroskedasticity and heterogeneity in the conditional variance using a Feasible Generalized Least Squares (FGLS) method; the weights determined by a regression of the squared residuals on the region of Oceania (see Edwards, 2002). The resulting model is:

Table 3.1: CPI Estimations

CPI	Estimate	P-value	T-statistic
inst	0.3056	0.008	2.693
agea	0.0221	0.001	3.258
dicadem	1.3745	0.000	4.753
effparty	-0.0091	0.084	-1.733
odwp	3.3729	0.000	4.098
openc	0.0103	0.000	4.187
strd	1.1182	0.000	3.904
$agea^2$	-0.000095	0.105	-1.628
$strd^2$	-0.0569	0.000	-4.026
Number of observations: 301			
Adjusted R^2 82.83			
Avg # obs per country 3.9			
F-test on fixed effects F(77,213) = 3.23 P-value = 0.000			
RESET test for linearity P-value = 0.1423			
Cook-Weisburg test for Homoskedasticity 0.1100			
Shapiro - Wilke test for normality 0.5922			
FGLS regression with the region of Oceania in the auxiliary regression.			
The dependent variable is the natural log of CPI.			
* implies significance at 10%			
** implies significance at 5%			

As indicated in table one, the independent variables that are ultimately used to explain inflation are (i) inst, (ii) agea, (iii) dicadem, (iv) effparty, (v)odwp, (vi) openc, and (vii) strd.[27] Below I define these variables and interpret their respective coefficient estimates.[28]

(i) **inst**: Classification of political regimes in which democracies are distinguished by the type of executive. Coded 0 if dictatorship; 1 if parliamentary democracy; 2 if mixed democracy; 3 if presidential democracies. Transition years are coded as the regime that emerges in that year.

The positive coefficient on inst implies that as a country becomes more democratic,

[27] The squared terms were included in the regression to correct for functional form problems indicated by a failing of the RESET test performed on the original regression.

[28] It must be warned that the explanations I give for the estimated influence of the political variables on inflation are highly subjective and incomplete. Research on the political economy of inflation is beyond the scope of this paper.

inflation increases. It has been suggested that democratic presidents tend to give signals for easier monetary policy more so than for tight monetary policy, the explanation for which is not clear (Froyen, 1997). Another explanation may be that democracies are breeding places for special interest groups who make competing demands for shares of the economy, and together these shares are greater than the economy's total product. This excess demand may be inflation generating (Hirsch, 1978; cited in Kirshner, 2001). On the other hand, a dictatorship may promote an atmosphere of economic stagnation whereby increases in incomes are limited and price floors are common, hence inflationary pressures are limited by decree.

(ii) **agea:** Age in years of the current regime.

The overall effect of agea and agea squared over the observation range is positive and implies that the longer a current regime is in power, the higher the inflation of that country. The reason for this positive influence may be that the longer a regime is in power, the more vulnerable it may feel and the government may not be able to resist from caving in to social pressures and will increase the money supply to boost short term output (Kirshner, 2001).

(iii) **dicadem:** Dummy variable coded 1 for a year in which a dictatorship follows a democracy, 0 otherwise.

The positive coefficient on dicadem implies that there is higher inflation in the years following a transition from a democracy to a dictatorship. Given that (i) tells us that a democracy has higher inflation than does a dictatorship, the reason for this positive correlation must be a stability argument. Typically, if a country becomes a dictatorship, it is probably because of a military coup or a similar form of overthrow of the democratic regime. This could result in lower output and higher inflation.

(iv) **odwp:** Percentage of democratic regimes in the current year (other than the regime under consideration) in the world.

The positive coefficient on odwp implies that the greater the percentage of democracies in the world, the higher is inflation in the country under consideration. The explanation for this effect is highly speculative, but if there is a high percentage of democracies in the world, this could drive global prices for tradable goods higher because of special interest groups such as labor unions and environmental regulations forcing up wages and prices of consumables.

(v) **openc:** The sum of exports and imports divided by GDP.

Openc implies that the more a country is involved in trade, the higher the inflation in that country. The explanation for this result is simply descriptive and is based on previous results. If dictatorships have lower inflation, as indicated by the positive relation of inst, and if dictatorships are less open than democracies, then we would expect a positive relationship between openc and inflation.

(vi) **strd:** The sum of past transitions to democracy in a country.

The initial positive correlation of this quadratic behavior can be explained with the same stability argument as in (iii), however, the reversing of this affect is more speculative. One explanation may be that these transitions result in an environment where citizens may eventually get accustomed to the frequent transitioning, resulting in a stabilization of prices.

(vii) **effparty:** Number of effective parties, defined as 1/(1-F), where F=Party Fractionalization Index.

Effparty has a negative influence on inflation which implies that the more effective parties that are involved in a government, the lower the inflation. The key to this coefficient is that the variable in question measures 'effective parties' and not parties who have little affect on policy decisions except for to impede the efficiency of resource allocation. We might think that governments who consist of parties who *can* effectively influence government expenditure and policy may actually try to work together toward common interests, hence creating an atmosphere of stability for the common good.

As mentioned in the introduction, in general, the more democratic the government, the higher the inflation, with government transitioning adding to inflationary pressures. I also find that countries with freer trade tend to have higher inflation, and that countries with a lower houses that work together for the common interest tend to have lower inflation.

IV. Inflation and Investment (initial plots)

Over the years, there have been dozens of studies about the effects of inflation on investment and growth. Some of the more frequently cited studies are Barro (1995, 1996), DeGregorio (1995), Andres and Hernando (1997), and Cukeirman et al. (1993). The initial reason these studies were made was because of the potential benefits (Mundell, 1965; Tobin, 1965) or costs of inflation (Briault, 1995). The more recent literature has focused on the costs because of the weak empirical support that shows a negative correlation between inflation and investment or growth, particularly in high inflation countries.

A few of the most common arguments for the costs of inflation are that in a world where there is no interest paid on *cash* holdings, when inflation is present, agents incur 'shoeleather' costs from having to increase the frequency of trips to banks. Briault (1995) states that people spend time and energy trying to "synchronize cash expenditures with the receipt of cash income." In addition, high inflation results in an uncertainty (provided that inflation and the variation in inflation are positively correlated as has been found in many studies) that will increase the complexity of contracts, raising the frequency of negotiation, and hence increasing the costs and risks of entering into contracts altogether. These reasons imply that there should exist a negative correlation between inflation and investment or growth.

Even though the notion that high inflation has a negative effect on investment and growth dominates the literature, there have also been several studies that suggest this correlation is non-existent. These conflicting results may reflect the fact that inflation and investment are endogenous.

There are several studies that address the endogeneity issue by using instruments, such as CBI, and political events such as riots and coup attempts (see Cukierman et al. for an example) in growth regressions. These studies have yielded results in line with the negative correlations mentioned above. As noted in the previous section, over 82% of inflation can be explained by governmentally influenced variables and country specific effects. This implies that the endogeneity problem between inflation and growth can be remedied with a highly correlated set of instruments. Nonetheless, it has been argued that inflation influences growth indirectly through its impact on investment (Fischer, 1993). As a preliminary exercise, I explore this relationship graphically.

Even though plots of panel data are typically not useful for cross country analysis, I will use one here and compare it to the averaged plot that will be used for the cross section analysis later. The plots below are of the estimated natural log of inflation attained from the inflation regressions above on the natural log of the investment to GDP ratio.

Figure 1A: Investment on Estimated Inflation, Panel Data

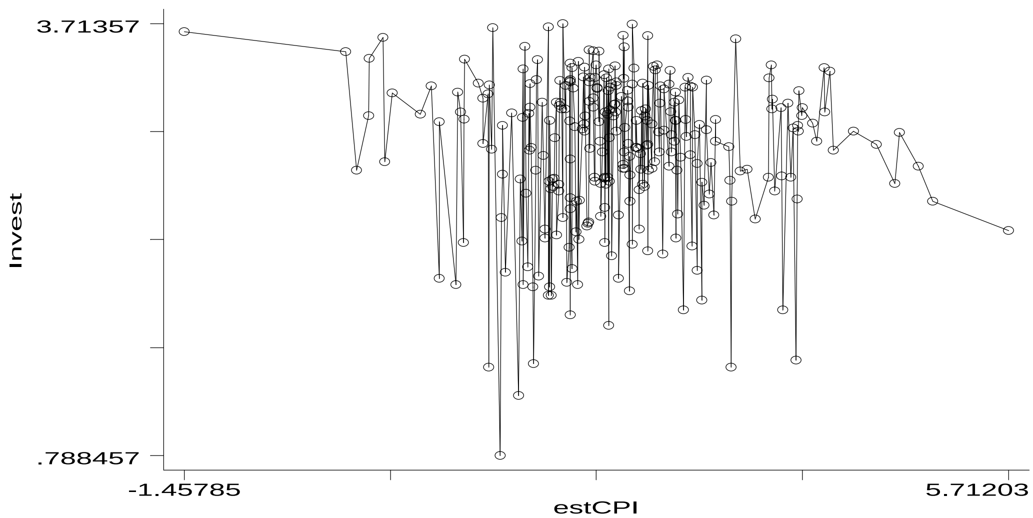


Figure 1B: Investment on Estimated Inflation, Cross Section Data

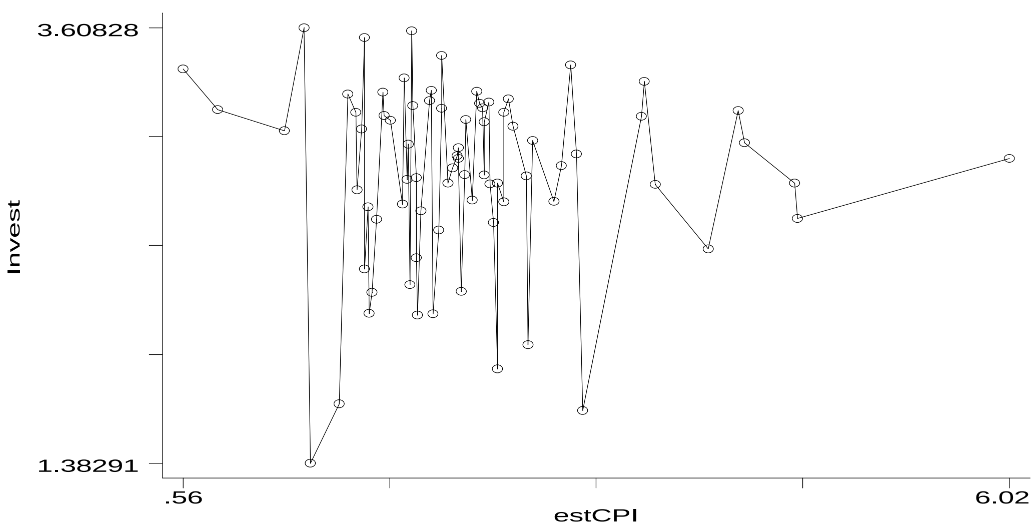
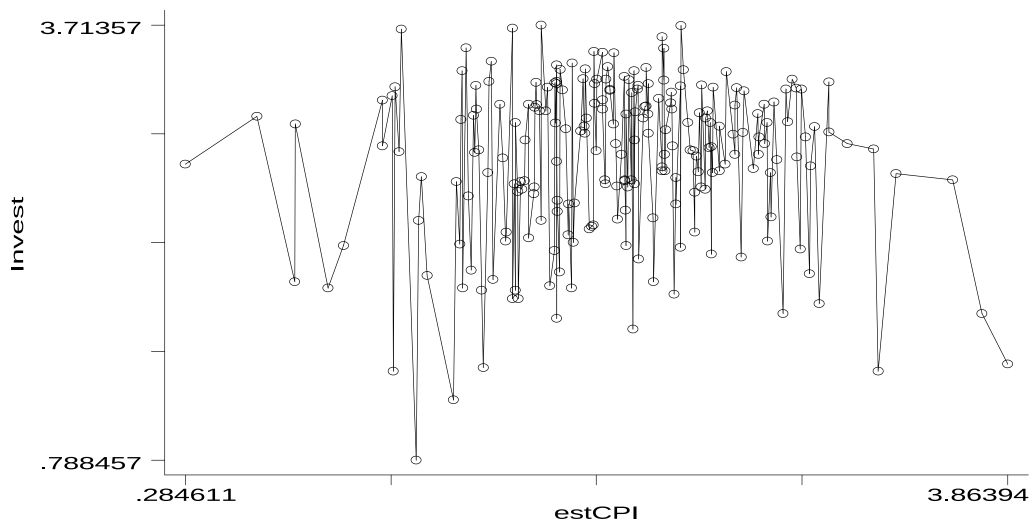


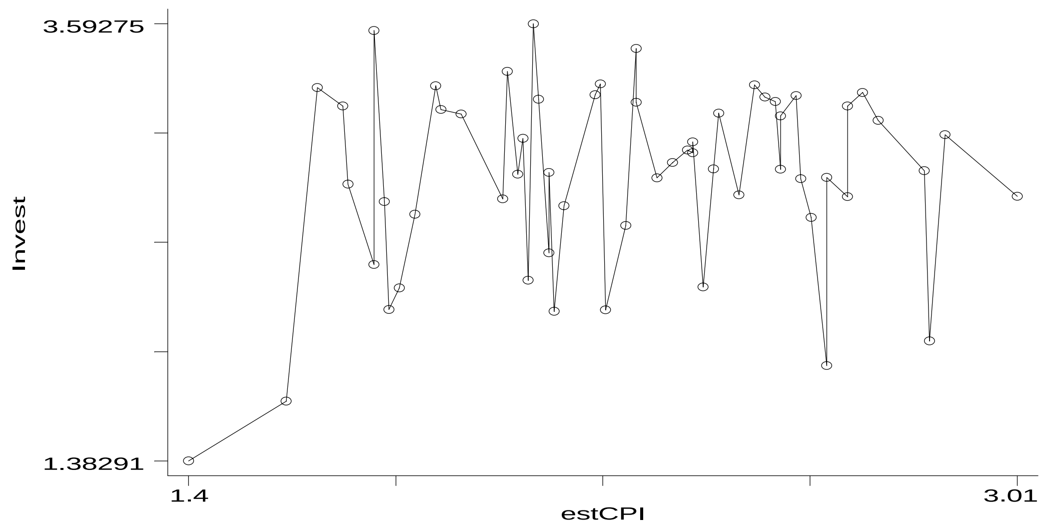
Figure 1A using panel data is very similar to Figure 1B using cross section data. Of course there is much more noise in the panel plot, however, a general pattern emerges where there is a slight negative correlation on the front and back of both plots, with the center seeming to have an either piecewise linear or a quadratic form. Chopping off the fronts and backs of the cross section plot makes these features stand out, and since observations are not always grouped together for plots of panels, I simply drop the same *countries* from the panel and the cross section. These truncated figures are below.[29]

Figure 2A: Investment on Estimated Inflation, Panel Data



[29] The 58 countries pertaining to these observations are listed in Appendix M, page 127.

Figure 2B: Investment on Estimated Inflation, Cross Section Data



These truncated figures for both the panel and cross section, illustrate an obvious non linear, or piecewise relationship between investment and inflation, where there seems to exist an inflation rate (or range of inflation) that maximizes investment. I now attempt to investigate these graphical observations using econometrics. First, I describe the results from the analysis of the panel data. Later, in Section VI, I analyze the cross-sectional data.

V. Investment and Growth- -the Panel Results

First, I simply regress the natural log of the investment to GDP ratio on the natural log of inflation. I do not use an LSDV method as I did with inflation because, as will be seen below, it is not needed, however, I do include regional effects that are common to the literature (i.e., North America, South America, Africa, Europe, Oceania, and Asia). This formula saves on degrees of freedom while still allowing for some heterogeneity.

Table 3.2: Initial Investment/Inflation Panel Estimations

The dependent variable is the investment to GDP ratio		P-value	T-stat
Constant*	3.0091	0.000	25.301
North America	-0.1997	0.037	-2.099
Europe	0.3205	0.000	3.606
Asia	-0.0253	0.791	-0.266
Oceania	0.3095	0.060	1.866
Africa	-0.4856	0.000	-5.266
CPI	-0.0350	0.219	-1.233

*South America is the control region
No. of Obs: 293
Adjusted R^2: 0.32
RESET test for linearity: 0.1466
Cook-Weisburg test for homoskedasticity: 0.0000
Shapiro-Wilk test for normality: 0.0016
76 countries
CPI is the annual rate of growth of the consumer price index.

What we find above is the typical negative correlation that other authors get when regressing investment or growth on inflation (Barro (1996) gets an estimate of -0.059 when using lagged inflation as an instrument, and -0.044 when using prior colonial status as an instrument). It turns out, however, that this regression model is misspecified. Tests of the normality and homoskedasticity assumptions indicate potential problems, thus no inference should be made based on this model. Specifying a piecewise model to account for structural breaks in the data at 3.4%, 7.3%, and 27% inflation, I get the following:

Table 3.3: Respecified, Peicewise Investment/Inflation Panel Estimations

Dep. Variable: ln(Investment)	Coefficient	P-value	T-stat
Constant*	2.6256	0.000	6.279
North America	-0.2175	0.022	-2.303
Europe	0.2943	0.001	3.306
Asia	-0.0410	0.663	-0.436
Oceania	0.2564	0.116	1.579
Africa	-0.5041	0.000	-5.350
d(0.2 - 3.4%)	0.5921	0.164	1.396
d(7.3 - 27%)	1.2374	0.010	2.607
d(27 - 1480%)	0.3134	0.571	0.567
CPI	0.1297	0.585	0.547
d(0.2 - 3.4%) * CPI	-0.4476	0.101	-1.643
d(7.3 - 27%) * CPI	-0.4738	0.065	-1.854
d(27 - 1480%) * CPI	-0.1469	0.563	-0.579

South America is the control region
CPI is the control slope range
No. of Obs: 293
Adjusted R^2: 0.3695
RESET test for linearity: 0.0.000
Cook Weisburg test for homoskedasticity: 0.0000
Shapiro-Wilk test for normality: 0.0847

Unlike table one, we find a positive correlation between investment and estimated inflation between 3.4% and 7.3% inflation. The slopes of the other three structural ranges are all negative. However, one can also see that both tests for linearity and homoskedasticity fail, signaling that our estimates are biased and should be suspect when making inferences about the relation between investment and inflation. Viewing Figure 1A and Figure 1B once more, and taking into consideration the estimates above, it is reasonable to assume that the 'front' observations and 'back' observations of each plot are negatively correlated with investment. Taking this into consideration, I drop the corresponding countries from each data set, and proceed to respecify the model. I correct the misspecification of this model by checking for structural changes and possible non-linearities in the data, and also perform FGLS regressions to account for heterskedasiticity, as I did above for the inflation regression (the regions of Africa and Oceania were included in the auxiliary regression of the FGLS system to account for the heterogeneity in the conditional variance). The results are below.

Table 3.4: Final Investment/Inflation Panel Estimations

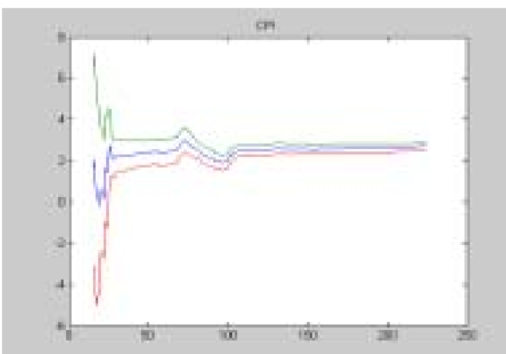
The dependent variable is the natural log of the ratio of investment to GDP					
Variables	(i)	(ii)-8%	(iii)-8%	(iv)-6 & 7.5%	(v)-6 & 7.5%
Constant	15.8184 (0.000)	16.2916 (0.000)	14.8654 (0.000)	15.6400 (0.000)	15.0337 (0.000)
North America	-4.9001 (0.001)	-3.5769 (0.093)	-4.8209 (0.001)	-3.6025 (0.054)	-4.8606 (0.001)
Asia	-3.3922 (0.016)	-1.5305 (0.456)	-3.2222 (0.020)	-1.5598 (0.386)	-3.3092 (0.018)
Africa	-12.3130 (0.000)	-11.2369 (0.000)	-13.0239 (0.000)	-11.9996 (0.000)	-13.4211 (0.000)
Europe	3.0878 (0.023)	4.6248 (0.020)	3.2619 (0.014)	5.3500 (0.002)	3.1275 (0.020)
Oceania	30.9768 (0.000)	38.5862 (0.000)	35.7278 (0.000)	34.1062 (0.000)	35.1084 (0.000)
d1		-0.6922 (0.747)	4.7021 (0.054)	2.4249 (0.302)	5.0232 (0.114)
d2				1.1733 (0.633)	3.7141 (0.239)
CPI	2.2496 ** (0.000)	1.0655 ** (0.000)	2.3514 ** (0.000)	1.2096 ** (0.000)	2.3877 ** (0.000)
CPI^2	-0.6094 ** (0.000)		-0.6544 ** (0.000)		-0.6791 ** (0.000)
d1*CPI		-0.3821 ** (0.000)	-0.0969 (0.473)	-0.3666 ** (0.000)	-0.1844 (0.305)
d1*CPI^2			-0.0002 (0.853)		0.0013 (0.535)
d2*CPI				-0.6689 ** (0.000)	0.0119 (0.948)
d2*CPI^2					-0.0014 (0.554)
Adjusted R^2	0.9530	0.9024	0.9549	0.9221	0.9540
RESET test for linearity Cook-Weisburg test for homosked Shapiro-Wilk test for normality	0.1437 0.1981 0.0517	0.1184 0.0000 0.1857	0.5572 0.3979 0.0660	0.3881 0.0003 0.0990	0.9294 0.3408 0.0746

P-values are in parentheses . ** is significance at 5%, and * is significance at 10%.
Number of observations in each regression is 225
Each of these regressions are FGLS regressions where Africa and Oceania were included in the auxiliary regression due to variance heterogeneity.
For completeness, models (iii) and (v) have dummies * CPI squared to test for non linearities outside the control range, CPI.
58 countries in this sample.

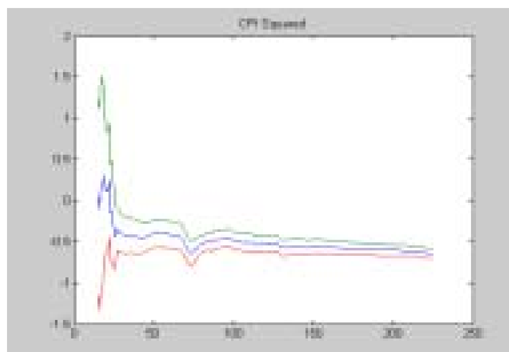
The first six variables are the regional dummies, while d1 and d2 are dummies delineating the structural breaks in plot B (panel). Model (i) is a regression of the investment ratio on CPI and CPI squared to account for a possible quadratic structure in the data. Models (ii) and (iv) assume a standard piecewise linear regression whereby model (ii) puts the break somewhat in the middle of plot B, at an inflation rate of approximately 8%, and model (iv) assumes two breaks at approximately 6 and 7.5% inflation. Models (iii) and (v) assume the same relative breaks as in models (ii) and (iv), but also include squared CPI for each section of the data between the breaks.[30]

The first thing that stands out is that models (ii) and (iv) fail the homoskedasticity testing even though these regressions are FGLS regressions.[31] The obvious source for this failing is that there are non linearities present in the errors. I can deduce this because when CPI^2 is added to the regressions in models (i), (iii), and (v), each passes all *statistical* tests. The only assumption left to test is parameter stability to examine whether the regional effects capture all the heterogeneity. I estimate the model using recursive least squares and examine plots of the recursive estimates.[32]

RLS plot of CPI



RLS plot of CPI^2



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[30] There may be some question regarding the orthogonality between estimated CPI and the residuals of this regression. Orthogonality may break down if investment is not only a function of estimated CPI, itself a function of political variables, but also of politics itself. To test this theory, I regressed the residuals from model (i) above on the same political variables used to determine CPI. The test for joint significance of the political variables returned a p-value of 0.2264, with an R^2 of 0.01. RESET test was 0.6880, CW test was 0.1143, and the SW test was 0.0711, indicating that the results are accurate and orthogonality is upheld.

[31] Spanos (1986, pg 463) states that “the assumption of homoskedasticity is inextricably related to the assumption of normality and we cannot retain one while rejecting the other. . .”, and as we notice, both models highly pass normality.

[32] Recursive least squares simply estimates a regression with less than the full data set and plots the resulting parameter estimates, then adds one observation to the regression until all observations are exhausted, all the while plotting the estimated parameters.

Viewing the recursive plots of the parameters, we find that we have parametric stability and convergence. Hence, the natural log of investment is best modeled as a quadratic function of the natural log of estimated inflation. Further support of this observation is that the structural changes in the slope coefficients are significant without CPI^2, and insignificant with it. This indicates that the changes in the slopes are picking up the non linearity of the data, of which the quadratic term is a better description.

Another observation that is of interest is that in models (ii) and (iv) CPI is positive, while in models (i), (iii) and (v), the correlation is estimated to be concave with the maximum of each model being 6.33%, 6.03% and 5.80% respectively. Plot B above starts at an inflation rate of approximately 1.33% and ends at an inflation rate of 47.47%. Hence, inflation increases investment from 1.33 to around 6% inflation, and decreases investment thereafter. This could be indicative of the Mundell-Tobin effect for low inflation rates.

There could be an argument made that the R^2 - values are too high- -that it does not seem reasonable for politically driven inflation to explain 95% of the variation in investment. However, this argument does not consider the fact that there are regional effects in both the regression above and the FGLS auxiliary regression, that the regressions above are also controlling for a quadratic structure in the data, and furthermore, there are country specific fixed effects in the inflation estimations. Considering all of this together, it seems plausible that these models explain 95% of the variation in investment. Below, I extend the analysis to growth.

Growth:

The growth regressions modeling the panel data will take the form of country specific fixed effect regressions of the following form:

$$\begin{aligned}\Delta \ln GDP_{it} &= \alpha_{0i} + \alpha_1 \ln GDP_{i,t-1} + \alpha_2 \ln(I/GDP)_{it} + \alpha_3 \ln(n+0.05)_{it} \\ &\quad + \alpha_4 \ln School_{it} + e_{it}\end{aligned}$$

where the left hand side variable will be the difference of the natural log of GDP in period t and GDP in period t-1 where t-1 is the five year lag.[33] The right hand side variables will be the five

[33] In these panel regressions of growth, the method used for investment of only requiring regional effects to account for mean heterogeneity was not sufficient, hence, I had to use country

year lag of the natural log of GDP, the estimated values of the natural log of investment to GDP, the log of population plus 0.05 to account for the technology and depreciation factors, and the *percentage* of agents with secondary schooling over the age of 25 (and separately with *levels* of schooling for people over 25). As a comparison to using the *estimated* investment ratio, I also run regressions using the *actual* investment to GDP ratio. This econometric setup for growth is common in the literature, and was first estimated with panel data in Islam (1995).

Table 3.5: Growth/Endogenous Investment Estimations

Dependent variable is the five year difference of the natural log of GDP						
Model Type	Estimated (L)	Estimated (P)	Actual (L)	Actual (P)	Standard (L)	Standard (P)
GDP_{t-1}	-0.3439 **	-0.3631 **	-0.2950 **	-0.3114 **	-0.3696 **	-0.4534 **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Population	-0.0148	-0.0246	-0.0461	-0.0533 *	-0.0332	-0.0422
	(0.590)	(0.398)	(0.102)	(0.054)	(0.513)	(0.507)
Investment	1.2585 *	1.1985 *	0.5767 **	0.5391 **	0.2485 **	0.1386 **
	(0.081)	(0.088)	(0.020)	(0.037)	(0.000)	(0.001)
$Investment^2$	-0.2148 *	-0.2081 *	-0.0630	-0.0610		
	(0.083)	(0.087)	(0.142)	(0.169)		
School	0.0162	0.0032 *	0.0184	0.0027	0.0412 **	0.0072 **
	(0.229)	(0.082)	(0.159)	(0.112)	(0.022)	(0.007)
Adjusted R^2	0.5145	0.5151	0.5732	0.5793	0.4522	0.3797
RESET Test	0.5979	0.6615	0.0749	0.0551	0.0036	0.0003
Cook-Weisburg	0.9158	0.9840	0.4343	0.6113	0.2856	0.1577
Shapiro-Wilk	0.4143	0.1263	0.3515	0.7443	0.0000	0.0000
No. of Obs.	194	194	194	194	197	197

P-values in parentheses
* implies significance at 10%
** implies significance at 5%
'L' implies levels of schooling
'P' implies schooling percents
No. of Countries for each is 51

[Note: The *Estimated* regressions are so called because I am using the estimated value of the natural log of investment attained from the inflation regressions, while the *Actual* regressions use the actual value of the natural log of investment. The regressions marked *Standard* are called this

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specific effects. Furthermore, this model was corrected through an FGLS method because of fixed effects in the variance where the panel required Europe and Oceania in the weighting regression (see Edwards, 2002, for an additional application of this).

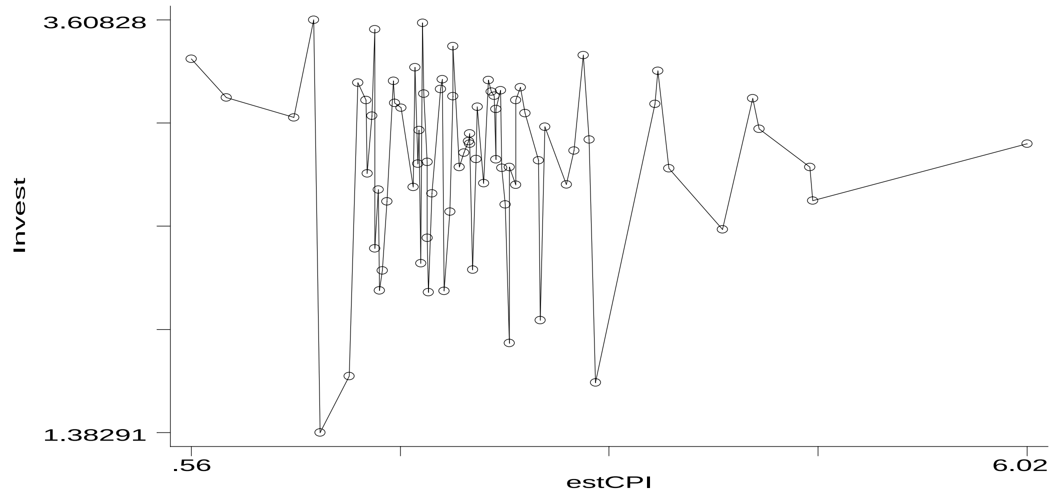
because these are the standard form LSDV regressions that are unweighted and are found in most studies (see, for example, Islam (1995).]

We can see that all coefficients have the expected signs, furthermore, the Standard estimates are very close to Islam (1995) where he gets coefficient estimates of lagged GDP and investment of -0.23 and 0.16 respectively. The Estimated models highly pass all testing, where the Actual regressions borderline pass the RESET test with p-values of only 0.07 and 0.05. In addition, investment squared is significant in the estimated models and not significant in the actual models. The suggested level of investment for the estimated model is around 19 times GDP per capita, and for the actual model is around 115 times GDP per capita. One additional observation that should be considered is that the standard models that most authors regress, disregarding specification and outliers, fails the linearity and normality tests. For instance, in Islam's paper, the p-values for the RESET and Shapiro-Wilk tests in the duplicated Non-Oil and Intermediate regressions were each only about 0.01, hence, failing both tests (see Edwards, 2002). A more fundamental lesson we learn by having to include the quadratic form of the investment ratio is that the log-linearizing method of approximating around the steady state, as derived by MRW, may not be appropriate empirically- -but this is an area for further research.

VI. Investment and Growth- -the Cross Section Results

The first thing that should be noticed is that when average investment is plotted against the average of the estimated values of inflation, we see an apparent delineation of inflation into at least 3 areas.

Figure 1B: Investment on Estimated Inflation, Cross Section Data



Looking again at plot A, we see that the first few observations are negatively correlated with investment, the next group appears to have a negative correlation with a different slope and intercept, and the last several also a negative correlation with a different slope and intercept. The range of estimated inflation rates this plot covers are from 1.75% average inflation to 411% average inflation. Running this regression, while ignoring the obvious structural differences in the plot but accounting for regional effects, I get the following:

Table 3.6: Initial Investment/Inflation Cross Section Estimations

The dependent variable is ln(I/GDP)		P-value	T-stat
Constant*	3.0391	0.000	12.622
North America	-.2128	0.215	-1.252
Europe	.3141	0.055	1.955
Asia	-.0367	0.834	-0.211
Oceania	.2992	0.314	1.015
Africa	-.5001	0.004	-2.998
CPI	-.0438	0.480	-0.710

* South America is the control region
No. of Obs: 76
Adjusted R^2: 0.41
RESET test for linearity: 0.2717
Cook Weisburg test for homoskedasticity: 0.0000
Shapiro-Wilk test for normality: 0.0678

As we can see above, these results are not inconsistent with results attained in the panel regression where there is a negative correlation between inflation and investment, even though insignificant. However, looking at the plot again, we see obvious heteroskedasticity– –supported by the low p-value for the heteroskedasticity test, and furthermore, we can see that even though the normality tests are borderline passing (the p-value for the Shapiro-Wilk test is 0.067), there are obvious structural changes to the intercepts and slope coefficients that are not being accounted for. To allow for these structural changes, I will run a piecewise linear regression with breaks at approximately 3.9%, and 18% (the dummy variables that represent these breaks are labeled in the table below as d(1.7-3.9%), and d(18- 411%)). The results are below:

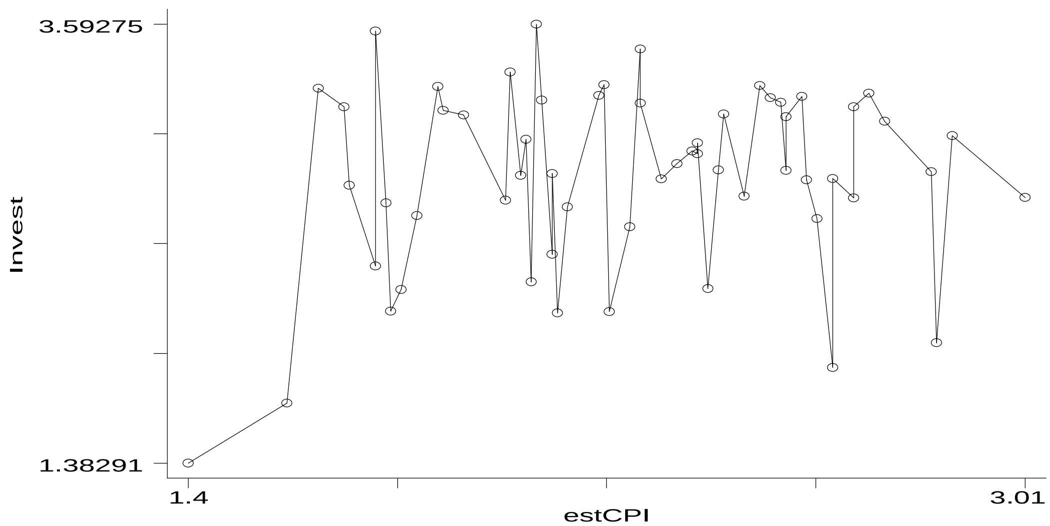
Table 3.7: Respecified, Peicewise Investment/Inflation Cross Section Estimations

Dep. Variable: ln(Investment)	Coefficient	P-value	T-stat
Constant*	2.9412	0.000	7.811
North America	-0.1818	0.319	-1.005
Europe	0.3337	0.056	1.943
Asia	-0.0314	0.864	-0.172
Oceania	0.3201	0.303	1.039
Africa	-0.4701	0.012	-2.589
d(1.7-3.9%)	0.1641	0.836	0.208
d(18- 411%)	-0.1532	0.797	-0.258
CPI	-0.0095	0.946	-0.068
d(1.7-3.9%) * CPI	0.0419	0.959	0.051
d(18- 411%)* CPI	0.0287	0.878	0.154

*South America is the control region
**CPI is the control slope range
No. of Obs: 76
Adjusted R^2: 0.3312
RESET test for linearity: 0.4805
Cook Weisburg test for homoskedasticity: 0.0000
Shapiro-Wilk test for normality: 0.0373

In agreement with the results in Table 5, here we find a negative coefficient for inflation (CPI), however, we also find that the correlation up to 3.9% and from 18 to 411% are positive, although, insignificant. A statistical explanation for these results may be that the assumption of normality is not satisfied and the estimates are biased. We will see below that when the plot is cropped like the panel case, the estimates become robust and all statistical assumptions are valid. Hence, I will simplify this analysis by focusing on the center set of inflation points in Plot A as I did in the panel. The resulting range of observations spans inflation rates from 4% estimated average inflation to 20% estimated average inflation.

Figure 2B: Investment on Estimated Inflation, Cross Section Data



Reviewing Plot B above, where the 'front' and 'back' observations have been dropped, we find evidence that there may be two different structural ranges. A priori, I would expect there to be a positive slope for the range 4-7%, and a negative slope for the range 7-20% (remember, the scale on the plot is of the natural log of inflation, and by exponentiating, we get actual inflation). There may also be some criticism of the suspected break, hence, for completeness, I also put the break at 7.8% inflation. Like the panel case, I also check for a possible quadratic structure. Evidence of this would be beneficial by increasing the robustness of my estimation with regard to the panel case. The total number of observations is 58 in all three regressions. The results of these regressions are below where model (i) is a simple quadratic function of estimated inflation, model (ii) - 7% is a piecewise linear model with the break at 7%, model (iii) - 7.8% is a piecewise linear model with the break at 7.8%, model (iv) - 7% is the same as model (ii) - 7% only with inflation squared added, and model (v) - 7.8% is the same as model (iii) - 7.8% again with inflation squared added to the regression.

Table 3.8: Final Investment/Inflation Cross Section Estimations

The dependent variable is the natural log of the ratio of investment to GDP.					
Variables	Model (i)	Model (ii) - 7%	Model (iii)- 7.8%	Model (iv) - 7%	Model (v)- 7.8%
Constant	0.6533	0.0465	0.3356	0.0798	-0.4087
	(0.502)	(0.971)	(0.777)	(0.950)	(0.743)
North America	-1.6263	-1.5801	-1.5917	-1.6444	-1.6886
	(0.056)	(0.067)	(0.066)	(0.057)	(0.048)
Asia	-1.2045	-1.0338	-1.0450	-1.2420	-1.3475
	(0.149)	(0.217)	(0.213)	(0.147)	(0.112)
Africa	-1.6924	-1.3982	-1.2332	-1.7662	-1.7126
	(0.036)	(0.080)	(0.123)	(0.041)	(0.043)
Europe	0.8739	1.0208	1.1920	0.7862	0.8202
	(0.265)	(0.198)	(0.132)	(0.334)	(0.308)
Oceania	0.8851	1.0521	0.7046	0.9204	0.5191
	(0.465)	(0.394)	(0.576)	(0.456)	(0.676)
d1		3.3239 **	3.0728 **	-0.7630	-1.7186
		(0.000)	(0.000)	(0.832)	(0.559)
CPI	2.6431 **	1.6724 **	1.5593 **	3.0321 **	3.3667 **
	(0.000)	(0.000)	(0.000)	(0.015)	(0.003)
CPI^2	-0.5947 **			-0.7253	-0.8579 *
	(0.000)			(0.253)	(0.101)
d1 * CPI		-1.8180 **	-1.6363 **	0.2981	0.7210
		(0.000)	(0.000)	(0.873)	(0.618)
Adjusted R^2	0.8474	0.8418	0.8415	0.8429	0.8471
RESET test for linearity	0.9334	0.7417	0.4557	0.9861	0.9356
Cook-Weisburg test for homosked	0.8138	0.7847	0.9884	0.6622	0.7236
Shapiro-Wilk test for normality	0.2105	0.1344	0.2804	0.2391	0.4220
P-values are in parentheses , * implies significance at 10%, ** implies significance at 5% Number of observations in each regression is 58 Each of these regressions are FGLS regressions to correct for heteroskedasticity					

We see that the control range we want to evaluate, the slope coefficient to CPI, is positive and significant in all five models. There are further consistencies across regressions in the adjusted R^2. Furthermore, the structural changes are significant in models (ii) and (iii). It seems, however, that the quadratic model (i) may be a better description of the variation in investment. This can be seen by evaluating both the misspecification testing statistics and the sensitivity of d1*CPI to the inclusion of CPI^2. Models (i), (iv) and (v) have higher overall linearity, homoskedasticity and normality p-values than model (ii) and (iii), furthermore, d1*CPI in models (iv) and (v) is highly insignificant while CPI^2 is only moderately insignificant (we also see that model (i) has a negligibly higher R^2 than the other four models). Therefore, for further analysis, I will only consider model (i).

Interestingly, model (i) comes close to duplicating the results from the panel case. The maximum of model (i) in the panel case is at 6.33% estimated inflation, whereas the maximum of model (i) in the cross section case is at 9.19% estimated inflation. Heretofore, regardless of whether the data is a panel spanning 10 to 15 years, or a cross section averaged over the time period, the results are robust with respect to the estimates attained, and the structural form of the econometric model. Furthermore, the explanatory power of each model is similar--the R^2 for model (i) of the panel model is 0.95 and for the cross section is 0.85.

Growth:

The growth regressions modeling the cross section data will take the form of a linear least squares regression where I test for the possibility that there are regional effects. These regressions are of the following general form:

$$\begin{aligned}\Delta \ln GDP_i = {} & \beta_0 + \beta_1 \ln GDP_{1970} + \beta_2 \ln(I / GDP)_i + \beta_3 \ln(n + 0.05)_i \\ & + \beta_4 \ln School_i + v_i\end{aligned}$$

The model marked *Estimated* uses the estimated values of the investment to GDP ratio from the investment/inflation relationship. The model marked *Actual* uses the actual values of investment that are assumed to be exogenous, while the model marked *Endogenous* includes estimated investment as well as the errors from the investment/inflation relationship. The reason for this regression will become clear shortly. Also like the panel case, L uses the levels of schooling while P uses percentages.

Table 3.9: Growth/Endogenous Investment Estimations

Dependent Variable: Average growth of GDP over the period 1970-1985						
Model Type	Estimated (L)	Estimated (P)	Actual (L)	Actual (P)	Endogenous (L)	Endogenous (P)
GDP_{1970}	-0.0290 (0.198)	-0.0336 (0.113)	-0.0450 ** (0.046)	0.0518 ** (0.017)	-0.0339 (0.112)	-0.0425 ** (0.038)
Pop	-0.1056 ** (0.011)	-0.1030 ** (0.011)	-0.0823 ** (0.033)	-0.0781 ** (0.037)	-0.1137 ** (0.004)	-0.1070 ** (0.006)
Investment	-0.0573 (0.202)	-0.0560 (0.210)	0.0457 (0.143)	0.0446 (0.146)	-0.0329 (0.443)	-0.0325 (0.448)
Endogenous Inv.					0.0214 ** (0.009)	0.0205 ** (0.011)
School	0.0015 (0.820)	0.0007 (0.499)	0.0001 (0.991)	0.0007 (0.508)	-0.0020 (0.750)	0.0004 (0.645)
Constant	0.3016 (0.039)	0.3321 (0.014)	0.1880 (0.175)	0.2403 (0.054)	0.2705 (0.049)	0.3327 (0.009)
Adjusted R^2	0.0752	0.0833	0.0856	0.0943	0.1872	0.1892
RESET test	0.2312	0.1322	0.2123	0.1033	0.0171	0.0068
Cook-Weisburg	0.6433	0.7717	0.9544	0.7954	0.6347	0.5278
Shapiro-Wilk	0.5392	0.6886	0.0844	0.1284	0.0364	0.0247
Regions	0.1900	0.2260	0.2484	0.3094	0.1158	0.1353
No. of Obs	51	51	51	51	51	51

P-values in parentheses
* implies significance at 10%
** implies significance at 5%
'Levels' implies levels of schooling
'Percentage' implies schooling rates

Like the panel regressions, we see that in the *Actual* case, all coefficients have the expected signs--GDP in 1970 is negative indicating conditional convergence, population growth is negative, investment is positive, and schooling is also positive. We also find that the *Estimated* and *Actual* models pass all statistical testing and that the p-values for the f-tests on regional effects are all well above significance levels indicating that we can accept the null of no regional effects, hence no mean heterogeneity. It is interesting to note, however, that investment is only significant in the *Actual* case (at least to 15% significance). Whether this is due to the endogeneity issue or not is an area of future research and debate, however, I suspect that it is.

As an ad hoc exercise, I ran the same regressions as the *Estimated* and *Actual* models, but this time included the residuals from the investment/inflation regressions. These residuals can be interpreted as the endogenous part of investment. Even though I am essentially re-entering the bias into the regression, I can still get an idea of the influence of endogenous investment.

We can see above that the endogenous part of investment is highly significant regardless of which schooling variable I use, while the politically influenced, exogenous part of investment is still insignificant. Furthermore, both tests fail for linearity and normality in each case. Given that the residual to the investment/inflation relationship is only 15% of unexplained investment, it is likely that there is feedback between growth and investment.

VII. Conclusion

The purpose of this paper was to implement a broader set of political stability variables as instruments for inflation. With the limited set of instruments that current literature uses, a correlation between inflation and investment, or inflation and growth, has been non-existent across low inflation countries.

By using a set of 39 political variables, I have found that 7 can account for nearly 80% of the variation in inflation. While the explanations of the estimates of these variables is speculative, the explanations make intuitive sense. Essentially, democracies, countries with governments that change regimes frequently, and countries with more active trading all have higher inflation, while countries that have political parties in lower houses of government that are effective in the policy-making process tend to have lower inflation. By using estimated inflation determined by these 7 political variables, I plotted investment on inflation for an initial assessment of the correlation between the two. There are obvious non-linear patterns in the data with areas of positive correlation. The implications are two-fold: (i) economists using linear regressions that do not account for structural changes or non-linearities in their data have models that are not correctly specified statistically, (ii) there does exist an area in low inflation ranges whereby investment is an increasing function of inflation. I will address (ii) first and come back to (i). For inflation rates from approximately 1 % to 9 %, investment is positively correlated with inflation, and this correlation is robust over panel or cross sectional data. There are also some interesting results concerning investment and growth.

For the panel case, when investment is considered endogenous to growth, and is instrumented with estimated inflation, that growth is a quadratic function of investment, implying that MRW's method of log-linearizing around the steady state to determine the speed of convergence may not be appropriate. On the other hand, when investment is assumed to be exogenous to growth, and entered into the regression directly, as in MRW and Islam, growth is a linear function of investment, validating the use of the linearizing method of MRW. My results are robust to whether we control for schooling percentages or levels of schooling.

Concerning the cross-sectional case, when investment is instrumented using the estimated values of inflation, average investment is typically not a long run determinant of growth, while if considered exogenous, as in past literature, investment is a marginally significant determinant of growth. Hence, these results and the panel results may be an indication that investment should not be controlled for exogenously in empirical growth models.

Addressing (i) from above, researchers are finding no correlation between inflation and investment or growth in low inflation countries. In both the inflation and investment regressions in this paper, whether using a panel or cross section, there are quadratics and regional effects in the inflation and investment regressions. It is common knowledge that mean heterogeneity and non-linearities not only produce biased estimates, but also invalidate any inference drawn from the hypothesis testing of the parameters. Furthermore, there are fixed effects in the variance of the panel regressions invalidating the statistical assumption of a constant variance for hypothesis testing.

Overall, the instruments for inflation presently being used are not sufficiently correlated with inflation to induce a change in investment or growth in low inflation countries, that most models in the literature are not correctly specified statistically, and when they are, there does exist a positive and significant correlation between inflation and investment for inflation rates of approximately 1- 9 %.

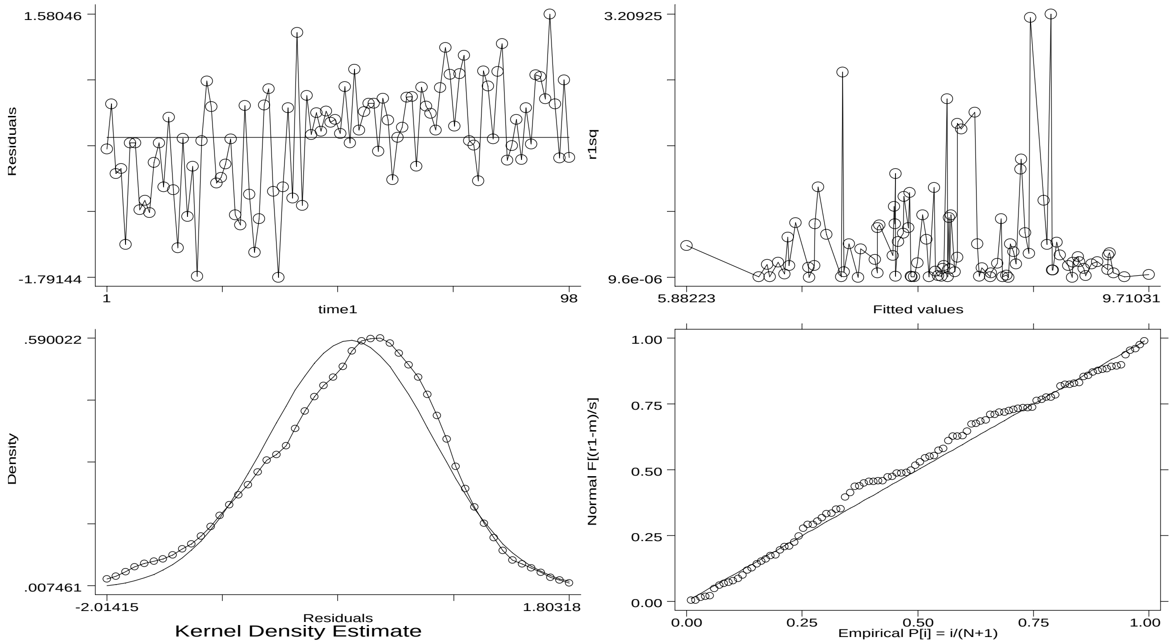
Appendix A

This appendix is interpreted as follows:

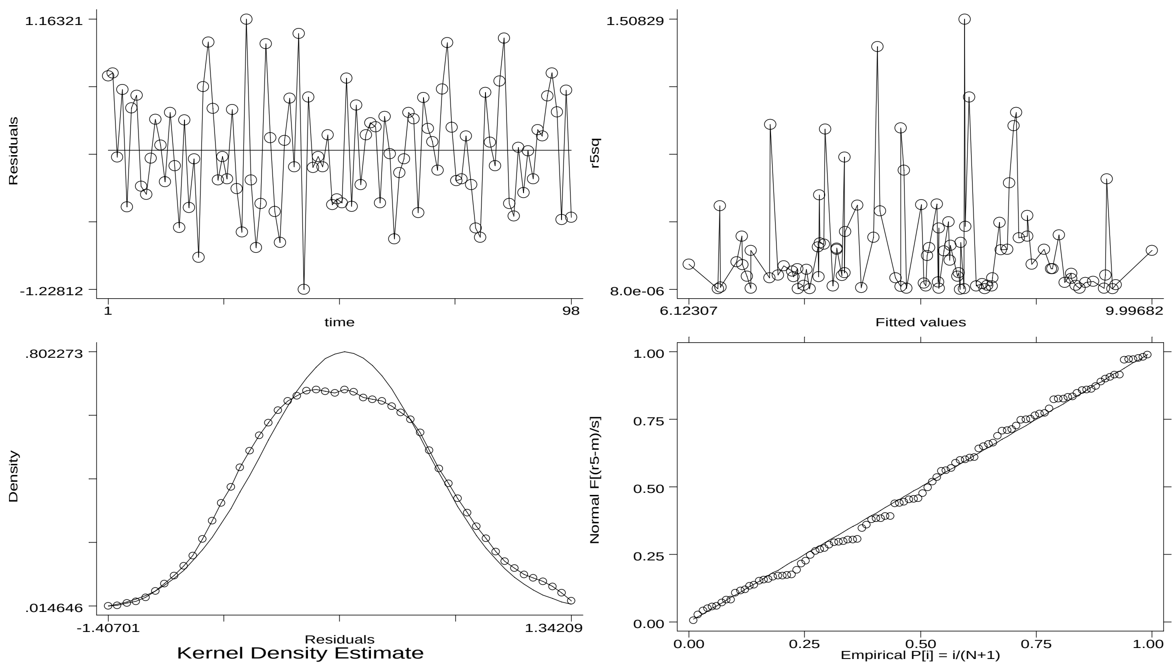
Preceding each set of four figures is the description of the data set (Non-Oil, Intermediate, OECD), whether the dependent variable was the level of GDP or the growth of GDP, whether the estimated model had the restriction for the coefficients (this restriction is explained in the paper) enforced or not, and whether the estimated model was the originally estimated model or the statistically respecified model.

In each set of four figures, the upper left-hand figure is a plot of the estimated residuals from the respective regressions, and are ordered over the regions within which the countries are located. From left to right, these regions are delineated as Africa, Asia, Europe, the Americas, and Oceania. The upper right-hand figure is a plot of the squared, estimated residuals on ordered estimated values of the dependent variable. The bottom-left figure is a graph of a smoothed histogram of the conditional distribution of the estimated model, overlaid with the correct normal distribution. The bottom-right figure is a probability plot (p-p plot) which shows us that if our conditional distribution is normal, the converted estimated residuals should be on the solid line.

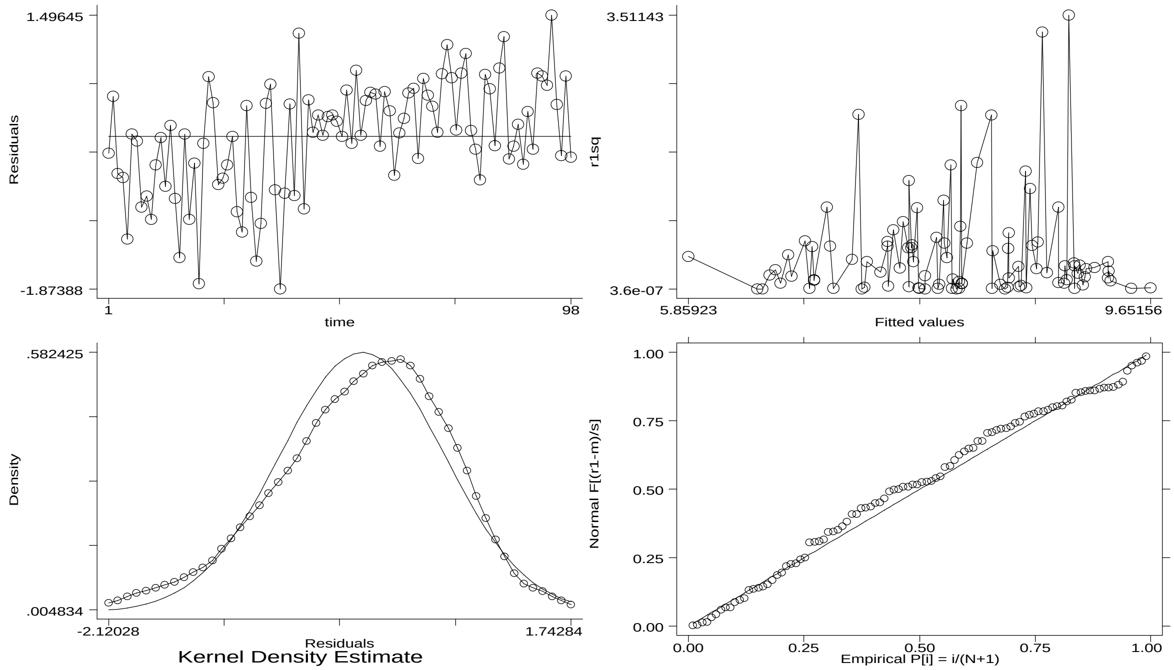
MRW, Non-Oil, No School, Levels, Unrestricted, Original:



MRW, Non-Oil, No School, Levels, Unrestricted, Respecified:



MRW, Non-Oil, No School, Levels, Restricted, Original:



There is no respecified form for this Non-Oil case because the restriction imposed by MRW and specified by the theory is not an applicable restriction. This is discussed further in the body of the paper.

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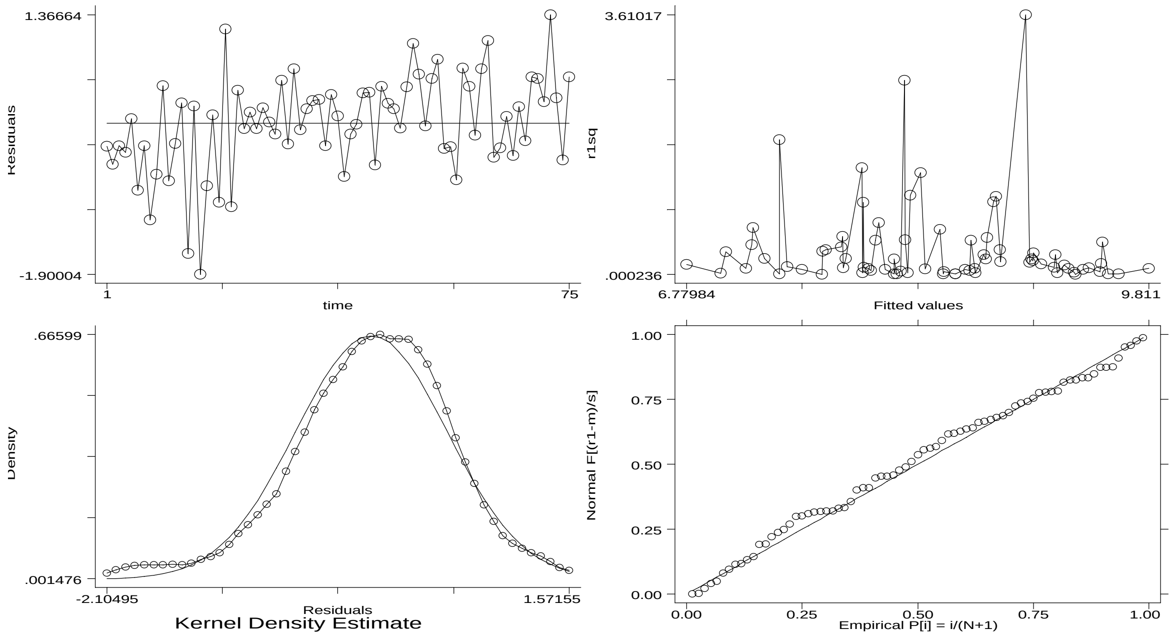

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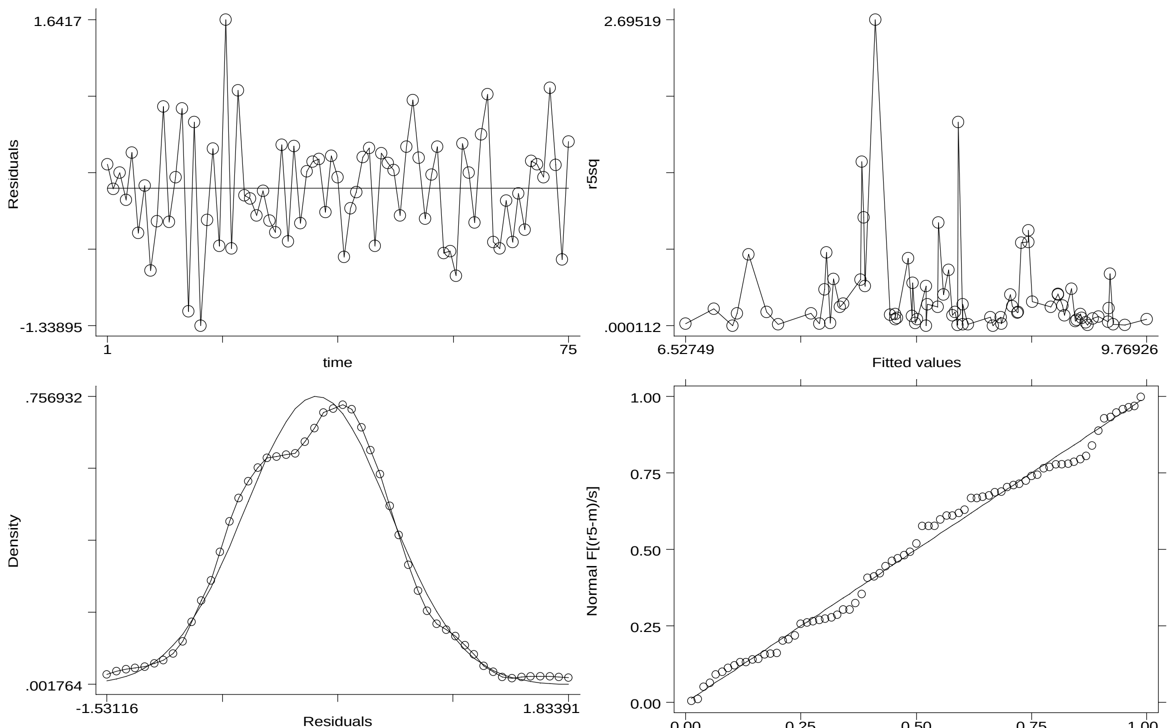

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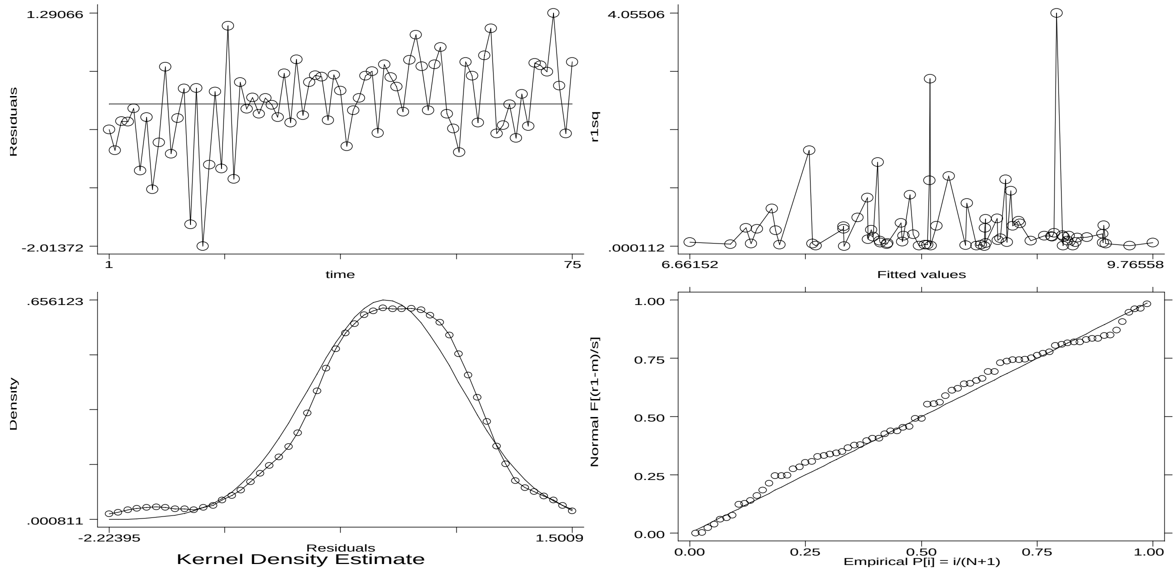

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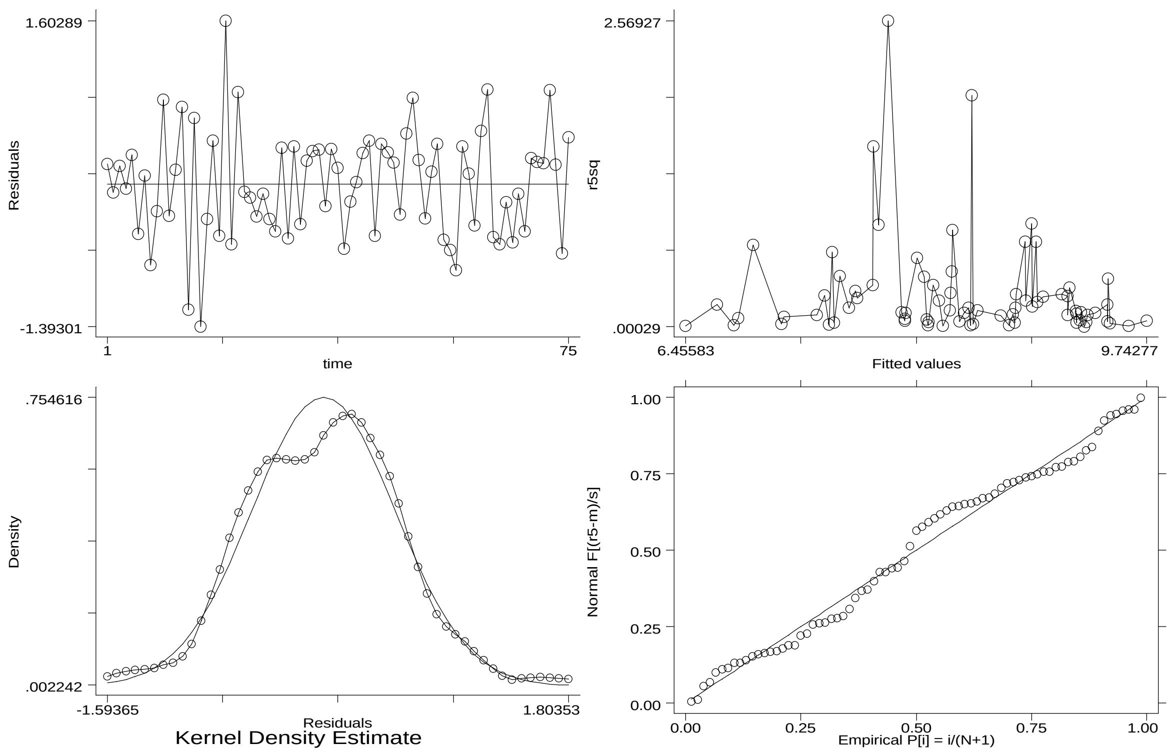
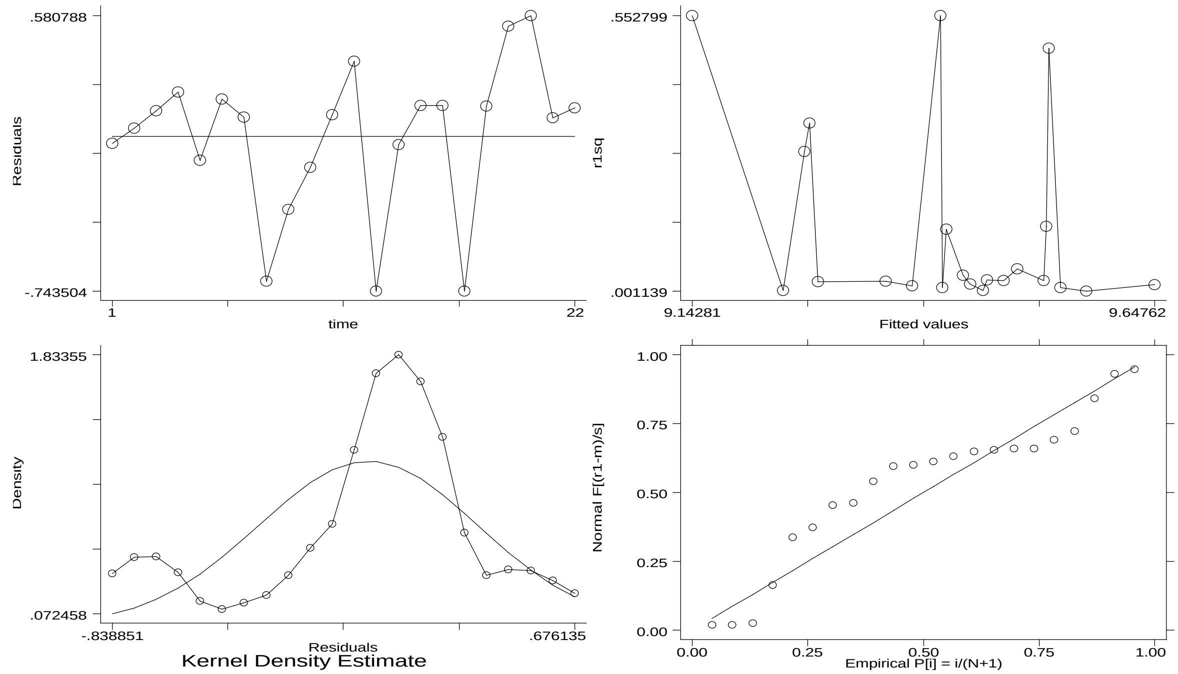
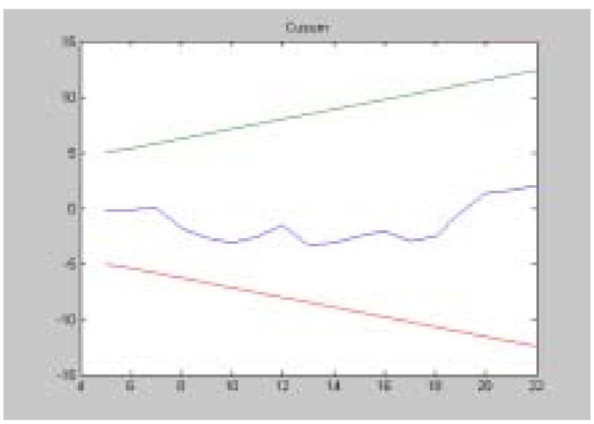
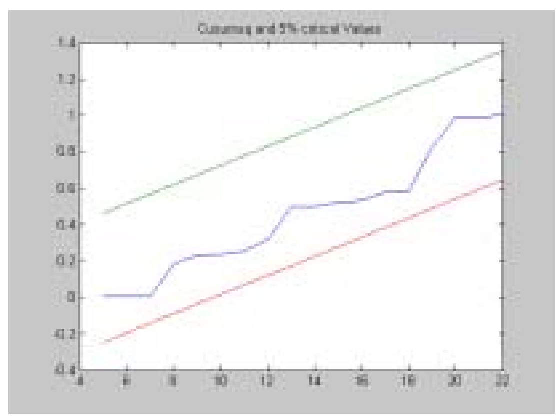
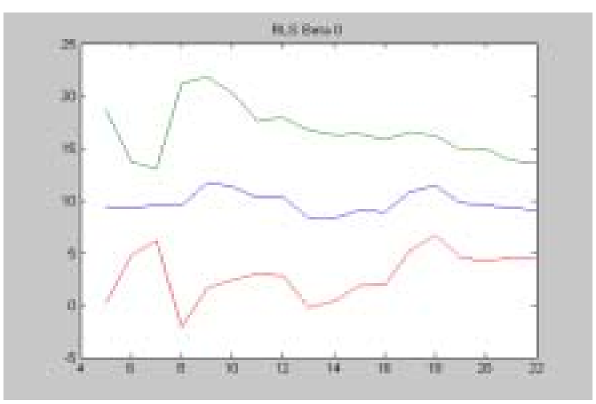


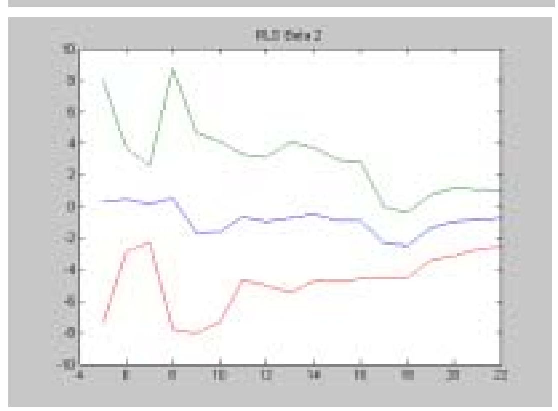
MRW, OECD, No School, Levels, Unrestricted, Original:



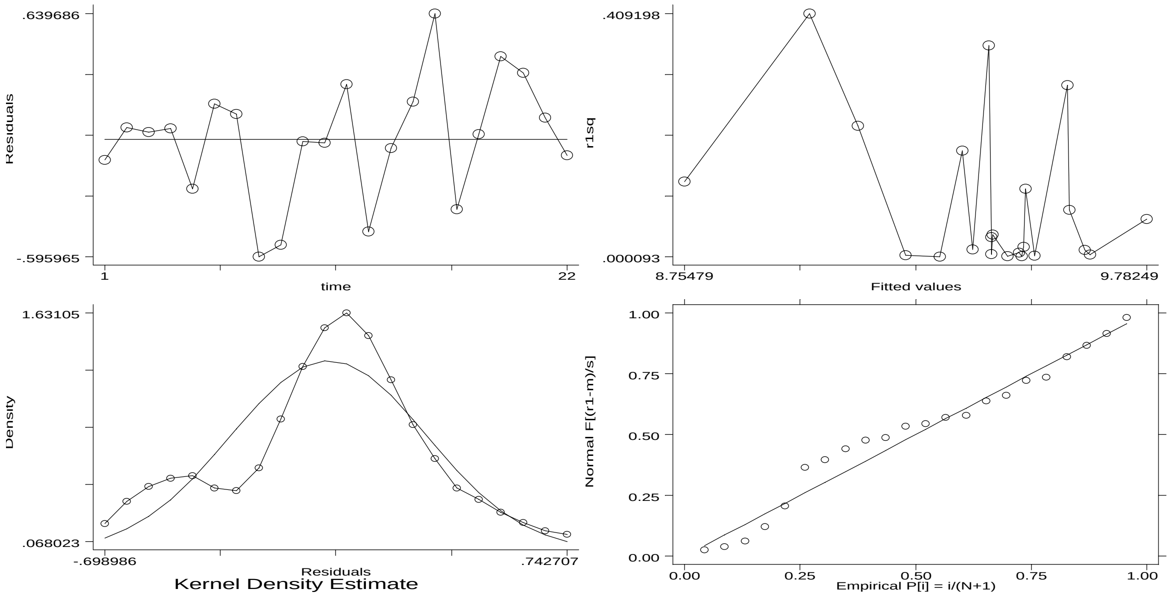


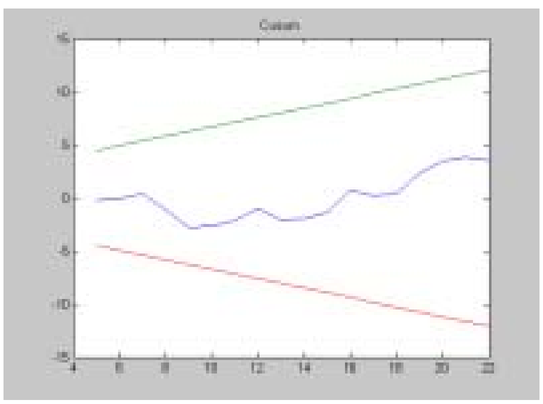


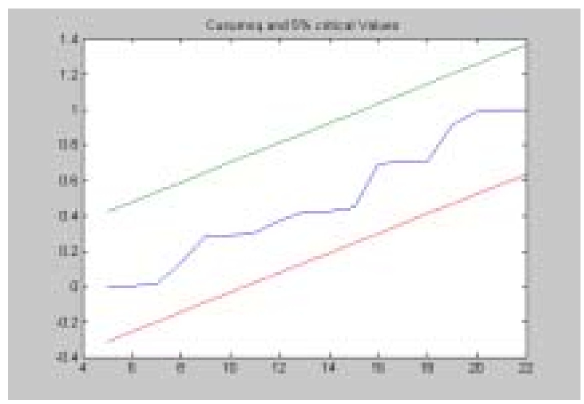


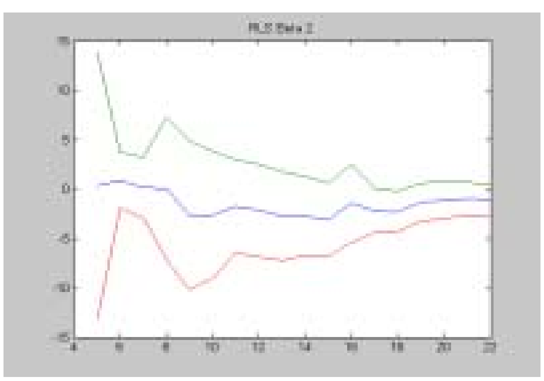


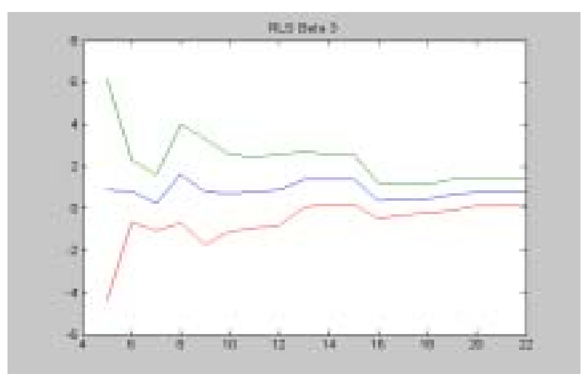
MRW, OECD, With School, Levels, Unrestricted, Original:



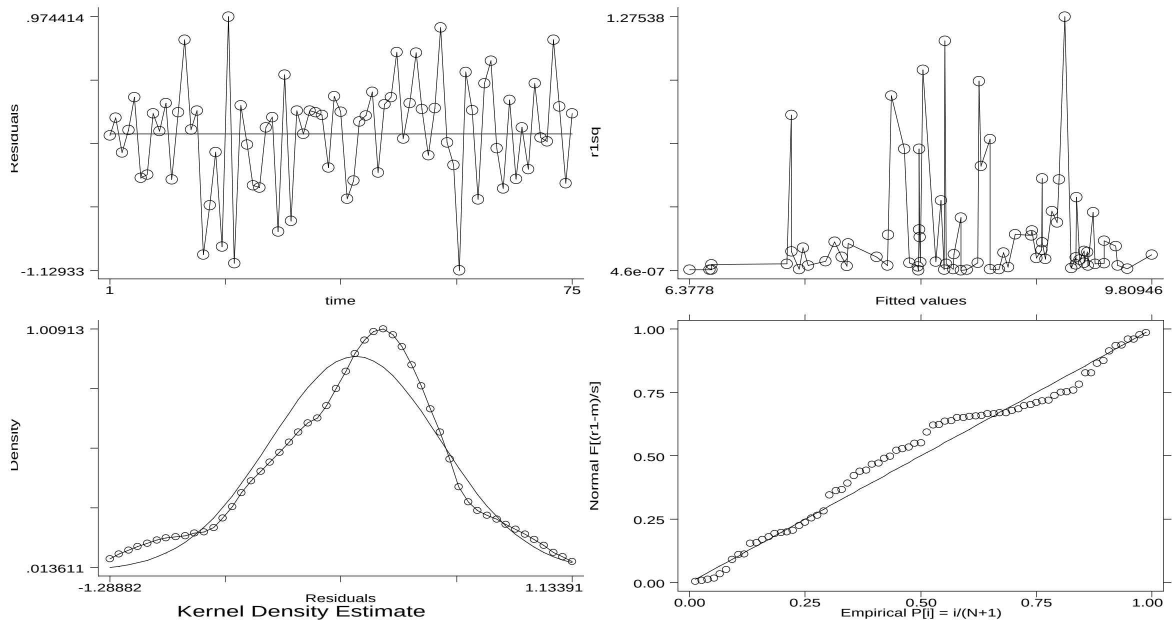




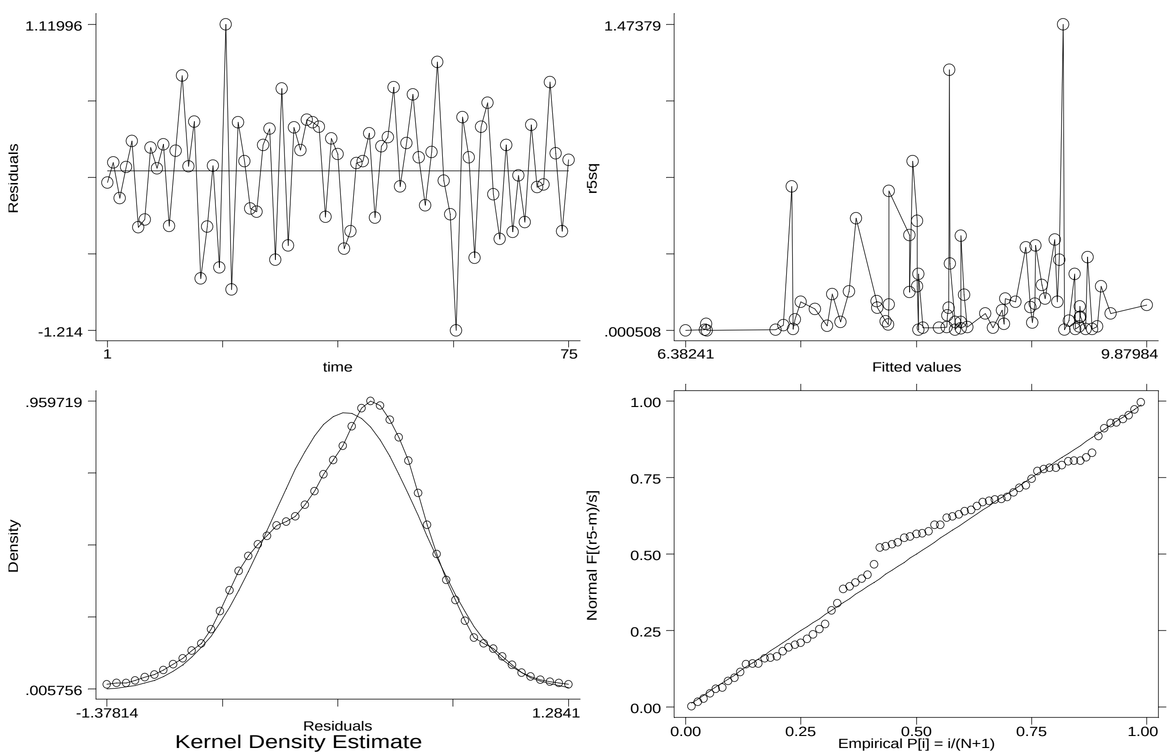




MRW, Intermediate, With School, Levels, Unrestricted, Original:



MRW, Intermediate, With School, Levels, Unrestricted, Respecified:



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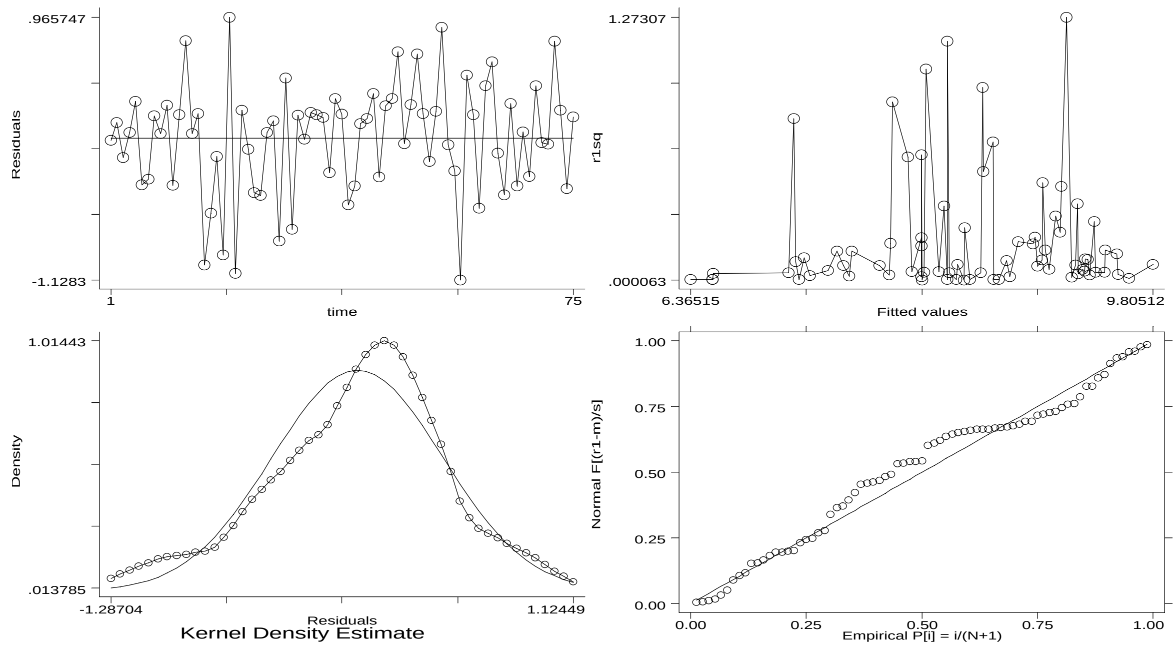

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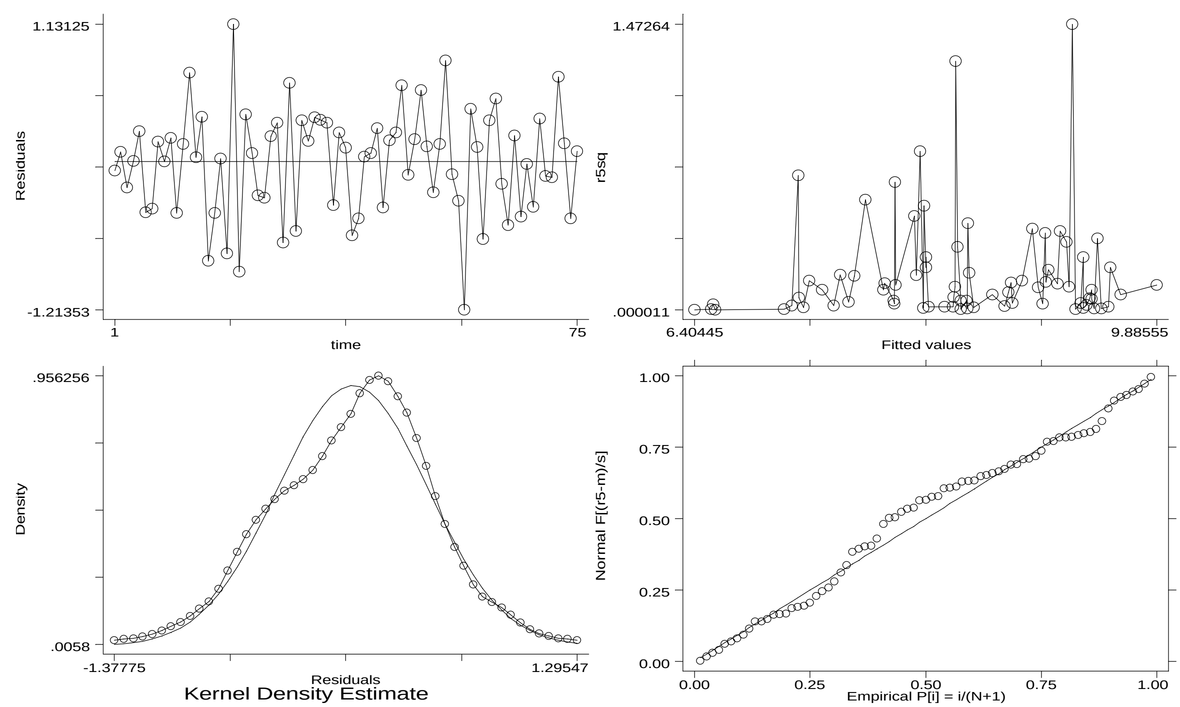
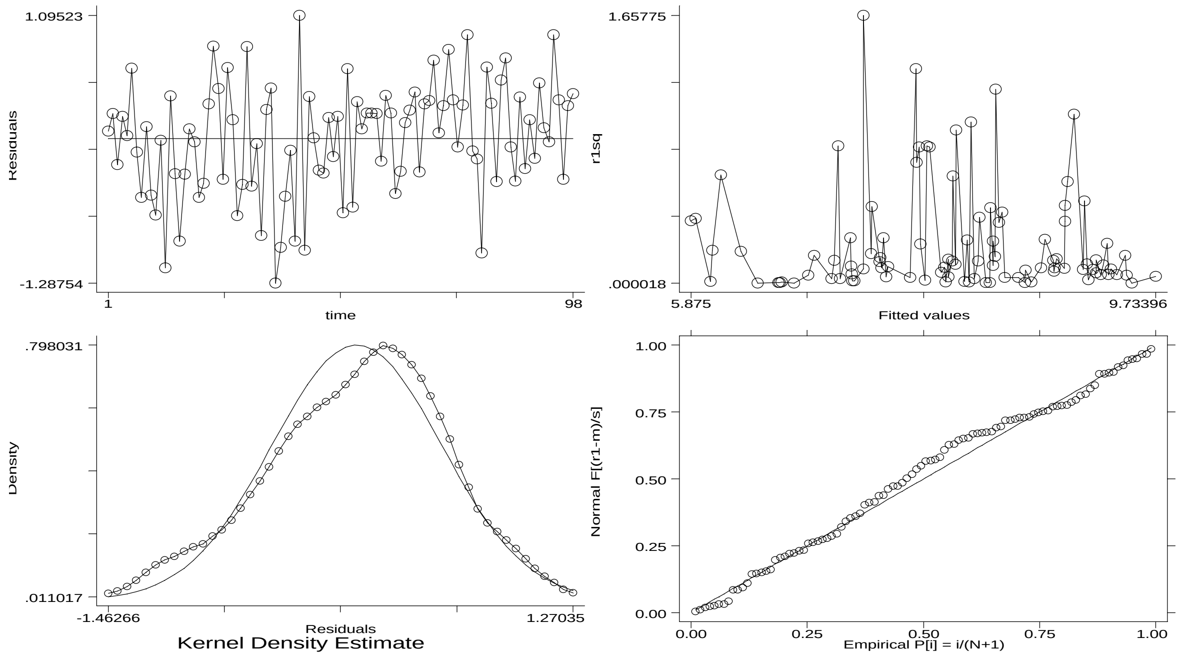


MRW, Non-Oil, With School, Levels, Unrestricted, Original:



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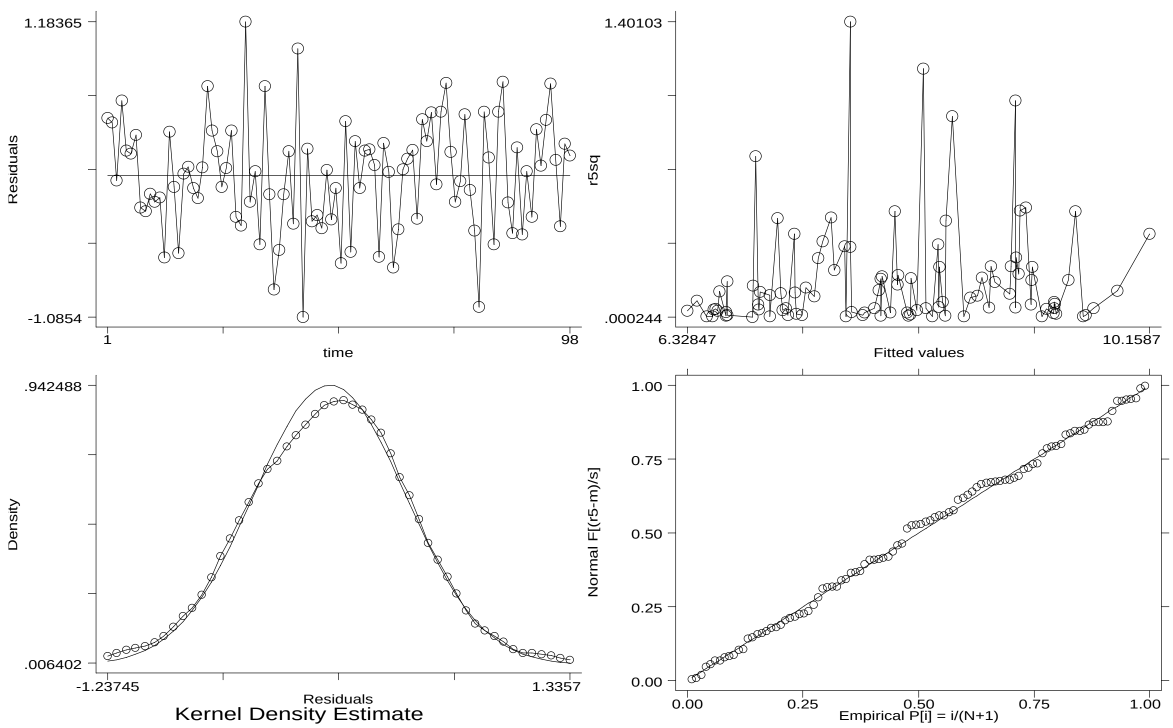
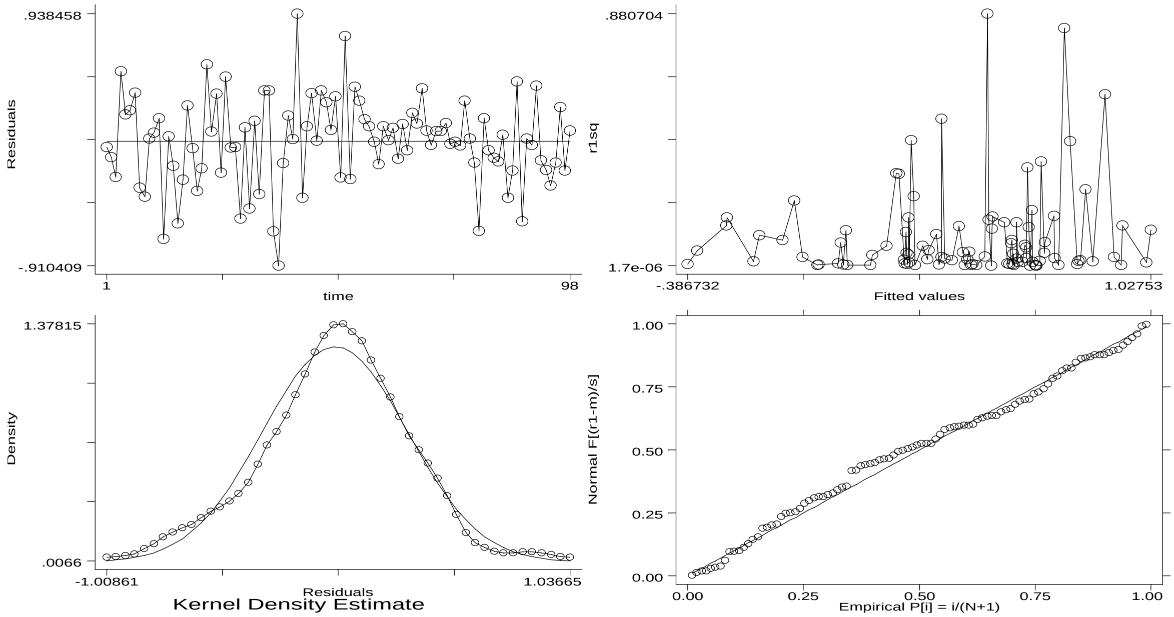


MRW, Non-Oil, With School, Growth, Unrestricted, Original:



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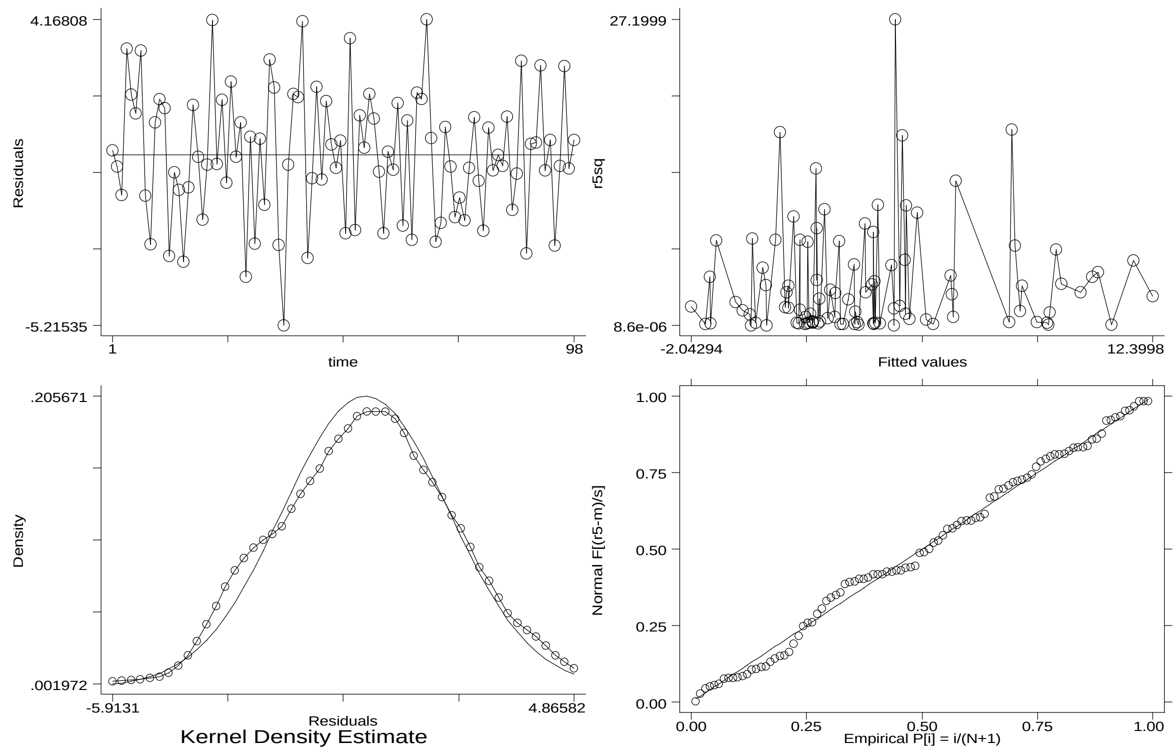

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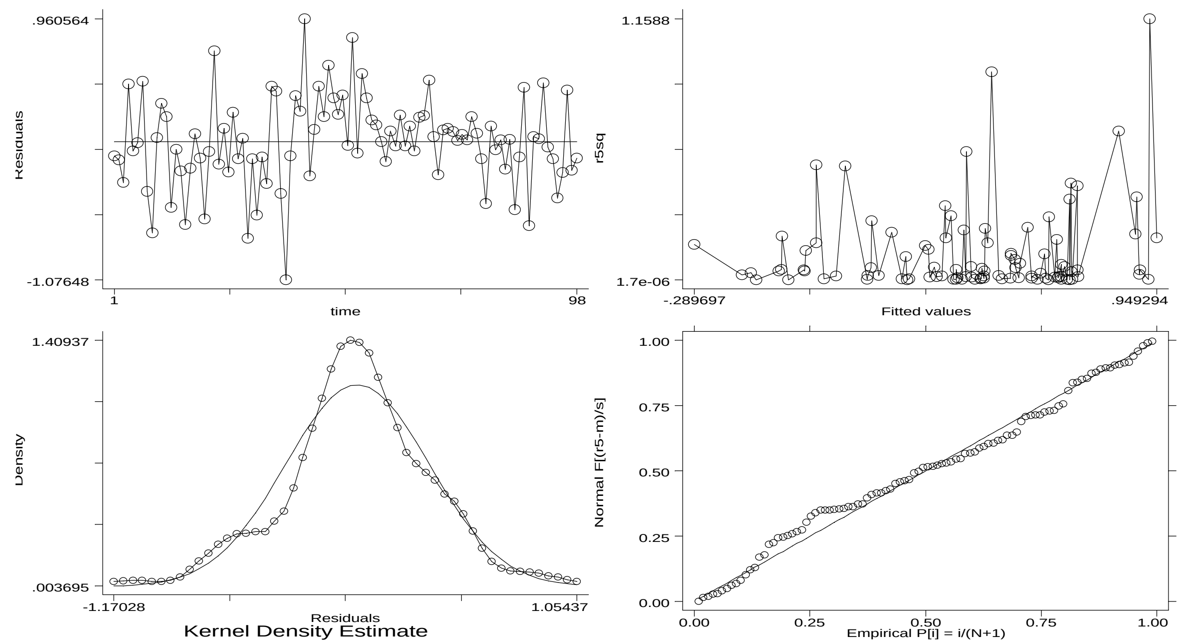

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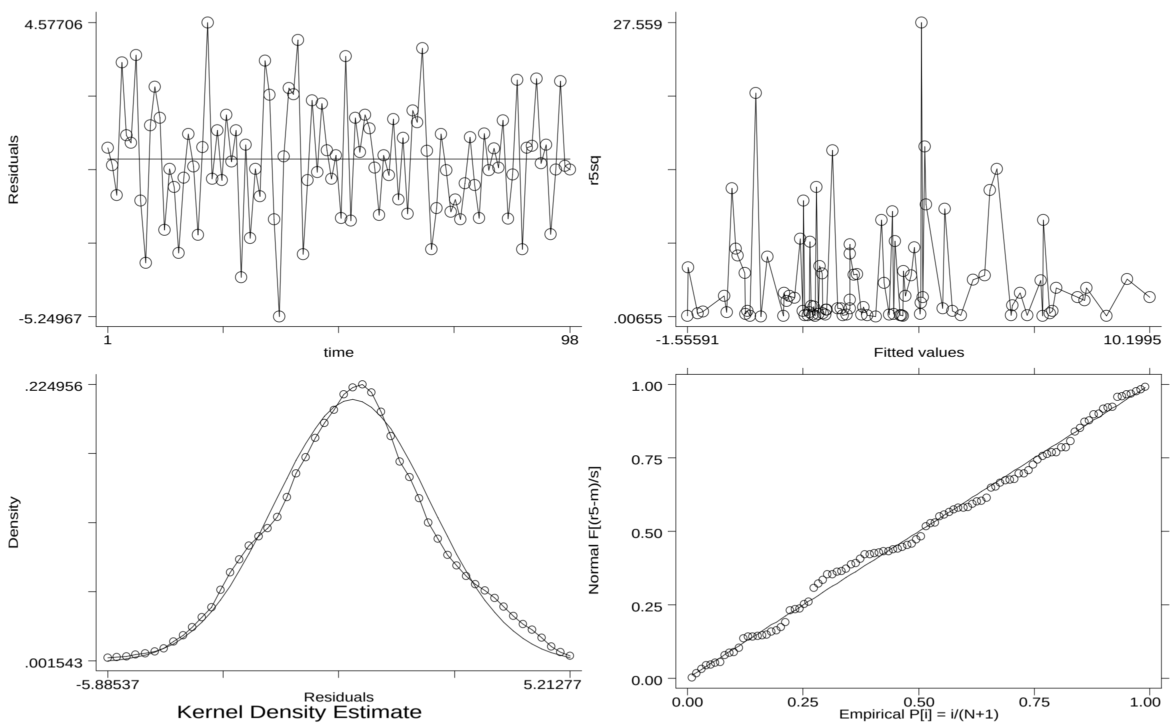

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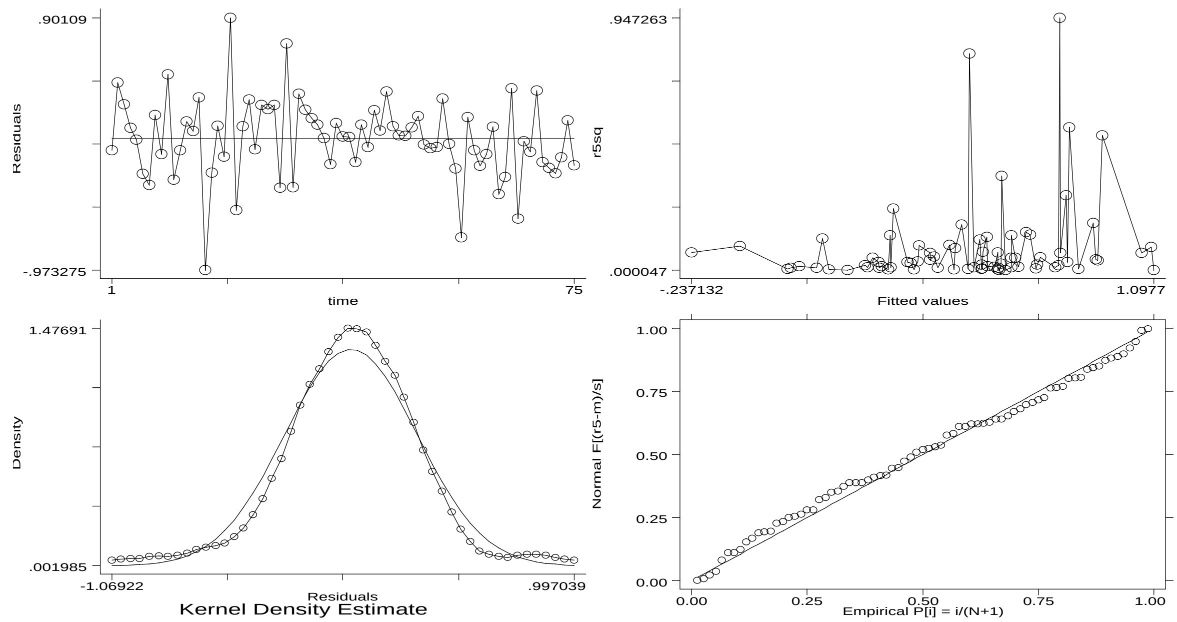

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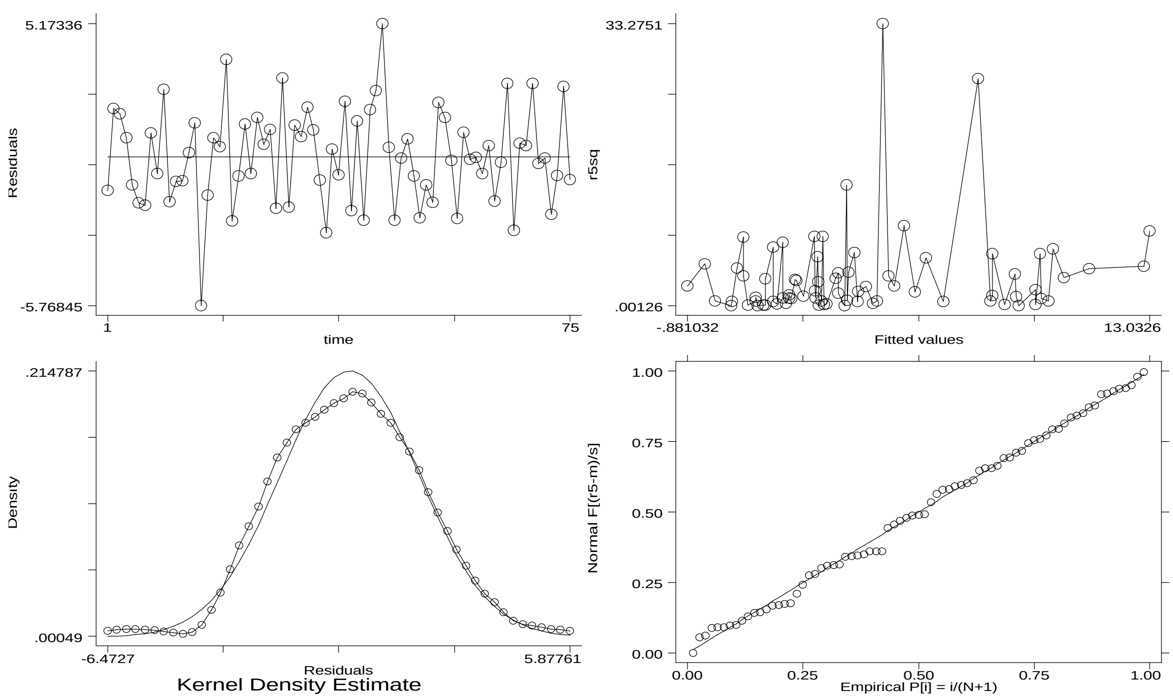
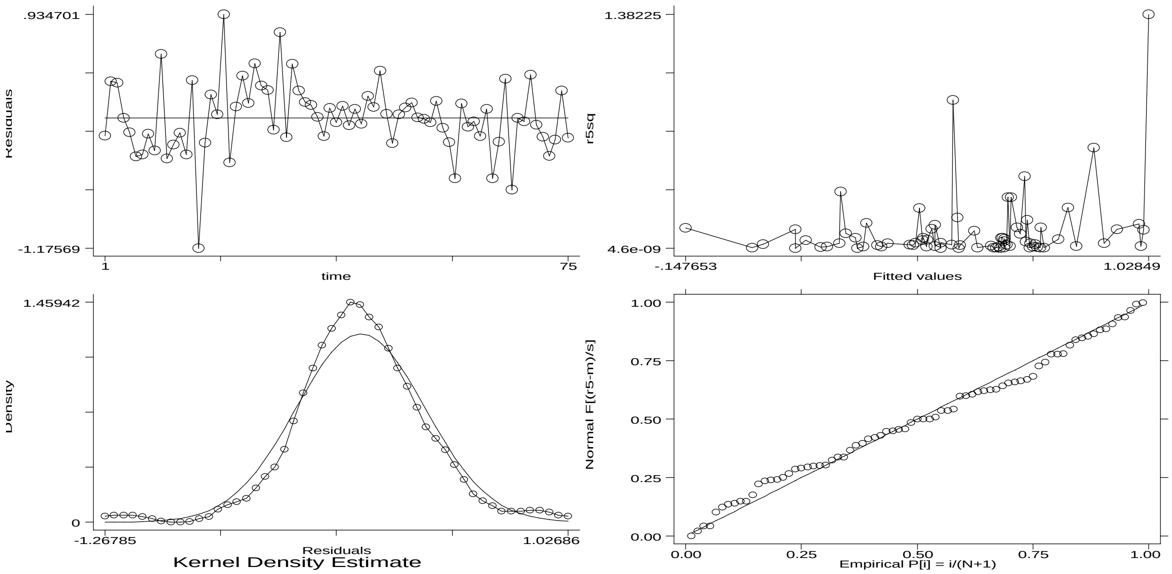


MRW, Intermediate, No School, Growth, Unrestricted, Original:



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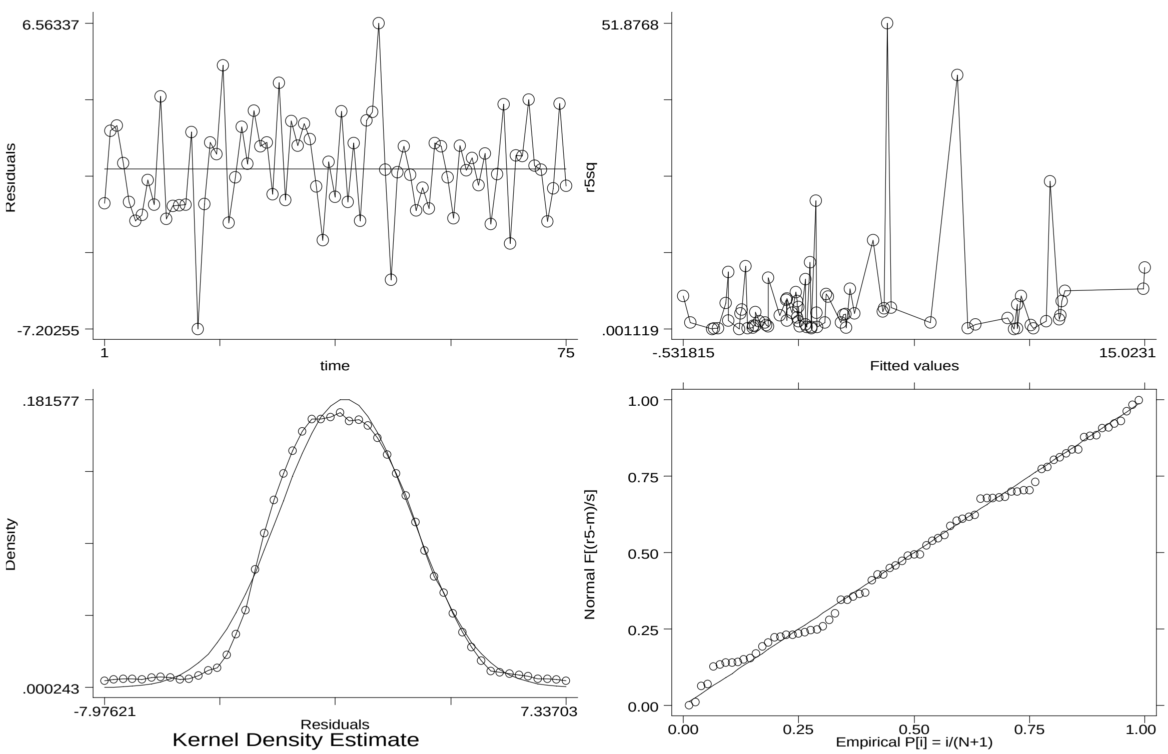


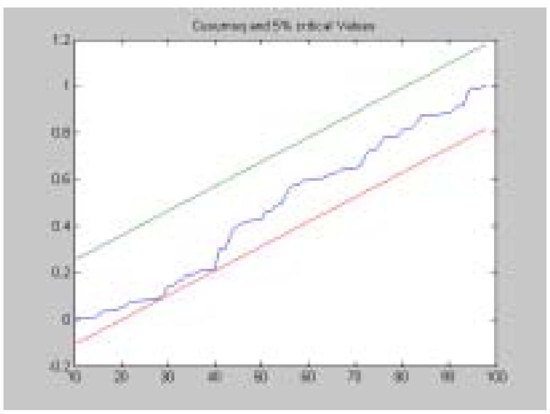
Appendix B

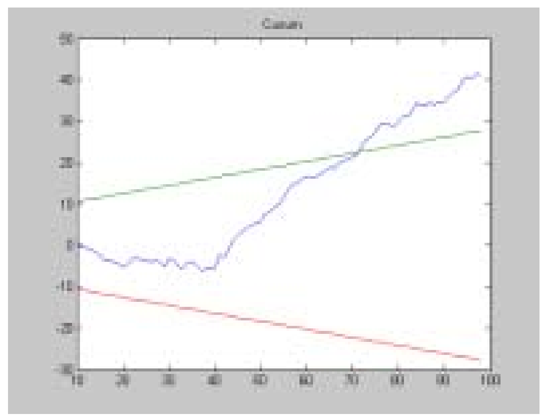
This appendix is interpreted as follows:

Preceding each set of figures is the description of the model type used to produce the figures. First is the data set description, followed by the type of dependent variable that was used, followed by whether the restriction of the coefficients described in the paper was implemented, and whether the model estimated was of the augmented form (with schooling included in the regression), or non-augmented form (without schooling included in the regression).

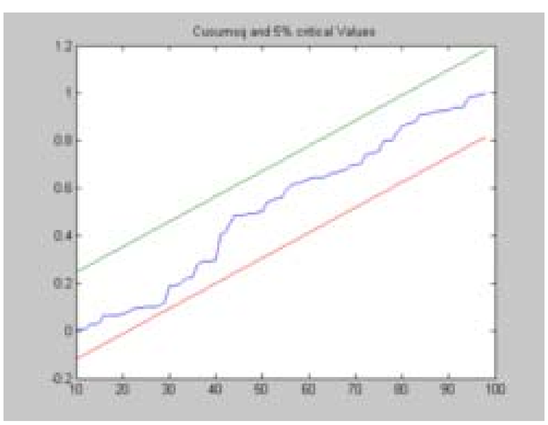
The figure on the left-hand side of each set represents the CuSumSq test as described in the paper, and the figure on the right-hand side of the set is the CuSum test as described in the paper.

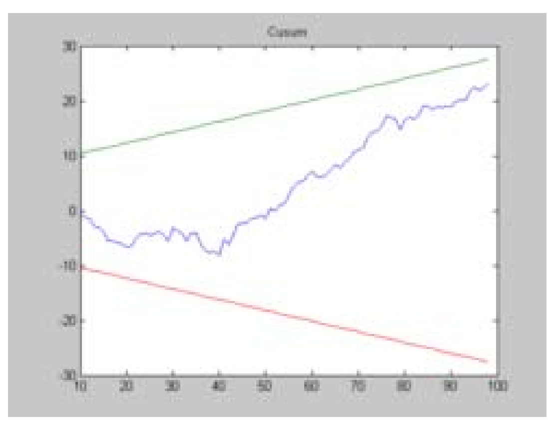
Non-Oil, Levels, Unrestricted, No School:



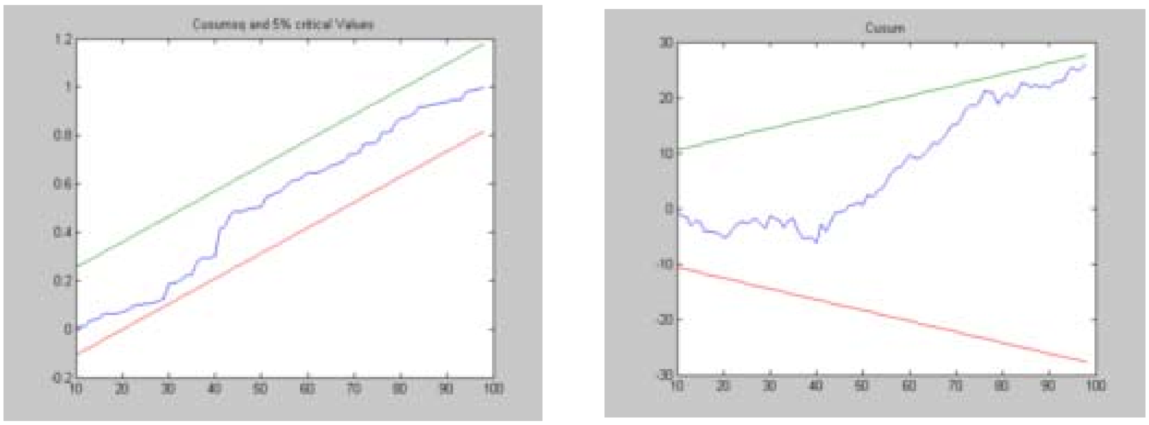


Non-Oil, Levels, Unrestricted, With School:

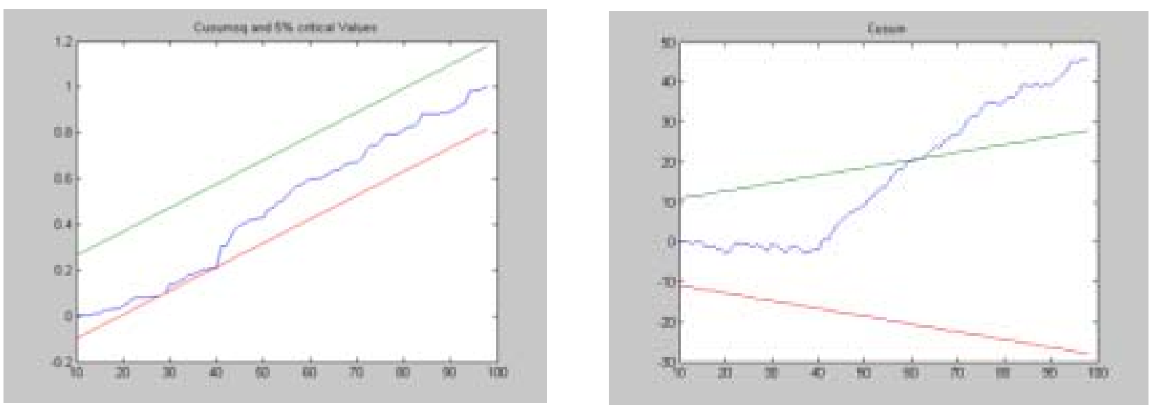




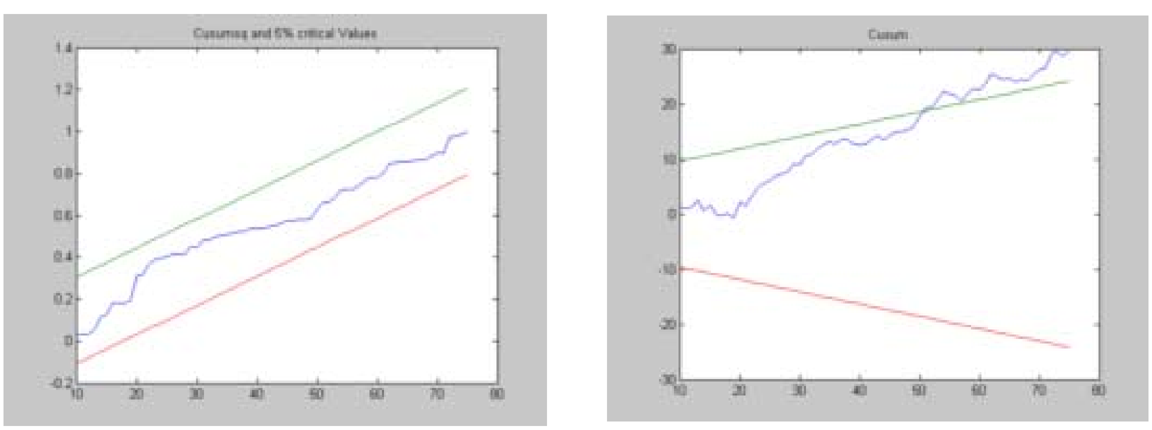
Non-Oil, Levels, Restricted, With School:



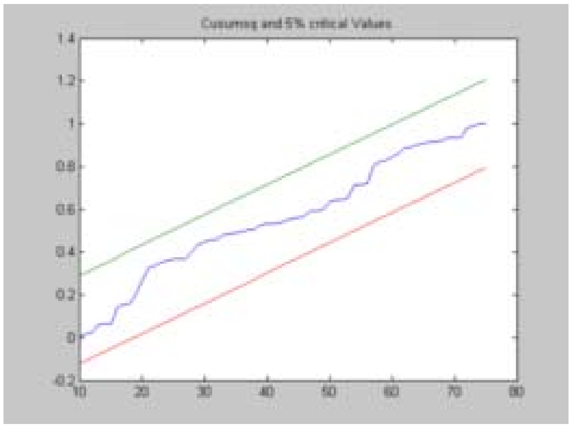
Non-Oil, Levels, Restricted, No School:

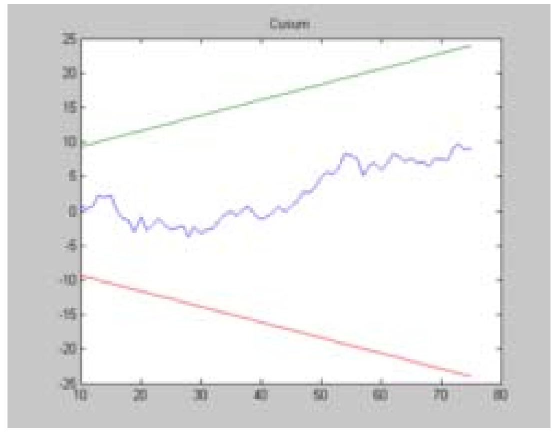


Intermediate, Levels, Unrestricted, No School:



Intermediate, Levels, Unrestricted, With School:





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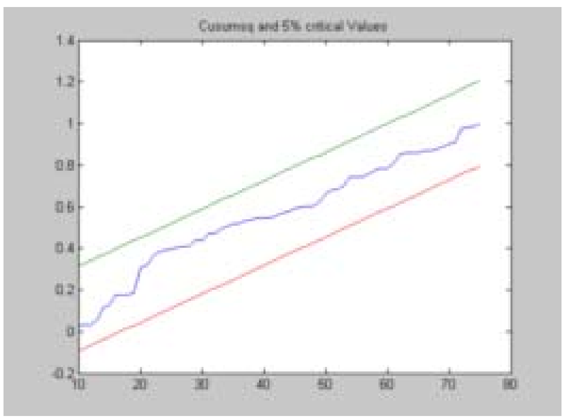

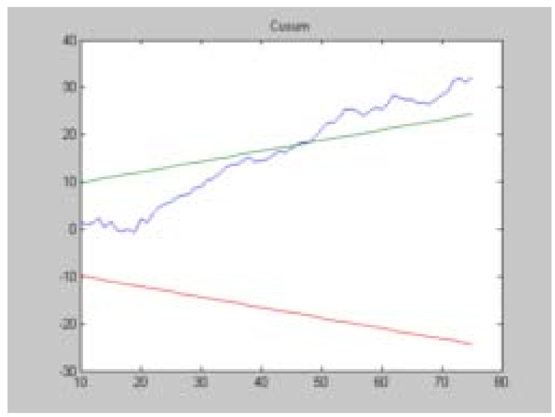

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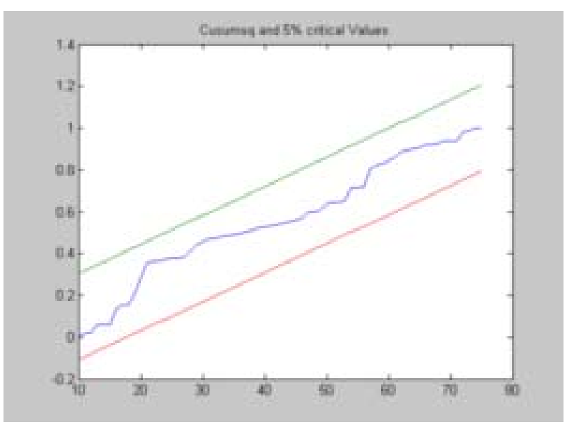
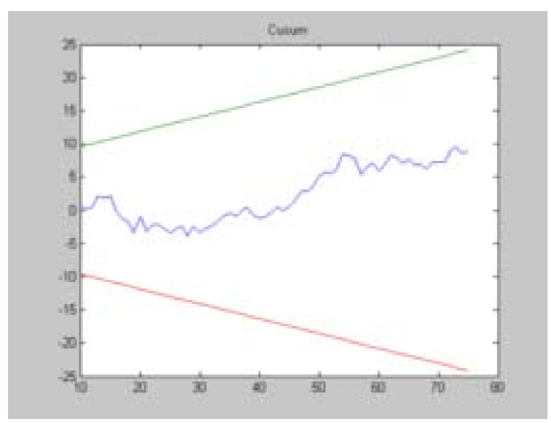
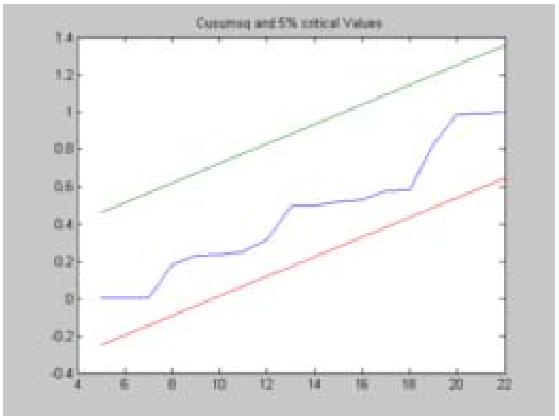
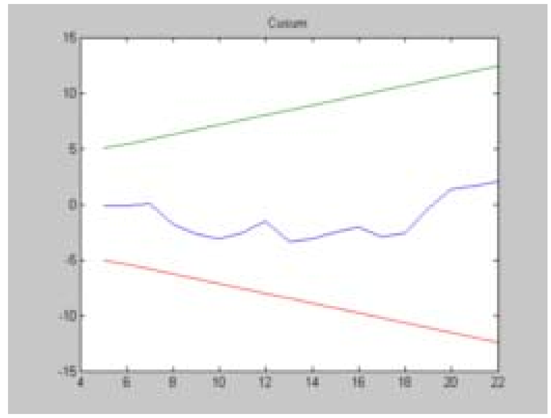




OECD, Levels, Unrestricted, No School:





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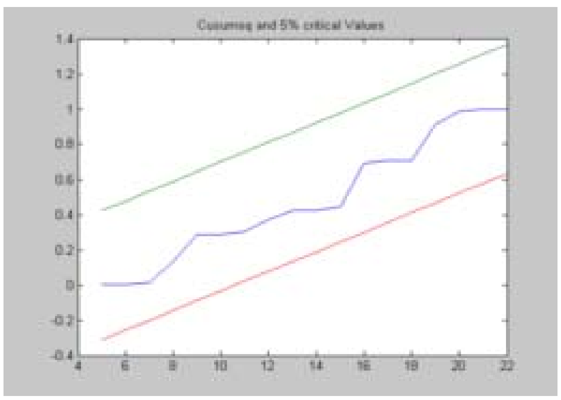

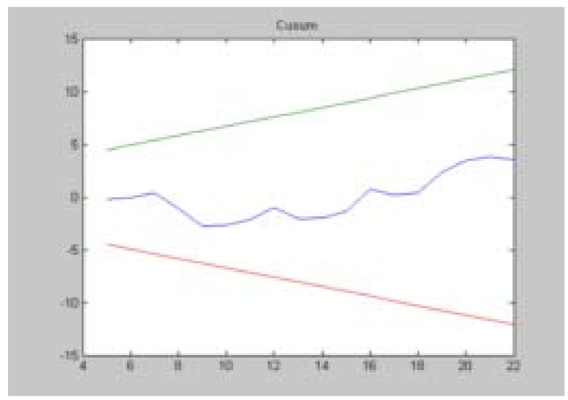

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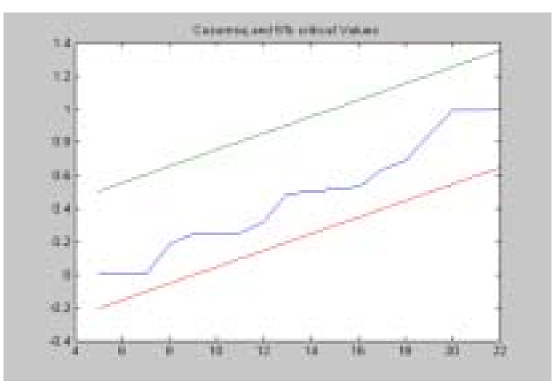
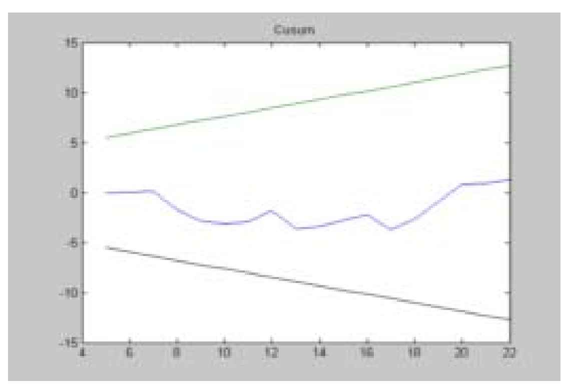
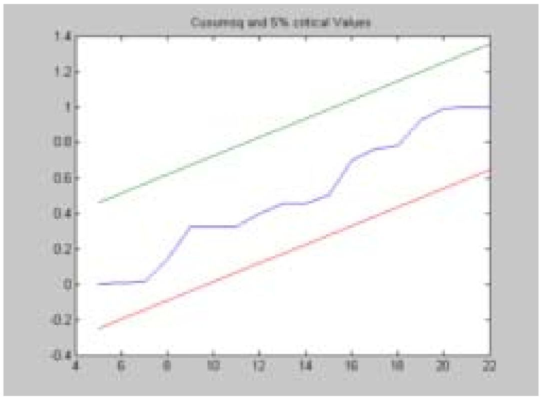
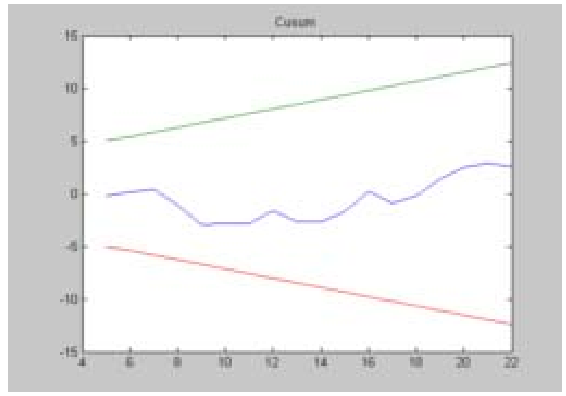


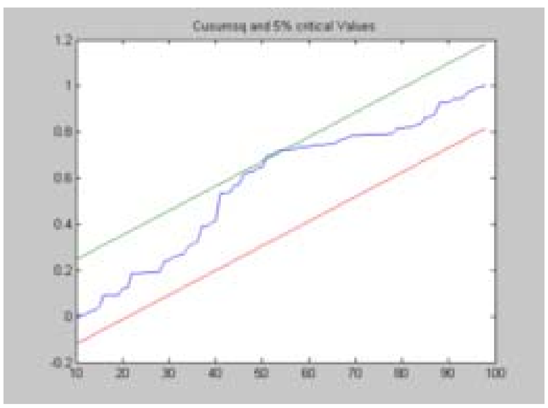


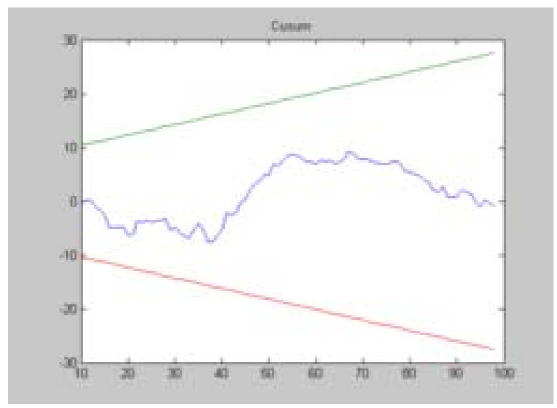
OECD, Levels, Restricted, With School:



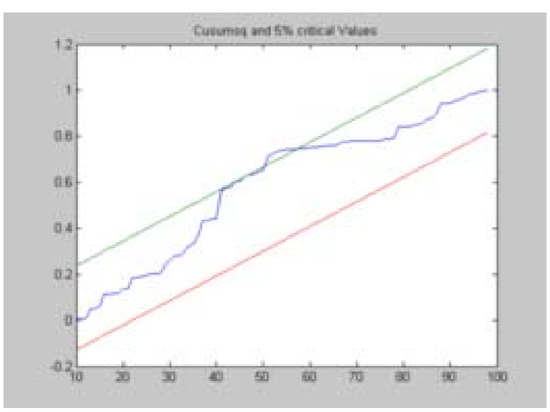


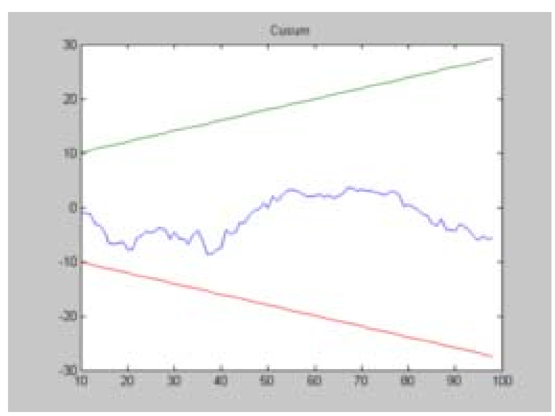
Non-Oil, Growth, Unrestricted, No School:



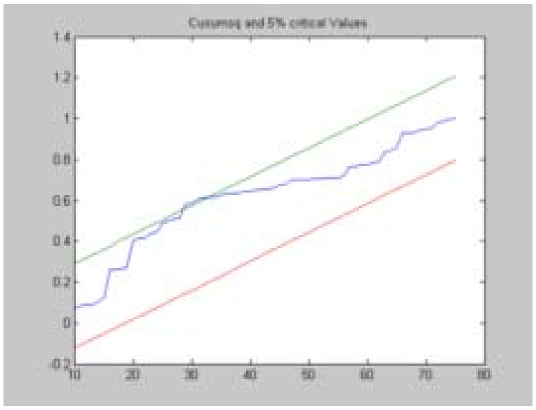


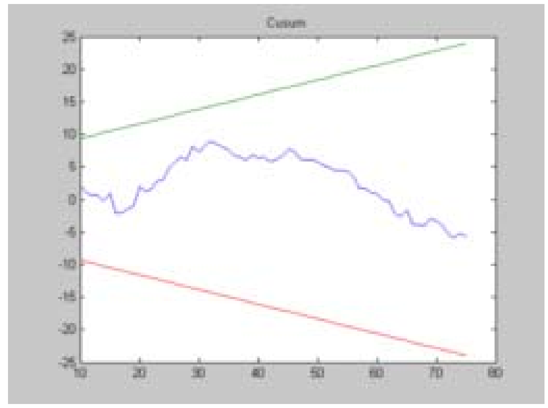
Non-Oil, Growth, Unrestricted, With School:



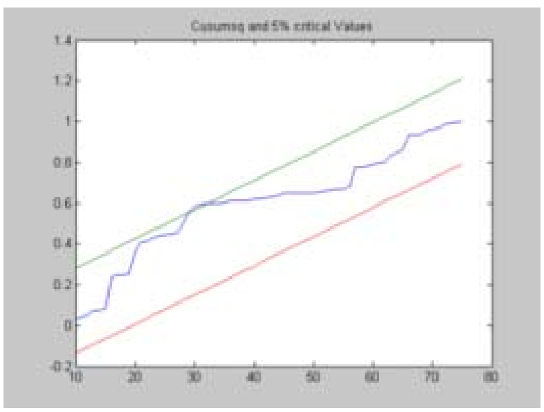


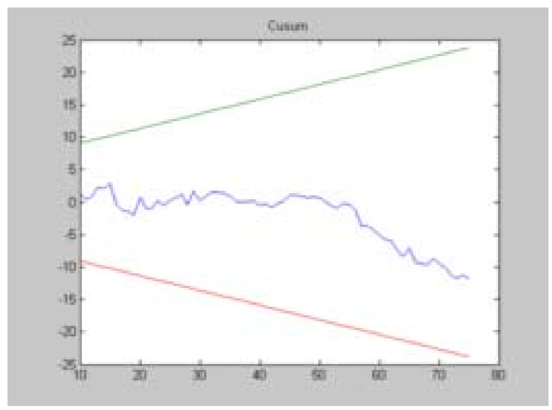
Intermediate, Growth, Unrestricted, No School:



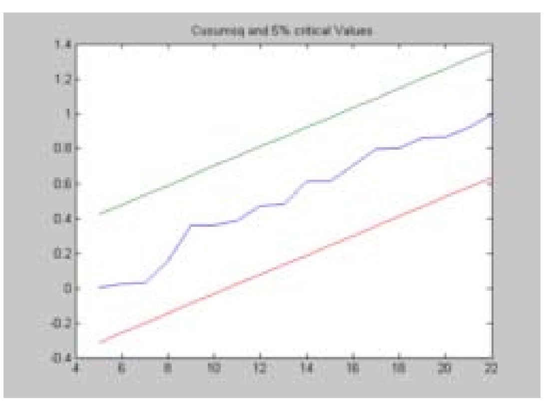


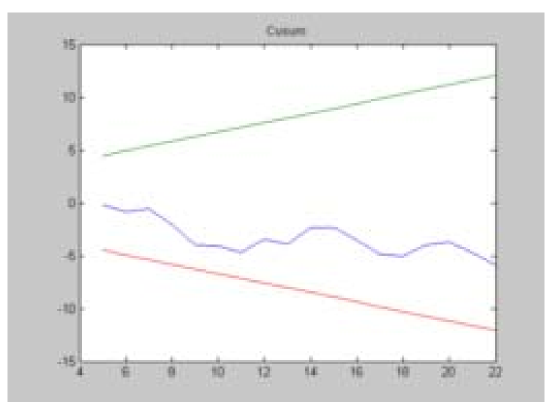
Intermediate, Growth, Unrestricted, With School:



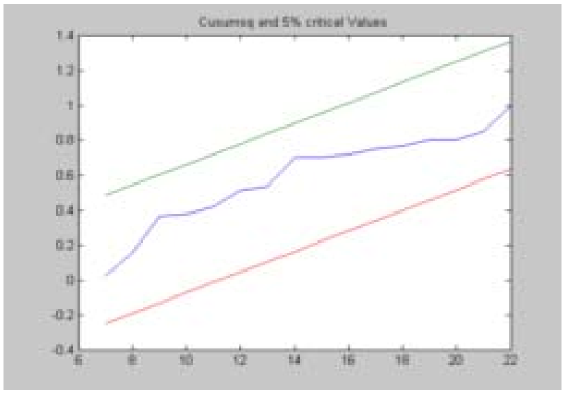


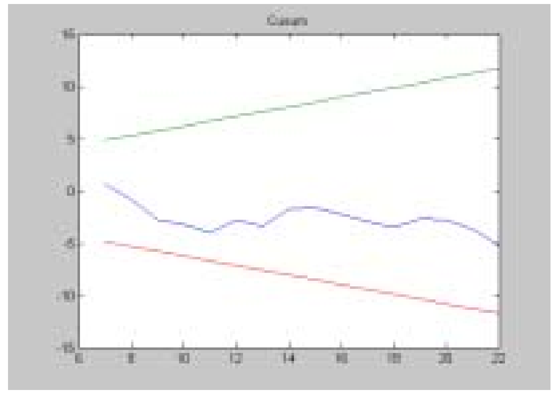
OECD, Growth, Unrestricted, No School:





OECD, Growth, Unrestricted, With School:





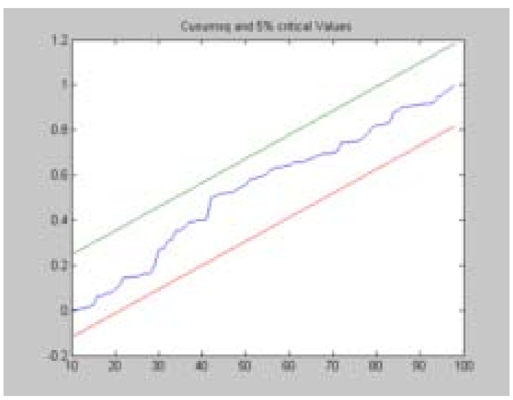
<u>**Appendix C**</u>

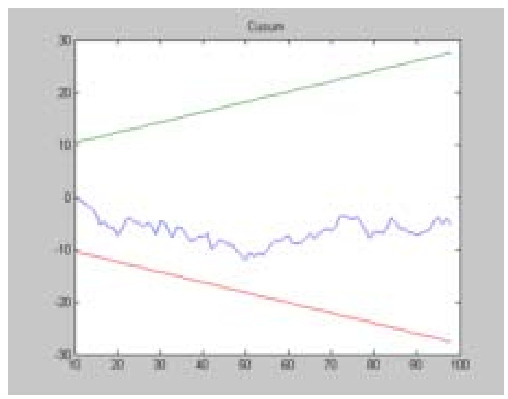
This appendix is interpreted as follows:

Preceding each set of figures is the description of the model type used to produce the figures. First is the data set description, followed by the type of dependent variable that was used, followed by whether the restriction of the coefficients described in the paper was implemented, and whether the model estimated was of the augmented form (with schooling included in the regression), or non-augmented form (without schooling included in the regression).

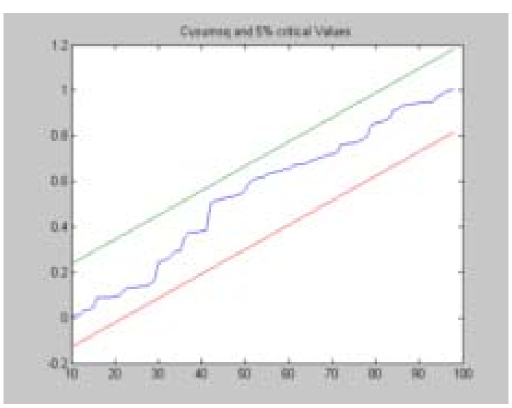
The figure on the left-hand side of each set represents the CuSumSq test as described in the paper, and the figure on the right-hand side of the set is the CuSum test as described in the paper. These figures are after respecification.

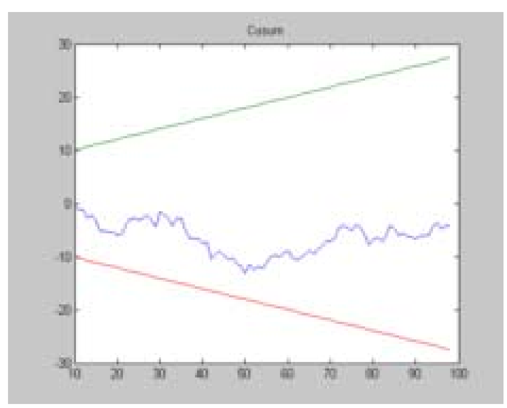
Non-Oil, Respecified, Level, Unrestricted, No School:



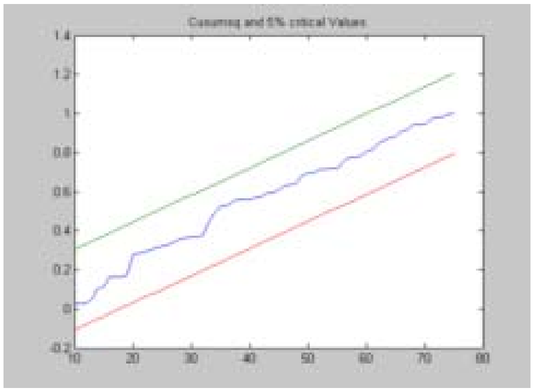


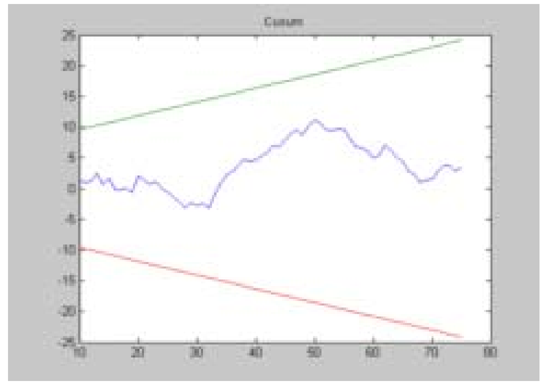
Non-Oil, Respecified, Level, Unrestricted, With School:



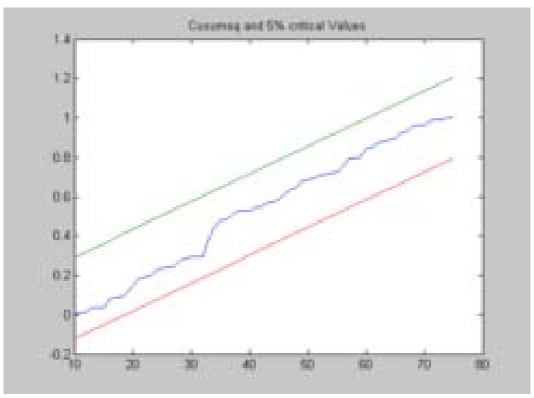


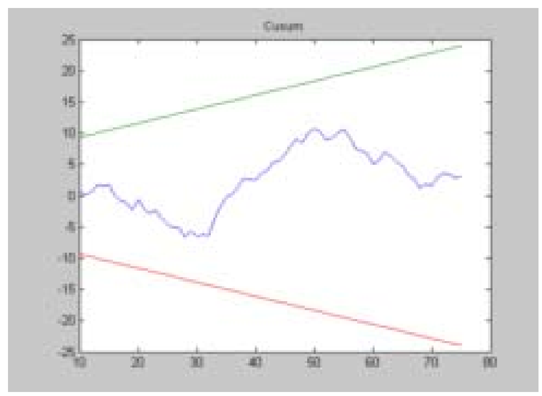
Intermediate, Respecified, Levels, Unrestricted, No School:



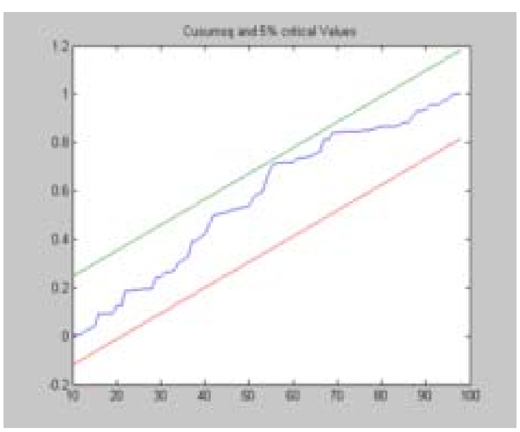


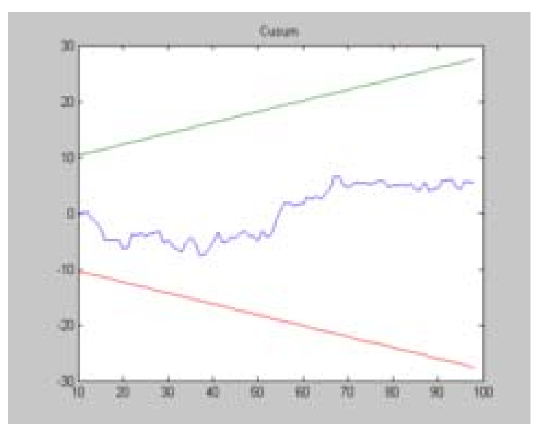
Intermediate, Respecified, Levels, Unrestricted, With School:



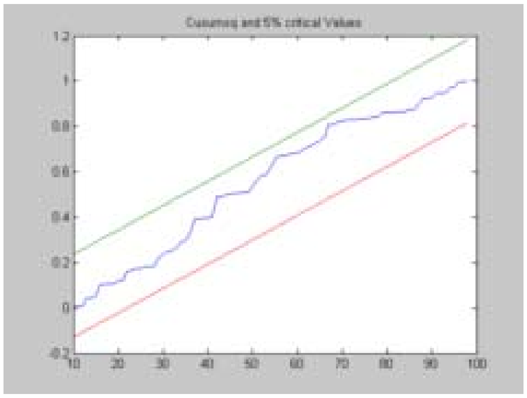


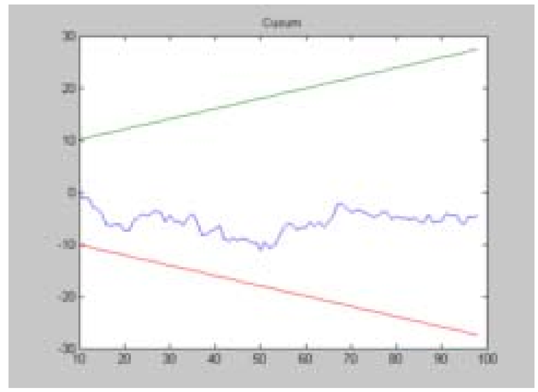
Non-Oil, Respecified, Growth, Unrestricted, No School:



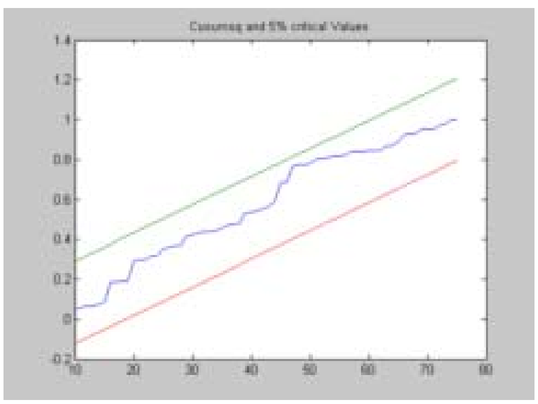


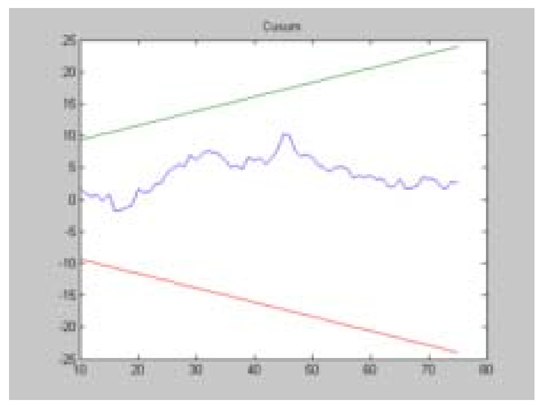
Non-Oil, Respecified, Growth, Unrestricted, With School:



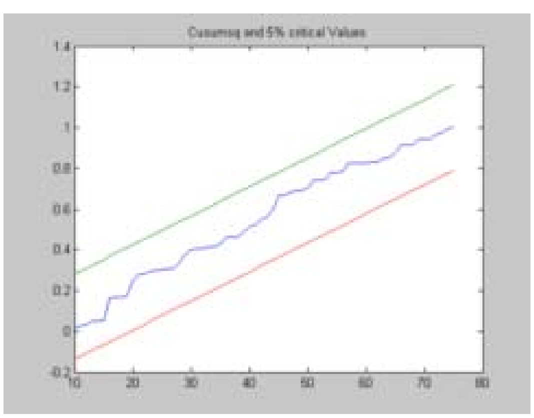


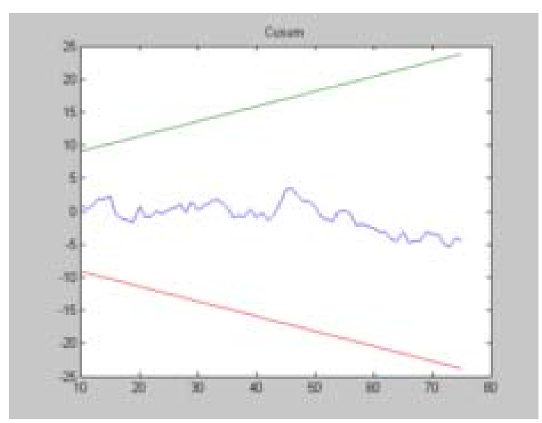
Intermediate, Respecified, Growth, Unrestricted, No School:





Intermediate, Respecified, Growth, Unrestricted, With School:





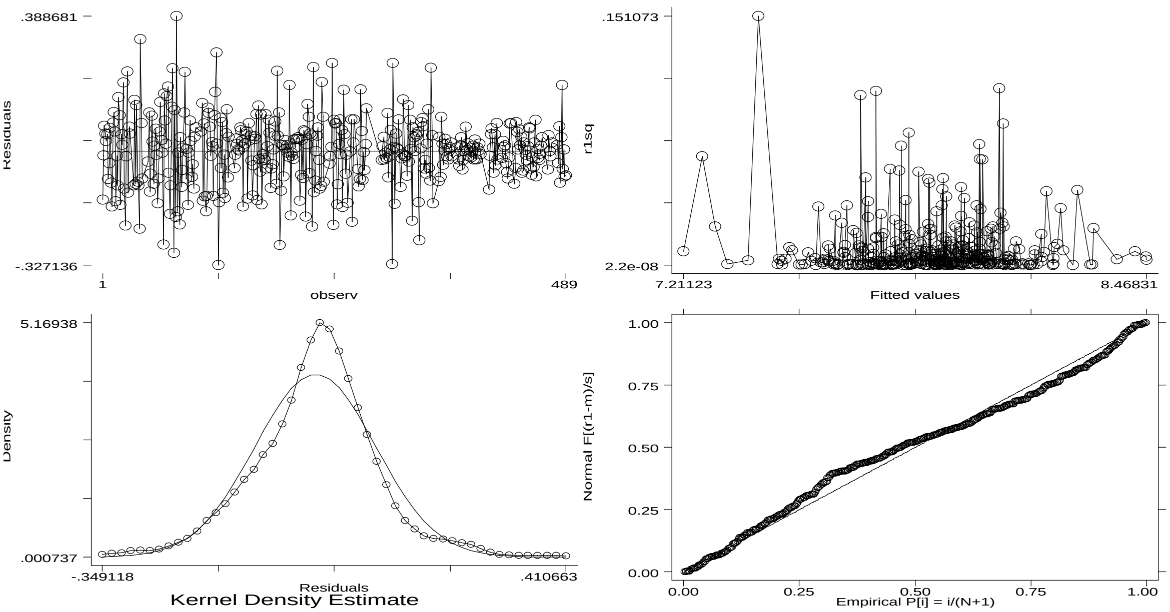
Appendix D

This appendix is interpreted as follows:

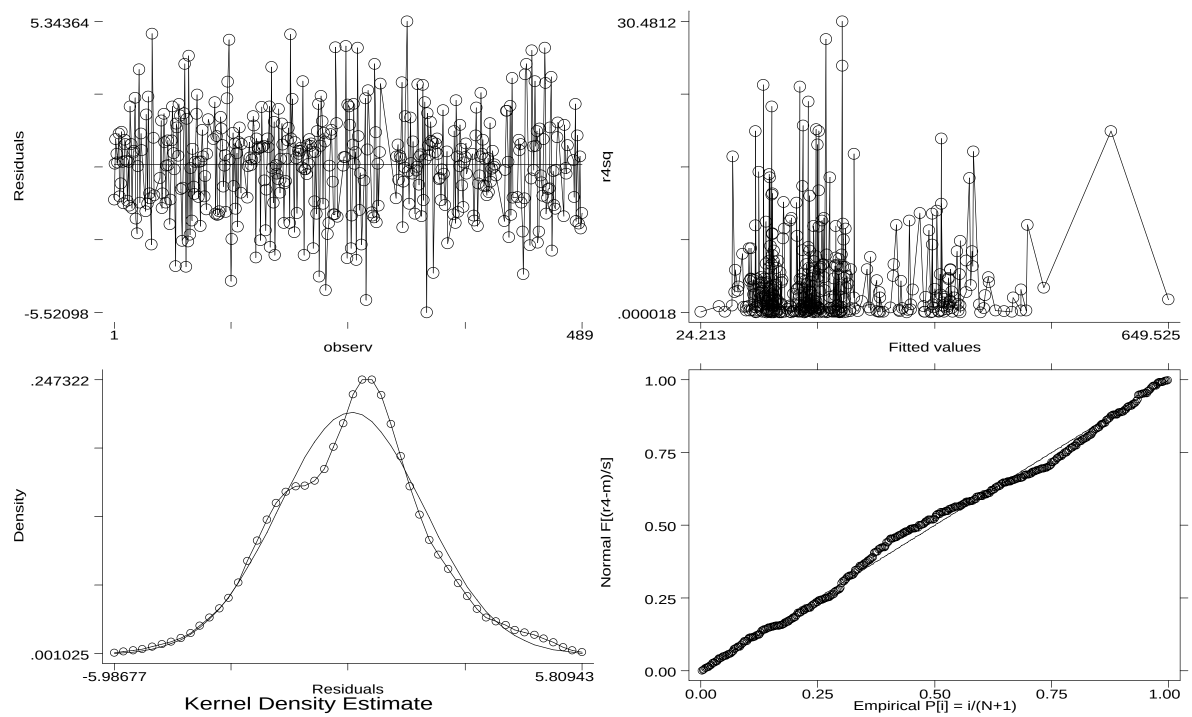
Preceding each set of four figures is the description of the data set (Non-Oil, Intermediate, OECD), whether the estimated model had the restriction for the coefficients (this restriction is explained in the paper) enforced or not (also as explained in the paper, for the Islam section, using the version of the Penn World Tables that I used, this restriction is no longer viable. Hence, all models shown are unrestricted models), and whether the estimated model was the originally estimated model or the statistically respecified model (all of these models are growth models).

In each set of four figures, the upper left-hand figure is a plot of the estimated residuals from the respective regressions, and are ordered over the regions within which the countries are located. From left to right, these regions are delineated as Africa, Asia, Europe, the Americas, and Oceania. The upper right-hand figure is a plot of the squared, estimated residuals on ordered estimated values of the dependent variable. The bottom-left figure is a graph of a smoothed histogram of the conditional distribution of the estimated model, overlaid with the correct normal distribution. The bottom-right figure is a probability plot (p-p plot) which shows us that if our conditional distribution is normal, the converted estimated residuals should be on the solid line.

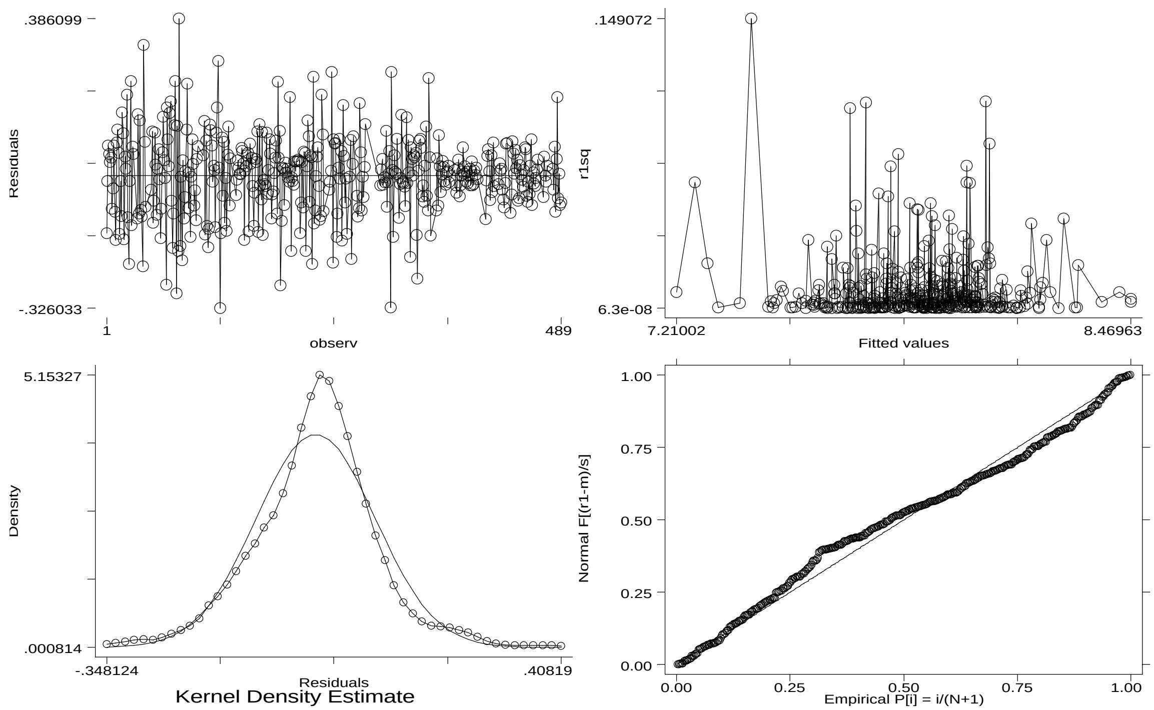
Non-Oil, Unrestricted, No School, Original:



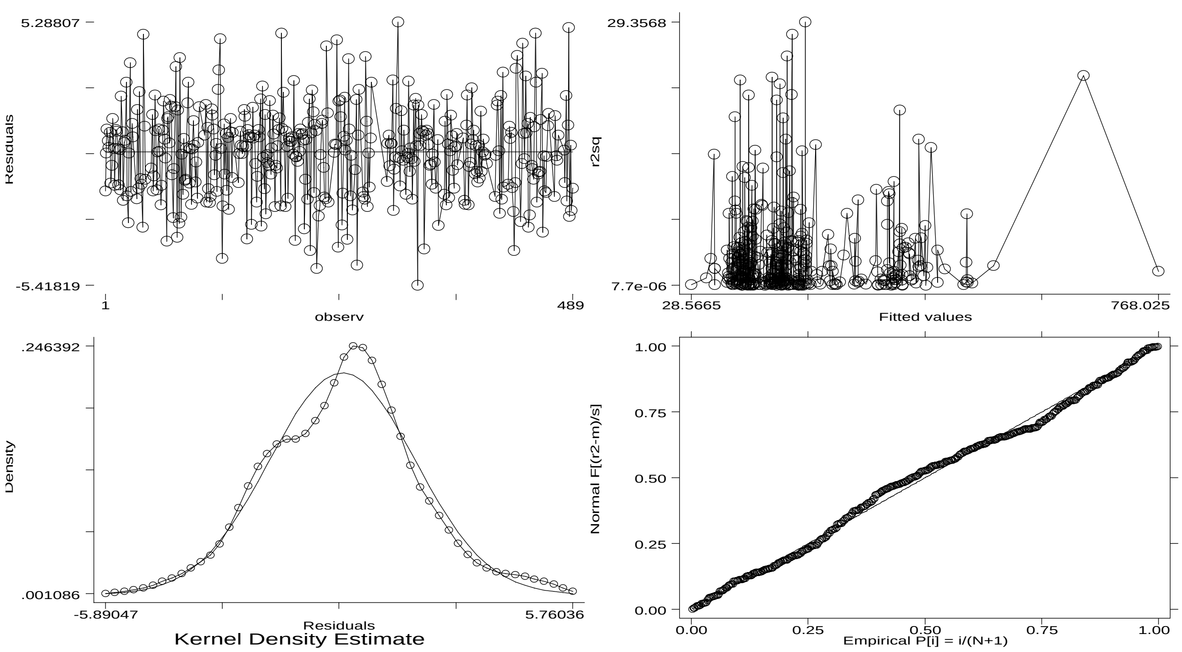
Non-Oil, Unrestricted, No School, Respecified:



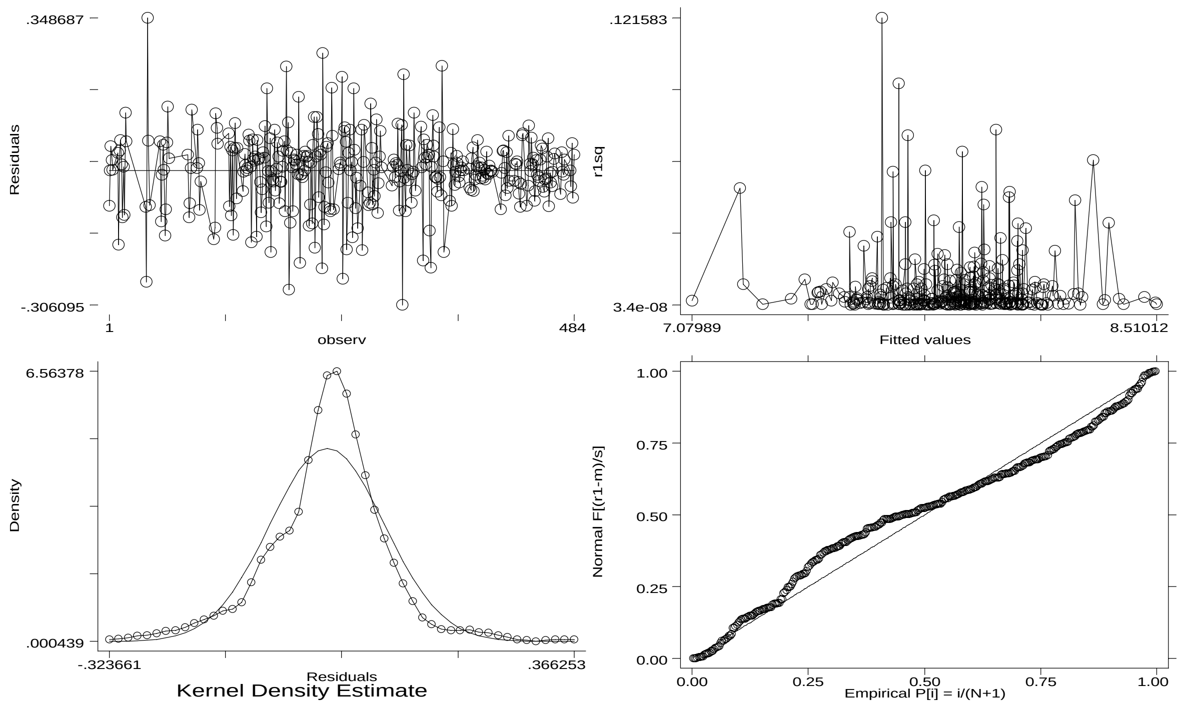
Non-Oil, Unrestricted, With School, Original:



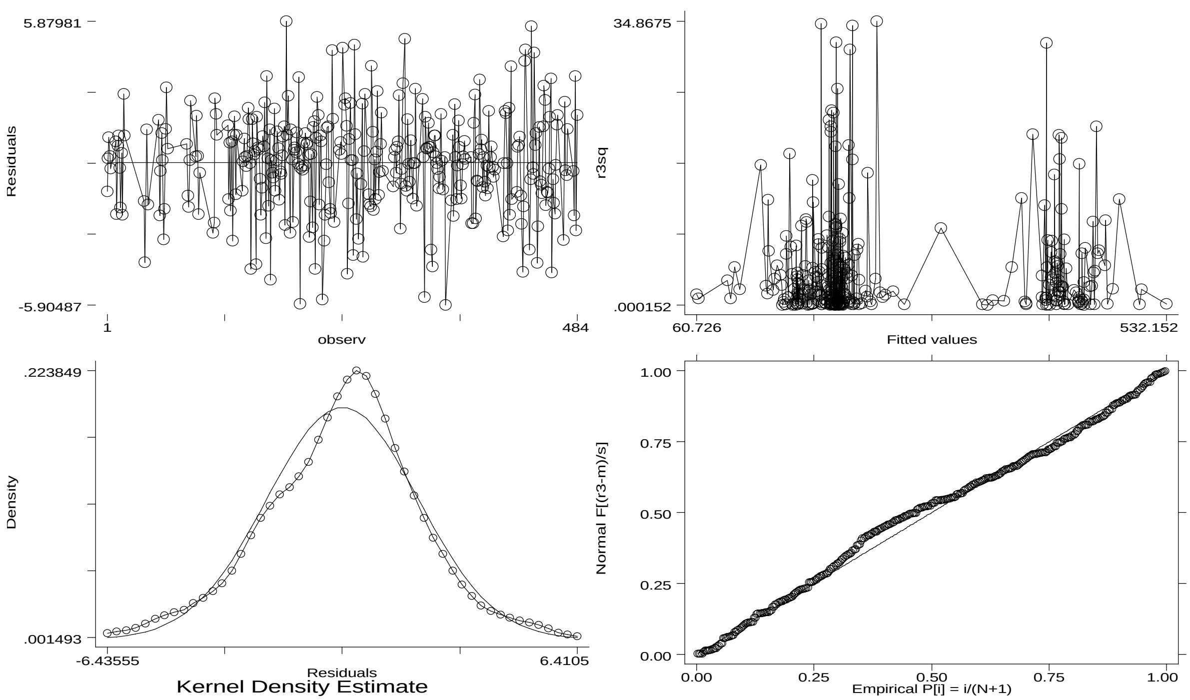
Non-Oil, Unrestricted, With School, Respecified:



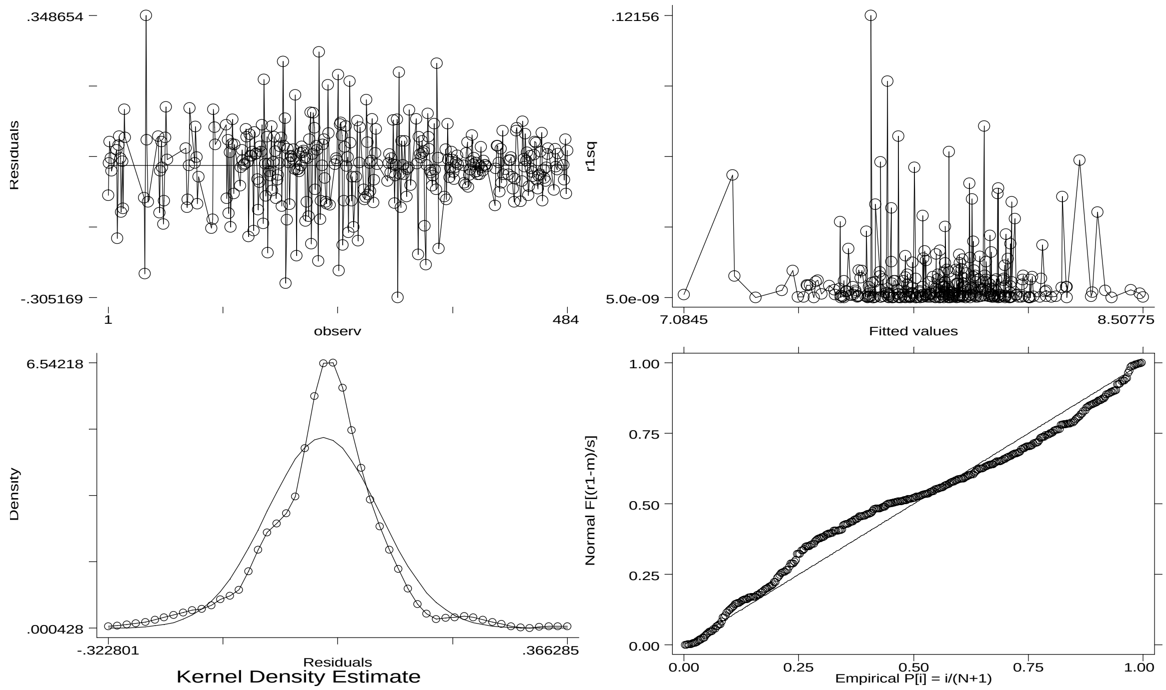
Intermediate, Unrestricted, No School, Original:



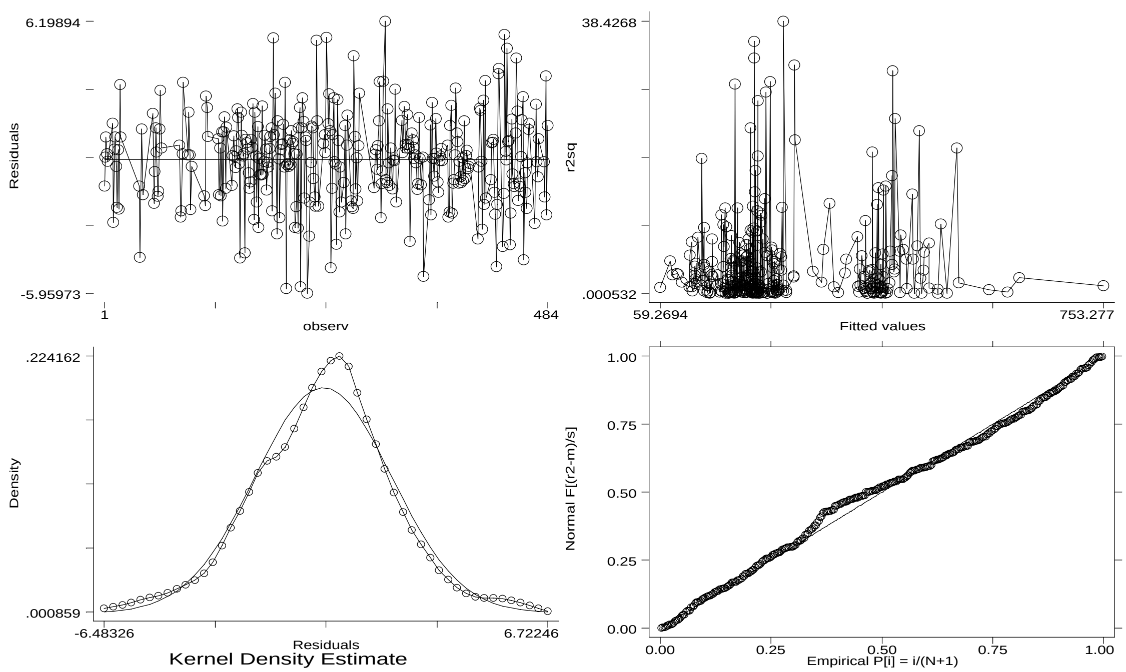
Intermediate, Unrestricted, No School, Respecified:



Intermediate, Unrestricted, With School, Original:



Intermediate, Unrestricted, With School, Respecified:



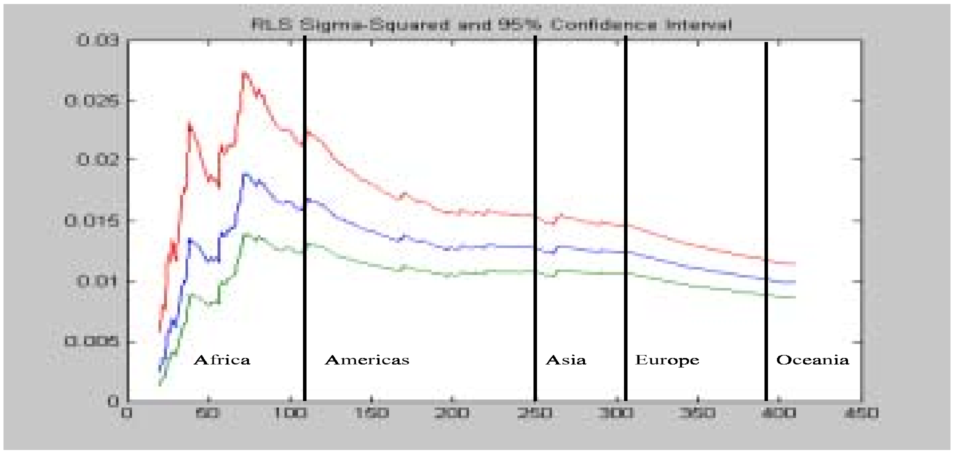
Appendix E

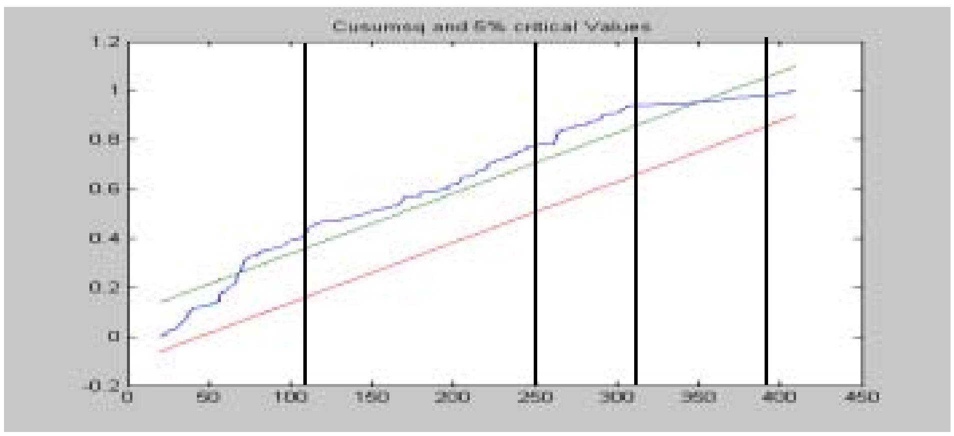
This appendix is interpreted as follows:

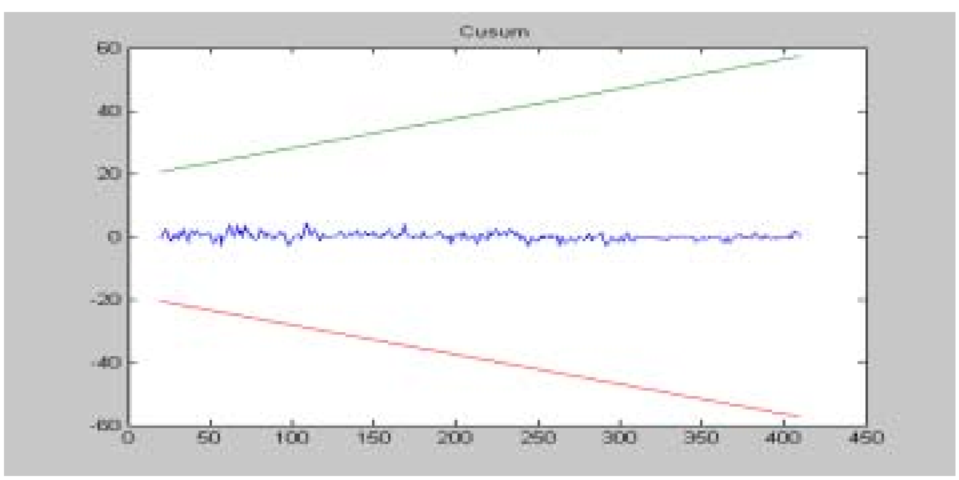
Each page is a set of figures for each type of model as described. The first description is the type of data set used, the second is whether the model is restricted or not as described in the body of the paper (I do include the restricted models here to show the reader that even the restricted model has the same problems with the variance as does the unrestricted models), and finally whether the model is augmented with schooling or not.

The first figure in each set is a recursive plot of the variance, where the estimated conditional variance is plotted for each additional observation that is added to the regression. The second figure is the CuSumSq test as described in the body of the paper, while the final figure is the CuSum test as described in the paper.

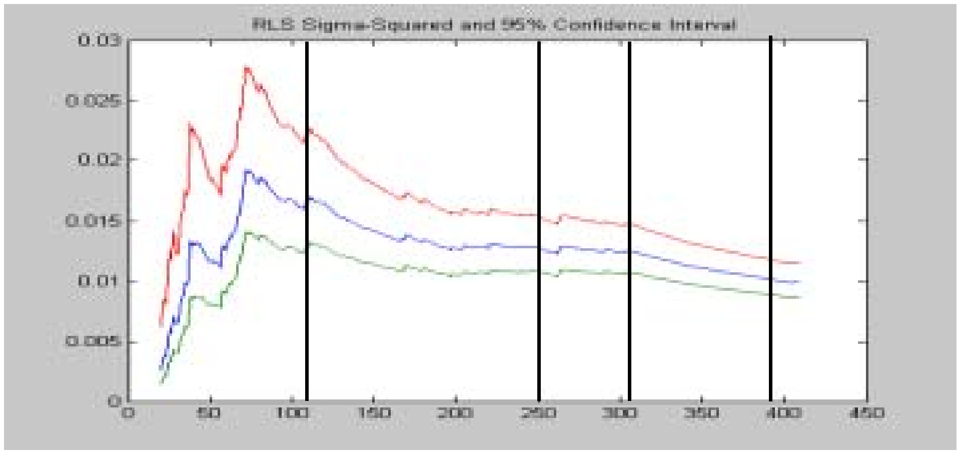
Non-Oil, Unrestricted, No School:

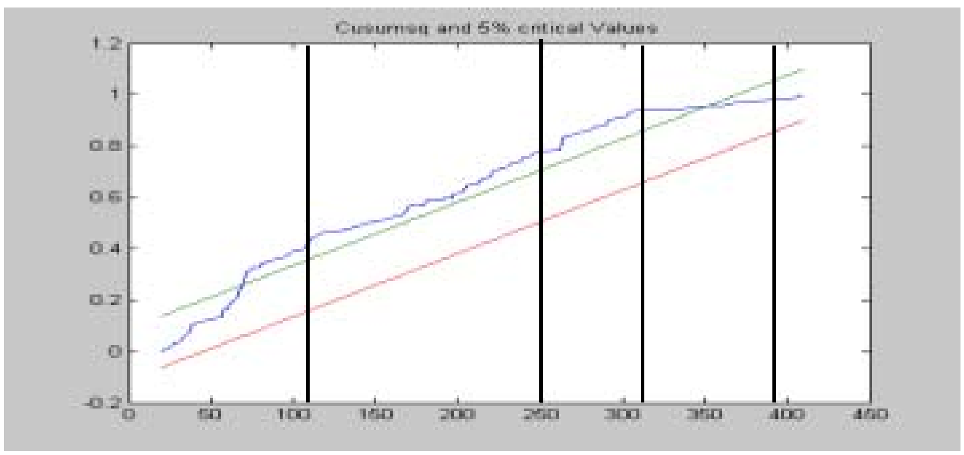


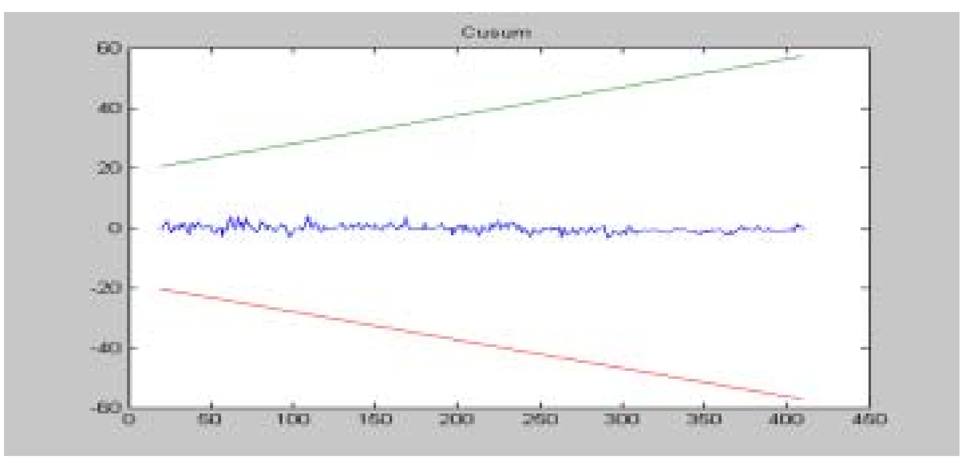




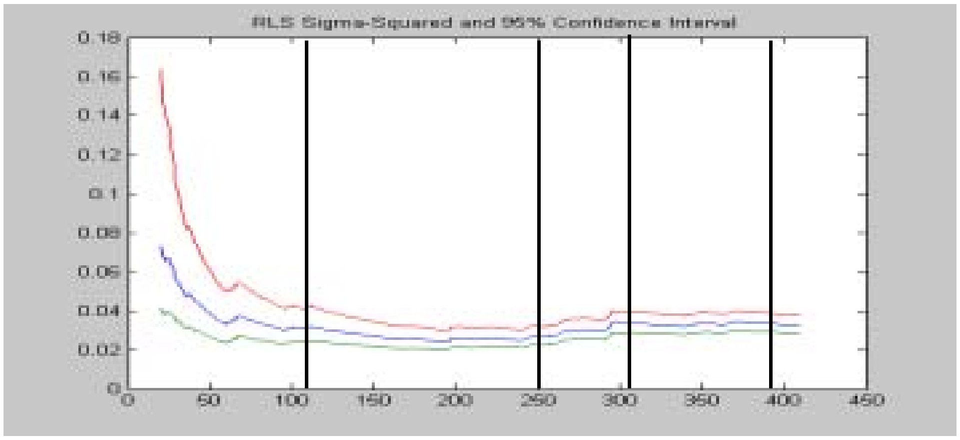
Non-Oil, Unrestricted, With School:

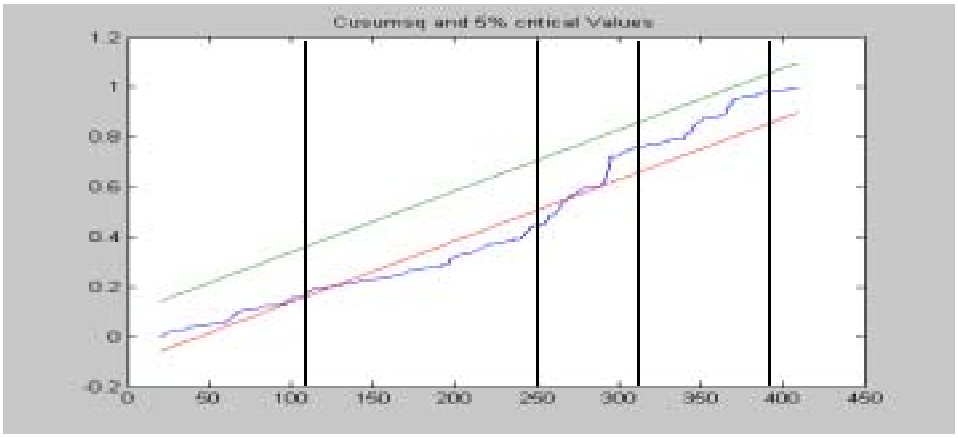


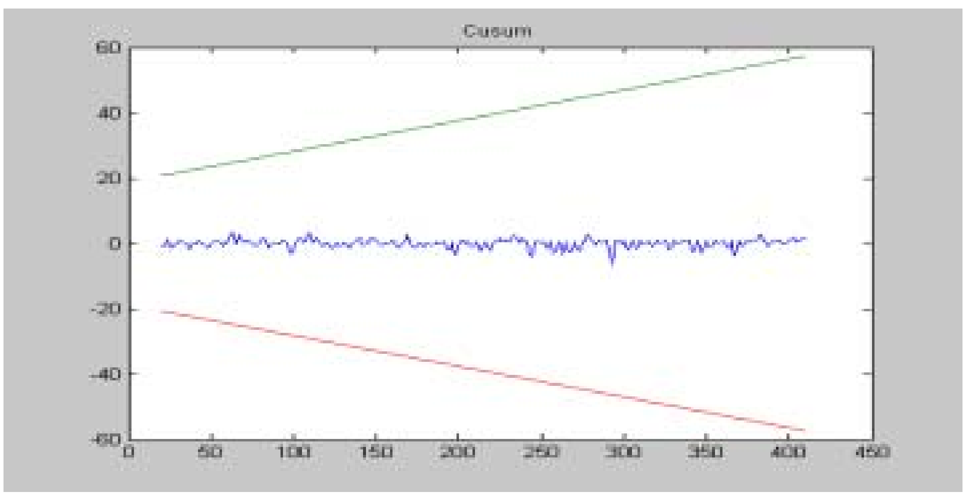




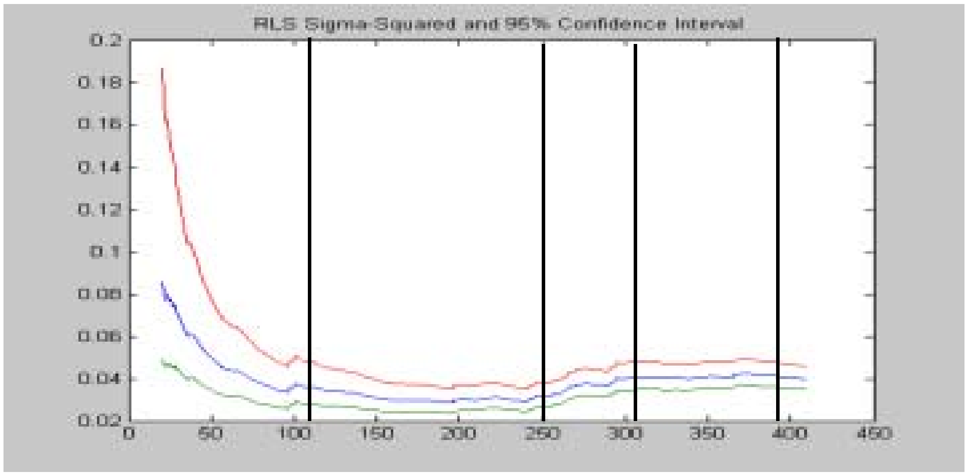
Non-Oil, Restricted, With School:

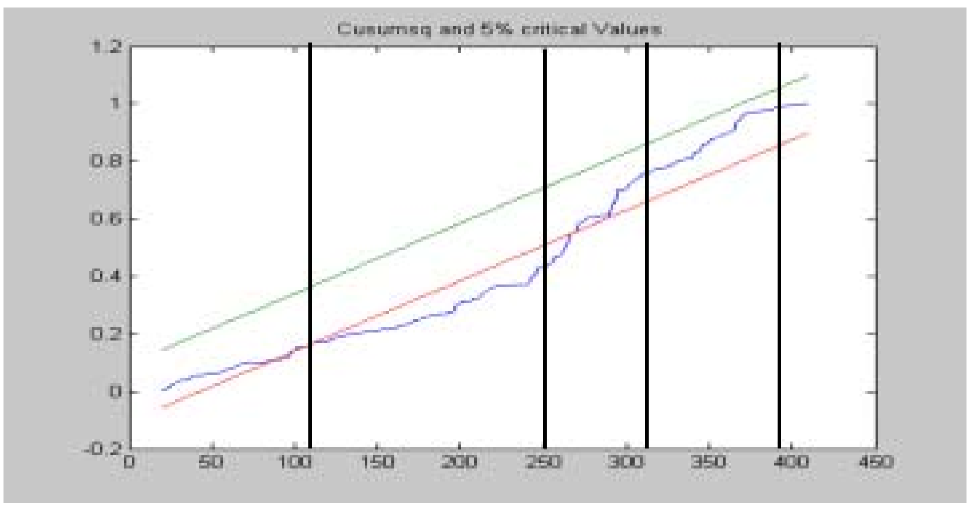


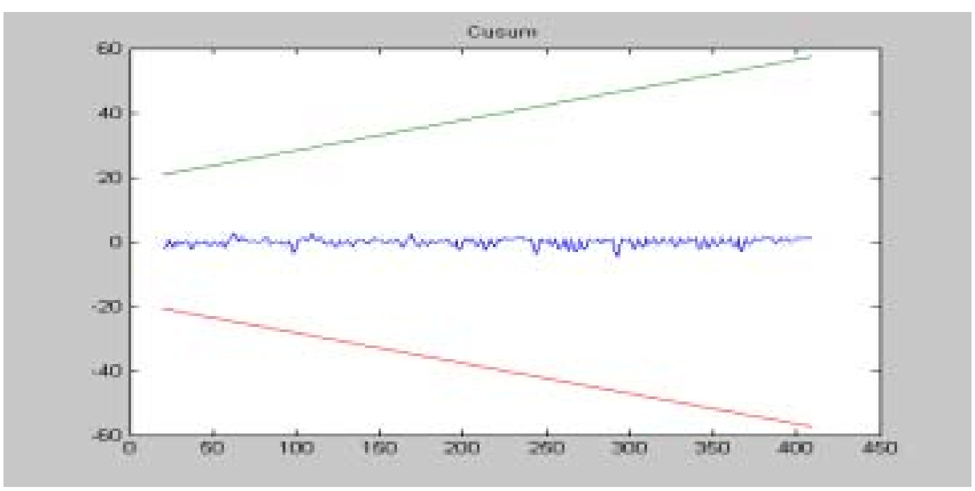




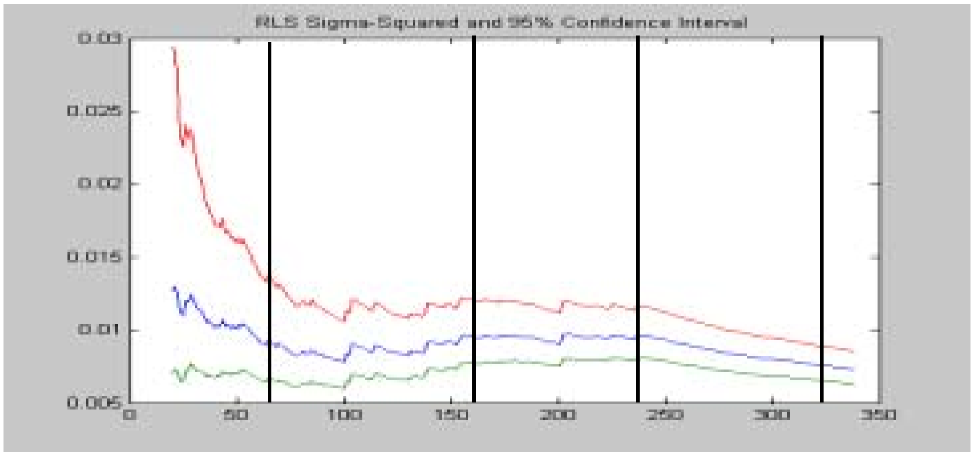
Non-Oil, Restricted, No School:

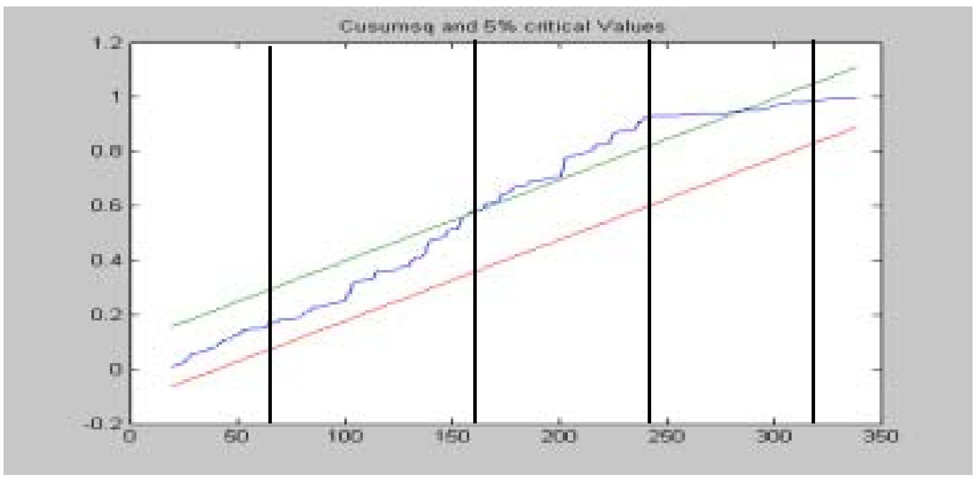


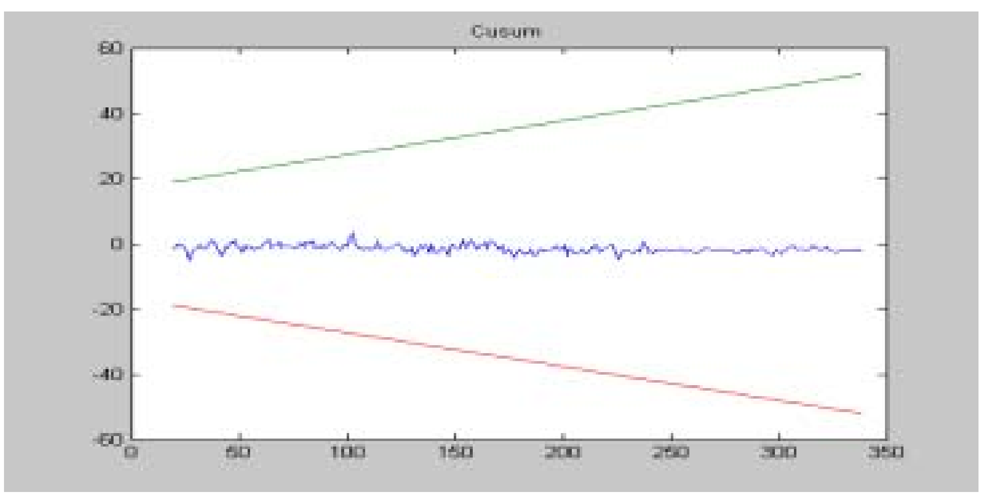




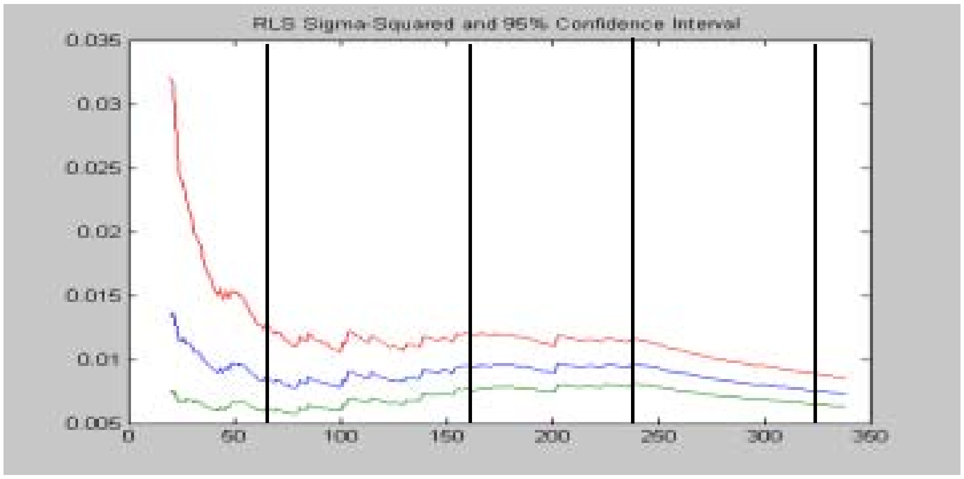
Intermediate, Unrestricted, No School:

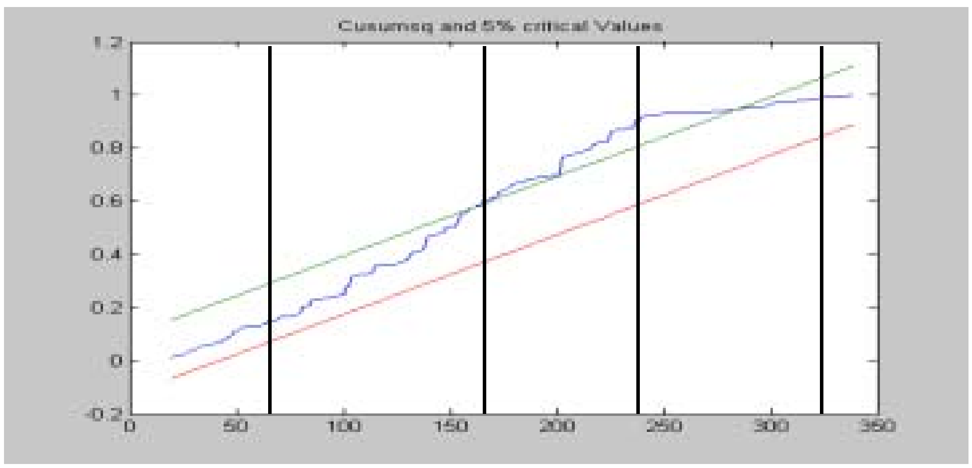


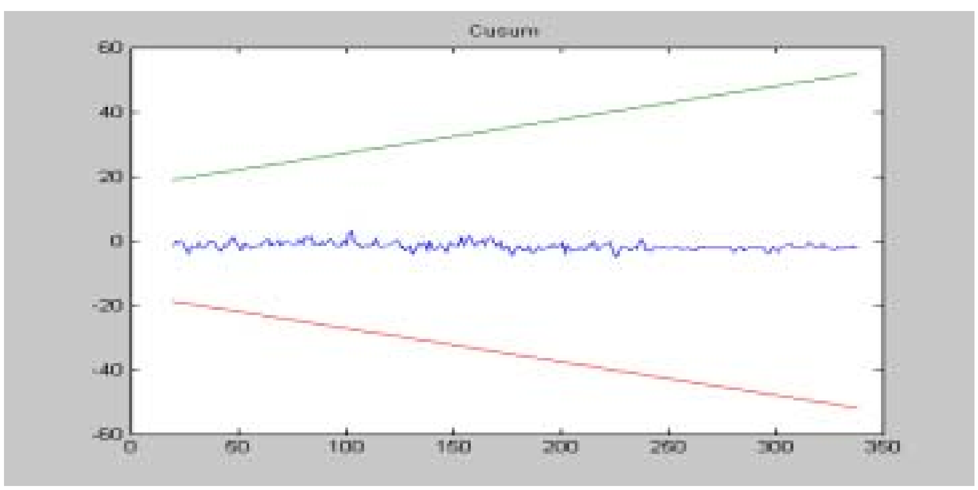




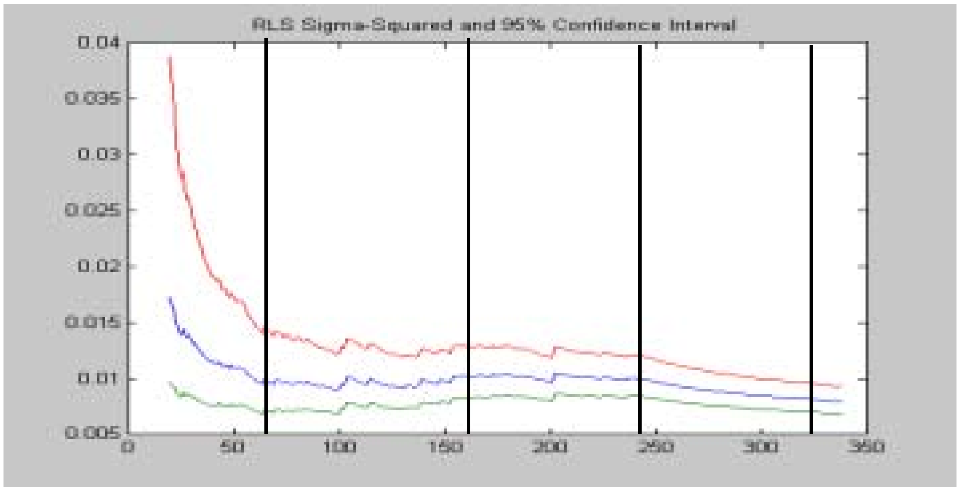
Intermediate, Unrestricted, With School:

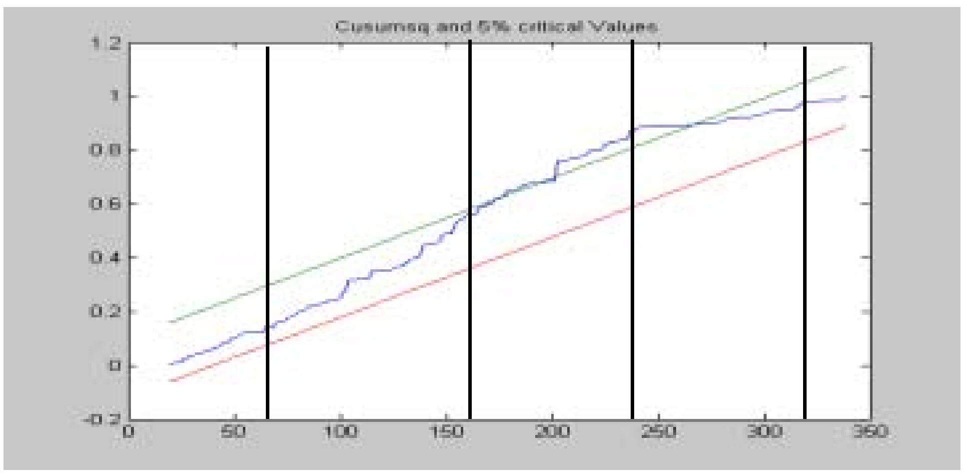


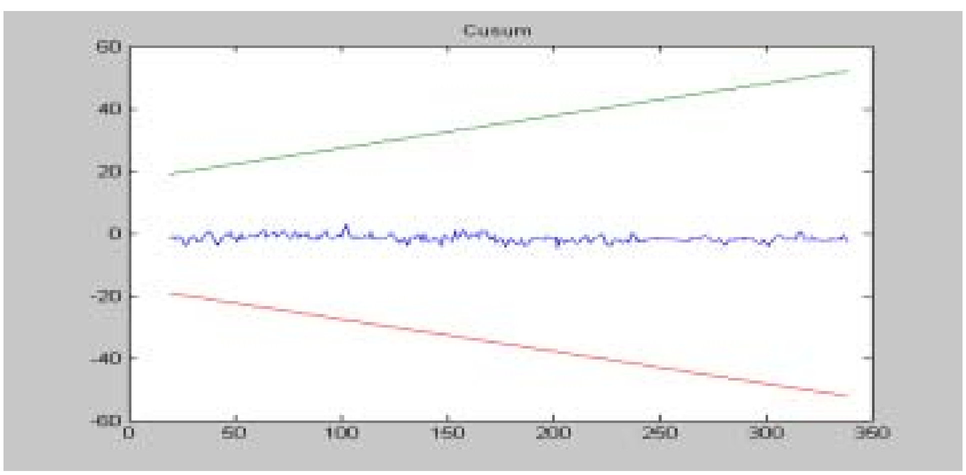




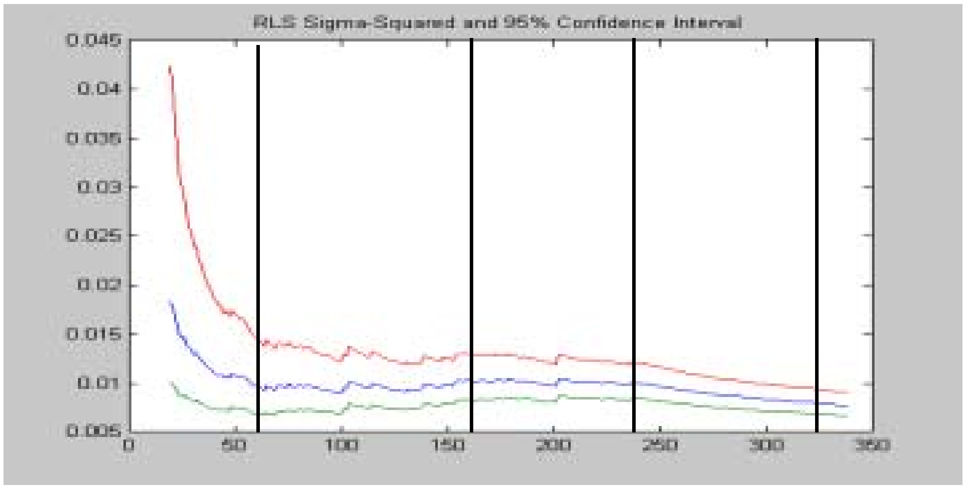
Intermediate, Restricted, No School:

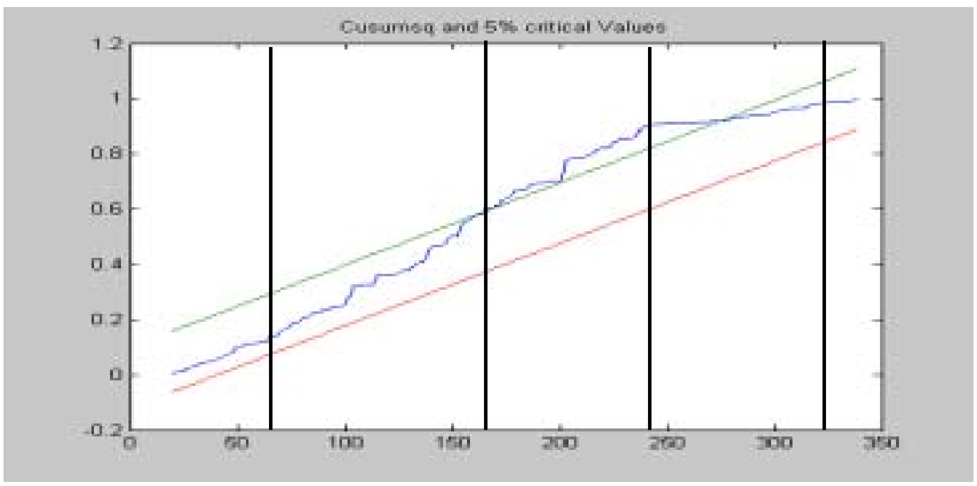


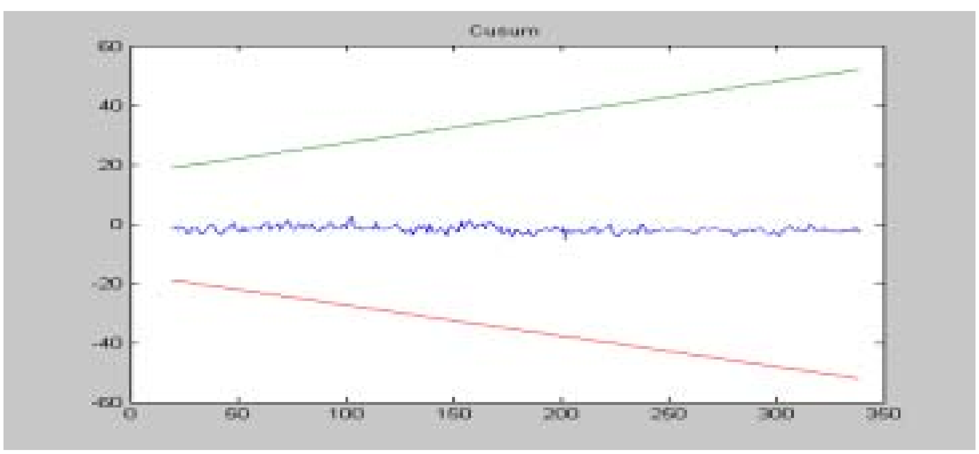




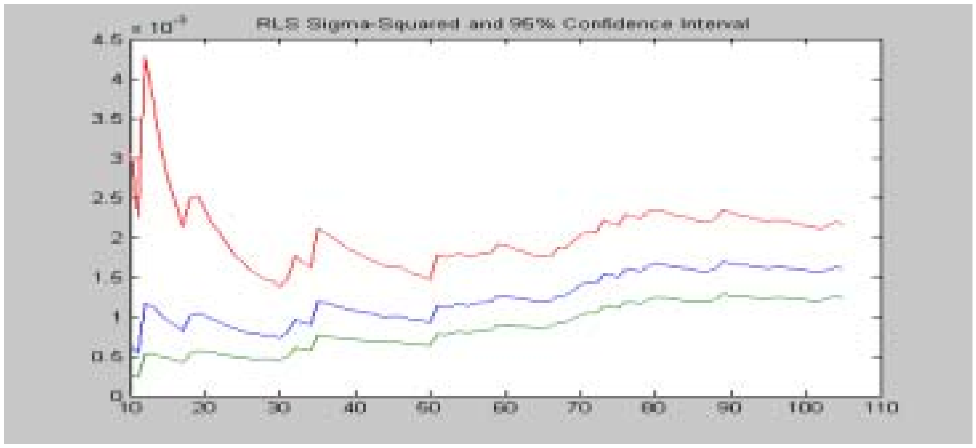
Intermediate, Restricted, With School:

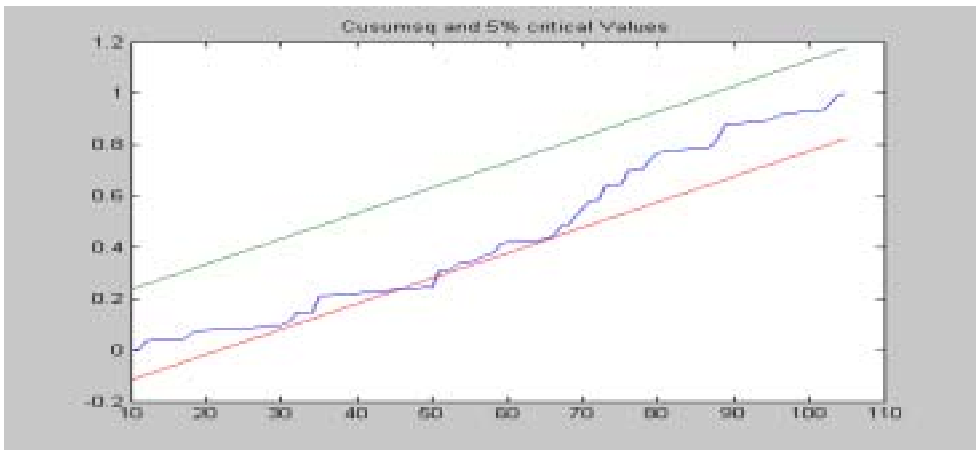


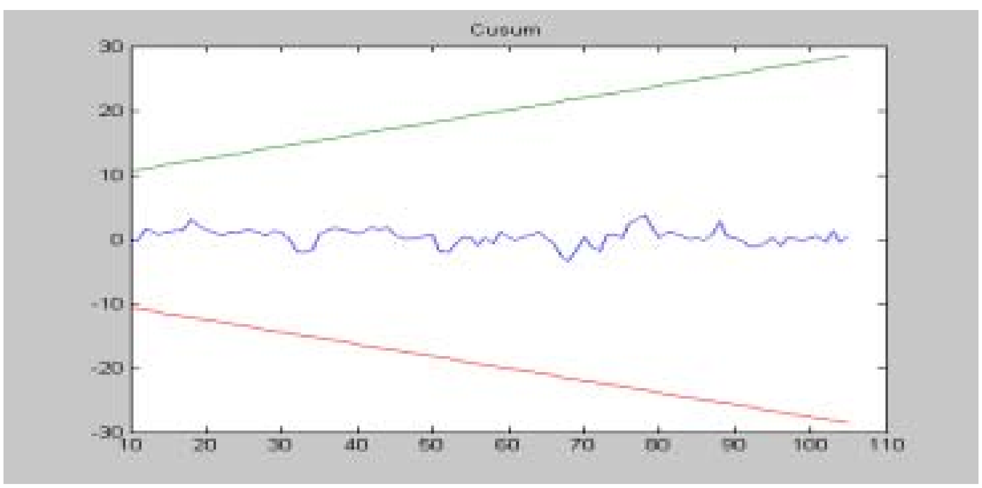




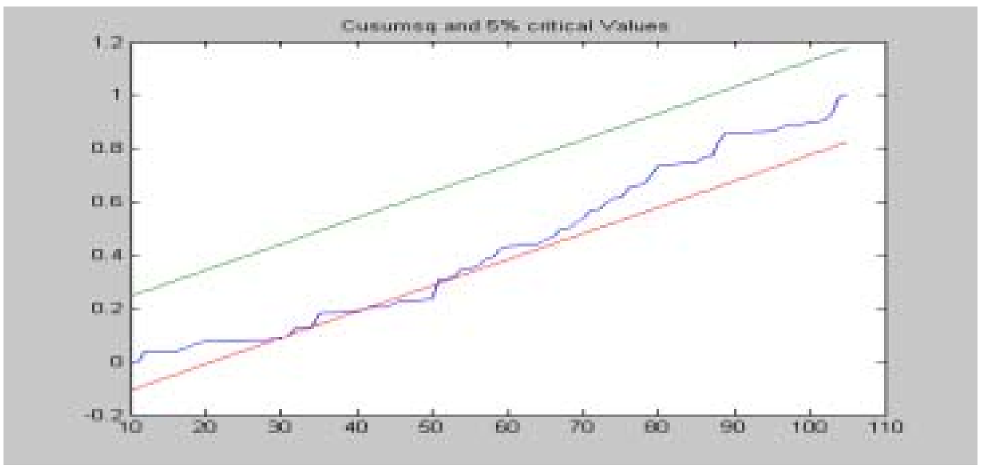
OECD, Unrestricted, No School:

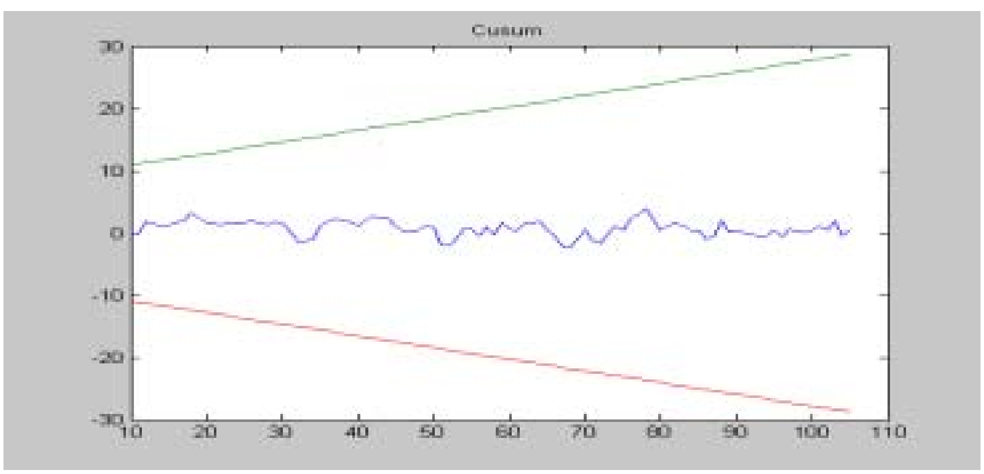




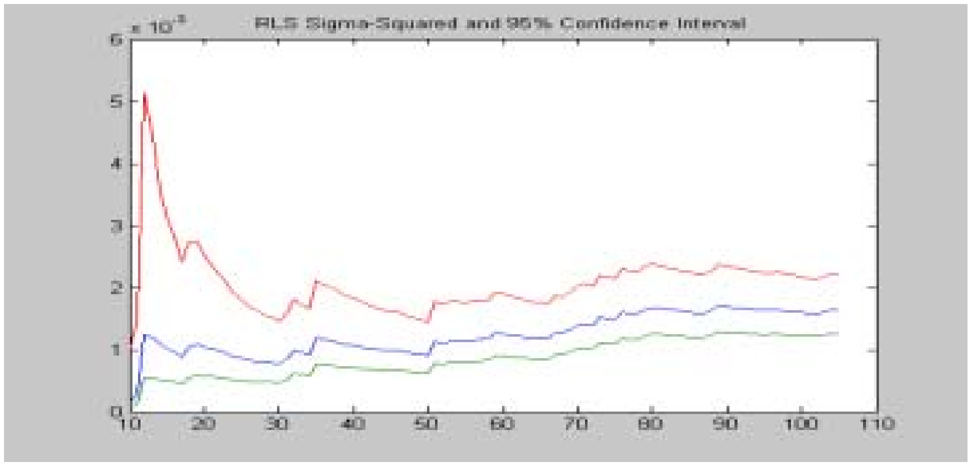


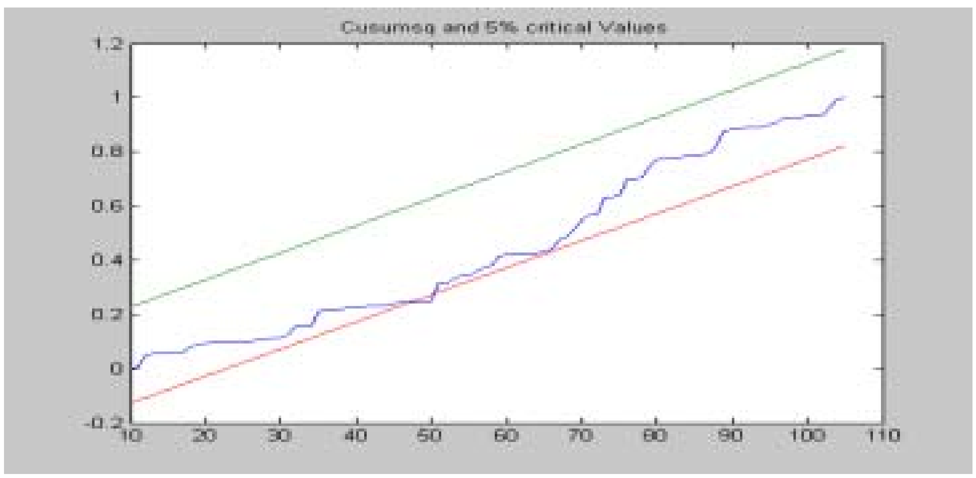
OECD, Restricted, No School:

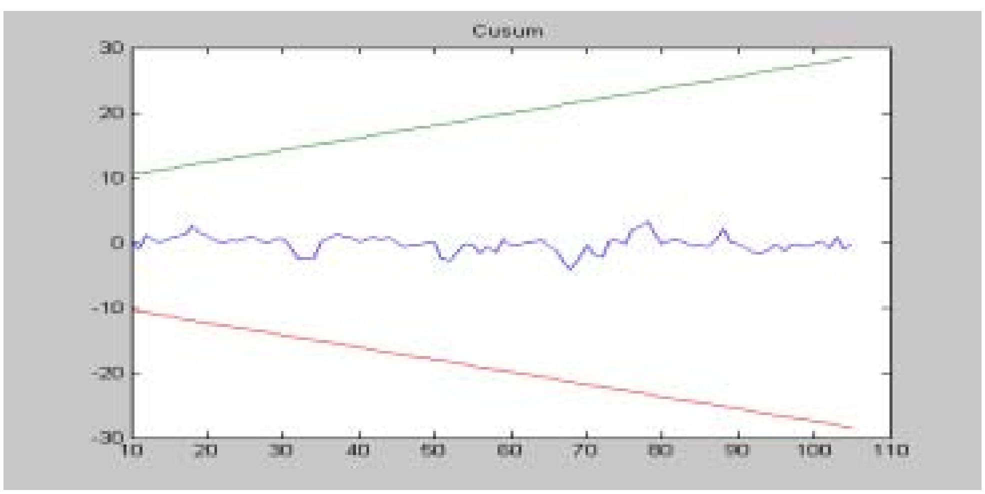




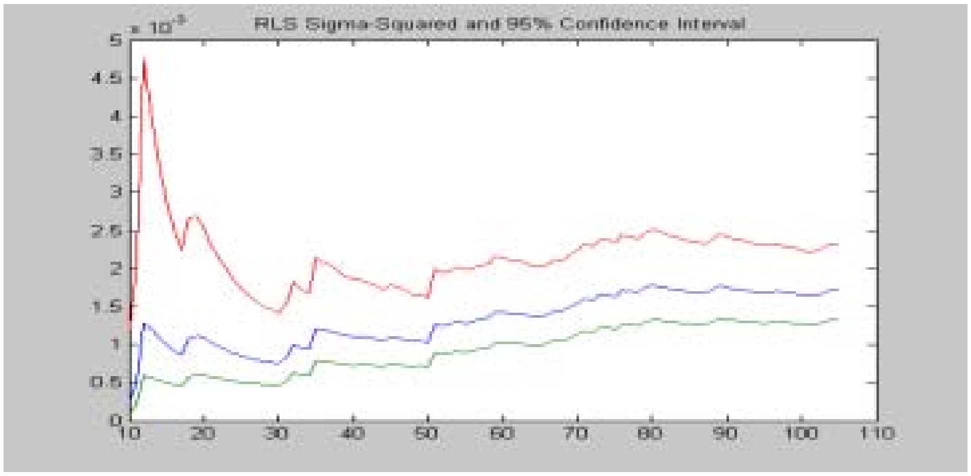
OECD, Unrestricted, With School:

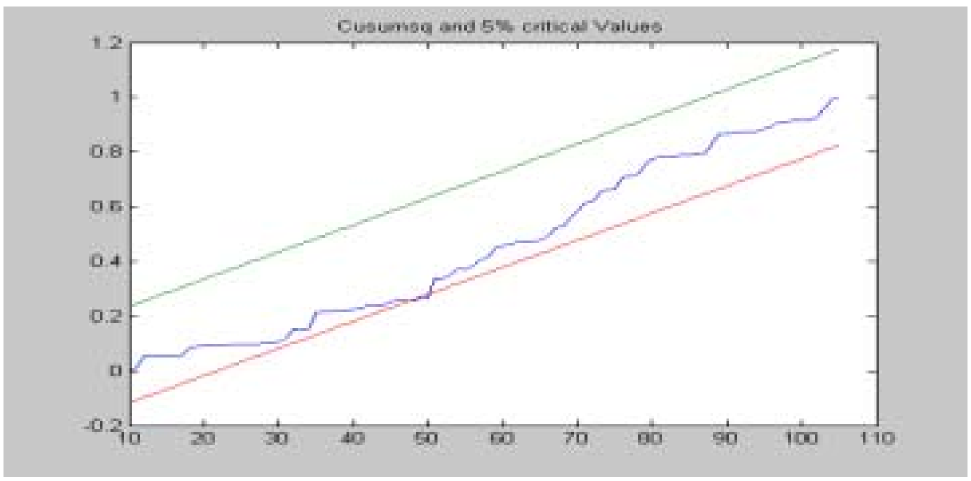


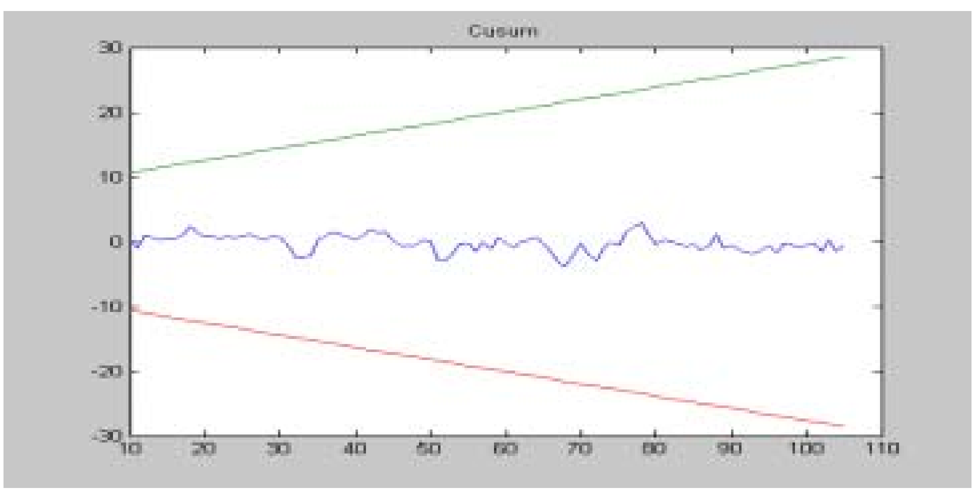




OECD, Restricted, With School:





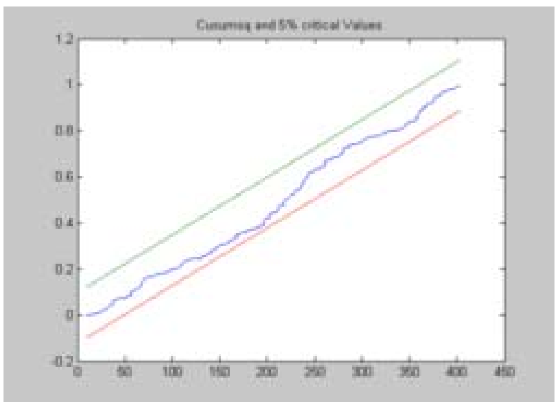


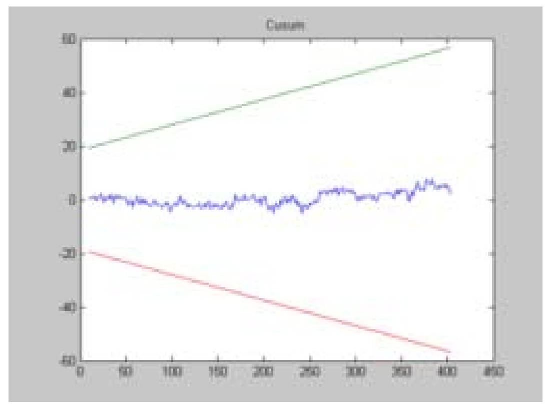
Appendix F

This appendix is described as follows:

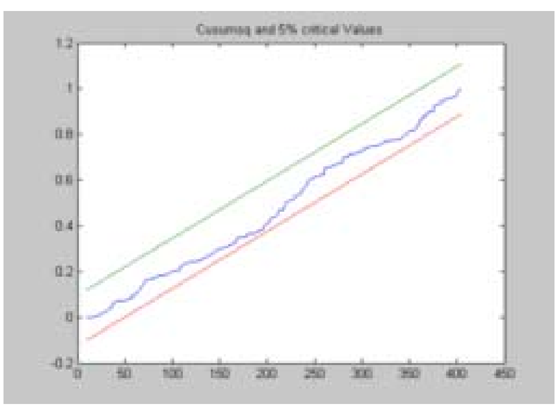
Each set of figures is preceded by the description of the data set used, the fact that this are the CuSumSq (on left) and CuSum tests for the respecified Islam models, whether the restriction is enforced as described in the body of the text, and whether augmented or non-augmented.

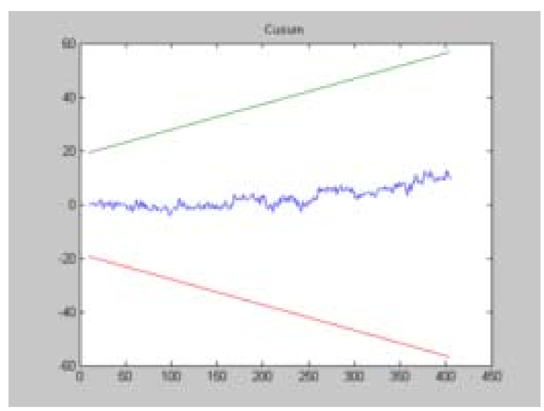
Non-Oil, Respecified, Unrestricted, No School:



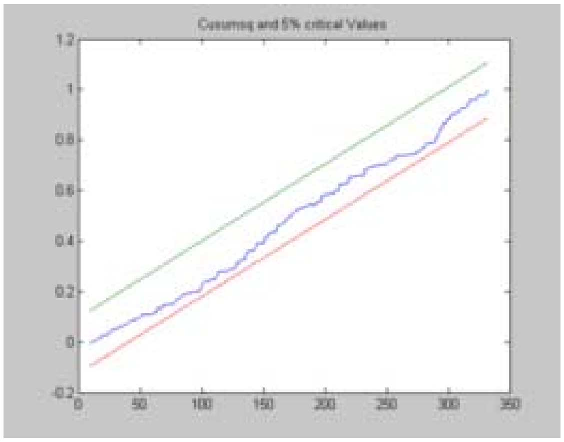


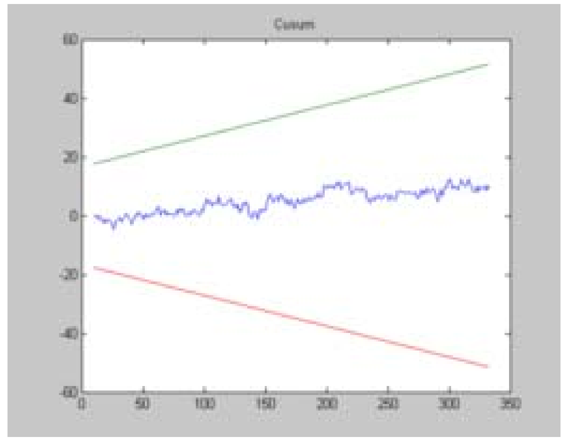
Non-Oil, Respecified, Unrestricted, With School:



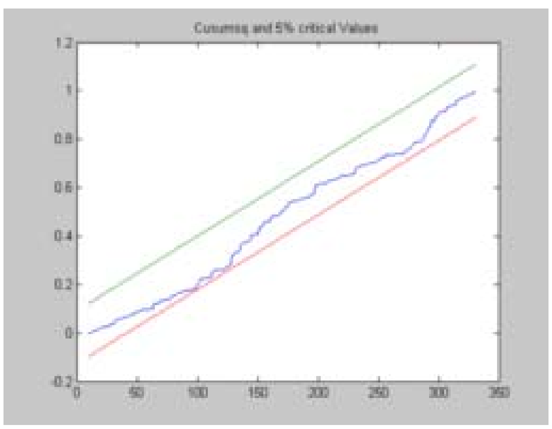


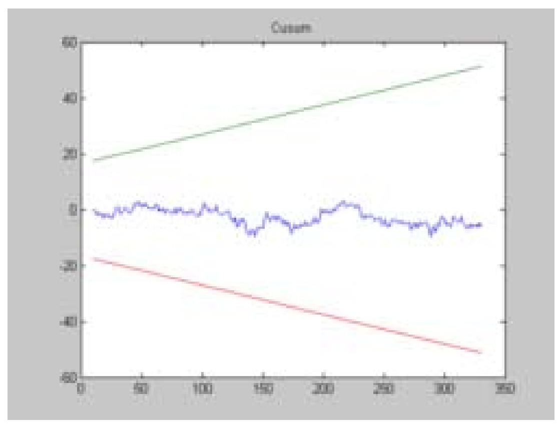
Intermediate, Respecified, Unrestricted, No School:





Intermediate, Respecified, Unrestricted, With School:





Appendix G

Replicated Islam Results						
Dependent variable is the natural log of GDP per worker. Estimates in the left-hand column are Islam's, mine are in the right-hand column.						
	Non-Oil		Intermediate		OECD	
$\ln GDP_t$	0.7762 (0.0353)	0.7404 (0.0211)	0.7935 (0.0388)	0.7743 (0.0188)	0.5864 (0.0532)	0.7995 (0.0177)
ln(I/GDP)	0.1595 (0.0237)	0.1802 (0.0181)	0.1709 (0.0256)	0.2478 (0.0186)	0.1215 (0.0586)	0.2487 (0.0413)
$\ln(n+g+\delta)$	-0.4092 (0.1024)	-0.1088 (0.0301)	-0.2466 (0.1007)	-0.0759 (0.0273)	-0.0698 (0.1007)	-0.0758 (0.0220)
Adj R^2	0.7404	0.7805	0.8254	0.8603	0.9659	0.9611
Standard errors are in parentheses.						

Appendix H

Duplicated MRW results for the non-augmented model using levels.

Table 1						
Dependent variable is the natural log of GDP per worker in 1985. Estimates in the left-hand column are MRW's, mine are in the right-hand column.						
Variables	Non-Oil (98 obs)		Intermediate (75 obs)		OECD (22 obs)	
[Unrestricted]						
ln(I / GDP)	1.42 (0.14)	1.42 (0.14)	1.31 (0.17)	1.32 (0.17)	0.50 (0.43)	0.50 (0.43)
$\ln(n + g + \delta)$	-1.97 (0.56)	-1.99 (0.56)	-2.01 (0.53)	-2.02 (0.53)	-0.76 (0.84)	-0.74 (0.85)
$\overline{R}^2$	0.59	0.59	0.59	0.59	0.01	0.01
[Restricted]						
ln(I / GDP)- $\ln(n + g + \delta)$	1.48 (0.12)	1.49 (0.12)	1.43 (0.14)	1.43 (0.14)	0.56 (0.36)	0.55 (0.37)
$\overline{R}^2$	0.59	0.59	0.59	0.59	0.06	0.06
Standard errors are in parentheses.						

Duplicated MRW results for the augmented model using levels.

Table 3						
Dependent variable is the natural log of GDP per worker in 1985. Estimates in the left-hand column are MRW's, mine are in the right-hand column.						
Varibles	Non-Oil (98 obs)		Intermediate (75 obs)		OECD (22 obs)	
[Unrestricted]						
ln(I / GDP)	0.69 (0.13)	0.70 (0.13)	0.70 (0.15)	0.70 (0.15)	0.28 (0.39)	0.28 (0.39)
$\ln(n + g + \delta)$	-1.73 (0.41)	-1.75 (0.42)	-1.50 (0.40)	-1.50 (0.40)	-1.07 (0.75)	-1.07 (0.76)
ln(school)	0.66 (0.07)	0.65 (0.07)	0.73 (0.10)	0.73 (0.10)	0.76 (0.29)	0.77 (0.29)
$\overline{R}^2$	0.78	0.78	0.77	0.77	0.24	0.24
[Restricted]						
ln(I / GDP)- $\ln(n + g + \delta)$	0.73 (0.12)	0.74 (0.12)	0.71 (0.14)	0.71 (0.14)	0.29 (0.33)	0.28 (0.33)
ln(school)- $\ln(n + g + \delta)$	0.67 (0.07)	0.66 (0.07)	0.74 (0.09)	0.73 (0.09)	0.76 (0.28)	0.77 (0.28)
$\overline{R}^2$	0.78	0.78	0.77	0.77	0.28	0.28

Appendix I

A brief overview of problems resulting from statistical misspecification:

With respect to (1), the consequences of heteroskedasticity are that the estimators, and subsequent forecasts, are still unbiased and consistent, but the estimators no longer adhere to the Gauss-Markov theorem because of inefficiency. Furthermore, the estimated variance/covariance matrix will be biased and inconsistent invalidating any testing of the parameters of the model in question.

Formally, assume we have the model[34]

$$\hat{Y} = X\hat{B} \quad \text{and} \quad \hat{u} = Y - \hat{Y}$$

the process is to minimize

$$\begin{aligned} \hat{u}'\hat{u} &= (Y - X\hat{B})'(Y - X\hat{B}) \\ &= (Y'Y - 2\hat{B}'X'Y + \hat{B}'X'X\hat{B}) \end{aligned} \qquad \text{(i)}$$

the necessary condition for minimizing (i) is

$$\frac{\partial \hat{u}'\hat{u}}{\partial \hat{B}} = -2(X'Y + X'X\hat{B}) = 0$$

It follows then that

$$\hat{B} = (X'X)^{-1}X'Y \qquad \text{(ii)}$$

where the matrix $X'X$ is positive definite. Plugging in for Y into (ii), we have

$$\begin{aligned} \hat{B} &= (X'X)^{-1}X'Y \\ &= (X'X)^{-1}X'(XB + u) \\ &= (X'X)^{-1}X'XB + (X'X)^{-1}X'u \\ &= B + (X'X)^{-1}X'u \end{aligned} \qquad \text{(iii)}$$

And because of orthogonality between X and u, we get our unbiased result. We must go one step further, however, and derive the conditional variance of $\hat{B}$ from (iii). We have

[34] This and the following mathematical proofs of the consequences of ignoring properties (1)-(4) are found in Patterson, 2000.

$$
\begin{aligned}
&E[(\hat{B}-B)(\hat{B}-B)'|X] \\
&\quad = E[((X'X)^{-1}X'u)((X'X)^{-1}X'u)'|X] \\
&\quad = ((X'X)^{-1}X')E[uu'|X]X(X'X)^{-1} \\
&\quad = (X'X)^{-1}X'(\sigma^2 I)X(X'X)^{-1} \\
&\quad \text{ where } E[uu'|X] = \sigma^2 I \\
&\quad = \sigma^2(X'X)^{-1}
\end{aligned}
\qquad \text{(iv)}
$$

where σ^2 is a constant scalar. Whereas for a particular sample where $X = x$ then

$$
Var(\hat{B}|x) = \sigma^2(x'x)^{-1} \qquad \text{(v)}
$$

where the square root of this expression is the standard error of $\hat{B}$ from which all testing of $\hat{B}$ is based. However, if $\sigma^2(x'x)^{-1} \neq c_0 \;\forall x$, then we can see that the conditional variance of $\hat{B}$ is no longer constant invalidating any testing of our estimates.

The consequences of ignoring (2) are that even though the OLS estimates are unbiased and consistent, they are not efficient (see Ramanathan, 1995) and hence do not coincide with the Gauss-Markov implication of relatively most efficient parameters.

Formally, if we express (iv) as

$$
var(\hat{B}) = (X'X)^{-1}X'\Omega X(X'X)^{-1}
$$

where in (iv), $\Omega = \sigma^2 I$, with dependence, i.e., $E(u_t, u_{t-s}) \neq 0$ for $t \neq s$, then it must be the case that $\Omega \neq \sigma^2 I$.

The violation of assumptions (3) and (4) are probably the most serious of all the above assumptions. The consequences of ignoring non-linearities in the conditioning variables are that estimates are biased and inconsistent, and moreover, testing and forecasts derived from them are also invalid. It is easy and intuitive to show this formally.

Assume we estimate the model

$$Y = XB + u$$

and as above we get

$$\hat{B} = (X'X)^{-1} X'Y$$

But now assume the true model is

$$Y = XB + ZC + e$$

where

$$Z = f(x)$$

is a nonlinear function of X (or this could be a deterministic trend). Then we have

$$\begin{aligned}\hat{B} &= (X'X)^{-1} X'(XB + ZC + e) \\ &= (X'X)^{-1} X'XB + (X'X)^{-1} X'ZC + (X'X)^{-1} X'e \\ &= B + (X'X)^{-1} X'ZC + (X'X)^{-1} X'e\end{aligned}$$

and even if $E[X'e] = 0$, we still have

$$E[\hat{B} - B] = E[(X'X)^{-1} X'ZC] \neq 0$$

Appendix J

Testing and respecification procedures:

White's Test:

The procedure for the White's test is as follows:

$$\text{(i)} \qquad Y_{it} = b_0 + b_1 X_{it1} + b_2 X_{it2} + e$$

Estimate (i) by OLS and get the estimates of the b's. Estimate the residuals and square them. Regress the squared residuals on a constant and squares and cross-products of all the X's. Compute the statistic nR^2 where R^2 is the unadjusted, population correlation coefficient. This statistic is distributed $\chi^2(m)$ where m is the number of regressers in the auxiliary regression.

Cook - Weisburg Test:

Formally, the CW test takes the following form:

Let U be and $n \times 1$ vector with *i*th entry

$$u_i = \frac{e_i^2}{\hat{\sigma}^2},, \hat{\sigma}^2 = \frac{\sum e_i^2}{n}$$
$$\hat{e}_{i0} = y_i - x_i \hat{B}_{\delta_0}$$

Define *D* as an $n \times q$ matrix with entries $\partial w(z_i, \delta)/\partial \delta$ evaluated at $\delta = \delta *$ and *z* is equal to the fitted values $x\hat{B}$. Also define $\overline{D}$ as an $n \times q$ matrix obtained from D by subtracting column averages, then the test statistic takes the form

$$CW = \frac{U'\overline{D}(\overline{D}'\overline{D})^{-1}\overline{D}'U}{2}$$

where $CW \sim \chi^2(m)$.

Feasible Generalized Least Squares:

The procedure used to correct for the heteroskedasticity is widely known as the Feasible Generalized Least Squares procedure (Harvey, 1976), and is expressed clearly in Ramanathan (1998) and Greene (2000). The procedure is as follows:

Assume we have a model as in (i) where $\mathrm{Var}(e_t) = \sigma_t^2$ for $t = 1,2,\ldots,n$ and each t represents a particular observation on x, and σ_t^2 is unknown.

(i) Obtain the OLS estimates of the b's from (i).

(ii) Compute the residuals $\hat{e}_t = y_t - \hat{b}_0 - \hat{b}_1 x_{1t} - \hat{b}_2 x_{2t} - \cdots - \hat{b}_i x_{it}$.

(iii) Regress $\ln(\hat{e}_t^2)$ against a constant and $z_{1t}, z_{2t}, \ldots, z_{pt}$ where the z's are the original x's, their squares and cross products and obtain OLS estimates, c's, of the coefficients for this regression.

(iv) Obtain $\hat{\sigma}_t^2$ by the regression $\ln(\hat{\sigma}_t^2) = \hat{c}_0 + \hat{c}_1 z_{1t} + \hat{c}_2 z_{2t} + \cdots + \hat{c}_p z_{pt}$ and exponentiating.

(v) Weight equation (i) with the reciprocal of the square root of $\hat{\sigma}_t^2$.

RESET Test:

The RESET procedure is as follows (see Ramanathan, 1998):

(i) Estimate the general model by OLS and save the predicted values, $\hat{Y}_t$.

(ii) Generate the variables $\hat{Y}_t^2$, $\hat{Y}_t^3$, $\hat{Y}_t^4$, add to the model in step (i) and estimate.

(iii) Use an F-test for the significance of the estimated coefficients for the variables in step (ii).

Shapiro - Wilk Test:

The derivation of the statistic is as follows (see Shapiro and Wilk, 1965):

Let $m' = (m_1, m_2, \ldots, m_n)$ be the expected values of the standard normal order statistics, and

$V = (v_{ij})$ be the $n \times n$ covariance matrix where if the $x's$ are an ordered random sample of

size *n* and is distributed normal with mean zero and variance one, then

$$E(x)_i = m_i \qquad (i = 1,2,\ldots,n)$$

and

$$\text{cov}(x_i, x_j) = v_{ij} \qquad (i, j = 1,2,\ldots,n).$$

Let $y' = (y_1, y_2, \ldots, y_n)$ be a vector of ordered random observations, and if the $\{y_i\}$ are a

normal sample, then we may express y_i as

$$y_i = \mu + \sigma x_i \qquad (i = 1,2,\ldots,n).$$

Based on the BLUE estimates of μ and σ, we can express the SW statistic as

$$SW = \left(\sum_{i=1}^{n} a_i y_i\right)^2 \Big/ \sum_{i=1}^{n} (y_i - \bar{y})^2 ,$$

$$a' = (a_1, a_2, \ldots, a_n) = \frac{m'V^{-1}}{(m'V^{-1}V^{-1}m)^{1/2}} .$$

Skewness-Kurtosis Test:

The skewness-kurtosis testing procedure is a simple test, based on the test statistic

$$SK = \frac{n}{6}\hat{\alpha}_3^2 + \frac{n}{24}(\hat{\alpha}_4 - 3)^2 \overset{H_0}{\underset{\alpha}{\sim}} \chi^2(2)$$

where

$$\hat{\alpha}_3 = \frac{\frac{1}{n}\sum_{k=1}^{n}(X_k - \overline{X})^3}{\left(\sqrt{\frac{1}{n}\sum_{k=1}^{n}(X_k - \overline{X})^2}\right)^3} \quad , \quad \hat{\alpha}_4 = \frac{\frac{1}{n}\sum_{k=1}^{n}(X_k - \overline{X})^4}{\left(\sqrt{\frac{1}{n}\sum_{k=1}^{n}(X_k - \overline{X})^2}\right)^4}$$

Durbin-Watson Test:

The DW test takes the following form:

Assume the estimated model is:

$$Y_t = B_1 + \sum_{j=2}^{k} B_j X_{tj} + u_t$$

with

$$u_t = \rho u_{t-1} + e_t$$

which is an AR(1) process. The null hypothesis is

$$H_0 : \rho = 0$$

The DW test statistic takes the form

$$DW = \frac{\sum_{t=2}^{T}(\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{T}\hat{u}_t^2}$$

Appendix K

The Gauss-Markov Thereom:

The Gauss-Markov theorem, as stated most eloquently in Spanos, 1999, (pg. 650) is as follows:

"Let the statistical relationship between y_t and the x_{it} 's be as follows:

$$y_t = \sum_{i=0}^{k} a_i \phi_i (x_t) + e_t \ , \quad t = 1,2,\ldots,T,$$

where $\phi_0(x), \phi_1(x), \ldots, \phi_k(x)$ are known functions of x. Under the assumptions:

(i) $E(e_t) = 0, \quad t = 1,2,\ldots,T,$

(ii) $Cov(e_t, e_s) = \begin{cases} \sigma,^2 & t = s, \\ 0, & t \neq s, \end{cases} \quad t,s = 1,2,\ldots,T,$

(iii) $\phi_0(x), \phi_1(x), \ldots, \phi_k(x)$ are linearly independent functions of x,

we can deduce that the least-squares estimators:

$$\hat{\alpha} = \sum_{t=1}^{T} \gamma_t(i) y_t, \quad i = 0,1,2,\ldots,k,$$

(where $\gamma_t(i)$ are functions of $\phi_0(x), \phi_1(x), \ldots, \phi_k(x)$), are:

(a) **Best** (relatively most efficient): $Var(\hat{a}_i) \leq Var(\tilde{a}_i), \quad i = 0,1,2,\ldots,k,$ for ever other *linear* and unbiased estimator $\tilde{a}_i$ which is also *unbiased*,

(b) **Linear** functions of $(y_1, y_2, \ldots, y_T)$,

(c) **Unbiased** estimators of a_i: $E(\hat{\alpha}_i) = a_i, \quad i = 0,1,2,\ldots,k.$

That is, the least-squares estimators are best within the class of all linear and unbiased estimators."[35]

---

[35] For an excellent proof of this theorem and the implicit properties that fall from it, see Patterson, 2000.

Appendix L

This appendix describes the political variables used in this paper, and originally found verbatim in *Democracy and Development: Political Institutions and Material Well-Being in the World, 1950-1990,* authored by Alvarez, Cheibub, Limongi and Przeworski (1996) [again, these definitions are taken verbatim from the website of Cheibub that can be found at http://pantheon.yale.edu/~jac236/Research.htm).

REG: Dummy variable coded 1 for dictatorships and 0 for democracies. Transition years are coded as the regime that emerges in that year. For instance, there was a transition from democracy to dictatorship in Argentina in 1955. In that year, REG=1.

INST: Classification of political regimes in which democracies are distinguished by the type of executive. Coded 0 if dictatorship; 1 if parliamentary democracy; 2 if mixed democracy; 3 if presidential democracies. Transition years are coded as the regime that emerges in that year.

DIVIDED: Classification of political regimes in which dictatorships are distinguished by the number of formal powers. Coded 0 if democracy; 1 if dictatorship with a legislature or at least one political party; 2 if dictatorship with executive only. Transition years are coded as the regime that emerges in that year.

MOBILIZE: Classification of political regimes in which dictatorships are distinguished by the presence of political parties. Coded 0 if democracy; 1 if mobilizing dictatorship (with parties); 2 if exclusionary dictatorship (without parties). Transition years are coded as the regime that emerges in that year.

AUT: Classification of political regimes in which dictatorships are distinguished by the existence of a legislature (elected or appointed). Coded 0 if democracy; 1 if bureaucracy (dictatorships with a legislature); 2 if autocracy (dictatorships without a legislature). Identical to LAWS, except that coding was adjusted for transitional regimes. See appendix 3 for a summary of these adjustments. Transition years are coded as the regime that emerges in that year.

LAWS: Classification of political regimes in which dictatorships are distinguished by the existence of a legislature (elected or appointed). Coded 0 if democracy; 1 if bureaucracy (dictatorships with a legislature); 2 if autocracy (dictatorships without a legislature). Transition years are coded as the regime that emerges in that year.

ACCHEAD: Number of changes of chief executives (HEADS) accumulated during the life of a particular political regime as defined by REG.

AGDEMONS: Any peaceful public gathering of at least 100 people for the primary purpose of displaying or voicing their opposition to government policies or authority, excluding demonstrations of a distinctly anti-foreign nature. [Banks 1996]

AGEA: Age in years of the current regime as classified by AUT.

AGEH: Number of years chief executive has been in power. The year the chief executive comes to power is coded 1. In cases in which chief executive changed more than once during one year (HEADS>1) AGEH=1. Also, AGEH=1 for the first year of countries that became independent after 1950 (even in cases where the chief executive served as a prime-minister or governor general of the colony). AGEH is missing for Switzerland, Uruguay (1951-1966) and Yugoslavia after 1980 due to their collective executive. [Banks 1997, Da Graça 1985, Bienen and Van De Walle 1991]

ASPELL: Number of successive spells of political regimes as classified by AUT. A spell is defined as years of continuous rule under the same regime.

BRITCOL: Dummy variable coded 1 for every year in countries that were British colonies any time after 1918, 0 otherwise.

CIVLIB: Civil liberty. This variable can take values from 1 (least free) to 7 (most free). [Freedom House 1992].

CIVMIL: Civil-military relations coded 1 if a government was controlled by a nonmilitary component of the nation's population; 2 if outwardly civilian government effectively controlled by a military elite; 3 if direct rule by the military, usually (but not necessarily) following a military coup d'etat; 4 if other (all regimes not falling into one or another of the foregoing categories, including instances in which a country, save for reasons of exogenous influence, lacks an effective national government). [Banks 1996].

DICADEM: Dummy variable coded 1 for all the years of a dictatorships that follows a democracy (as defined by REG), 0 otherwise.

DICBDEM: Dummy variable coded 1 for all the years of a dictatorship that precedes a democracy (as defined by REG), 0 otherwise.

EFFPARTY: Number of effective parties, defined as 1/(1-F), where F=Party Fractionalization Index. [Banks 1996].

EXSELEC: Mode of effective executive selection:1 if direct election (election of the effective executive by popular vote or the election of committed delegates for the purpose of executive selection); 2 if indirect election (selection of the effective executive by an elected assembly or by an elected but uncommitted electoral college); 3 if nonelective (any means of executive selection not involving a direct or indirect mandate from an electorate). [Banks 1996, but modified and completed where appropriate].

HEADS: Number of changes of the chief executive in each year. Chief executives are presidents in presidential democracies, prime ministers in parliamentary and mixed democracies, and whoever is the effective ruler in dictatorships (designated explicitly as "dictators," or as "heads of military juntas," "presidents," "leaders of the ruling party," "executers of the state of emergency," or "kings"). Contrary to Bienen and Van del Walle (1991), we did not exclude acting or provisional governments, on the assumption that one cannot distinguish between cases in which heads attempted to consolidate power and failed from cases in which heads did not try to do so. HEADS is coded as missing for Switzerland, Uruguay from 1951 to 1966, and Yugoslavia after 1980, cases of a collective executive with specific rules for rotation of the chief executive. For Portugal the president was considered to be the chief executive between 1976-1982 and the prime minister between 1983-90. [da Graça 1985, Bienen and Van de Walle 1991, and Banks 1996].

LEGELEC: Number of elections held for the national lower chamber in a given year. [Mostly taken from Banks 1996; complemented by Keesing's Contemporary Archives.]

LEGSELEC: Legislative selection. Coded 0 if no legislature exists (includes cases in which there is a constituent assembly without ordinary legislative powers); 1 non-elective legislature (examples include the selection of legislators by the effective executive, or on the basis of heredity or ascription); 2 if elective (legislators, or members of the lower house in a bicameral system, are selected by means of either direct or indirect popular election). [Banks 1996, but modified and completed where appropriate].

ODRP: Other democracies in the regions, percentage. Percentage of democratic regimes (as defined by REG) in the current year (other than the regime under consideration) in the REGION to which the country belongs. For example, in 1980 Kenya had an authoritarian regime. The number of democracies in the region equalled 4 and the total number of regimes in the region equalled 44. ODRP for Kenya 1980 then equals 4/44. In turn, Austria had a democratic regime in 1980. The number of other democracies in the region was 24 and the total number of regimes in the region was 25. ODRP for Austria 1980 then equals 24/25.

ODWP: Other democracies in the world, percentage. Percentage of democratic regimes (as defined by REG) in the current year (other than the regime under consideration) in the world. Constructed in the same way as ODRP.

PARTY: Number of political parties in a given year. Coded 0 if no parties (political parties were banned, or elections were held on a non-partisan basis, or incumbents used their electoral victory to establish a non-party rule by banning all parties, or the current term in office ended up in a later year in the establishment of a non-party rule; 1 if one party (the share of seats in the lower house of the national legislature held by the largest party was 100%, or there was only one party list presented to voters, or incumbents used the electoral victory to establish a one-party rule by banning all opposition parties or forcing them to merge with the ruling party, or the current term in office ended up in a later year in the establishment of a one-party rule); 2 if more than one party. [Banks 1996, but modified and completed where appropriate].

POLLIB: Political liberty. This variable can take values from 1 (least free) to 7 (most free). [Freedom House 1992].

PRESELEC: Number of presidential elections held in a given year. [Mostly taken from Banks 1996; complemented by Keesing's Contemporary Archives].

RIOTS: Number of violent demonstrations or clashes of more than 100 citizens involving the use of physical force. [Banks 1996].

RSPELL: Number of successive spells of political regimes as classified by REG. A spell is defined as years of continuous rule under the same regime.

STRA: The sum of past transitions to authoritarianism (as defined by REG) in a country. If a country experienced one or more transitions to authoritarianism before 1950, STRA was coded 1 in 1950.

STRD: The sum of past transitions to democracy (as defined by REG) in a country. If a country experienced one or more transitions to democracy before 1950, STRD was coded 1 in 1950.

STRIKES: Number of strikes of 1,000 or more industrial or service workers that involves more than one employer and that is aimed at national government policies or authority. [Banks 1996].

TURNOVER: Rate of turnover of chief executives per year of life of a regime. Defined as ACCHEAD/T, where T is the cummulative year of life of the regime from the first observation.

WAR: Dummy variable coded 1 when there is a war of any type (international or civil) on the territory of a country, 0 otherwise. [Singer and Small 1994].

Appendix M

All countries

Africa	North America	South America	Asia	Europe
GHANA	EL SALVADOR	CHILE	SINGAPORE	CZECHOSLOVAKIA
RWANDA	GUATEMALA	ARGENTINA	PAKISTAN	SWEDEN
GAMBIA	NICARAGUA	URUGUAY	MALAYSIA	NETHERLANDS
BURKINA FASO	TRINIDAD&TOBAG	BRAZIL	SRI LANKA	FRANCE
BURUNDI	HONDURAS	PARAGUAY	PHILIPPINES	SPAIN
IVORY COAST	PANAMA	PERU	CHINA	U.K.
CAMEROON	DOMINICAN REP.	VENEZUELA	SYRIA	AUSTRIA
CONGO	COSTA RICA	COLOMBIA	IRAN	BELGIUM
MOROCCO	U.S.A.	BOLIVIA	INDIA	LUXEMBOURG
KENYA	CANADA	ECUADOR	INDONESIA	NORWAY
TOGO	MEXICO		JORDAN	FINLAND
TUNISIA	JAMAICA		ISRAEL	DENMARK
ZAMBIA			THAILAND	PORTUGAL
SOUTH AFRICA			KOREA, REP.	TURKEY
ZIMBABWE	**Oceania**		JAPAN	IRELAND
NIGERIA				GREECE
GABON	NEW ZEALAND			ICELAND
ALGERIA	AUSTRALIA			ITALY
				YUGOSLAVIA

58 Countries

Africa	North America	South America	Asia	Europe
GHANA	EL SALVADOR	PARAGUAY	PAKISTAN	SWEDEN
GAMBIA	GUATEMALA	VENEZUELA	SRI LANKA	SPAIN
BURKINA FASO	TRINIDAD&TOBAG	BOLIVIA	INDIA	FRANCE
RWANDA	HONDURAS	ECUADOR	JORDAN	U.K.
BURUNDI	DOMINICAN REP.		SYRIA	BELGIUM
IVORY COAST	COSTA RICA		THAILAND	DENMARK
CAMEROON	U.S.A.		PHILIPPINES	NETHERLANDS
CONGO	CANADA		INDONESIA	NORWAY
MOROCCO			IRAN	AUSTRIA
KENYA			KOREA, REP.	LUXEMBOURG
TOGO			JAPAN	FINLAND
ZAMBIA	**Oceania**			PORTUGAL
SOUTH AFRICA	AUSTRALIA			GREECE
TUNISIA	NEW ZEALAND			IRELAND
NIGERIA				ITALY
ZIMBABWE				
GABON				
ALGERIA				

51 Countries

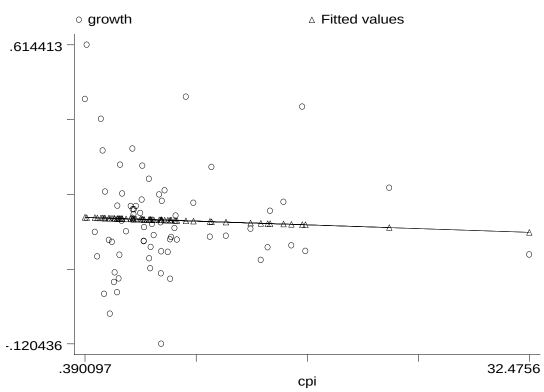
Africa	**North America**	**South America**	**Asia**	**Europe**
GHANA	EL SALVADOR	PARAGUAY	PAKISTAN	SWEDEN
GAMBIA	GUATEMALA	VENEZUELA	SRI LANKA	SPAIN
RWANDA	TRINIDAD&TOBAG	BOLIVIA	INDIA	FRANCE
CAMEROON	HONDURAS	ECUADOR	JORDAN	U.K.
CONGO	DOMINICAN REP.		SYRIA	BELGIUM
KENYA	COSTA RICA		THAILAND	DENMARK
TOGO	U.S.A.		PHILIPPINES	NETHERLANDS
ZAMBIA	CANADA		INDONESIA	NORWAY
SOUTH AFRICA			IRAN	AUSTRIA
TUNISIA			KOREA, REP.	FINLAND
ZIMBABWE			JAPAN	PORTUGAL
ALGERIA	**Oceania**			GREECE
	AUSTRALIA			IRELAND
	NEW ZEALAND			ITALY

Appendix N

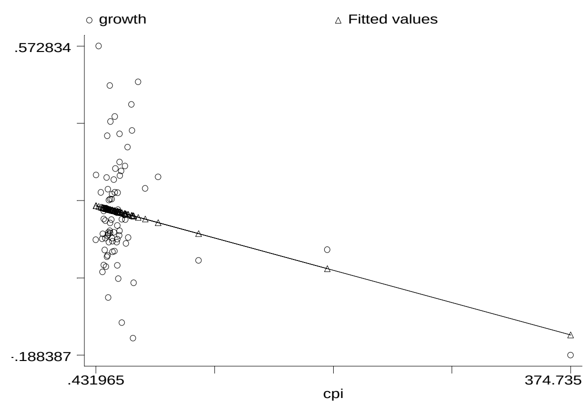
The Comparisons:

The sole purpose of this section is to compare the characteristics of my data with the results attained in work such as Barro's piece (1996) *Inflation and Growth* published for the Federal Reserve Bank of St. Louis. Below are plotted estimations of inflation on growth for the years 1970, 75, 80 and 85 using standard least squares regressions and using the full range of inflation rates in my data set:

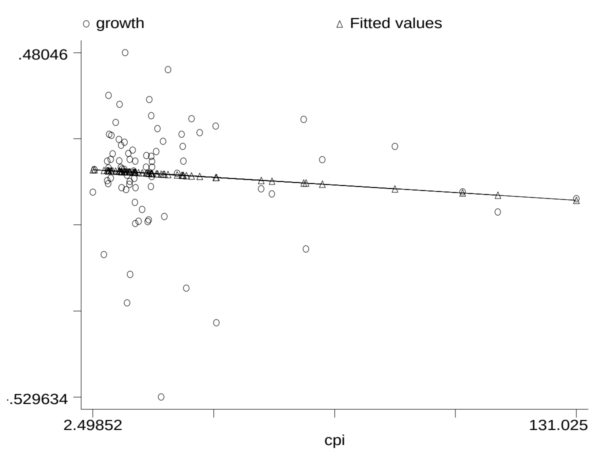
Year = 1970



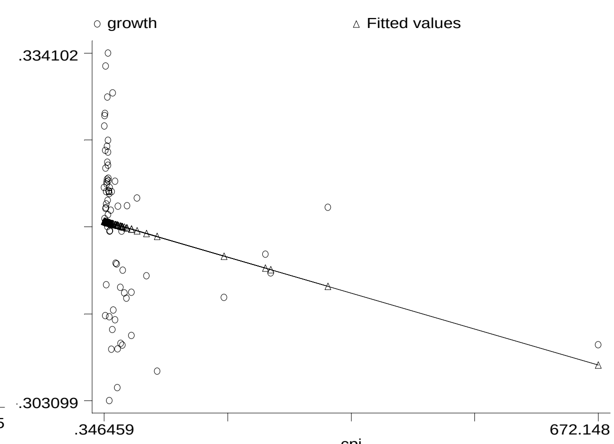
Year = 1975



Year = 1980

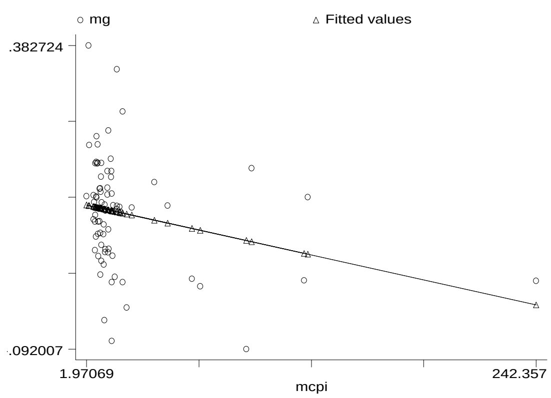


Year = 1985

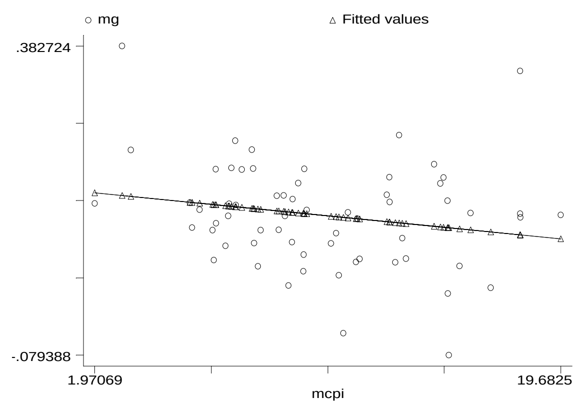


The variability of the year the cross section is based becomes apparent in these plots. We see that for the years 1970 and 1980, there is a slightly negative correlation, while the years 1975 and 1985 show highly negative correlation. However, these negative correlations are dominated by only a few outliers where the inflation rates typically exceed 300%.[36] However, I use averages over the entire period which in a sense, splits the difference of the above plots as seen below.

All inflation levels



Inflation below 20%



We can see in the left hand figure that there is still a negative correlation (the coefficient is -0.0006 with a p-value of 0.021), but larger in absolute value than the correlation for 1975 and less than for the cross section year of 1985 (those coefficients are -0.0008 with a p-value of 0.011 and -0.0003 with a p-value of 0.030, respectively).[37] However, to support the validity of

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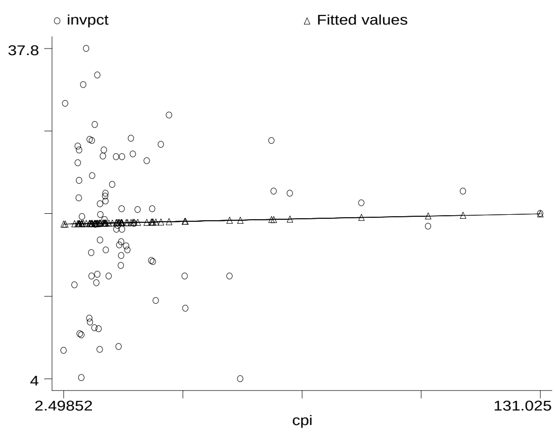
[36] We also see that heterskedasticity is a significant problem.

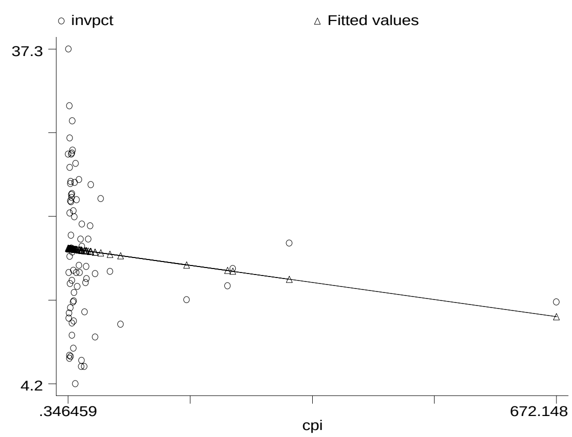
[37] This plot looks almost identical to Barro (1996), figure 3, bottom panel. We still see, however, that the correlation continues to be dominated by an outlier.

my data to that of others, in the right hand figure, I show the averages over the same period as above, however, for inflation rates below 20% as in Barro (1996). Here we see only a slightly negative, but insignificant, correlation as in other studies (the coefficient for CPI here is - 0.003 with a p-value of 0.122, or not significant at 10%). However, because this paper is predominantly about how inflation affects investment directly, and growth indirectly, below I show estimated plots of investment on CPI.

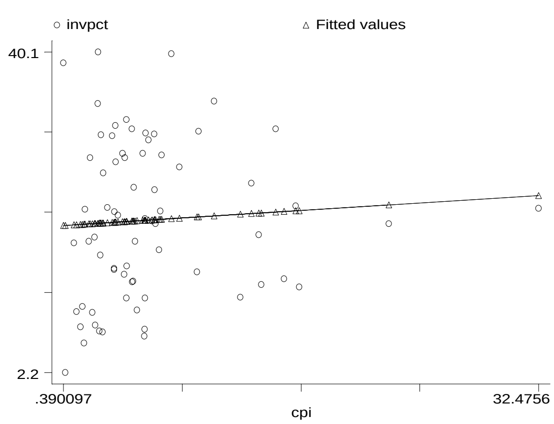
Year = 1970



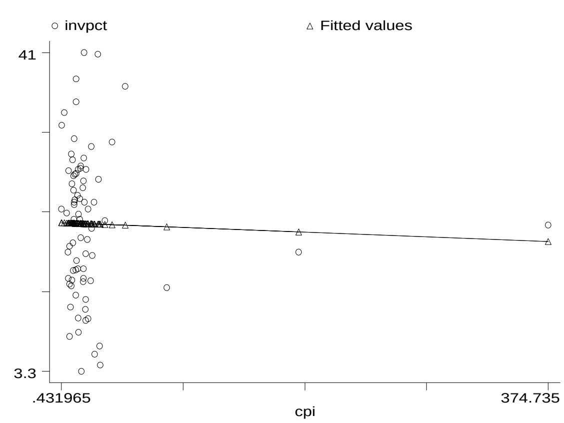
Year = 1975



Year = 1980

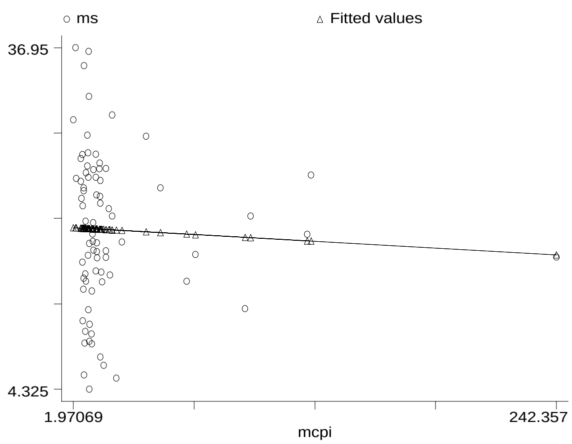


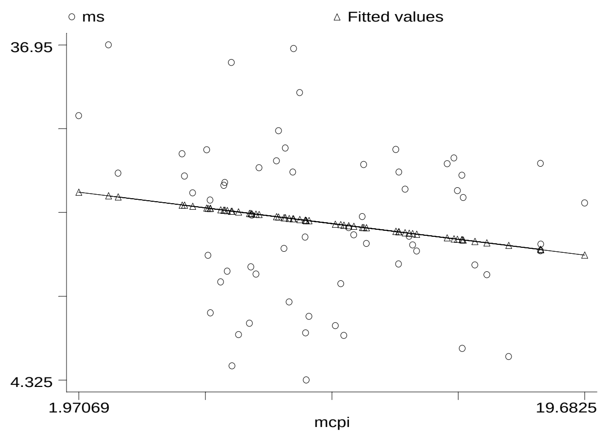
Year = 1985



For these investment regressions, we find that the correlation varies in a much more critical way than did the growth regressions. There seems to be a slightly positive influence for the years 1970 and 1980, while slightly negative for the years 1975 and 1985.

All inflation levels | Inflation below 20%





Above we find that by taking the means of inflation and investment over the period 1970-85, we get a negative correlation between inflation and investment, however, insignificant in both cases (the p-values for the coefficient on inflation from left to right are 0.663 and 0.154 respectively).

In concluding this section, it seems as though my data supports recent empirical work when regressed over the countries I chose to include because of my explanations earlier in this section.

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