Nonlinearity in the Efficacy of Foreign Aid on Economic Growth

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This paper finds evidence of nonlinearities in the efficacy of foreign aid on a country's growth using a cross sectional data set of 75 countries that received Official Development Aid between 1985 and 2013. Using a multivariate adaptive splines (MARS) model the findings suggest that, for low-income countries, the efficacy of foreign aid is not constant across the range of foreign aid. The results suggest that when foreign aid is large enough the efficacy of foreign aid switches signs from negative to positive. Higher levels of schooling in the recipient country appear to amplify this effect.

INTRODUCTION

For a standard neoclassical growth model (Solow, 1956), the concept of conditional convergence has been exhaustively analyzed and empirically supported (Mankiw, Romer, and Weil, 1992 and Barro and Sala-i-Martin, 2004). Mankiw, Romer, and Weil (1992), henceforth MRW, augmented the standard textbook Solow growth model by controlling for human capital accumulation within the country. Their model rectified previous inconsistency in the literature with empirical evidence that was consistent with theory, and has become the seminal work for the majority of subsequent neoclassical growth research. Later research, by Karras (2008), has shown that subsequent data has shown further strengthened the augmented Solow model's results.

Generally, neoclassical growth research has focused on using ordinary least squares estimations, thus, the estimate is forced to exhibit a constant effect regardless of level. This paper relaxes the linearity assumption and allows for the existence of non-constant effects. Recent literature, by Azariadis and Drazen (1990), Durluaf and Johnson (1995), Liu and Stengos (1999), Galor and Weil (2000), Hansen (2000), and Odell (2009 and 2012), has found evidence of inconsistencies with a standard linear model, supporting a movement towards using nonlinear estimation techniques.

Within the standard growth literature, there remains limited empirical evidence of conditional convergence amongst developing countries (Karras, 2006 and Easterly, 2006). Alternatively, Rostow (1960) and Sachs (2004) posit that countries may not be able to conditionally converge if they are trapped in a low steady state equilibrium. A possible solution would be for these countries to receive a sizable foreign aid package that pushes them out of the poverty trap. This large amount of foreign aid will supplement a developing countries' investment enough to ignite their stagnant growth, thus, pushing them to the higher stable steady state level. But, if the amount of foreign aid they receive is not large enough they will remain trapped in the poverty trap.

Multiple steady state levels found in a poverty trap model necessitate the relaxation of the linearity assumption normally used in the standard Solow growth model. These nonlinearities can theoretically be introduced in one of three ways. First, the production function could have regions that exhibit increasing

returns to scale, similar to a technologically-induced poverty trap that follows from research by Rosenstein-Rodan (1943, 1961), Singer (1949), Nurkse (1953), Lewis (1954), Myrdal (1957), Rostow (1960), Murphy et al. (1989), and Barro and Sala-i-Martin (2004). The second way is the savings rate is not constant across all levels of income. Kuznets (1966), Ogaki et al. (1996), and Loayza et al. (2000) have found evidence supporting a violation of a constant savings rate. The third example is nonlinearity in population growth. A demographic nonlinearity, consistent with research by Malthus (1798), Leibenstien (1954, 1957), Nelson (1956) and Becker and Lewis (1973), occurs when a countries population growth is a function of their respective income level.

The existence of multiple steady state levels implies that the impact of foreign aid is not constant across all levels of foreign aid. To date the majority of efficacy of foreign aid literature has focused on linear models that are incapable of capturing a possible nonlinear effect of foreign aid. This reliance could contribute to the literature finding inconsistent results. These results have ranged from a negative relationship found by Boone (1996), Brautigam and Knack (2004) and Obstfield (1999), to a positive relationship found in Papanek (1973), Dowling and Himenz (1982), Gupta and Islam (1983), Hansen and Tarp (2000), Dalgaard et al. (2004) and Karras (2006), or a conditional relationship found by Burnside and Dollar (2000), Hansen and Tarp (2001), Dalgaard and Hansen (2001), Collier and Dehn (2001), Lensink and White (2001), Collier and Dollar (2002), and Easterly et al. (2004). That is, the efficacy of foreign aid is dependent upon the policy environment within the country. This suggests donor countries should be selective on which countries should, or should not, receive foreign aid.

By relaxing the assumption of linearity, and subsequently finding results that suggests the inconsistency in the literature could be caused by their reliance upon using linear estimations, this paper contributes to the literature by estimating a nonlinear model with a better fit that provides evidence that is consistent with a poverty trap. The results suggest that a threshold exists for low-income countries at 6.7 percent of foreign aid to gross national income, or $24.97 per capita. At these thresholds the coefficient for foreign aid goes from negative, or statistically zero, to large and positive.

The MARS model also detects significant interactions between foreign aid and other independent variables. There appears to be a significant interaction between schooling and foreign aid. This interaction includes a threshold effect for schooling at approximately 2.9 years. When a country averages less than 2.9 years, the marginal effect of foreign aid to growth is only 0.79 percent, but if the average years of schooling are greater than 2.9 years the marginal effect increases to 1.79 percent. There also appears to be significant nonlinear effects for both the savings rate and population growth. These results would be consistent with the existence of a poverty trap.

METHODOLOGY

This paper extends the human capital augmented Solow growth model presented in MRW, by also controlling for the level of foreign aid and corruption within a developing country. Furthermore, the paper extends the model by considering that the coefficients of growth variables are not constant across all levels.

Econometrically the economic growth for country *i* can be estimated by:

$$\ln\left(\frac{Y}{N}\right)_{2014i} - \ln\left(\frac{Y}{N}\right)_{1985i} = \beta_0 + \beta_1 \ln\left(\frac{Y}{N}\right)_{1985i} + \beta_2 \ln(s_k)_i + \beta_3 \ln(n+g+d)_i + \beta_4 \ln(s_h)_i + \beta_5 \ln(aid)_i + \beta_6 \ln(corruption)_i + \varepsilon_i \quad (1)$$

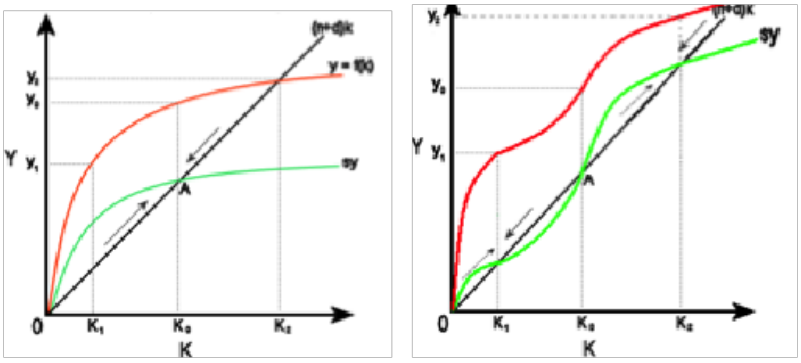
The dependent variable is the difference of the natural log of country *i*'s gross domestic product (GDP) per capita between the initial and terminal year, while the independent variables are the savings rate for physical capital (s_k), the total depreciation of capital due to population growth and depreciation $(n+d+g)$, the savings rate for human capital accumulation (s_h), the amount of foreign aid that is received (aid), and the level of corruption (corruption). Diagrams 1 and 2 graphically illustrate the differences between the

textbook Solow and poverty trap models. For the textbook Solow model, point A would represent the stable steady state level capital per worker for country *i*.

Using the textbook Solow model, the previous literature, by focusing on linear methods, has found inconsistent empirical evidence for the coefficient on foreign aid. The theoretical effect of foreign aid depends on whether the country is already at the steady state, or not. If they are below the steady state then the foreign aid could speed up the convergence process. While if they are already at the steady state the foreign aid will push them to an unsustainable level.

Diagram 2 presents the graphical example of a country trapped in a poverty trap because of nonlinearity in the production function, savings rate, or population growth. In this specific example, the poverty trap could be caused by a production function with a minimum capital stock threshold; though the other poverty traps have similar multiple steady state equilibriums. Sachs (2004) provides a detailed theoretical treatment of a poverty trap model for an AK production function.

DIAGRAMS 1 AND 2
COMPARISON BETWEEN SOLOW MODEL EQUILIBRIUM AND MULTIPLE STEADY STATES CONSISTENT WITH A POVERTY TRAP MODEL



Source: Barro RJ, Sala-i-Martin X. (2004)

The multiple stable steady states—k_1 and k_2—are a violation of the classic Solow Models assumption of conditional convergence. With a poverty trap, if a country received foreign aid that is sufficiently large enough—increasing the countries capital labor ratio by more than k_0-k_1—the recipient country will converge to the long run steady state equilibrium at k_2. But, if the foreign aid received is less the country will remain trapped at the low steady state. Thus, provided that a country is at the lower stable steady state, the non-constant coefficient on foreign aid implies that countries that receive sizable amounts of foreign aid will diverge from those that do not.

Therefore, a necessary condition for the efficacy of foreign aid is that is not constant over its whole range of values. To model this, threshold level indicator can be included in the empirical model:

$$\ln\left(\frac{Y}{N}\right)_{2014i} - \ln\left(\frac{Y}{N}\right)_{1985i} = \ldots\alpha_1(\text{aid}>\text{threshold})*\ln(\text{aid})_i + \alpha_2(\text{aid}<\text{threshold})*\ln(\text{aid})_i \ldots \quad (2)$$

Regarding the coefficients, α_1 and α_2, there are potentially three important cases. The first case is $\alpha_1 = \alpha_2$, this implies no significant threshold effects. The effect of foreign aid is constant across all levels of foreign aid, and not consistent with a poverty trap. The second case is a threshold level exists of the form $\alpha_1 > \alpha_2 = 0$, this is would be consistent with the poverty trap model. The last case is $\alpha_1 > \alpha_2$, but $\alpha_2 < 0$, possibly caused by corruption. This case would also be consistent with the poverty

trap hypothesis. Unfortunately, these threshold effects are not known beforehand. To get around this issue a non-linear technique is used to estimate the threshold levels.

A Multivariate Adaptive Regression Splines (MARS) model, originally proposed by Freidman (1991a), is a nonlinear estimation procedure that utilizes splines to detect thresholds in the independent variables. The MARS procedure relaxes the assumptions of linearity, though retains an ordinary least squares (OLS) estimation as a special case if no nonlinearities are detected. The MARS procedure systematically automates the searching and testing of threshold effects across the data using maximization functions and can be used as a test for the violation of the linearity assumption (Stokes 2011) and has been shown to improve the efficiency of estimating a Solow growth model (Odell 2009). This paper focuses primarily on lower income countries, as they are most likely to be trapped in the poverty trap. The MARS procedure estimates the nonlinear function

$$y = f(x_1,...,x_m) + e \tag{3}$$

by estimating the equation

$$f(x) = \sum_{j=1}^{s} c_j K_j(x), \tag{4}$$

where $K_j(x)$ is a basis function that is either: a constant, a hinge function, or some interaction between two or more hinge functions.

Following the theoretical model for a poverty trap, countries that are trapped in the lower steady state level, will have two possible effects for foreign aid depending on the level of aid that is received

$$\begin{aligned} &\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = ...\beta_1 \ln(\text{aid})_i ... \quad \text{when aid > threshold} \\ &\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = ...\beta_2 \ln(\text{aid})_i ... \quad \text{otherwise} \end{aligned} \tag{5}$$

The MARS model is able to express this as follows:

$$\begin{aligned} &\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = ...\beta_1 (\text{aid}>\text{threshold})*\ln(\text{aid})_i + \beta_2 (\text{aid}<\text{threshold})*\ln(\text{aid})_i ... \\ &= \\ &\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = ...\beta_1 \ln[\max(0, \text{aid}-\text{knot})]_i + \beta_2 \ln[\max(0, \text{knot}-\text{aid})]_i ... \end{aligned} \tag{6}$$

When foreign aid is larger than the threshold level the coefficient of foreign aid will be β_1. While when the foreign aid received is smaller than the threshold the coefficient will be β_2.

Since the MARS procedure is systematically testing for significant thresholds across all levels of the variables, the threshold levels do not need to be known before hand. Additionally, the procedure will test for possible significant interactions between the other independent variables. Interaction terms will be an important consideration in light of Burnside and Dollar's (2000) conditionality result.

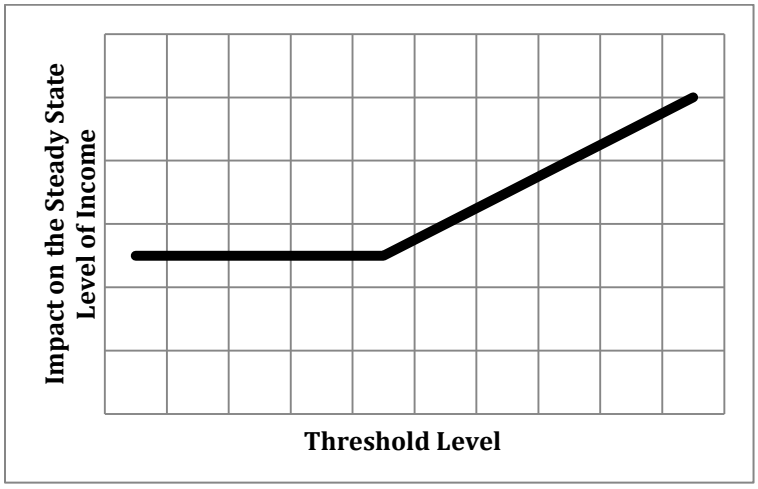
The MARS model's estimation of equation (1) can be expressed as a linear combination of maximization functions of the independent variables:

$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \beta_0 + \beta_1 \ln[\max(0, \frac{Y}{N}_{1985} \text{-knot})]_i + \beta_2 \ln[\max(0, s_k \text{-knot})]_i +$$
$$\beta_3 \ln[\max(0, (n+g+d) \text{-knot})]_i + \beta_4 \ln[\max(0, s_h \text{-knot})]_i + \quad (7)$$
$$\beta_5 \ln[\max(0, corruption \text{-knot})]_i + \beta_6 \ln[\max(0, aid \text{-knot})]_i +$$
$$\beta_7 \ln[\max(0, knot - aid)]_i + [\text{anysignificantinteractions}] + \varepsilon_i$$

Upon estimating this linear function of additive basis functions in single variables, along with possible interaction terms, the user is able to interpret the results using an analysis of variance. To estimate the MARS model, and generate the resulting contribution plots of significant threshold levels, this paper utilizes the B34s statistical package built by Houston H. Stokes at the University of Illinois at Chicago (Stokes 2011).

Diagram 3 is the theoretical contribution plot from a MARS model consistent with a $\alpha_1 > \alpha_2 = 0$ poverty trap hypothesis:

DIAGRAM 3
A THEORETICAL CONTRIBUTION PLOT USING THE MULTIVARIATE ADAPTIVE REGRESSIVE SPLINES CONSISTENT WITH A POVERTY TRAP HYPOTHESIS



When the foreign aid the country receives is small there is no effect (or possibly a negative effect) as the country remains trapped in the initial low steady state level. But, if the amount of foreign aid received is large—i.e. greater than the threshold level—the effect becomes positive, as the country is able to escape the poverty trap, diverging from the other countries stuck at the lower steady state.

DATA

The data consists of a cross-section of 72 countries that received foreign aid during the 1985-2013 time period. All of the variables, except for foreign aid and corruption, are defined similarly to MRW. The dependent and independent variables are defined as follows.

Dependent Variable:

1. Natural log of GDP/N_{2014} – Natural log of GDP/N_{1985}.
    - From databank.worldbank.org.

Explanatory Variables:

1. Natural log of initial year GDP/N.
    - From databank.worldbank.org.
2. Natural log of average percent of investment to GDP from 1985-2014. (Ln S)
    - From databank.worldbank.org.
3. Natural log of average years of schooling (Ln School)
    - From Barro and Lee Educational Attainment 2010.
    - Use as a measure of human capital: Average years of educational attainment divided by 100 for people over the age of 25 years within the country from 1985-2010.
4. Natural log of population growth plus depreciation (Ln (n+g+d))
    - Population growth is the averaged growth rate of the population from 1985-2014
    - The other terms, g+d, are assumed to be .05.
    - From databank.worldbank.org.
5. Natural log of average percentage of foreign aid per Gross National Income (GNI) a country receives over the time period.
    - Measured as the nominal Official Development Aid over the nominal GNI averaged from 1985-2013.
    - ODA is from oecdstat at www.oecd.org
6. Natural log of average percentage of foreign aid per capita a country receives over the time period.
    - Measured as the real Official Development Aid per capita averaged from 1985-2013.
    - ODA is from oecdstat at www.oecd.org.
7. Measurement for corruption from transparency international.
    - Averaged measurement from a number of surveys, with 1 being high level of corruption and 10 being low level of corruption.
    - Due to data availability 2014 year is used for the measurement of a countries corruption.
    - Data is found at: https://www.transparency.org/cpi2014/results#myAnchor1

Based on the hypothesis of multiple steady states, various bounds are considered for the low steady state. For this analysis, a low-income country is defined as any country with an initial income per capita less than $2700, in 2005 dollars, a level consistent with Burnside and Dollar (2000). Additionally, low-income levels of $3059 and $3463 are considered. This reflects 0.5 percent and 1 percent annual growth rates, respectively, from the suggested Burnside and Dollar levels.

RESULTS AND DISCUSSION

We find OLS results, for both all and low-income countries (not always statistically significant, but directionally correct), that are consistent with MRW results for the savings, population growth, and human capital accumulation variables. Additionally, the coefficient on the initial GDP per capita suggests evidence of conditional convergence.

In regards to the efficacy of foreign aid, the OLS results suggest a 1 percent increase in foreign aid, as a percent of GNI, would slow a countries growth by .239 percent for all countries, while not being statistically significant for the lower income countries. These results would be consistent with the Boone (1996) results.

TABLE 1
ORDINARY LEAST SQUARES ESTIMATION OF GDP/N GROWTH, INCLUDING AID PER GROSS NATIONAL INCOME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	All Countries		GDP 1985 < $2700		GDP 1985 < $3059		GDP 1985 < $3463	
Ln(Initial GDP/N)	-0.079	-0.289***	-0.287	-0.373*	-0.242	-0.356*	-0.215	-0.304*
	(0.077)	(0.079)	(0.163)	(0.145)	(0.148)	(0.131)	(0.140)	(0.121)
Ln(s)	0.091	0.012	0.088	-0.018	0.104	-0.010	0.092	-0.053
	(0.082)	(0.076)	(0.107)	(0.116)	(0.100)	(0.109)	(0.101)	(0.102)
Ln(n)	-1.247***	-0.642*	-1.295*	-0.806	-1.348**	-0.764	-1.319**	-0.684
	(0.345)	(0.321)	(0.513)	(0.472)	(0.484)	(0.443)	(0.486)	(0.436)
Ln(School)	0.280	0.232	0.226	0.133	0.184	0.137	0.198	0.155
	(0.142)	(0.122)	(0.179)	(0.159)	(0.171)	(0.149)	(0.173)	(0.148)
Ln(Aid/GNI)		-0.239*		-0.387		-0.348		-0.122
		(0.094)		(0.456)		(0.420)		(0.395)
Corruption		0.244		0.199		0.174		0.025
		(0.127)		(0.390)		(0.358)		(0.345)
Ln(Aid)*Corruption		0.020		0.036		0.026		-0.037
		(0.023)		(0.130)		(0.118)		(0.111)
Constant	-1.785	-0.464	-0.690	-0.871	-1.243	-0.748	-1.320	-0.374
	(1.347)	(1.382)	(2.288)	(2.444)	(2.128)	(2.315)	(2.145)	(2.289)
Observations	72	72	39	39	42	42	45	45
R-squared	0.342	0.545	0.322	0.528	0.315	0.536	0.295	0.534
Adj R-sq	0.303	0.495	0.243	0.422	0.241	0.440	0.224	0.446
Mean	-0.208	-0.208	-0.360	-0.360	-0.346	-0.346	-0.349	-0.349
Standard Deviation	0.511	0.511	0.526	0.526	0.513	0.513	0.514	0.514
RSS	12.195	8.433	7.116	4.952	7.395	5.015	8.214	5.428

Standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

Because the OLS model is assuming linearity, the finding of a negative result does not reject the poverty trap hypothesis. The OLS model is used as a comparison to the MARS model results, which would be identical to the OLS estimation if there were no significant nonlinearities. Additionally, the OLS model also allows for a comparison of the fit to the nonlinear estimation.

With linear estimations, the negative foreign aid coefficient may be indicative of reverse causality between foreign aid and growth. This reverse causality would create a downward bias on foreign aid's coefficient. To rectify the endogeneity of foreign aid an instrumental variable approach could be utilized, but that would not be consistent with this estimation technique. More importantly, one of the contributions of this paper is the nonlinear estimation. As long as the effect of the downward bias is systematically constant, thus not causing the threshold level, the existence of threshold levels would be consistent with a poverty trap. Furthermore, the existences of a threshold level—having a different effect

below and above the threshold level—is not consistent with the case of reverse causality, but rather indicative of evidence of a poverty trap.

Table 2 and 3 report the estimated MARS models for both all and low income countries:

TABLE 2
MULTIVARIATE ADAPTIVE REGRESSIVE SPLINES FOR GROWTH, INCLUDING AID PER GROSS NATIONAL INCOME, FOR ALL COUNTRIES

	Coefficient	Variable	SE	T-Stat	RSS
Ln(Growth)=	-0.345		0.1	-3.46	5.386
	-0.381	* max(Ln(Aid/GNI) - -3.7675764, 0.0)	0.077	-4.97	
	0.124	* max(Corrupt - 3.6000000 , 0.0)	0.046	2.69	
	-0.193	* max(3.6000000 - Corrupt, 0.0)	0.084	-2.3	
	0.505	* max(7.0787828 - Ln(GDP1985),0.0)	0.186	2.71	
	2.458	* max(7.0787828 - Ln(GDP1985),0.0)	0.589	4.17	
		* max(-3.8503442 - Ln(Aid/GNI), 0.0)			
	0.502	* max(Ln(School) - -3.4493377 , 0.0)	0.138	3.64	
	0.533	* max(-3.4493377 - Ln(School), 0.0)	0.264	2.01	
		* max(Ln(Aid/GNI) - -2.7158565 , 0.0)			
	2.079	* max(-3.4493377 - Ln(School), 0.0)	0.907	2.29	
		* max(-2.7158565 - Ln(Aid/GNI), 0.0)			
	-0.572	* max(-2.0826879 - Ln(s), 0.0)	0.23	-2.48	
		* max(-3.7675764 - Ln(Aid/GNI), 0.0)			

TABLE 3
MULTIVARIATE ADAPTIVE REGRESSIVE SPLINES FOR GDP GROWTH, INCLUDING AID PER GROSS NATIONAL INCOME, FOR LOWER INCOME COUNTRIES

	Coefficient	Variable	SE	T-Stat	RSS
Ln(Growth)=	-0.737		0.08	-9.2	1.711
	-1.134	* max(Ln(Aid/GNI) - -2.7006466 , 0.0)	0.215	-5.27	
	0.25	* max(-2.7006466 - Ln(Aid/GNI), 0.0)	0.091	2.76	
	2.921	* max(Ln(School) - -3.5244956 , 0.0)	0.833	3.5	
		* max((Ln(Aid/GNI) - -2.7006466 , 0.0)			
	1.932	* max(-3.5244956 - Ln(School), 0.0)	0.292	6.61	
		* max(Ln(Aid/GNI) - -2.7006466 , 0.0)			
	2.536	* max(-2.5486531 - Ln(n), 0.0)	0.658	3.85	
		* max(-2.7006466 - Ln(Aid/GNI), 0.0)			
	1.115	* max(Ln(s) - -1.6988683 , 0.0)	0.245	4.55	
	0.396	* max(-1.6988683 - Ln(s), 0.0)	0.141	2.81	

By relaxing the assumption of linearity, we observe a significant improvement in the fit of the model. The MARS model improves the residual sum of squares (RSS) for both the all country sample (5.386 from

8.433) and the lower income countries (1.711 from 4.952), as reported in Table 1 columns 2 and 4 compared to Tables 2 and 3. This improvement indicates that by relaxing the assumption of linearity, the MARS procedure is better able to estimate the cross-country variation in country growth. Finding that a nonlinear estimation is able to provide a better fit of the growth model is consistent with the findings of Odell (2009 and 2012).

The MARS procedure is a shrinkage approach that will systematically eliminate any variables that are not statistically significant, and is identical to the OLS estimation if no nonlinearities are found. For the lower income countries, all of the growth variables are found to be statistically significant. This is a significant difference between the OLS and MARS estimations. By allowing for nonlinearities and interaction terms, we find a model that is not only providing a better fit to the data, but also reporting results more consistent with theory.

The MARS procedure tests if interactions between independent variables are statistically significant, without necessarily knowing beforehand which interactions could be significant. A contribution graph is used to visualize the effect (slope of the contribution graph) of foreign aid, conditional upon interaction terms. Three possible cases are going to be considered. The first case is a country that exhibits the best possible conditions for economic growth, maximum levels of savings and schooling and minimum levels of population growth. The second case is opposite, a country that exhibits the worst possible conditions for economic growth. The last case is a median country example where all of other independent variables are set to their median values.

Figure 1 is the contribution graph for the low-income countries. The contribution graphs that the MARS procedure generates graphically shows the marginal effect of foreign aid on the dependent variable. We see a threshold effect at Ln(AID)=-2.700 (or foreign aid is approximately 6.7 percent of GNI). While below the threshold the effect is negative effect, while above the threshold the effect increases to a large positive effect for both the optimal and median interactions. Under the optimal growth assumptions—having high savings, high schooling, and low population growth—the marginal effect of foreign aid suggests that a 1 percent increase in foreign aid over the samples time period would increase the growth of the country by 1.789 percent when foreign aid is greater than the threshold level.

For lower income countries, the threshold at 6.7 per cent of GNI (shown by equation 8):

$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots \beta_{aid>6.7\%} * \ln(aid) \ldots$$
$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots \beta_{otherwise} * \ln(aid) \ldots \quad (8)$$

is found to interact with both schooling and population growth. The schooling threshold suggests that regardless of the level of schooling, if foreign aid is greater than 6.7% to GNI, the efficacy of foreign aid is positive. But, this effect is even larger for countries that have high levels of schooling. Equation 9 isolates the main effect of foreign aid when foreign aid received is larger than the threshold level and the partial effects of foreign aid when schooling is both above and below the threshold. A higher level of schooling appears to amplify foreign aid's contribution to growth. For countries that have higher than the threshold level of schooling, the contribution of foreign aid to growth is 1.787, while for countries with schooling below the threshold the contribution of foreign aid to growth is 0.798.

$$\begin{aligned} \ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots & -1.134 * [[\max(\ln(\frac{Aid}{N}) - -2.700, 0)]_i + \\ & 2.921 * [[\max(\ln(School) - -3.524, 0)]_i * [[\max(\ln(\frac{Aid}{N}) - -2.700, 0)]_i + \\ & 1.932 * [[\max(-3.524 - \ln(School), 0)]_i * [[\max(\ln(\frac{Aid}{N}) - -2.700, 0)]_i \ldots \end{aligned} \quad (9)$$

The contribution graph for all countries shows a threshold level in all three cases. Below the threshold the effect is negative and increases to be less negative, or statistically zero, depending on the case. Since the hypothesis is only lower income countries are going to be in the poverty trap this is not evidence against the existence of a poverty trap.

FIGURE 1
CONTRIBUTION GRAPH FOR LOW INCOME COUNTRIES AID PER GNI: UNDER THREE CASES

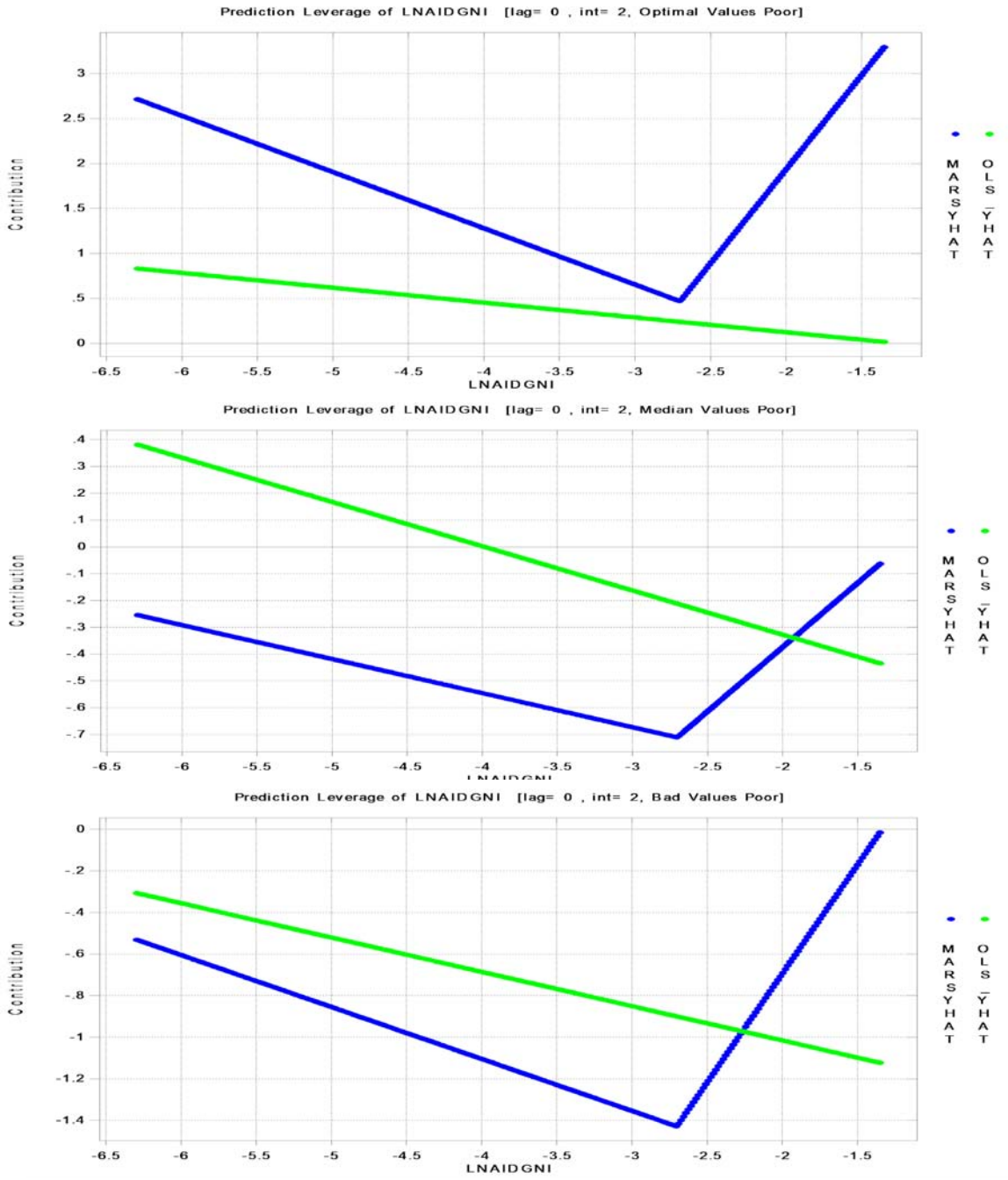
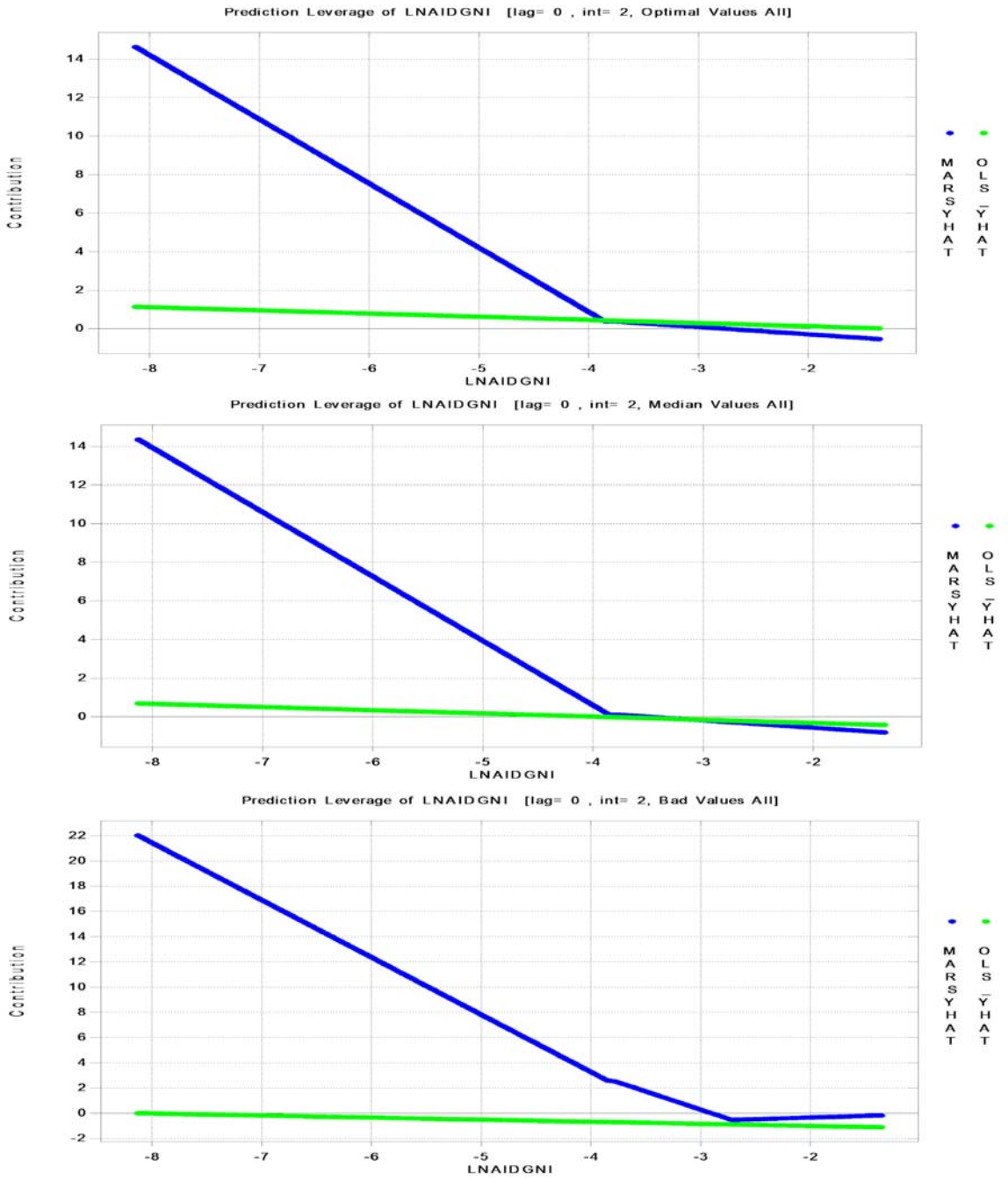


FIGURE 2
CONTRIBUTION GRAPH FOR ALL INCOME COUNTRIES FOR AID PER GNI: UNDER THREE CASES



An alternative definition of foreign aid, per capita instead of as a percent of GNI, is presented in Table 4. These results are not remarkably different from the previous results. In all cases the coefficient of foreign aid is negative in sign, though not statistically significant. Directionally all of the variables that are traditionally used in growth models are consistent with MRW, but only the population growth appears to be statistically significant. Notably, we find evidence of conditional convergence, the negative sign on

the initial GDP variable, though it is not statistically significant. Similar to before, the finding of a negative result does not invalidate the poverty trap hypothesis. In Table 5 and 6 we relax the linearity assumption and report the MARS model's results.

TABLE 4
ORDINARY LEAST SQUARES ESTIMATION OF GDP/N GROWTH, INCLUDING AID PER CAPITA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	All Countries		GDP 1985 < $2700		GDP 1985 < $3059		GDP 1985 < $3463	
Ln(Initial GDP/N)	-0.079	-0.132	-0.287	-0.241	-0.242	-0.191	-0.215	-0.152
	(0.077)	(0.074)	(0.163)	(0.162)	(0.148)	(0.144)	(0.140)	(0.138)
Ln(s)	0.091	0.021	0.088	-0.001	0.104	0.010	0.092	-0.033
	(0.082)	(0.077)	(0.107)	(0.123)	(0.100)	(0.116)	(0.101)	(0.112)
Ln(n)	-1.247***	-0.760*	-1.295*	-1.007	-1.348**	-1.012*	-1.319**	-0.946
	(0.345)	(0.343)	(0.513)	(0.514)	(0.484)	(0.486)	(0.486)	(0.484)
Ln(School)	0.280	0.256	0.226	0.200	0.184	0.168	0.198	0.181
	(0.142)	(0.131)	(0.179)	(0.175)	(0.171)	(0.165)	(0.173)	(0.165)
Ln(Aid/N)		-0.074		-0.049		-0.083		-0.074
		(0.091)		(0.163)		(0.144)		(0.137)
Corruption		0.171**		0.106		0.111		0.176
		(0.053)		(0.111)		(0.107)		(0.101)
Ln(Aid)*Corruption		-0.021		-0.039		-0.031		-0.032
		(0.031)		(0.043)		(0.040)		(0.039)
Constant	-1.785	-0.684	-0.690	-0.623	-1.243	-1.001	-1.320	-1.368
	(1.347)	(1.383)	(2.288)	(2.243)	(2.128)	(2.097)	(2.145)	(2.078)
Observations	72	72	39	39	42	42	45	45
R-squared	0.342	0.476	0.322	0.420	0.315	0.418	0.295	0.408
Adj R-sq	0.303	0.418	0.243	0.289	0.241	0.298	0.224	0.296
Mean	-0.208	-0.208	-0.360	-0.360	-0.346	-0.346	-0.349	-0.349
Standard Deviation	0.511	0.511	0.526	0.526	0.513	0.513	0.514	0.514
RSS	12.195	9.714	7.116	6.089	7.395	6.283	8.214	6.893

Standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

The MARS procedure shows a significant improvement in the fit of the models. For the all country sample, the improvement in the RSS is from 9.714 to 7.432, while for the low-income country the improvement is from 6.089 to 2.619, as reported in Table 4 columns 2 and 4 compared to Tables 5 and 6. This improvement in the fit of the model shows the improvements in fit that can be had by modeling the data nonlinearly instead of linearly.

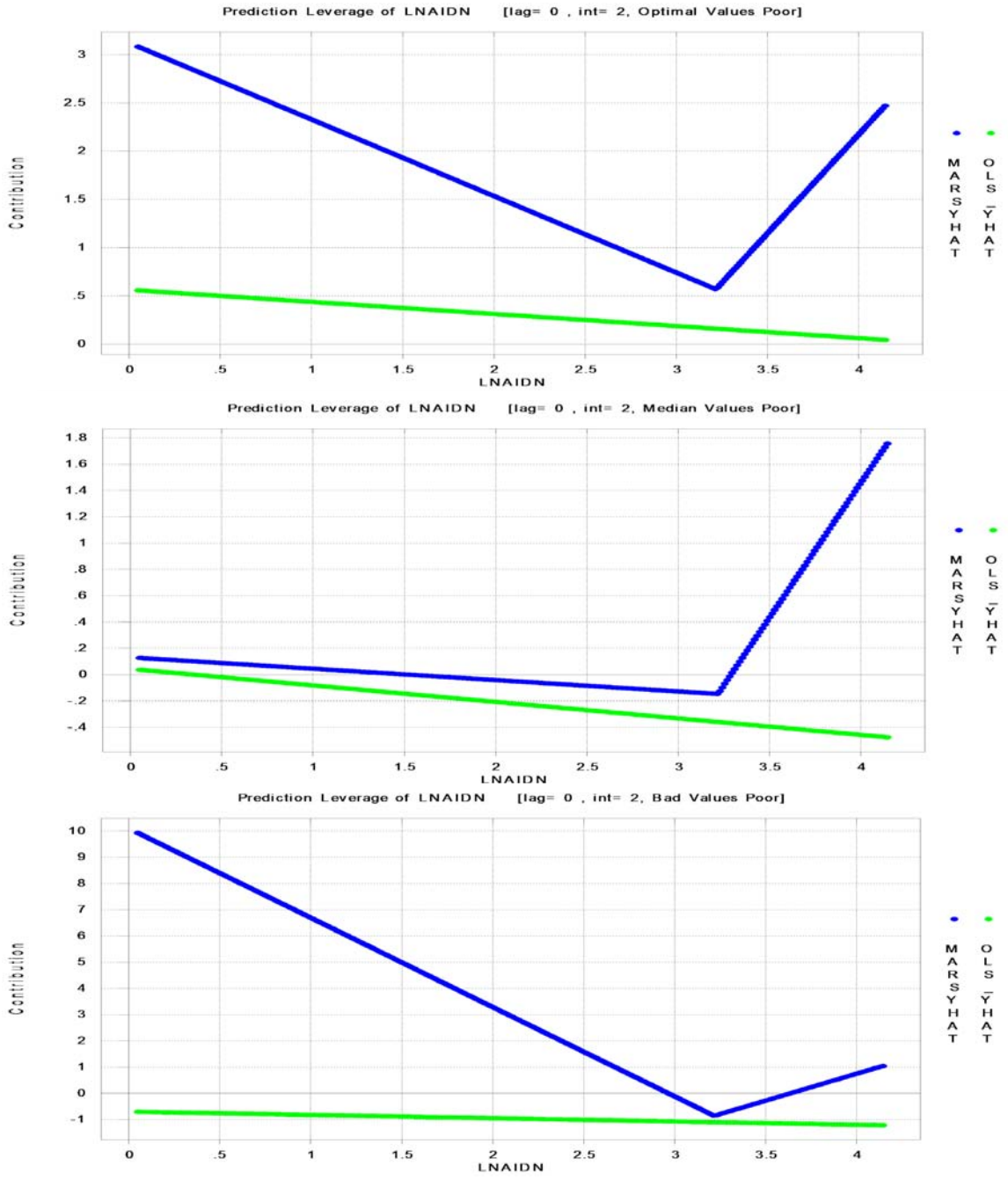
TABLE 5
MULTIVARIATE ADAPTIVE REGRESSIVE SPLINES FOR GDP GROWTH, INCLUDING AID PER CAPITA, FOR ALL COUNTRIES

	Coefficient	Variable	SE	T-Stat	RSS
Ln(Growth)=	-0.185		0.113	-1.63	7.432
	-1.607	* max(Ln(n) - -2.6816397 , 0.0)	0.4	-4.01	
	0.248	* max(Corruption - 3.6000000 , 0.0)	0.056	4.45	
	12.573	* max(Ln(s) - -1.4849759 , 0.0)	2.589	4.85	
		* max(-2.6816397 - Ln(n), 0.0)			
	-0.215	* max(8.2142160 - Ln(GDP1985), 0.0)	0.114	-1.88	
		* max(Corruption - 3.6000000 , 0.0)			
	-7.252	* max(-2.6816397 - Ln(n), 0.0)	2.106	-3.44	
		* max(Ln(School) - -2.8738097 , 0.0)			
	-24.207	* max(-2.6816397 - Ln(n), 0.0)	12.537	-1.93	
		* max(-2.8738097 - Ln(School), 0.0)			
	0.282	* max(Ln(School) - -3.4493377 , 0.0)	0.157	1.8	

TABLE 6
MULTIVARIATE ADAPTIVE REGRESSIVE SPLINES FOR GDP GROWTH, INCLUDING AID PER CAPITA, FOR LOWER INCOME COUNTRIES

	Coefficient	Variable	SE	T-Stat	RSS
Ln(Growth)=	-0.862		0.084	-10.200	2.619
	0.736	* max(Ln(s) - -1.6988683 , 0.0)	0.154	4.780	
		* max(3.2177718 - Ln(Aid/N), 0.0)			
	1.290	* max(-1.6988683 - Ln(s), 0.0)	0.410	3.140	
		* max(3.2177718 - Ln(Aid/N), 0.0)			
	1.718	* max(6.9166725 - Ln(GDP1985), 0.0)	0.384	4.470	
		* max(Ln(Aid/N) - 3.2177718 , 0.0)			
	1.294	* max(Ln(School) - -3.5244956 , 0.0)	0.244	5.310	
	-1.722	* max(Ln(GDP1985) - 6.8218792 , 0.0)	0.440	-3.910	
		* max(Ln(School) - -3.5244956 , 0.0)			
	0.700	* max(Ln(GDP1985) - 6.9166725 , 0.0)	0.257	2.720	

FIGURE 3
CONTRIBUTION GRAPH FOR LOW INCOME COUNTRIES AID PER CAPITA: UNDER THREE CASES



The MARS procedure continues to find thresholds given this alternative definition of foreign aid for the low-income countries. Under all of the cases the partial effect of foreign aid on growth goes from being negative to positive, though the positive effect is clearly dampened for the bad values case. For all countries the MARS procedure does not find foreign aid to be statistically significant.

For the lower income countries, the MARS procedure finds results that are very supportive of the poverty trap hypothesis. The MARS procedure detects a threshold effect at Ln(AID)= 3.22 (or when foreign aid was greater than about $24.97 per person). Figure 3 is the contribution graphs generated by the MARS procedure for the low income, again broken down by optimal, median, and bad cases. The support for the poverty trap hypothesis is of the form:

$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots\beta_{aid>\$24.97} * \ln(aid)\ldots$$
$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots\beta_{otherwise} * \ln(aid)\ldots \quad (10)$$

One interesting interaction term is detected between the initial GDP and foreign aid (shown in equation 11). The interpretation of this interaction supports evidence of divergence. For countries at very low levels of income per capita, less than $1009, a high enough level of foreign aid, greater than $24.97 per person, could speed up the countries growth as they are escaping the poverty trap. Diverging them from the countries that did not receive enough aid. This is very different from the OLS results that offered only weak evidence of conditional convergence, and is supportive of a possible poverty trap. One of the necessary conditions of a poverty trap being that countries that receive sizable amounts of foreign aid are able to escape the poverty trap.

$$\ln(\frac{Y}{N})_{2014i} - \ln(\frac{Y}{N})_{1985i} = \ldots 1.718 * [\max(6.917 - \ln(\frac{Y}{N}_{1985}),0)]_i * [\max(\ln(\frac{Aid}{N}) - 3.218,0)]_i \ldots \quad (11)$$

CONCLUSION

Though the efficacy of foreign aid has been a much-researched area, to this point the previous literature has found inconsistent empirical evidence. In this paper a nonlinear estimation is used, a MARS model, to attempt to explain why the inconsistency has persisted in the literature. Under two different specifications of foreign aid evidence is found that is not only consistent with a poverty trap hypothesis, but also results in a better fitting model.

The improvement that is found, measured as an improvement in the residual sum of squares, suggests that nonlinear models can provide an improvement in fit compared to the more normally used linear methods. This result is consistent with Odell (2012), who found, using a Generalized Additive Models, similar results for all countries in regards to their steady state level of income.

One policy consideration from this paper's results is that the amount of foreign aid being sent to a low-income country matters. Foreign aid that is lower than the threshold—either 6.7 percent of GNI or $24.97 per person—has a significantly different impact on growth than when it is larger. Furthermore, small amounts of foreign aid could actual impede the growth of the country. These results support Sachs (2004 and 2005) argument that the amount of money being sent just has not been great enough, even while controlling for the level of corruption within the country.

The interaction terms further suggests that there is some evidence that selectivity (Burnside and Dollar 2000) in which countries receive foreign aid is important. Namely, that the threshold in years of schooling, at 2.9 years, provides a significant amplification in the effect of foreign aid. This would suggest that human capital accumulation is not only important for economic growth (MRW 1992), but also for determining the impact of foreign aid. Countries that have been investing in human capital already could be better situated to allocate the foreign aid towards growth generating areas than countries that have not been investing in human capital.

The MARS model is able to take Sach's (2004) theoretical poverty trap one-step further by providing empirical evidence that effect of foreign aid is not constant across all levels of foreign aid. Additionally, the nonlinear procedure finds significant threshold levels in the standard growth variables, allowing for a

better fit compared to linear techniques. Furthermore, these nonlinearities offer insight into what type of poverty trap exists.

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STATISTICAL APPENDIX

TABLE 1
ALL COUNTRIES THAT RECEIVED FOREIGN AID THROUGHOUT THE TIME PERIOD
(* DENOTES LOW INCOME COUNTRIES)

Country		Country		Country	
Algeria	DZA	Ghana	GHA*	Niger	NER*
Argentina	ARG	Guatemala	GTM	Pakistan	PAK*
Bangladesh	BGD*	Guyana	GUY*	Panama	PAN
Barbados	BRB	Honduras	HND	Papua New Guinea	PNG*
Benin	BEN*	India	IND	Paraguay	PRY
Bolivia	BOL*	Indonesia	IDN*	Peru	PER
Botswana	BWA	Jamaica	JAM	Philippines	PHL*
Brazil	BRA	Jordan	JOR	Rwanda	RWA*
Burundi	BDI*	Kenya	KEN*	Senegal	SEN*
Cameroon	CMR*	Laos	LAO*	Sierra Leone	SLE*
Central African Republic	CAF*	Lesotho	LSO*	Sri Lanka	LKA*
Chile	CHL	Liberia	LBR*	Sudan	SDN*
China	CHN*	Malawi	MWI*	Swaziland	SWZ
Colombia	COL	Malaysia	MYS	Thailand	THA
Congo	COG*	Mali	MLI*	Togo	TGO*
Costa Rica	CRI	Mauritania	MRT*	Trinidad and Tobago	TTO
Côte d'Ivoire	CIV*	Mauritius	MUS	Tunisia	TUN
Cuba	CUB	Mexico	MEX	Turkey	TUR
Dominican Republic	DOM	Mongolia	MNG	Uganda	UGA*
Ecuador	ECU	Morocco	MAR*	Uruguay	URY
Egypt	EGY*	Mozambique	MOZ*	Venezuela	VEN
El Salvador	SLV	Namibia	NAM	Viet Nam	VNM*
Gabon	GAB	Nepal	NPL*	Zambia	ZMB*
Gambia	GMB*	Nicaragua	NIC	Zimbabwe	ZWE*

TABLE 2
DESCRIPTIVE STATISTICS FOR COUNTRIES THAT RECEIVED FOREIGN AID

All Countries	Obs	Mean	Std. Dev.	Min	Max
Ln(GDP/N 2014)	72	7.49	1.19	5.02	10.33
Ln(GDP/N 1985)	72	7.70	0.94	5.72	10.00
Ln(s)	72	-1.78	0.67	-4.34	-0.62
Ln(n)	72	-2.58	0.17	-3.01	-2.23
Ln(School)	72	-3.11	0.54	-4.65	-2.42
Ln(Aid/N)	72	2.80	1.08	0.05	4.40
Ln(Aid/GNI)	72	-4.13	1.70	-8.12	-1.33
Corruption	72	3.68	1.19	1.10	7.40
Countries GDP/L<$2700					
Ln(GDP/N 2014)	39	6.61	0.71	5.02	8.19
Ln(GDP/N 1985)	39	6.97	0.53	5.72	7.88
Ln(s)	39	-2.00	0.72	-4.34	-0.89
Ln(n)	39	-2.53	0.17	-3.01	-2.27
Ln(School)	39	-3.39	0.55	-4.65	-2.43
Ln(Aid/N)	39	3.04	0.93	0.05	4.16
Ln(Aid/GNI)	39	-3.15	1.07	-6.29	-1.33
Corruption	39	3.21	0.80	1.10	4.90
Countries GDP/L<$3059					
Ln(GDP/N 2014)	42	6.70	0.76	5.02	8.19
Ln(GDP/N 1985)	42	7.05	0.58	5.72	8.00
Ln(s)	42	-1.92	0.75	-4.34	-0.72
Ln(n)	42	-2.53	0.17	-3.01	-2.27
Ln(School)	42	-3.36	0.55	-4.65	-2.43
Ln(Aid/N)	42	3.03	0.94	0.05	4.16
Ln(Aid/GNI)	42	-3.23	1.12	-6.29	-1.33
Corruption	42	3.26	0.80	1.10	4.90
Countries GDP/L<$3463					
Ln(GDP/N 2014)	45	6.76	0.78	5.02	8.41
Ln(GDP/N 1985)	45	7.11	0.61	5.72	8.06
Ln(s)	45	-1.90	0.74	-4.34	-0.72
Ln(n)	45	-2.53	0.16	-3.01	-2.27
Ln(School)	45	-3.34	0.54	-4.65	-2.43
Ln(Aid/N)	45	3.10	0.94	0.05	4.36
Ln(Aid/GNI)	45	-3.22	1.10	-6.29	-1.33
Corruption	45	3.28	0.82	1.10	4.90