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Measuring the Effect of Foreign Aid on Growth and Poverty Reduction or The Pitfalls of Interaction Variables

Catherine Pattillo, Jacques Polak, and Joydeep Roy

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Prepared by Catherine Pattillo, Jacques Polak, and Joydeep Roy[1]

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Abstract

Regressions in a number of recent papers written by staff members of the World Bank and the IMF rely on an interaction variable (IAV) to establish the effects of foreign aid on economic growth or the reduction of poverty. The common assumption in these papers is that if the coefficient of this IAV is statistically significant, then both of its components have a significant effect on the dependent variable. That assumption is not justified in its generality, and this paper develops two techniques that show a high probability that in at least two of the three studies analyzed one of the components of the IAV may not have a significant effect.

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Authors' E-Mail Addresses: CPattillo@imf.org; JPolak@imf.org; jr399@georgetown.edu

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[1]Catherine Pattillo is a senior economist in the African department of the IMF; Jacques Polak was director of the IMF Research Department, 1958–1979; Joydeep Roy is an economist at the Economic Policy Institute in Washington and an affiliated professor at Georgetown University. We are grateful to Young Kim for excellent research assistance and to Andrew Berg and Ashoka Mody for useful comments.

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I. Introduction

There is a large literature that attempts to measure, using cross-country regressions, the effects of foreign aid on growth or poverty in the receiving countries. Many of those attempts did not find a clear influence of foreign aid—positive or negative—when the amount of aid, or some proxy for it, was entered as a separate explanatory variable in the regressions (Rajan, 2005). Researchers then often used the technique of interaction variables (IAVs),[2] where the aid variable was brought into the regressions packaged together with another variable whose relevance to the causation process had been separately established. If the IAV turned up with a coefficient of the right sign and a respectable t-ratio, the conclusion was then drawn that the aid component did contribute to the effect on the dependent variable that the coefficient implied.

Three recent examples of this piggyback approach to measuring the impact of foreign aid, all done in the Bretton Woods institutions, may be mentioned here.

- By far the most prominent is the work of two World Bank economists (Burnside and Dollar 2000). They established a clear effect on growth of income per capita of an index of good economic policies (a combination of budget surplus, inflation, and openness) but found that an aid variable was not significant by itself. Based on arguments that the impact of aid may depend on the policy environment, they entered policies times aid as an IAV. The significantly positive coefficient found for the IAV led them to conclude that aid does benefit growth, but only if it is accompanied by good policies. That conclusion has been widely welcomed and accepted as a valuable guideline for aid policies.
- At about the same time, William Easterly, also from the World Bank, produced a paper which he first presented to the IMF 2000 Research Conference, in which he sought to demonstrate the negative effect on poverty of some forms of aid, namely the assistance provided by the IMF and the World Bank in the context of structural adjustment programs (Easterly 2001a; references below are to a slightly revised version, Easterly 2003). Easterly contends that the larger the number of Fund and Bank programs per year agreed between a country and the Bretton Woods institutions, the smaller the poverty reduction that accompanies a given amount of growth. That finding is again based on the inclusion of an IAV, one that combines growth (which was highly significant by itself) with the number of Bank and Fund programs. While the number of programs is not by itself significant, the coefficient on the IAV is both significant and positive. Easterly infers from this the simple conclusion: the more programs, the smaller the smaller the impact of of growth on poverty.
- In a recent IMF Working Paper Rajan and Subramanian (2005a) study the mechanism by which foreign aid may have a negative effect on growth. By means of cross-country/industry regressions they attempt to establish the fact that large ratios of aid

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[2] Interactions, it will be recalled, refer to an "interplay among predictors that produce an effect on the outcome that is different from the sum of the effects of the individual predictors" (Cohen et al, 2003, p. 255).

to GDP may raise wage levels, as a result of which labor-intensive industries in countries receiving large flows of aid could be expected to show lower rates of growth in output than industries that are less labor -intensive or in countries receiving less aid. To verify their proposition they introduce an IAV that is defined as the product of each country's ratio of aid to GDP and each industry's ratio of wage costs to value added.[3]

The common assumption underlying these three papers is that a significant t-ratio for the coefficient found for an IAV can be interpreted as indicating a significant impact on the dependent variable of *both* of its components. Our conclusion is that, in its generality, this assumption is wrong, and, accordingly, that the regressions in these papers do not provide conclusive statistical support for their apparent findings.

We developed our view by analyzing the Easterly paper and the main part of our presentation follows the line of that analysis. In a final section we apply our findings to the two other papers.

II. Easterly's Model

To test the effect of IMF and World Bank adjustment lending, Easterly regresses the changes in the poverty rate on five variables: (1) the growth of mean income, (2) the number of adjustment loans per year, (3) the product of (1) and (2) as an IAV , (4) the initial Gini coefficient, and (5) the product of (1) and (4) as a second IAV.

The definitions of some of these variables, and the rather unusual database to which they are applied, require a brief description. Easterly starts out from the results of 155 pairs of household surveys, drawn from 65 developing and transition countries. The interval between the two surveys of the same households is called a spell. The median length of the spells studied is three years. Growth is the average annual change between the first and second surveys in real consumption or real income of the households sampled. The growth data reflect primarily cyclical variations: their median value is zero. The number of Fund/Bank adjustment programs per year for any country-spell is measured as the sum of the number of structural adjustment loans to the country from the Bank plus the number of general loans from the IMF (standby and extended arrangements as well as loans under the SAF and ESAF), initiated during the spell, divided by the length of the spell in years.

Poverty is defined as the proportion of the population earning less than $2 a day. The annual rate of change of poverty is calculated on the assumption that the change during the spell is log-linear; it is thus expressed as a percentage of the number of poor, not of the total population. The numbers for the annual percentage changes in the rate of poverty, in

[3] The same material is reprinted in NBER Working Paper No. 11657 (Rajan and Subramanian 2005b), which contains a different set of regressions that include the aid ratio by itself in addition to the aid times labor IAV. Our discussion is based on the approach used in the first paper (Rajan and Subramanian 2005a, henceforth R&S).

conjunction with numbers calculated in a similar manner for the annual percentage changes in growth, yield a poverty/income elasticity.[4]

Regressions using these data show a clear association between the change in poverty and both growth and income distribution; no effect on poverty of the number of programs by itself; but significant coefficients for the two IAVs. Because the coefficient found for the IAV that combines growth and the number of programs equals about 2 (regressions 2 and 3 in his Table 11.2) and has a high t-ratio, Easterly concludes that “the absolute value of the growth elasticity of poverty declines by about two points for every additional IMF or World Bank adjustment loan per year” (p. 367). He discusses possible causes for this relationship but, not finding one, concludes by asking “why structural adjustment lending reduces the sensitivity of poverty to growth” (p. 379).

But there is a prior question: *Does* structural adjustment lending reduce the sensitivity of poverty to growth? Specifically, is it admissible to infer a significant effect of the number of programs on the poverty elasticity of growth from the fact that the coefficient on the growth times program IAV is significant in the regressions?

III. Critique of Easterly’s Model

The economics underlying the Easterly model has been sharply criticized by Edwin Truman (2003), *inter alia* for failing to distinguish between IMF loans that aimed simply at macroeconomic stabilization and IBRD so-called structural adjustment loans that were, at least until well into the 1980s, merely disguised balance of payment loans. We would also question Easterly’s assumption that the degree of IMF influence on a country’s policies can be measured by the number of programs in place during a spell. A single 3-year program during a 3-year spell may represent a stronger IMF ‘presence’ than 3 consecutive 1-year programs. Yet those 3 programs would be entered as 1 program per year, while the 3-year program would be counted as 0 programs per year if it had been agreed shortly before the start of the spell and as 0.33 programs per year if it had been agreed at any time during the spell—even a few months before the end of it. Not a minor difference: the average number of programs in the whole exercise was 0.62 per year.

But the ultimate judgment of Easterly’s findings must derive from the statistical technique he uses, and there is a simple way to test that. If the program component of the growth times program IAV made a significant contribution to the regression, then replacing the program numbers by a random set of numbers should result in a coefficient that is not significant, except in a few cases by chance.

For this test, we created a large number of permutations of Easterly’s program numbers and attached them randomly to his country/spell data, thus generating a nonmeaningful matchingof programs with spells.[5]

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[4] When the poverty rate at either end of the spell is very low, even the annual percentage poverty change can become a very large number. True, cases (there are five among the spells studied) where poverty = 0 at either end of the spell drop out from the calculations. But in 10 spells one of the two poverty percentages is less than 1 percent, and in 16 the annual percentage change in poverty exceeds 50 percent (including four in which it exceeds 100 percent).

Table 1 shows the result of two sets of 1,000 "throws of the dice": regressions that use a growth times (randomized program) IAV. The permutation exercise at the left-hand block of the table uses Easterly's actual program numbers; the exercise at the right-hand block uses his instrumented program numbers. In Table 2 we repeat the experiment with two sets of 1,000 permutations of a slightly smaller, but probably more homogeneous, sample that excludes transition countries.[6]

Table 1. Significance of 1,000 Coefficients for Growth *times* Artificial Program Variable
Full Sample
(Percent significant or not significant)

	Actual Program Variable Randomized			Instrumented Program Variable Randomized		
Coefficient Sign>>	Total	Positive	Negative	Total	Positive	Negative
At 1 percent	47	21	26	12	5	7
At 5 percent	61	26	35	29	12	17
At 10 percent	**67**	29	38	**40**	16	24
Not significant	**34**	15	19	**60**	28	32

The tables show the percent of cases where the coefficient of the growth times (randomized program) variable appeared significant at three different significance levels, with a breakdown by positive and negative values. They indicate a startlingly large percentage of cases where the coefficient for the IAV, regardless of sign, is statistically significant: 67 and 40 percent for the full sample and about 30 percent for the smaller sample. These numbers

Table 2. Significance of 1,000 Coefficients for Growth *times* Artificial Program Variable
Sample Without Transition Countries
(Percent significant or not significant)

	Actual Program Variable Randomized			Instrumented Program Variable Randomized		
Coefficient Sign>>	Total	Positive	Negative	Total	Positive	Negative
At 1 percent	10	3	7	7	2	5
At 5 percent	21	7	14	21	8	13
At 10 percent	**30**	12	18	**31**	13	18
Not significant	**70**	37	33	**69**	33	36

are far in excess of what one would expect to find on the basis of chance; at levels of significance up to 10 percent, for example (90 percent confidence intervals), we would

[5] The technique is one of permuting the program variable, as opposed to bootstrapping. That is, we draw a new sample of observations by sampling randomly from the original data vector without replacement.

[6] Ravallion (2001), who compiled the poverty and growth data used by Easterly, excludes the transition countries from his analysis because of the questionable quality of their data. Their exclusion reduces the sample from 126 to 113 country/spell observations.

expect chance to produce false indications of significance in no more than 10 percent of the cases. The fact that, in a large share of cases, the economically meaningless interaction of growth with an artificial program variable produced 'significant' coefficients, more than half of them negative, indicates that Easterly's regressions do not support his conclusion.

That still leaves an important question unanswered: How can it be that regressions that incorporate a meaningless variable yield a statistically significant coefficient for that variable? Is this related to some hidden feature of the data used in this particular paper? Or does it cast a more general doubt on the use of interaction variables?[7]
One clue to this question can be found in the nature of Easterly's data. The median value of his figures for growth per country/spell is zero: half are positive, half negative. By contrast, his program numbers are, by their nature, all greater than or equal to zero and all the Gini numbers are, of course, positive. It follows that his two IAVs, growth times programs and growth times Gini, always have the same sign as the growth variable, except for the spells without a program. The insertion of these two IAVs may thus amount to little more than adding two variants of the growth variable.

This view seems to be confirmed by the bottom line of Table 3, which shows that the total effect of growth on poverty in Easterly's Regressions 2 and 3 hardly differs from that in his Regression 1, in spite of the insertion of the two IAVs (as well as the GINI coefficient and the program variables by themselves).This total effect remains close to –2, while the (negative) coefficient for growth by itself jumps from –1.9 to –5.5.

Table 3. Effect of Growth on Poverty
(Dependent variable: poverty)

Easterly's Regressions							
		Regression 1		Regression 2		Regression 3	
Variable	*Weight*	*Coefficient*	*Effect*	*Coefficient*	*Effect*	*Coefficient*	*Effect*
Growth	1.0	–1.89	–1.89	–5.48	–5.48	–5.64	–5.64
Growth times Gini	39.5			0.058	2.29	0.057	2.25
Growth times program	0.62			1.79	1.11	2.03	1.26
Total effect of growth			–1.89		-2.08		–2.13

Notes: Regressions 1 and 2 are based on Ordinary Least Squares; in Regression 3 the program numbers are instrumented. Note that the coefficients in Regressions 2 and 3 (which also include the Gini coefficient and the program variable by themselves) are almost exactly the same. The number 39.5 for growth times Gini in the column marked *Weight* shows the average of all Gini numbers; similarly, the number 0.62 for growth times program in the same column is the average of all program numbers.

[7] We also explored whether Easterly's dependent variable, the percentage poverty change, was in any way distorted by censoring which would make the OLS results problematic (Cohen et al, p. 596-99), but found this was not the case.

IV. IMPLICATIONS OF OUR FINDINGS

The insight into the nature of IAVs derived from our analysis of the Easterly paper (2001a) also enhances our understanding of the interaction effects in the other two papers mentioned in our introduction.

The Rajan/Subramanian (R&S) Papers

These papers pursue evidence for a two-pronged proposition: (i) that in countries receiving large amounts of foreign aid as a percentage of GDP, the resulting 'Dutch disease' may reduce growth, and (ii) that the Dutch disease effect of aid on growth operates through a rise in wages, so that the impact on any one industry will be stronger the higher that industry's ratio of labor costs to value added.

The statistical approach the authors take to explain a set of country/industry growth data is implicitly based on a regression containing three main variables: a country dummy, an industry dummy, and the particular industry's initial period share in the country's total value added. (The latter variable is said to control for convergence-type effects, but its extremely robust negative coefficient through all exercises may well indicate that it functions as a kind of globalization dummy, accounting for the rapid growth of a few new industries, such as mass-produced textiles in some countries, electronics in some others, that started from a very low base in 1980.) That regression, which is not shown in their paper, shows that these three variables account for a reasonable share of the variation in the growth rates studied, with $R^2 =$ 0.40 for the 1980s and 0.30 for the 1990s (our calculations, on the basis of data kindly provided by the authors). The inclusion of these three dummies is also essential, at least for the 1980s regression: a calculation by the authors that omits the country dummies but includes the two other dummies, plus six country characteristics that are widely recognized as relevant to growth, including the aid/GDP ratio, plus the IAV discussed below, achieves an R^2 of 0.17 for the 1980s and 0.28 for the 1990s.

The R&S core model consists of the three main variables mentioned plus a single variable designed to bring out both the impact of aid and the channel through which they believe aid impacts the economy. The latter is an IAV that is the product of (a) each country's ratio of foreign aid to GDP (average for the decade) and (b) a measure of the labor intensity of each industry (the average, for the sample of countries included for the decade, of that industry's ratio of the cost of labor divided by its value added).[8]

The insertion of this IAV raises the R^2 of the regression from 0.40 to 0.41 for the 1980s and from 0.30 to 0.33 for the 1990s (R&S Table 2A, columns (1) and (4)) and produces coefficients that are highly significant and robust against a wide variety of tests. The authors

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[8] The combination of these two features into a single variable, rather than including each separately in the regressions, was dictated by the nature of the basic equation. The regression procedure will not accept both a country dummy and an aid ratio that has the same value for all observations within a country; similarly, it will not allow both an industry dummy and a labor intensity variable that is the same across all countries for a particular industry.

then proceed on the assumption that the coefficients they have found for the IAV reflect the joint effect of its two components.

As we have learned from the discussion of the Easterly paper, this assumption is not necessarily justified. In fact, the data on the two variables that compose the IAV convey a presumption that one of them, the aid ratio, is primarily (and perhaps entirely) responsible for the significant coefficient found for the IAV. The reason for this presumption is that the coefficient of variation of the aid ratio—its standard deviation divided by its mean—is more than three times as large as that of the labor ratio.[9] Consequently, the aid ratio dominates the aid-labor IAV and there is a close correlation between the two: 0.95 for the 1980s and 0.93 for the 1990s.

In spite of this high degree of correlation, we found that random permutation of the labor ratios in the IAV (corresponding to what we did for the Easterly data) yielded significant coefficients for the IAV with a frequency only slightly higher than one would expect from the use of random numbers for the labor ratios (14 to 16 percent as against an expected 10 percent at the 90 percent confidence level, see Table 5 below).

We explored, therefore, another test that might provide information on the role played by the labor component in the IAV in the explanation of the growth differential between industries. In this test we varied the formula for the IAV to see whether increasing or decreasing the relative weight of the aid/GDP ratio raised or lowered the t-ratio for the IAV. We generated 10 alternative versions of an *(x,z)* IAV for each decade by combining 5 different powers (¼, ½, 1, 2 and 3) of the aid/GDP ratio with the unchanged labor intensity ratio, and the same 5 different powers of the labor intensity ratio with the unchanged aid/GDP ratio, which we then substituted in turn into the basic regressions.

The results, in terms of the t-ratios for the coefficients for the alternative IAVs, are shown in Table 4. In interpreting these data one should remember that the two underlying ratios are both less than one, so that higher powers of the variables mean smaller numbers.

Table 4. T-Ratios of the Interaction Variable for Different Exponents of (a) the Aid/GDP Ratio, Keeping the Labor Intensity Ratio Constant, and (b) the Labor Intensity Ratio, Keeping the Aid/GDP Ratio Constant

Exponent	(a) Changing the Exponent of the Aid/GDP Ratio		(b) Changing the Exponent of the Labor Intensity Ratio	
	1980s	1990s	1980s	1990s
¼	–2.64	–2.86	–2.07	–2.42
½	–2.55	–2.79	–2.16	–2.49
1	–2.34	–2.61	–2.34	–2.61
2	–1.82	–2.28	–2.62	–2.82
3	–1.31	–2.08	–2.83	–2.96

[9] For the 1980s (1990s) the aid ratio has a standard deviation of 4.2 (4.8) percent and a mean of 5.8 (5.0) percent; the corresponding numbers for the labor ratio are 8.4 (8.8) percent and 40.3 (35.8) percent (R&S Table 1).

The columns in this table show a remarkable consistency: the numbers in the (A) columns decline as the exponent increases and the numbers in the (B) columns just as regularly increase as the exponent increases. In economic terms, increasing the weight of the aid ratios in the IAV (moving up the (A) columns) raises the t-ratio of the IAV, while increasing the weight of the labor ratios (moving up the (B) columns) lowers the t-ratio.

In the top row, the role of the aid variable has been raised nearly ten-fold in terms of its average value: $0.058^{1/4} = 0.49$ (for the 1980s) and $0.050^{1/4} = 0.47$ (for the 1990s). That comes close to including the aid ratio itself instead of an IAV, but, as noted in footnote 8, the regression model does not make this possible.

It is clear from this table that the aid/GDP ratio dominates the IAV because the t-ratio of the coefficient associated with the labor intensity ratio falls as its weight increases. The impact of the IAV on the differential growth rates, as shown by the regression, is attributable, mostly or wholly, to the aid component of the IAV, although this does not preclude some marginal contribution from the labor component.[10]

In conclusion, the data in Table 4 do not provide statistical support for the specific mechanism postulated by R&S for the working of Dutch disease caused by a large supply of foreign aid, namely that the growth rates of individual industries would be lower, the higher their labor shares in value added.

To generate additional evidence on the extent to which changing the composition of the IAV affects the frequency of apparently significant coefficients if the labor ratios in the IAV are randomized, we repeated the randomization exercise for the different combinations listed in Table 4. The results are shown in Table 5:

Table 5. Frequency of Significant Coefficients for IAV with
Randomized Labor Intensity Ratios
Percentage of 'Significant' Coefficients for IAV

	1980s			1990s		
Significance Level>>	1%	5%	10%	1%	5%	10%
Power of Aid/GDP ratio						
¼	2.3	6.5	11.9	1.3	5.6	11.4
½	2.7	7.0	11.1	1.4	6.2	12.1
1	2.5	7.0	12.5	1.9	6.4	12.8
2	2.6	8.6	13.0	2.2	7.6	14.2
3	3.3	9.1	14.3	2.8	8.9	16.0

These figures also show a strong regularity, with the percentage of excess significant numbers decreasing (reading the columns from higher to lower powers) as the t-ratios in the

[10] This is based on an individiual small sample, not on an average in a large number of samples.

regressions improve (see Table 4). In the top rows of the table, where the t-ratios for the IAV are highest, the chance of finding a false significant value for the coefficient is smallest.

The Burnside and Dollar (B&D) Paper

Burnside and Dollar found that, when entered separately in regressions explaining the growth of per capita income, a policy variable was highly significant while an aid variable was not significant. But adding the policy times aid IAV produced a significant coefficient for that variable, while policy by itself remained significant, and aid by itself stayed insignificant (B&D, Table 4).

Although these findings were widely hailed, their robustness was soon questioned in various papers, including Easterly et al. (2004). They found that the B&D results were not robust to small changes in the sample of countries or to extensions of the time periods. But they did not pursue the question whether the regression model used by B&D might explain their finding of a significant and positive coefficient for their IAV.

As our findings on the first two papers suggest,, the significant coefficient for the policy times aid interaction variable found by B&D does not justify, without further investigation, their inference that *both* components of this IAV have a significant effect on growth. The data available in their paper do not permit one to reach a conclusion as to whether the second component, the amount of foreign aid, is or is not significant when combined with the policy variable in an IAV. But the paper does contain some suggestive negative evidence on this score. Although they find a significant coefficient for their IAV in column (4) of their Table 4 using OLS, the coefficient for the same variable is not significant at the 10 percent level when two-stage least squares is used; the t-ratio of the coefficient for the policy variable falls from 7 to 4; and the inclusion of the IAV does not improve the R^2 (B&D Tables 2 and 4). To make a clearer judgment, however, one would like to see the result of either a permutation exercise or some experimentation with alternative versions of the IAV based on different powers of the policy variable.

V. CONCLUSION

Both the paper by Easterly and that by Burnside and Dollar use an interaction variable $x*z$ with the same statistical objective: to answer the question whether in explaining variations of a dependent variable y, which is known to depend on a primary independent variable x, a role can also be discerned for an additional dependent variable z, even though the coefficient on z is not significant in a linear equation ($y = \alpha x + \beta z$). Rajan and Subramanian use the same technique to test for the significance of x and z simultaneously.

All three papers find a significant coefficient for the IAV used and infer from that that both of its components have a significant impact on the dependent variable. We show that this inference is not justified in its generality. Where the impact on the dependent variable of one of the components of the IAV is statistically dominant, the IAV may do little else than duplicate that variable, providing little or no information on the influence of the other component.

Taking the analysis one step beyond the finding that a significant IAV does not prove that the secondary component of the IAV is significant, we show that in at least two of the three studies that we analyzed there is strong evidence that the secondary component of the IAV is *not* significant. With respect to the Easterly paper, we made a direct test of the significance of *z* by means of multiple permutations that replaced the actual value of *z* in any set of observations by a randomly selected different value, *z'*. The coefficient on the resulting interaction variables *x*z'* was still 'significant' in a large proportion of the regressions made—more than half of them with the opposite sign to that found by Easterly.

The same permutation technique did not give convincing signals of the absence of significance of the secondary variable in the IAV used by R&S, the degree of labor intensity of different industries. But an alternative technique, using different powers (¼, ½, 1, 2, and 3) of their main variable, the aid/GDP ratio, showed increases in the t-ratios for the coefficient of the IAV as the relative role of that ratio was raised, suggesting at most a minor influence on the outcome attributable to the labor ratio.

The information contained in the B&D paper did not permit us to apply either of the two tests mentioned to their findings, although their paper does contain some suggestive evidence that puts the significance of their secondary variable (the amount of aid received) into question.

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