ECONOMIC ANALYSIS OF RADIO EDUCATION:

Evaluation of a Proposal to Use Radio to Teach Mathematics in the Dominican Republic, 1984-89

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THE PROBLEM

There are two problems with respect to mathematics achievement in the Dominican Republic. First, the level of mathematics achievement is too low. According to a recent study of eighth grade learning, mathematics achievement in even the best private schools falls below average mathematics achievement in most other countries (Luna Ramia, et.al., 1984). Second, there is substantial variation in mathematics knowledge between different types of schools. In particular, learning levels at the eighth grade vary between 42% in urban, private schools and 25% in rural, public schools. Surprisingly, differences in learning between urban and rural public schools are insignificant at the eighth grade.

What are the causes of such low levels of mathematics achievement and such high variation in learning? The typical model of educational achievement posits that the current level of learning (ACH_t) is determined by the prior level of learning (ACH_{t-1}), the socio-economic environment of the home (HE_t), and the school environment (SE_t):

$$ACH_t = f(ACH_{t-1}, HE_t, SE_t)$$

In support of this learning model, one finds that between fifty and sixty percent of private school students are of upper or upper-middle income status, and those students have an average achievement score of 46%. Middle-income students in those same schools have average scores of 31%. One also finds that 81% of students in public schools are of low-income status,

and average eighth grade achievement in those schools is only 25%. Thus, differences in socio-economic status undoubtedly explain some of the observed variation in mathematics achievement in the Domirican Republic.

Variables in the school environment also undoubtedly play an important role in explaining both the low average level of mathematics achievement as well as variations in that achievement at the eighth grade level. School variables that are likely to influence learning include teacher quality, curriculum design, time spent on the subject, and the socio-economic and educational background of school peers. The study of eighth grade achievement cited above, for example, noted relatively strong student performance on numerical computations and weak performance on understanding analysis and principles of mathematics. These learning disparities as well as the low level of learning may be partly explained by a curriculum that emphasizes computational skills.

THE CHOICES

USAID and GODR face a number of choices in improving mathematics education in the Dominican Republic. One choice is whether to improve average mathematics achievement or to improve knowledge among the lowest achievers. While these need not be mutually exclusive choices, they are often so in practice. Improving average mathematics achievement might be best done through a broad curriculum revision that would offer no disproportionate benefit to low achievers. On the other hand, low achievers

might be best helped by improving educational quality and access in rural schools.

Once this choice is made, the question arises as to the best alternative to pursue in improving the learning of mathematics. Here the choices range from improving teacher preparation to curriculum revision, provision of basic educational materials and textbooks, and the use of radio to compensate for the lack of both educational materials and teacher preparation.

Given past USAID experience in radio-education, its prior investments in radio-education to teach mathematics, and its prior investments in radio-education in the Dominican Republic, a proposal has been made to use radio to improve mathematics achievement in grades 1-4 in the Central and Cibao regions. The question we address next is how best to evaluate this proposal.

EVALUATION METHODOLOGY

USAID has funded two radio education projects in the Dominican Republic. The Radio Santa Maria Project is a non-formal adult literacy program. The Radio-Assisted Community Basic Education Project (RADECO) is a non-formal primary school program designed to provide low-cost educational opportunities to children who have inadequate access to formal education. A new proposal is to use radio in still a different manner by enhancing the quality of mathematics education within the formal classroom.

Prior to funding this new proposal an assessment is required to determine if this is a wise use of AID and GODR resources. This assessment

can proceed in four ways. First, the proposal can be evaluated in and of itself using cost-benefit analysis. The lack of any data on the private and social monetary returns from mathematics achievement in the Dominican Republic (or anywhere else) makes cost-benefit analysis infeasible.

The second method of evaluating the proposal is to compare radio-education with other means of attaining the same objective of improved mathematics learning. This approach entails the calculation of the costs and the effectiveness of alternative educational policies and determining which policy is the most cost-effective. Maximum mathematics learning for given resources is attained when, on the margin, the ratio of effectiveness to costs is identical for all policy choices. For example, in the case of two policy choices, a and b:

$$\frac{\text{marginal effectiveness(a)}}{\text{marginal cost (a)}} = \frac{\text{marginal effectiveness (b)}}{\text{marginal cost (b)}}$$

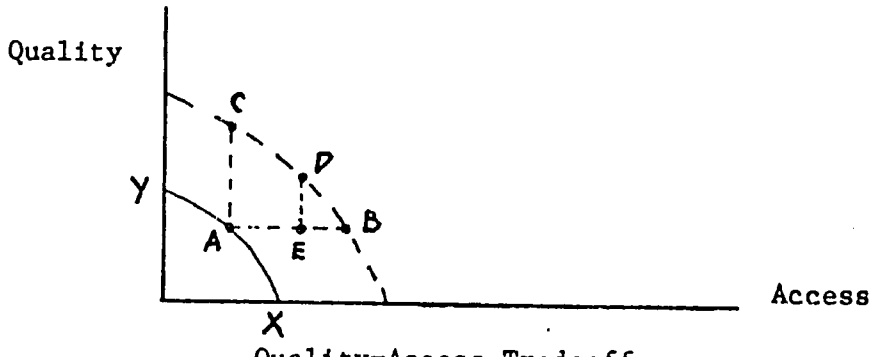
In evaluating the proposed radio-education project for the Dominican Republic, an attempt is made to compute cost-effectiveness, but this can be compared with only very crude cost-effectiveness computations for alternative policy choices.

A third possible method of evaluating radio-education for mathematics is to regard this as one of several proposals for improving the overall quality of education. Under this assumption, the cost-effectiveness of radio-education for mathematics can be compared with the cost-effectiveness of other proposals in the PID (Project Identification Document) for enhancing the overall quality of elementary education. These proposals include

development of educational materials and the upgrading of teachers, administrators, and technicians. The lack of common measures of effectiveness and lack of data on effectiveness of these other proposals makes it unfruitful to pursue this evaluation method.

The fourth evaluation method is perhaps the most appropriate one for the proposal at hand. This approach is to simply determine the tradeoff in terms of educational objectives implicit in adoption of radio-education as a component of the new PID for the Dominican Republic. The new PID has two principal components--improved access to elementary education and enhanced quality of elementary education, especially in mathematics. These two components represent two of the principal objectives present in most educational systems--expanding educational opportunity and enhancing quality of the educational experience.

Any society with relatively fixed resources to expend on education faces a tradeof between increasing enrollments and providing higher quality instruction for students already in the system. More of one objective can be had only at the expense of less of another. The diagram below depicts this more graphically.



Quality-Access Tradeoff

The diagram demonstrates the nature of this tradeoff; in economics such a tradeoff is labeled the production-possibilities curve and represents what can be produced given the educational resources available. At one extreme, point Y, these resources yield an elite, high-quality educational system. At the other extreme, point X, these resurces generate universal access with low-quality. Each society's position on the tradeoff curve is politically determined, but most are located at some intermediate point between the extremes.

The tradeoff curve is constructed for a given amount of educational resources. External assistance adds more resources to the educational system and thereby permits a given country to obtain improved access and/or higher quality. These additional resources are represented by the dotted tradeoff curve in the figure.

External assistance can also alter the nature of the tradeoff curve by providing aid for only improvements in quality or for only improvements in access. External assistance which is earmarked in this manner influences recipient countries to provide more or less of each educational objective than probably would have occurred under unconditional aid. Of course, to the extent external assistance is fungible, earmarked funds are equivalent to unconditional aid.

The new PID for the Dominican Republic can be interpreted in terms of the tradeoff diagram. The PID proposes funding activities which both improve quality and increase access in elementary education. The principal proposal for increasing access is construction or rehabilitation of some 803

classrooms. One proposal for enhancing quality is to introduce mathematics instruction via radio for grades 1-4.

In terms of the diagram, if the solid line represents GODR educational resources, the dotted line may be taken to represent educational resources inclusive of the new PID. Point A on the solid line represents the existing combination of educational opportunity and quality provided in the country. If additional resources provided under the new PID are earmarked soley for improved educational access, the new combination of opportunity and quality is point B. If, on the other hand, the additional resources are earmarked soley for improved quality, the new combination of opportunity and quality is point C.

The PID requests a total of $3.5 million for improved educational access (school construction) and $4.5 million for enhanced educational quality, including $1.9 million for radio-education. The tradeoff between quality and access is now readily seen. To undertake quality improvements entails giving up educational opportunity in the amount EB. On the other hand, to put all funding into improved access requires giving up educational quality in the amount ED. Knowing the magnitude of these tradeoffs does not answer the question of how funding should be allocated, but it at least makes explicit the opportunity costs of alternative decisions.

Radio education is, of course, only one of several proposed activities that enhance quality. However, to undertake radio education entails an opportunity cost or tradeoff in terms of the increase in access that could have been provided with those same resources.

Of course, it is often the case that project requests are made for individual project components; if one component is rejected funds cannot be transferred to other components. The methodology illustrated above is still appropriate except that instead of revealing actual tradeoffs between quality and access, it reveals potential tradeoffs between those two objectives. In this situation, the recipient country views the opportunity costs of, say, the proposed radio education project as being very small, but the aid donor should view the opportunity costs of that project as unchanged from the situation where funds are transferrable between project components.

COSTS OF RADIO EDUCATION

The Project Paper requests funding in the amount of $1.9 million to adapt RADECO and Nicaragua materials, develop implementation plans, and purchase commodities required for implementation. The project anticipates expansion of classrooms and grades using radio education over time from one grade and 200 classrooms in the first year of operation (1985) to four grades and 16,400 classrooms in the fourth year of operation. Some 424,000 students are expected to be participating in the project by its end.

Documentation supporting the Project Paper calculates a project cost of $1.9 million and a recurrent cost to the GODR of $0.71 per student. These cost estimates are based on a number of critical assumptions:

* The radio system is an addition to the traditional educational system; it does not replace existing teaching personnel or educational materials.

* The RADECO curriculum is similar enough to the traditional curriculum that RADECO tapes for the first three grades require only minor modifications for use in the new project.

* The project will begin with 200 classes and 5,000 students in year one and smoothly progress to 16,400 classes and 424,000 students in year four of the project.

* All classrooms affected by the project have only one shift per day.

Changes in these assumptions can significantly affect both project costs and GODR recurrent costs during the life of the project.

Because the project entails a large amount of startup costs (technical assistance, preparing teacher training materials, modifying tapes, purchasing radios and other commodities), average costs per student of mathematics radio education will be high early in the program and diminish rapidly as the number of classrooms and pupils using the program increases. On the other hand, the total variable or recurrent costs of the program to the GODR will increase as the number of classrooms and pupils increases.

Post-project recurrent costs to the GODR for radio-education in the Central and Cibao regions amounts to $302,780 per year. Included in these costs are expected replacement rates for radios, tapes, and instructional materials. Assuming a total of 424,000 students in grades 1-4 by the end of the project, unit costs per student amount to $0.71 per student. Since there is a component of fixed costs (radio broadcasts, SEEBAC personnel, etc.), unit costs vary inversely with number of students receiving radio-mathematics instruction. In addition, costs will be slightly higher if broadcasts are made twice a day to accomodate schools having double-shifts.

Another means of analyzing costs of instructing mathematics via radio-education is in terms of a cost function (Jamison, Klees, and Wells, 1976). The cost function includes annualized project startup and development costs and takes the form:

$$TC = F + V_n N + V_h H$$

Where: TC = total annual costs

F = annualized start up costs + project administration cost

N = number of students enrolled

H = number of hours of lessons per year

V_n = marginal costs per student (e.g., teacher guides, radios, student materials)

V_h = transmission costs plus annualized production costs per hour

In deriving the cost function for the radio-education project in its fifth year of operation, the following assumptions are made:

* all technical assistance is included in start-up costs;
* the 170 half-hour sessions are broadcast twice daily to accomodate schools with double shifts;
* the number of students enrolled in the fifth year is 424,000;
* the real rate of interest (or discount) is 7.5% and the project will last 25 years.

Under these assumptions, the cost function takes the form:

$$TC = 97{,}760 + 0.46\ N + 73.0\ H$$

and the marginal cost per student is $0.46, while the average cost per student (inclusive of annualized start-up costs) is $0.81. As expected, including annualized start-up costs results in higher average costs associated with radio-education. Of course, were the program subsequently expanded to other regions of the country, average costs would diminish and eventually approximate marginal costs in magnitude.

An assumption in this analysis is that tapes used in RADECO can be used in grades 1-3 with very minor modifications; only grade 4 tapes need to be adapted from the original Nicaraguan tapes. If this assumption proves incorrect and extensive modifications are required, the principal cost would be that of technical assistance. But the above estimates are not highly sensitive to changes in outlays on technical assistance. In fact, were the budget for technical assistance doubled, average costs per student would increase by only ten cents, from $0.81 to $0.91. Either figure represents an increase in total average costs per elementary student in the Dominican educational system of at most 3.0 percent (assuming a current unit cost of $30).

Another uncertainty in the proposed radio-education project is the long-term commitment of the GODR to that project. In any country political regimes and accompanying priorities and educational ideologies change. Nicaragua, site of the major radio-education experiment to date, is a dramatic example. If the GODR were to decide to terminate radio-education two years after AID funding ended, annualized recurrent costs per student would rise from $0.81 under the assumption of a twenty-five year project to $1.06, a thirty-one percent increase.

EFFECTIVENESS OF RADIO EDUCATION

As was noted earlier, traditional mathematics education in the Dominican Republic has resulted in low achievement scores relative to other countries and scores which vary widely by type of school. Also, as already discussed, there are several causes of this low achievement, including poor teacher preparation and inadequate school materials. While one prescription for improving mathematics achievement is to improve these school resources, another is to introduce new instructional technology, in this case radio-education.

Since there is no current use of radio in traditional, formal Dominican education evidence on the effectiveness of radio for teaching mathematics must come from other country sources. These sources are consistent in demonstrating that radio education results in higher mathematics achievement even when teacher quality is higher in non-radio schools than in radio schools.

Supporting evidence for the effectiveness of radio in teaching mathematics comes from three different experiments conducted in Nicaragua, Thailand, and Barahona in the Dominican Republic. The principal measure of effectiveness used in all three experiements is performance on mathematics achievement tests. Nicaragua provides the most comprehensive evaluation of radio education to date. In Nicaragua radio was used for grades 1-4 within the formal classroom much as is proposed for the Dominican Republic. Given the similarities in culture, curriculum, and use of radio the Nicaraguan

results have the highest external validity with respect to the Dominican Republic.

The Nicaragua experiment yielded the following important findings (Searle and Galda, 1980):

* experimental groups using radio did significantly better than control groups both in terms of amount of learning and average level of post-test mathematics scores;

* urban-rural learning differences were smaller among schools in the experimental group than among schools in the control groups;

* the higher learning demonstrated by students in the experimental group was retained over the summer break as pre-test mathematics scores for students returning to school were higher among students having had prior radio experience.

The Nicaraguan results are corroborated by the results from Thailand (Galda, 1984) which again demonstrate higher mathematics achievement test scores among experimental than control groups. Thailand also confirms that radio education resulted in greater learning improvements outside than inside major urban areas.

Another experiment involving radio education is currently taking place in Barahona in the Dominican Republic. This project, labeled RADECO, uses radio for language and mathematics instruction in a non-formal setting. Post-test results for the first year of that experiment demonstrate significantly higher average achievement scores (mathematics plus language) for the experimental group (54%) than the control group of traditional, formal education (23%) in spite of the superior qualifications of instructional personnel in the formal setting.

Taken together, these experimental results provide convincing evidence that radio-education in a formal setting would increase mathematics achievement among children in grades 1-4 in the traditional, formal school setting in the Dominican Republic. There are, however, some factors in the Dominican setting which are likely to affect the magnitude of the increase in mathematics learning that would result from the introduction of radio education. These factors are:

* The area in which radio education will be introduced in the Dominican Republic is somewhat more highly urbanized than was true in Nicaragua; given that differences in urban learning (measured by post-test scores) were smaller than differences in rural learning between experimental and control groups, one might expect learning gains in the Dominican Republic to be lower than the average for Nicaragua.

* Radio programs were adapted to the traditional Nicaraguan curriculum via an elaborate feedback procedure; to the extent the Nicaraguan and RADECO mathematics curricula differ from the traditional Dominican and radio does not simply replace the traditional classroom instruction, learning gains may be lower.

* Preliminary results from the RADECO experiment demonstrate higher post-test achievement scores among the experimental group in spite of their lower quality instructional personnel; the higher quality instructional personnel in the schools where the new project will be implemented argue for larger mathematics achievement gains and higher post-test scores than found among the experimental group in RADECO.

Finally, one should note that while the evidence that radio-education can increase mathematics achievement is consistent and positive, the same cannot be said for other masures of effectiveness. The Nicaragua study concluded that radio-education had very little, if any, impact on dropout, attendance, and failure rates (George, 1980). There is some evidence that this neglible impact is a result of teachers responding to improved

achievement scores by setting higher standards for passing (Jamison, 1980). In the absence of scores on standardized achievement tests, many developing countries use dropout, attendance, and enrollment rates as measures of effectiveness. If teachers respond to higher achievement in the Dominican Republic as in Nicaragua, one should not expect changes in these commonly-used measures of effectiveness in the Dominican Republic.

EVALUATION

Earlier four alternative methodologies were presented for evaluating the desireability of undertaking an investment in radio-education--(i) cost-benefit analysis, (ii) ratios of marginal effectiveness to marginal cost for alternative means of increasing mathematics achievement, (iii) ratios of marginal effectiveness to marginal cost for alternative means of increasing more comprehensive measures of achievement, and (iv) tradeoffs between improving mathematics instruction and attaining other educational objectives. It was concluded that for the purposes of this analysis, methodologies (ii) and iv) are the only feasible ones.

Cost-Effectiveness

To analyze cost-effectiveness of radio-education requires comparison with alternative means of increasing mathemacics achievement. While we now have reasonably good data on the cost and effectiveness of radio education, the same cannot be said for other alternatives such as increasing teacher quality, curriculum revision, and improving and providing educational materials.

The Nicaragua study demonstrated gains in post-test mathematics achievement ranging from one percent at grade four to sixty percent at grade one (Searle and Galda, p. 127), for an average gain of twenty-five percent over all grades and years. Earlier, the annualized increase in cost for radio education was estimated to be at most 3.0 percent. Thus, the ratio of effectiveness to cost can be expressed as follows:

$$\frac{\text{percent gain in learning}}{\text{percent increase in cost}} = \frac{25\%}{3.0\%} = 8.3$$

The resulting number 8.3 can be interpreted as the elasticity of mathematics achievement with respect to input costs. While it is difficult to make direct comparisons between this and other production elasticities, the absolute magnitude of this elasticity is very high relative to that found in most production studies, including studies of human capital production. Deleting grade four results, which may be partly explained by extenuating circumstances, the resulting ratio of effectiveness to cost would be higher still.

The results to date for Thailand are not quite so impressive, but they have shown an average increase in mathematics achievement over grades and years of 10.3%. If the Dominican project were to achieve this same learning gain, the ratio of effectiveness to cost would be 3.4, smaller than 8.3 but still a high production elasticity.

Finally, preliminary results for the Dominican RADECO experiment in non-formal radio education show a 134 percent increase in combined linguistics and mathematics achievement. These data are not directly

comparable nor as reliable as those for Nicaragua and Thailand, but they are suggestive of the fact that radio-education in the Dominican Republic would be as cost-effective as has been found in other countries.

Comparable data on effectiveness and costs for alternative means of improving mathematics achievement are hard to come by. The only reliable study is one conducted by Jamison, Searle, Galda, and Heyneman (1980) of providing mathematics textbooks in Nicaragua. That study concluded that both textbooks and radio-education contribute to mathematics learning, but learning under radio-education was significantly larger. In addition, the costs of radio-education were lower than the costs of textbook production and distribution. As a result, one can conclude that radio-education is more cost-effective than textbook production and distribution.

Another alternative to radio-education and textbook production and distribution is improving teacher quality. There are no data to suggest the quantitative impact of changes in teacher quality on mathematics achievement. We can, however, at least determine how much improvement in teacher quality could result from spending an amount equal to the annualized recurrent costs associated with radio-education. The increase in spending associated with radio-education amounts to $0.81 per student or an aggregate $343,440 in recurrent expenditures for the anticipated 424,000 students.

The unit costs per graduate of teacher education are currently US$815 (at market exchange rate) and approximately 660 certificated teachers are graduated each year. With an additional $343,440 per year, the supply of certificated teachers could increased by 421 or 63 percent per year. This

grouwth in teacher supply would over a ten year period (with a ten percent attrition rate) increase certificated teachers in the country from the present 55 percent to 70 percent of all teachers.*

Tradeoff Between Quality and Access

Another means of evaluating the desireability of improving quality in mathematics education is to determine the opportunity cost or tradeoff in terms of access. At present, 143 thousand students in the Cibao-Oriental subregion are enrolled in elementary education. A proposal has been made to improve access through school rehabilitation and construction. Radio-education funds could in principle instead be used for this purpose.

The magnitude of radio-education funds potentially available for school construction can be determined in two ways. First, AID's proposed budget for radio-education is $1.9 million; hence, this figure can be regarded as the funds AID could instead allocate to school construction. Second, the annualized recurrent costs of radio-education including both AID funding of start-up costs and GODR funding of recurrent costs are $343,440. Assuming a 7.5% discount rate, the present value of these radio-education outlays is $3.8 million; hence, this figure can also be regarded as the funds AID and the GODR could jointly allocate to school construction.

The PID anticipates a cost of about RD$14,000 per classroom which (assuming the official 1:1 exchange rate) suggests AID funding of

*This calculation presumes (i) no growth in total stock of teachers, and (ii) present rate of production of certificated teachers only covers attrition in already existing stock of certificated teachers. These assumptions hold other things constant so the gain in proportion of certificated teachers is solely attributable to increased number of graduates.

radio-education could instead be used to construct an additional 136 classrooms, which assuming double-shifts and an average class size of 57.5 (the actual ratio of students to teachers in 1980-81) would provide schooling opportunities for an additional 15,640 students. This in turn would permit an increase in primary school enrollments in the Cibao-Oriental of approximately eleven percent. Similarly, joint AID and GODR funding of radio education could instead be used to construct 271 classrooms, assuming the GODR could in fact borrow funds for school construction at a 7.5% real rate of interest. Using the same assumptions given above, an additional 271 classrooms would permit an increase in primary school enrollments in the Cibao-Oriental of approximately 21.8 percent; alternatively, national primary school enrollments could be increased about three percent.

These computations regarding the opportunity cost of radio-education in terms of access denied primary school age children are based on strong assumptions. In particular, the official rather than market exchange rate is used in calculating USAID contributions in terms of Dominican currency. Were the market exchange rate of 1:2.70 used instead, the computed opportunity cost of radio-education would be larger. Irrespective of the assumptions, the numbers given here do visibly demonstrate the nature and magnitude of the tradeoff involved.

And, while these figures do not imply one objective is better than another, they do give decisionmakers a clear indication as to the magnitude of the tradeoffs involved. Whether or not radio-education should be funded depends in part on the priorities of the decisionmakers involved.

CONCLUSIONS

This analysis of the cost-effectiveness of the proposed radio-education project to teach mathematics in the Dominican Republic first through fourth grade classrooms provides no definitive answers. Evidence from other countries suggests radio-education is more effective than the traditional classroom in teaching mathematics. This is also likely to be true for the Dominican Republic, but the effectiveness of radio depends on its continued use. And actual teacher use of radio will depend on the effectiveness of teacher training in radio-education and, more importantly, the commitment of the Secretariat to radio-education.

The costs of radio-education include relatively high startup costs and relatively low recurrent costs. The startup costs can be annualized and added to recurrent costs to yield a single measure of the costs of radio-education. The resulting analysis shows that marginal costs are low, and average costs are low if the program is expanded to cover a large number of students as scheduled and if the program is not prematurely abandoned once AID funding is ended.

In and of itself, the elasticity of mathematics learning with respect to inputs appears to be large. Even changes in assumptions regarding the size and duration of the program do not change this conclusion. Furthermore, radio-education is a more cost-effective means of improving mathematics achievement than textbook production and distribution. In addition, the costs of some alternative means of improving mathematics instruction, such as

increasing teacher quality, are so high that they are unlikely to prove more cost-effective than radio-education.

Radio-education is one means of improving the quality of elementary education, an objective of both AID and the GODR. Another objective is that of improving access to elementary education through the construction of school buildings. The tradeoff analysis provided here reveals that resources allocated to radio-education could be used instead to significantly improve access. That tradeoff may be a more important factor than cost-effectiveness in deciding to fund radio-education.

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