A NOTE ON THE MEASUREMENT OF SPILLOVERS OF AGRICULTURAL RESEARCH RESULTS

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ABSTRACT

Three measures of agricultural research spillovers considered entail estimates based on (1) level of agricultural research expenditures, (2) marginal products of agricultural research and extension expenditures, and (3) marginal products of agricultural research and extension expenditures weighted by the level of agricultural research expenditures.

The methods produce diverse spillovers but results indicate that spillovers generally exceed regional benefits attributable to a region's investment in agricultural research and extension. Also, ratios of spillovers to regional benefits exceed ratios of federal to state expenditures on agricultural research suggesting potential social benefits from additional financial support of agricultural research by the federal government.

INTRODUCTION

This is an addendum to the article "Interregional Transfer of Agricultural Research Results: The Case of the Northeast," presented on pages 19-30 of this volume and this note elaborates on the measurement of spillovers. In the article a production function which includes conventional inputs and variables to reflect the own region and outside-the-region investments in production-oriented agricultural research is used to estimate the contribution of research to agricultural production. Region by region the coefficient of the variable representing outside-the-region investment in production-oriented agricultural research is weighted by the state and federal expenditures on production-oriented agricultural research outside-the-region to obtain the average annnual spill-ins for the region being considered. For example, for the Northeast the sum of the state and federal expenditures on production-oriented agricultural research in the other nine regions is the outside-the-region expenditure on agricultural research. This is done for each of the ten agricultural production regions and the sum is $5,857.45 million presented in Table 2 on page 26 and in Table 1 of this note. This figure is the sum of the spill-ins into the ten agricultural production regions and is also the sum of the spillovers or spill-outs among the ten agricultural production regions.

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Identifying and measuring the spill-ins by regional origin is a difficult problem. There are several alternative ways of doing this depending upon what assumptions one is willing to make. On pages 26-28 the allocation of spill-ins to originating regions was made on the basis of average funding of production-oriented agricultural research in the regions as measured by the state and federal expenditures on production-oriented agricultural research in the production regions. In subsequent paragraphs this method will be further elaborated upon and contrasted with an allocation method based upon the regional marginal products of investment in production-oriented agricultural research and a method based on the regional marginal products weighted by the average funding of production-oriented agricultural research in the regions.

SPILLOVERS ALLOCATION BASED ON AVERAGE FUNDING

The spillovers in Table 2 on page 27 and Column 3 in Table 1 are based on average funding of agricultural research as measured by the average research expenditures for the 1977-1981 period. The expression for computing the spillovers is equation (12) on page 27 and repeated here as:

$$(1)\quad S_i = \sum_{k \neq i} SI_k \left(R_i / \sum_{i \neq k} R_i\right)$$

where S_i is the value of spillover benefits from agricultural research expenditures in region i,

R_i is the level of research expenditures in region i,

$\sum_{i \neq k} R_i$ is the level of research expenditures in all regions that generate spillovers into region k, and

SI_k is the total of spill-ins of agricultural research benefits into region k.

To illustrate the procedure let the k^{th} region be the Northeast. SI_k = $368.88 million which is the estimated spill-ins into the Northeast. This total of spill-ins needs to be allocated as spillovers from the other nine agricultural production regions. $\sum_{i \neq k} R_i$ is the sum of expenditures on production-oriented agricultural research in the other nine regions. Since we are considering an average over a five year period, 1977-1981, then $\sum_{i \neq k} R_i$ is a sum of five year averages and R_i is the average expenditure on production-oriented agricultural research in the i^{th} region for the 1977-1981 period. Hence:

$$SI_k \left(R_i / \sum_{i \neq k} R_i\right)$$

is an estimate of the spillover from region i to region k. This can be done for each of the nine agricultural production regions to determine the magnitudes and origins of spill-ins into the k^{th} region (Northeast in this case). The entire procedure can be repeated for the spill-ins (SI)

Table 1: Regional Estimates of Average Annual Benefits Average Annual Spill-Ins, and Three Alternative Measures of Average Annual Spillovers for Production-Oriented Agricultural Research and Extension, 1977-1981 Expressed in 1972 Dollars

Region	Avg Ann Reg Benefits	Avg Ann Spill-Ins	Avg Ann Spillover Based on Avg Fund	Ratio of Avg Ann Spillover Based on Avg Fund to Reg Benefits	Avg Ann Spillover Based on Reg Marginal Products	Ratio of Avg Ann Spillover Based on Reg Marg Product to Reg Benefits	Avg Ann Spillover Based on Marg Product Weighted by Avg Fund	Ratio of Avg Ann Spillover Based on Marg Product Weighted by Avg Fund to Reg Benefits	Ratio of Fed-State Expenditures
	(Million Dollars)	(Million Dollars)	(Million Dollars)		(Million Dollars)		(Million Dollars)		
Northeast	254.23	368.88	839.04	3.30	269.44	1.06	399.04	1.57	1.03
Lake States	407.13	591.12	533.66	1.31	626.75	1.54	607.93	1.49	.67
Corn Belt	905.05	1,314.16	654.73	.72	948.90	1.05	1,097.32	1.21	.90
Northern Plains	482.05	699.31	449.33	.93	902.04	1.87	731.01	1.52	.56
Appalachian	309.87	449.29	685.00	2.21	363.16	1.17	451.46	1.46	.90
Southeast	292.02	423.49	663.98	2.27	369.02	1.26	443.13	1.52	.53
Delta	215.02	308.16	442.16	2.06	421.74	1.96	336.89	1.57	.64
Southern Plains	365.28	530.00	335.64	.92	837.62	2.29	506.06	1.39	.69
Mountain	312.42	453.26	544.91	1.74	515.46	1.65	510.74	1.63	.72
Pacific	495.86	719.78	708.99	1.43	603.32	1.22	773.87	1.56	.32
Aggregate	4,038.93	5,857.45	5,857.45	1.45	5,857.45	1.45	5,857.45	1.45	.68

in each of the ten agricultural production regions. The total spillovers (S_i) for a particular agricultural production region are obtained by summing its spillovers into the other nine agricultural production regions. The allocation procedure, of course, constrains the total of spillovers to be equal to the total of spill-ins. The estimates of the regional spillovers using this procedure and the ratio of spillovers to the regional benefits attributable to a region's own investment in production-oriented agricultural research and extension are presented in Columns 3 and 4 respectively in Table 1, which are the same as Columns 4 and 5 in Table 2 on page 26.

This procedure allocates the spillovers solely on the basis of relative magnitude of funding of production-oriented agricultural research among the agricultural production regions. It does not allow for any productivity differences among regions in terms of their capability of producing spillovers. Underlying this is the assumption that an additional dollar invested in production-oriented agricultural research will produce the same spillovers regardless of the production region in which it is invested. This, of course, is a questionable assumption and is a weakness of this particular allocative procedure.

SPILLOVERS ALLOCATION BASED ON MARGINAL PRODUCTIVITY

Taking into account differences in research productivity when allocating spill-ins is intuitively appealing. One rather straightforward and simple procedure is to allocate the spill-ins to originating agricultural production regions on the basis of the marginal products presented in Column 1 of Table 2 on page 26. These are marginal products of a region's own investment in production-oriented agricultural research and extension. In using these marginal products the assumption is being made that the marginal productivity of generating spillovers is the same as the marginal productivity of generating own-regional benefits.

To illustrate the use of the marginal products in allocating spill-ins and generating the regional spill-overs, consider a $10 marginal investment in production-oriented agricultural research. By allocating one dollar to each of the ten agricultural production regions, the estimated regional marginal products are those given in Column 1 in Table 2 on page 26. The marginal product of the $10 investment is the sum of the regional marginal products which is $58.72. The proportion that each regional marginal product is of the sum of the marginal products for the ten agricultural production regions may be used to estimate regional spillovers. For example, the marginal product for the Northeast is $2.72 which is .046 of $58.72. Thus, 4.6 percent of the total spill-ins of $5,857.45 million is allocated to the Northeast which yields a spillover of $269.44 million. The annual spillovers and ratios of annual spillovers to regional benefits using this allocative scheme are given in Columns 5 and 6 in Table 1. For some regions the spillovers generated by this procedure differ substantially from spillovers based on average funding of production-oriented agricultural research. Regions with relatively lower levels of agricultural research funding but relatively high marginal products have larger spillovers using this procedure while regions with relatively high levels of funding but relatively low marginal products have considerably smaller spillovers. The Northeast is a striking case because of its low marginal product, its spillovers are considerably lower using this allocative procedure.

There are at least two shortcomings of using only the marginal products to generate regional spillovers. First, the estimated marginal products pertain to within-region effects of a region's own investment in production-oriented agricultural research and extension and the marginal productivity of generating spillovers into other regions may differ from the marginal productivity of generating own-region benefits. The analytical framework used to analyze the interregional transfer of agricultural research results did not yield estimates of marginal products of generating regional spillovers and it is doubtful that this is even possible. Second, using the marginal products for allocation of spill-ins to generate spillovers does not take into consideration the level of funding and hence the amount of regional resources available for production-oriented agricultural research does not affect the magnitude of spillovers generated. Thus the procedure will generate the same spillovers for two regions if both have the same marginal product even though one region may have considerably more research resources in terms of research funds.

SPILLOVER ALLOCATIONS BASED ON WEIGHTED MARGINAL PRODUCTS

A compromise allocative procedure is to use marginal products weighted by the level of funding for production-oriented agricultural research. Again the only estimates of marginal products available within the framework used are those in Column 1 of Table 2 on page 26 and these pertain to the marginal productivity of a region's own investment in production-oriented agricultural research and extension. These marginal products can be weighted by the average expenditures on production-oriented research in each of the agricultural production regions.

The computational procedure is similar to the one based on average funding. Equation (1) can be modified by letting R_i be the marginal product for region i weighted by the level of expenditures on production-oriented agricultural research in region i. With this modification and following the steps outlined in the section concerned with allocating spillovers based on average funding, the spillovers in Column 7 of Table 1 and the ratio of annual spillovers to regional benefits in Column 8 of Table 1 were estimated. The spillovers generated by this procedure differ substantially from the spillovers generated by the other two procedures. For several of the regions the estimates based on this procedure are between the estimates generated by the other two procedures. However, for the Cornbelt and Pacific regions the spillovers based on weighted mar-

ginal products are larger than the estimates based on the two other allocative procedures. For the Delta and Mountain regions the estimates are lower than those obtained from the other two procedures. The ratios of spillovers to regional benefits are all greater than one indicating that spillovers from all regions exceed the regional benefits attributable to a region's own investment in production-oriented agricultural research and extension. Furthermore, the ratios exhibit a smaller range and do not vary as much as do the ratios based on spillovers generated by the two other allocative procedures.

An appealing feature of this allocative procedure is that it takes into account both the level of funding and the marginal productivity of funds invested in production-oriented agricultural research and extension in each of the regions. A critical underlying assumption is that the marginal product of a region's investment in production-oriented agricultural research and extension is applicable to the generation of spillovers from the region. This is not contradictory to common sense but a priori there is no reason why these two marginal products should be the same. This needs to be recognized as a potential weakness of this procedure and one which may not be easily alleviated.

CLOSING REMARKS

Three alternative methods for allocating spillovers of agricultural research results among the ten agricultural production regions of the U.S. were considered. The three procedures resulted in substantial differences in the estimates of regional spillovers. The sensitivity of the magnitudes of spillovers to the allocation procedure suggests that caution needs to be exercised in interpreting the magnitude of specific regional spillovers.

Some of the general conclusions made on pages 28 and 29 are supported by all three allocative procedures. First, for most agricultural production regions the spillovers exceed the regional benefits attributable to a region's own investment in production-oriented agricultural research and extension. Second, the ratio of spillovers to regional benefits exceeds the ratio of federal to state expenditures on production-oriented agricultural research in all ten agricultural production regions. These suggest that regional benefits diverge from social benefits and action by federal government in terms of funding for agricultural research would lead to a more nearly optimal level of investment in agricultural research.

Finally, the differences in estimates of regional spillovers suggest that there are some challenging research opportunities to improve the measurement of the impacts of agricultural research and the spillovers of agricultural research results.

REFERENCES

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