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New Econometric Evidence on Agricultural Total Factor Productivity Determinants: Impact of Funding Sources

by

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Abstract: This paper examines the impact of public and private agricultural research and extension on agricultural total factor productivity at the state level. We test the hypothesis that the composition of agricultural experiment station funding—share of funding from impact of federal competitive grants and contracts and from federal formula and state government appropriations---affects the productivity of public agricultural research using data for the 48 contiguous states over 1970-1999. Our results show not only that sources of funding matter, but that an increase in federal competitive grant funding at the expense of federal formula funding would lower the productivity of public agricultural research. Furthermore, our simulation results show that a few states would most likely gain by a re-allocation of federal formula to grant and contract funding but most would lose.

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New Econometric Evidence on Agricultural Total Factor Productivity Determinants: Impact of Funding Sources

By all accounts, U.S. agriculture has had an amazing rate of total factor productivity increase in the post-World War two era. Using a newly constructed data set of state agricultural accounts, Ahearn, Yee, Ball, and Nehring (1998) report an average annual rate of aggregate agricultural TFP growth of 1.94 per cent over 1948 to 1994. Over the period 1980 to 1999, the rate is approximately three percent per year. Jorgenson and Stiroh (2000), using their own data sets for 37 sector of the U.S. economy over 1958 to 1999, show that the U.S. agricultural sector ranks third among 37 sectors in TFP grow. Furthermore, U.S. agriculture accounts for 21 percent of aggregate U.S. TFP growth over this time period but only two percent of GDP. Acquaye, Alston, and Pardey (2003) provide another perspective on U.S. agricultural TFP growth over the period 1948 to 1991.

Prior studies that have examined the impacts of public agricultural research and extension on agricultural productivity using regional or state level data include Griliches (1963), Huffman and Evenson (1993), Alston, Craig and Pardey (1998), and Yee, Huffman, Ahearn, and Newsome (2002). All of these studies have found positive and significant impacts of public agricultural research on agricultural productivity. The empirical evidence for public extension is somewhat mixed, some showing a positive effect and others not showing any effect. The work by Huffman and Evenson is the only one to include private agricultural R&D as a determinant of TFP for the agricultural sector. Although they found that private agricultural research had a positive impact on TFP, excluding it did not have much impact on the impact of public agricultural research on TFP.

Although the U.S. agricultural experiment station system has over 1970-1999 had modest dependence on federal grants and contracts, some states, e.g., Indiana, Oregon, and Wisconsin, have obtained more than 20 percent of their experiment station funds from these sources over the long run. In contrast, the experiment stations in New Hampshire, Vermont, and West Virginia have depended heavily upon federal formula funds—obtaining more than 45 percent of their funds from this source. Huffman and Just (1994) is the only study to examine specifically the effect of different public agricultural research funding sources on state agricultural productivity. They found that formula funding was more productive than competitive-grant funding for impacting state agricultural total factor productivity. The reason that they gave was possibly owing to high transaction costs for grant funds and misallocations of pork barrel funding.

This current paper presents new econometric evidence of the impacts of public agricultural research, private agricultural R&D, and public extension on state agricultural productivity. In particular, we test hypotheses about the impacts of federal competitive grants and contracts and federal formula and state government appropriations on the productivity of public agricultural research and undertake some simulation results associated with reallocating federal formula funds to federal grants and contracts. We use new annual state productivity data set constructed by the USDA (see Ball, 2003), new public agricultural research data by Huffman et al., new private R&D data associated with patenting by Johnson and Brown (2002), and new extension data by Ahearn, Lee, and Bottom (2002). We show that sources of SAES funding matter for determining the impact of public agricultural research funds on state agricultural TFP. Also, our simulation results show that a few states would gain by a re-allocation of federal formula to grant and contract funding but most would lose.

The TFP Model

Assume a state aggregate production function with disembodied technical change where Q is an aggregate of all types of farm outputs from farms within a state aggregated into one output index, A(RPUB, RPRI, EXT) is the associated technology parameter, and F( ) is a well-behaved function. K is state aggregate quality-adjusted physical capital input, L is state aggregate quality-adjusted labor input, and M is state aggregate quality-adjusted materials input. The technology parameter A( ) is a function of state public agricultural research capital (RPUB), private agricultural research capital (RPRI), and public agricultural extension capital (EXT). The state aggregate production function is then:

(1) $Q = A(RPUB, RPRI, EXT)\, F(L, K, M)$.

Now define state total factor productivity (TFP) as:

(2) $TFP = Q/F(L, K, M) = A(RPUB, RPRI, EXT)$.

Taking natural logarithms of both sides of equation (2) and adding a random disturbance term μ, we have

(3) $\ell n\, TFP = \ell n\, A(RPUB,RPRI,EXT) + \mu$.

For this study, we want to test that both the impact of the level of the public agricultural research stock and its composition, e.g., shares due to major funding sources, impact on state aggregate total factor productivity (also, see Huffman and Just 1994). The funding shares are interacted with the public agricultural research stock. Hence, the embellished version of the state agricultural TFP equation is:

$$
\begin{aligned}
(4)\ \ell n\, TFP = {} & \beta_1 + \beta_2\, \ell n\, RPUB + \beta_3\, [\ell n\, RPUB]SFF + \beta_4\, [\ell n\, RPUB](SFF)^2 \\
& + \beta_5\, [\ell n\, RPUB]GR + \beta_6\, [\ell n\, RPUB](GR)^2 + \beta_7\, \ell n\, EXT + \beta_8\, [\ell n\, PRUB]\, \ell n\, EXT \\
& + \beta_9\, \ell n\, RPUBSPILL + \beta_{10}\, \ell n\, RPUBSPILL + \beta_{11}\, \ell n\, RPRI + \mu
\end{aligned}
$$

where SFF is a state's share of SAES funding from federal formula and state government appropriations (i.e., programmatic funding), GR is a state's share of SAES funding from federal grants, contracts, and cooperative agreements (i.e., federal grants and contracts), RPUBSPILL is a state's public agricultural research capital spillin. The elasticity of state agricultural total factor productivity with respect to RPUB, RPUBSPILL, EXT, and RPRI is:

$$(5) \quad \frac{\partial \ell n TFP}{\partial \ell n RPUB} = \beta_2 + \beta_3 \, SFF + \beta_4 (SFF)^2 + \beta_5 \, GR + \beta_6 (GR)^2 + \beta_8 \, \ell n \, EXT,$$

$$(6) \quad \frac{\partial \ell n TFP}{\partial \ell n RPUBSPILL} = \beta_9,$$

$$(7) \quad \frac{\partial \ell n TFP}{\partial \ell n EXT} = \beta_7 + \beta_8 \, \ell n \, RPUB,$$

$$(8) \quad \frac{\partial \ell n TFP}{\partial \ell n RPRI} = \beta_{11}.$$

The elasticity of state agricultural productivity (TFP) with respect to a charge in the state's own public agricultural research capital, holding the funding composition—SFF and GR—constant, is given in equation (5). The elasticity of a state's agricultural TFP with respect to the public agricultural research capital spillin is displayed in equation (6). The elasticity of state agricultural TFP with respect to public agricultural extension input is given by equation (7). Its size is expected to depend on the size of a state's own public agricultural research capital (ℓn RPUB). In particular, if state public agricultural research and extension are compliments, β_8 will be positive, or if they are substitutes, it will be negative. The elasticity of state agricultural TFP with respect to private agricultural research capital is given in equation (8).[1]

The unique feature of equation (4) is that the productivity of a state's public agricultural research stock depends on and is proportional to the composition of funding sources---SFF and GR:

$$(9)\quad \frac{\partial \ell nTFP}{\partial SFF} = (\beta_3 + 2\beta_4\,SFF)\,\ell n\ RPUB,$$

$$(10)\quad \frac{\partial \ell nTFP}{\partial GR} = (\beta_5 + 2\beta_6\,GR)\,\ell n\ RPUB.$$

Equations (9) and (10) show how composition of public agricultural research funding affects state agricultural TFP. The proportional change of state agricultural TFP due to a one percentage-point change in SFF—a state's share of SAES funding from federal and state programmatic funding---is given in equation (9). Likewise, the proportional change of state agricultural TFP due to a 1 percentage-point change in GR—a state's share of SAES funding from federal grants and contracts—is given by equation (10). The inclusion of squared terms in these equations [$(SFF)^2$, $(GR)^2$] permits us to examine potential nonlinear impacts of funding composition on the productivity of public agricultural research at the state level.

We test the null hypothesis that SAES funding composition has no impact on state agricultural TFP; i.e., discoveries from all types of funds---federal formula and state government appropriations, federal grants and contracts, and "other" funding---are equally productive for causing technical change leading to growth in state agricultural TFP. This is the joint null hypotheses: $\beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$. If this hypothesis is accepted, then the state agricultural TFP equation, equation (4) will be of a traditional form. If, however, this hypothesis is rejected, a public agricultural research policy that changes both the size of state public's agricultural research capital and its composition, as reflected in SSF and GR, will have impacts on state agricultural TFP. The total impact of a marginal change of ℓn RPUB, SFF, and GR on TFP is:

$$(11)\quad d\,\ell nTFP = [\partial \ell n\,TFP/\partial \ell n\,RPUB]\,d\,\ell nRPUB + [\partial \ell n\,TFP/\partial SFF]\,d\,SFF$$
$$+ [[\partial \ell n\,TFP/\partial \ell n\,GR]\,d\,GR.$$

However, if changes are larger than marginal ones, taking differences between beginning and ending values of ℓn TFP gives results that are more reliable. First, evaluate equation (4) at the sample mean values for each state to establish a baseline. Second, define new values of the public R&D policy variables as $\ell n\ RPUB' = \ell n\ RPUB^{\circ} + \Delta\ \ell n\ RPUB$, $SFF' = SFF^{\circ} + \Delta\ SFF$, and $GR' = GR^{\circ} + \Delta GR$ and use these values to compute a new estimate of ℓn TFP. Third, compute the difference between new and baseline estimates:

$$(12)\quad \Delta \ell n\ TFP = \ell n\ TFP' - \ell n\ TFP^{\circ} = \beta_2\ \ell n\ RPUB' + \beta_3 (\ell n\ RPUB')\ SFF'$$

$$+ \beta_4 (\ell n\ RPUB')(SFF')^2 + \beta_5 (\ell n\ RPUB')\ GR' + \beta_6 (\ell n\ RPUB')\ (GR')^2$$

$$+ \beta_8 (\ell n\ PRUB')\ \ell n\ EXTF^{o} - \beta_2\ \ell n\ RPUB^{\circ} - \beta_3 (\ell n\ RPUB^{\circ})\ (SFF^{\circ})$$

$$- \beta_4 (\ell n\ RPUB^{\circ})\ (SFF^{\circ}) - \beta_5 (\ell n\ RPUB^{\circ})\ (GR^{\circ})^2 - \beta_8 (\ell n\ PRUB^{\circ})\ \ell n\ EXT^{o}$$

With the use of public funds allocated to agricultural research having alternative uses, it is interesting to ask what the social rate of return on these investments is. For example, if one million dollars of additional public funds is invested today in an average state, it will have benefits distributed over the next 34 years in this state and other states, which are recipient of spillin effects. By setting the net present value of the benefits equal to the cost, we can solve for the internal rate of return. When benefits are in constant prices, we obtain a real rate of return. The internal rate of return (r) computation is:

$$(13)\quad 1 = [\frac{\partial \ell nTFP}{\partial \ell nRPUB}\ Q/T + (n-1)\ \frac{\partial \ell nTFP}{\partial \ell nRPUBSPILL}\ Q/S]\ \sum_{0}^{m} w_i [1/(1+r)^t]$$

where Q is the sample mean value for state agricultural output, T is the sample mean for a state's own public agricultural research capital, (n -1) is the number of state into which agricultural research spillin effects flow. S is the sample mean of the public agricultural research spillin capital, w_is are timing weights used to create the stock of public agricultural research, and r is the internal rate of return including impacts of R&D spillover (see Yee et al. 2002, p. 191).

The Data and Results

The data set is a panel of state aggregates, 1970 to 1999, for 48 contiguous states, or 1,440 observations. We use the new annual state total factor productivity (TFP) data obtained from the USDA (see Ball 2003). The data on public agricultural research expenditures with a productivity focus were prepared by Huffman *et al*. The science of constructing research stock variables from expenditures remains in its infancy (Griliches 1979, 1998). Although a few researchers have included many lags of public agricultural research expenditures without much structure, e.g., Alston, Craig, and Pardey (1998), this generally asks too much of the data. Hence, by imposing priors about the share of timing weights, we reduce the demands on the data to identify parameters.

Griliches (1998) concludes that R&D most likely has a short gestation period, then blossoms, and eventual obsolescence. We approximate these patterns with a gestation period of 2 years during which the impacts are negligible, impacts are then assumed to be positive over the next 7 years and are represented by increasing weights, followed by 6 years of maturity during which weights are constant, and then 20 years of obsolescent with declining weights. This weighting pattern is what is known as trapezoid-shaped time weights, and they are used to construct public agricultural R&D stocks (see figure 1).[2] Although regional grouping of states in which spillin effects might occur are arbitrary, we choose to define spillovers using the geo-climate sub-region map of Huffman and Evenson (1993, p. 195).[3]

To construct state private agricultural R&D capital, we apply similar shaped but shorter in length timing-weights. The total length is 19 years, which is consistent with U.S. patent length. The number of agricultural patents issues (see Johnson and Brown 2002) is used to approximate private agricultural R&D in each state. A measure of public agricultural extension capital is constructed from staff days of agricultural and natural resource extension activity (Ahearn, Lee, and Bottom 2002). We assume that one-half of the impact of extension occurs in the current year, and the balance is distributed through declining weights over the next four years. See table 1 for definition of symbols and summary definitions.

Interaction terms between a state's public agricultural research stock were created with the funding shares---share of the SAES funds from federal formula and state government appropriations (SFF) and from federal grants and contracts (GR). However, given that the public agricultural research stock was derived using 34 years of data we lagged SFF and GR 12 years to place them roughly at the weighted mid-point of the total lag length. We also created an interaction term between the stock of public agricultural research and stock of agricultural extension.

Data for 48 states, 1970-1999, giving a total number of 1,440 observations, are pooled together and used to fit equation (4). Table 2 displays least squares estimates of the parameters of the model. All of the coefficients are significantly different from zero at the 1 percent level. The R^2 is 0.52, and a joint test of no explanatory power of the equation gives a sample F-statistic of 140. This test has 15 and 1,424 degrees of freedom, and the tabled F-value is about 2.0 at the 1 percent significance level. Hence, the state aggregate TFP model has significant explanatory power.

Using sample mean values of the data, the elasticity of TFP with respect to RPUB, RPUBSPILL, EXT, and RPRI is 0.231, 0.123, 1.267 [=1.364 – 0.075(1.292)], and 0.113, respectively. These elasticities are all positive. Public agricultural research capital and extension capital interact negatively, i.e., the estimate of β_8 is -0.075. Hence, public agricultural research and extension are substitutes. The coefficients of the variables describing the composition of SAES agricultural research funding, $\$_3$, $\$_4$, $\$_5$, and $\$_6$ are each significantly different from zero individually at the 1 percent level. Also, the joint test of no funding composition effects, i.e., $\beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$, is soundly rejected. The sample F-statistic for this joint test is 16.8, and the critical value of the F-statistic with 4 and 1424 degrees of freedom at the one percent significance level is about 3.4. Hence, the productivity of the state public agricultural research capital is affected significantly by composition of funding, i.e., all types of funding are not early productive with respect to impacts on state agricultural productivity.

To gain insight, we graph the relationship between MRn TFP/MSFF against SFF and MRn TFP/MGR against GR implied by the estimated coefficients. They are displayed in figures 2 and 3. The marginal impact of SFF on Rn TFP has an inverted U shape, which peaks at 0.702, and of GR on Rn TFP has a U shaped (see figure 3), which has a minimum at 0.237. In contrast, the sample mean value of SFF_{t-12} is 0.75 and of GR_{t-12} is 0.096. Furthermore, at the sample mean, the evaluation of equation (9) gives a marginal effect of changing SFF on Rn TFP of -0.124 [= -0.073 + 2(0.154)0.751] 16.29 and of GR on Rn TFP of -0.701 [= -0.073 + 2 (0.154)0.096] 16.129. *Hence, an incremental re-allocation of funds from SFF to GR, i.e., a decline in the share of programmatic funding offset by an equal increase in federal grants and contracts, will lower Rn TFP*.[4]

Simulation

Although any particular choice of a scenario to simulate is arbitrary, CSREES has proposed significant increases in federal competitive grant funding. Congress, however, has been unwilling to make dramatic changes (Committee on Opportunities in Agriculture 2003). One possible scenario, however, would be to reduce total federal SAES funding from federal formula funding (SFF1) by 10 percentage points, and, hence, reduce SFF ( )SFF =)SFF1). These funds then could be re-allocated to the USDA's competitive grant programs, e.g., to the National Research Initiatives, i.e., to increase GR. We assume that these funds actually go to the state agricultural experiment stations.[5] Two things are of significant interest, the long run impact on SAES funding (and the stock of public agricultural research) and on state agricultural TFP.

To implement this policy at the state level, we assume that each state would have their baseline federal formula funds rescaled by 13/23 and their federal grants and contracts funding would increase by a factor of 2.04 times the baseline value.[6] Following this policy, twenty-six states would have an increase in their public agricultural research stock, and six states (California, Indiana, Michigan, New York, Oregon, and Wisconsin) would have more than a 10 percent increase. See table 3. Twenty-two states would have a decline, and in six states (Kentucky, Massachusetts, New Hampshire, South Carolina, Vermont, and West Virginia), the decline would be by more than 10 percent. Using equation (12), we compute the implied change in Rn TFP for each state.[7] This change is not proportional to the change in the public agricultural research capital because SFF and GR are also changing, and we have shown that they impact Rn TFP, too. Forty-five states would experience a decline in Rn TFP from this policy change; the largest—approximately 8 percent would occur in Alabama, Nebraska and West Virginia.[8] Only three states would experience an increase—California, Oregon, and Wisconsin (see table 3). These latter states have a history of significant reliance on federal grants and contract for SAES funding.

Conclusions

This study has presented new econometric evidence of the determinants of state TFP, placing special emphasis on the composition of SAES funding on state agricultural TFP growth over 1970-1999. The results showed that complex interaction effects exist between a state's public agricultural research capital stock and SAES funding composition—shares of federal formula and state appropriations (programmatic funding) and of federal grants and contracts.

These results show that a marginal percentage point transfer of federal funds from formula to competitive grant programs would reduce state agricultural productivity. A more complex simulation, e.g., a 10-percentage point reduction in federal formula funds (a rescaling by the amount by 13/23) and transfer to federal competitive grants program (a rescaling of amount by 2.04), would cause non-marginal adjustments in ℓn TFP across the states. The results show that only 3 states would experience an increase in ℓn TFP, and the other 45 would face a decrease. Hence, it is not hard to imagine that most agricultural experiment station directors would be opposed to this re-allocation.

Returning to the broader issue of the social rate of return to public funds invested in agricultural research, our estimate is of a 56 percent real marginal return. This number is computed assuming a one-unit increment in public funding and benefits are measured at the sample mean and distributed over time using timing weights. This value compares favorably with estimates reported by Evenson (2001).

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Table 1. Variable Names and Definitions

Name	Symbol	Mean (St.D.)	Description
Total factor productivity	TFP	-0.205* (0.254)	Total factor productivity for the agricultural sector (Ball et al 2002)
Public agricultural research capital	PRUB	16.129* (0.870)	The public agricultural research stock for an originating state. The summation of past public sector investments in agricultural research with a productivity enhancing emphasis (Huffman, McCunn, and Xu) in 1984 dol (Huffman and Evenson 1993). Stock obtained by summing past research expenditures with a 2 through 34 year lag and trapazoidal shaped timing weights
Private agricultural research capital	RPRI	6.076* (0.248)	A state's stock of private patents of agricultural technology. The number of patents for each year (Johnson and Brown) obtained by weighting the number of private patents in crops (excluding fruits and vegetables and horticultural and greenhouse products) and crop services, fruits and vegetables, horticulture and greenhouse products, and livestock and livestock services by a states 1982 sales share in crops (excludes fruits, vegetables, horticultural and greenhouse products), fruits and vegetables, horticulture and greenhouse products and livestock and livestock products, respectively. The annual patent total are summed with a 2 thru 18 year lag using trapazoidal timing weights.
Public extension capital	EXT	1.292* (0.976)	A state's stock of public extension is created by summing public full-time equivalent staff in agriculture and natural resource extension applying a weight of 0.50 to the current year and then 0.025, 0.125, 0.0625, and 0.031 for the following four years.
Budget share from federal grants and contracts	GR_{t-12}	0.096 (0.076)	The share of the SAES budget from National Research Initiative, other CSRS funds, USDA contracts, grants and cooperative agreements, and nonUSDA federal grants and contracts (USDA), lagged 12 years.

Budget share from federal formula funds	$SFF1_{t-12}$	0.230 (0.112)	The share of the SAES budget from Hatch, Regional Research, McIntire-Stennis, Evans-Allen, and Animal Health (USDA), lagged 12 years
Budget share from state government appropriations	$SFF2_{t-12}$	0.521 (0.123)	The share of the SAES budget from state government appropriations (USDA), lagged 12 years
Budget share in federal Formula and state appropriate	SFF_{t-12}	0.751 (0.132)	$SFF1_{t-12} + SFF2_{t-12}$
Budget share from other funds	OR_{t-12}	0.165 (0.132)	The share of the SAES budget from private industry, commodity groups, NGO's and SAES sales (USDA), lagged 12 years
Regional indicators	Northeast		Dummy variable taking a 1 if state is CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, or VT
	Southeast		Dummy variable taking a 1 if state is AL, FL, GA, KY, NC, SC, TN, VA, or WV
	Central		Dummy variables taking a 1 if state is IN, IL, IA, MI, MO, MN, OH, or WI
	North Plains		Dummy variable taking a 1 if state is KS, NE, ND, or SD
	South Plains		Dummy variable taking a 1 if state is AR, LA, MS, OK, or TX
	Mountains		Dummy variable to buy a 1 if state is AZ, CO, ID, MT, NV, NM, UT, or WY
	Pacific		Dummy variable taking a 1 if state is CA, OR, or WA
Public agricultural Research Spillin	RPUBSPILL	17.763* (0.567)	The public agricultural research spillin stock for a state in constructed from state agricultural subregion data (see Huffman and Evenson, 1993, pp. 195)

*Numbers reported in natural logarithms.

Table 2. Least-Squares Estimate of Total Factor Productivity Equation, 48 States: 1970-1999[a/] [n=1,440]

Regressors[b/]	Coefficient	t-Values
Intercept	-8.701	18.38
Rn (Public Ag Res Capital)$_t$	0.290	12.15
Rn (Private Ag Res Capital)$_t$	0.113	4.40
Rn (Public Extension Capital)$_t$	1.364	7.07
Rn (Public Ag Res Capital)$_t$*SFF_{t-12}	0.123	4.60
Rn (Public Ag Res Capital)$_t$*$(SFF_{t-12})^2$	-0.087	4.85
Rn (Public Ag Res Capital)$_t$*GR_{t-12}	-0.073	6.11
Rn (Public Ag Res Capital)$_t$*$(GR_{t-12})^2$	0.154	4.55
Rn (Public Ag Res Capital)$_t$*Rn (Public Extension Stock)$_t$	-0.075	6.11
Rn (Public Ag Res Capital Spillin)$_t$	0.123	10.33
Regional Indicators		
Northeast (=1)	0.176	5.84
Southeast (=1)	0.066	2.89
Northern Plains (=1)	0.342	11.48
Southern Plains (=1)	0.079	3.41
Mountain (=1)	0.226	8.70
Pacific (=1)	0.112	4.20
R^2	0.501	0.524

[a/] The Central Region is the excluded region.
[b/] The dependent variable is Rn (TFP)$_t$

Table 3. Baseline and Simulation Results: Re-allocation of 10 percentage points of federal formula funds to federal grants and contracts[a]

	Mean Values, 1970-1999					Simulated Outcome			
STATE	SFF1t-12	SFF2t-12	GRt-12	ORt-12	REV1P[b]	ΔℝnPRUB3	ΔGRt-12	ΔSFFt-12	ΔℝnTFP
AL	0.2327	0.4141	0.0564	0.2967	19777.07	-0.0435	0.0636	-0.0769	-0.0841
AR	0.2087	0.5313	0.0333	0.2267	19657.41	-0.0581	0.0381	-0.0532	-0.0508
AZ	0.1203	0.6202	0.1157	0.1437	20078.46	0.0654	0.1038	-0.0944	-0.0358
CA	0.0520	0.6967	0.1662	0.0850	95084.71	0.1402	0.1286	-0.1209	0.0104
CO	0.2290	0.4831	0.1753	0.1126	18937.18	0.0487	0.0751	-0.0657	-0.0080
CT	0.2022	0.6167	0.1266	0.0545	7591.56	0.0394	0.1119	-0.1091	-0.0135
DE	0.3461	0.4132	0.0570	0.1836	4255.42	-0.0962	0.0695	-0.0883	-0.0660
FL	0.0625	0.7594	0.0600	0.1180	52301.81	0.0344	0.0571	-0.0531	-0.0284
GA	0.1913	0.5937	0.0427	0.1721	31351.12	-0.0397	0.0480	-0.0564	-0.0453
IA	0.1766	0.4234	0.1444	0.2557	31220.50	0.0709	0.1297	-0.1126	-0.0615
ID	0.2169	0.5562	0.0520	0.1749	10357.87	-0.0443	0.0495	-0.0568	-0.0467
IL	0.2049	0.4889	0.1137	0.1925	22467.72	0.0285	0.1107	-0.1059	-0.0602
IN	0.1562	0.3719	0.1980	0.2740	29789.08	0.1295	0.1568	-0.1236	-0.0318
KS	0.1285	0.5142	0.0991	0.2583	25025.89	0.0456	0.0919	-0.0804	-0.0617
KY	0.3454	0.6314	0.0023	0.0210	15319.23	-0.1603	0.0031	-0.0068	-0.0432
LA	0.1290	0.7666	0.0350	0.0694	25123.29	-0.0198	0.0379	-0.0392	-0.0241
MA	0.3629	0.5227	0.0464	0.0680	6012.92	-0.1184	0.0529	-0.0573	-0.0419
MD	0.2382	0.6250	0.0638	0.0729	10431.63	-0.0406	0.0626	-0.0657	-0.0333
ME	0.3264	0.3967	0.0660	0.2110	7038.70	-0.0786	0.0730	-0.0884	-0.0725
MI	0.1653	0.4958	0.1731	0.1658	30027.38	0.1026	0.1443	-0.1286	-0.0207
MN	0.1750	0.6304	0.1052	0.0894	32194.02	0.0328	0.1017	-0.0986	-0.0266
MO	0.2186	0.4676	0.1036	0.2102	20672.59	0.0124	0.1040	-0.1011	-0.0672
MS	0.2587	0.4480	0.0657	0.2275	22716.40	-0.0454	0.0753	-0.0851	-0.0790
MT	0.1819	0.4495	0.0900	0.2786	10514.76	0.0142	0.0899	-0.0862	-0.0764
NC	0.1804	0.5510	0.1350	0.1335	41020.45	0.0601	0.1234	-0.1157	-0.0335
ND	0.1776	0.6347	0.0528	0.1349	15453.58	-0.0226	0.0575	-0.0599	-0.0421
NE	0.1081	0.3799	0.0947	0.4174	29478.07	0.0500	0.0880	-0.0681	-0.0877
NH	0.5510	0.3618	0.0062	0.0811	2877.41	-0.2669	0.0084	-0.0333	-0.0331
NJ	0.1551	0.6264	0.0836	0.1349	14620.41	0.0189	0.0824	-0.0809	-0.0403
NM	0.2752	0.5318	0.0960	0.0970	7335.32	-0.0212	0.0998	-0.1022	-0.0412
NV	0.2740	0.4841	0.1055	0.1364	5072.64	-0.0102	0.1087	-0.1111	-0.0476
NY	0.1121	0.5443	0.1685	0.1750	44864.97	0.1185	0.1342	-0.1121	-0.0249
OH	0.2300	0.7187	0.0230	0.0283	23238.50	-0.0793	0.0275	-0.0294	-0.0338
OK	0.2204	0.5730	0.1081	0.0985	15940.21	0.0162	0.1069	-0.1058	-0.0337
OR	0.1207	0.4549	0.2232	0.2012	23783.39	0.1640	0.1576	-0.1291	0.0053
PA	0.2894	0.5384	0.0836	0.0886	20678.89	-0.0398	0.0934	-0.0970	-0.0465
RI	0.3765	0.3625	0.1791	0.0819	2678.67	0.0194	0.1700	-0.1694	-0.0099
SC	0.3242	0.6072	0.0033	0.0653	14304.31	-0.1495	0.0043	-0.0178	-0.0234
SD	0.2439	0.5530	0.0359	0.1671	8441.07	-0.0714	0.0420	-0.0542	-0.0492
TN	0.2811	0.3434	0.1395	0.2360	16770.50	0.0168	0.1181	-0.1181	-0.0730
TX	0.1616	0.5076	0.0895	0.2413	50730.37	0.0225	0.0889	-0.0836	-0.0693
UT	0.2343	0.4819	0.1743	0.1095	9576.64	0.0762	0.1538	-0.1464	-0.0076
VA	0.2059	0.4897	0.1423	0.1622	24834.60	0.0569	0.1318	-0.1228	-0.0418
VT	0.4728	0.4322	0.0299	0.0651	3172.35	-0.1953	0.0374	-0.0460	-0.0545
WA	0.1698	0.5274	0.0993	0.2035	21602.13	0.0279	0.0943	-0.0880	-0.0596
WI	0.1512	0.4933	0.2490	0.1065	36581.87	0.1765	0.1755	-0.1582	0.0594
WV	0.4821	0.3523	0.0512	0.1144	5300.50	-0.1700	0.0724	-0.0937	-0.0790
WY	0.2993	0.5706	0.0655	0.0645	4731.49	-0.0648	0.0752	-0.0793	-0.0415

[a] See text for full discussion of the context of the change.
[b] Total value of SAES funds for all uses in 1984 dollars (1,000s)

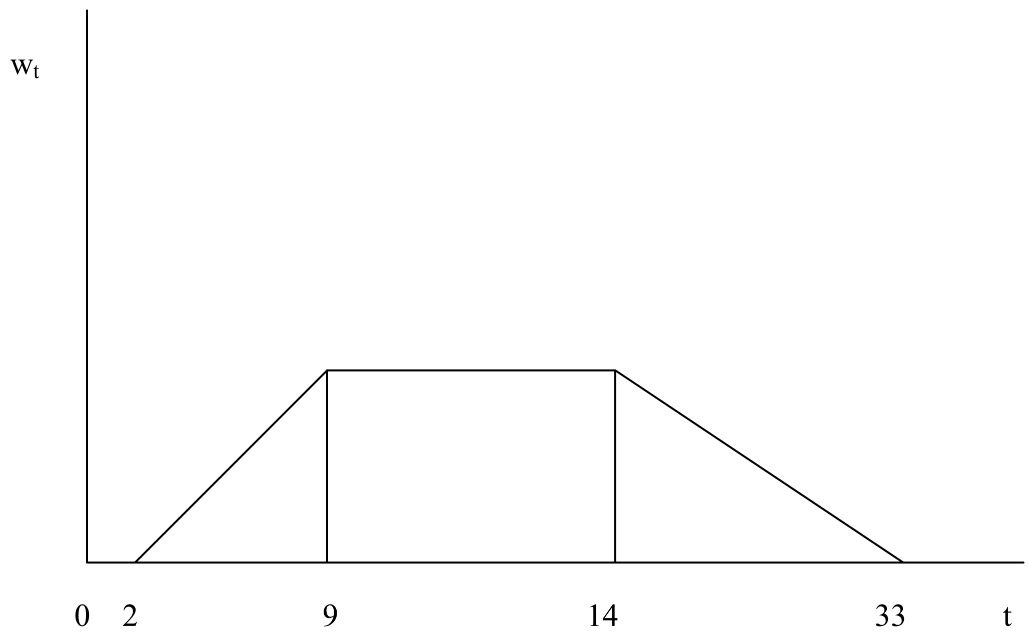

Figure 1. Public Agricultural Research Timing Weights.

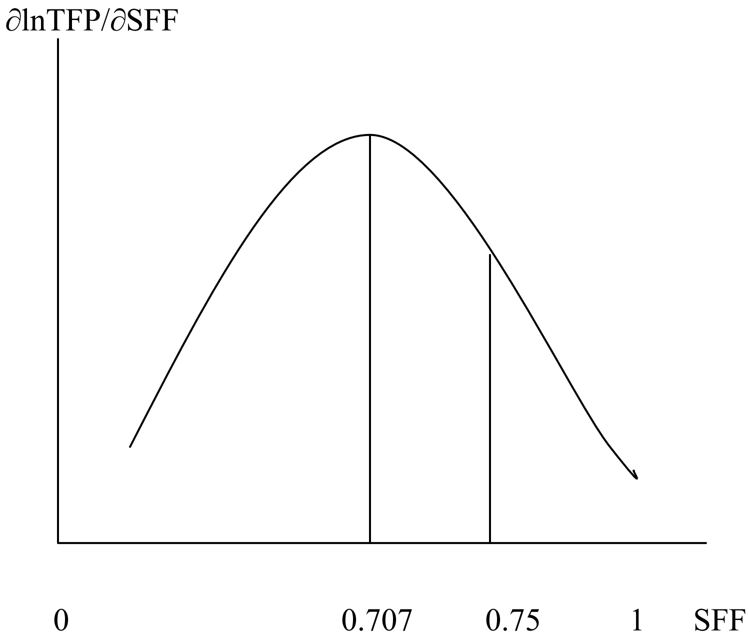

Figure 2. Marginal Effect of SFF on lnTFP.

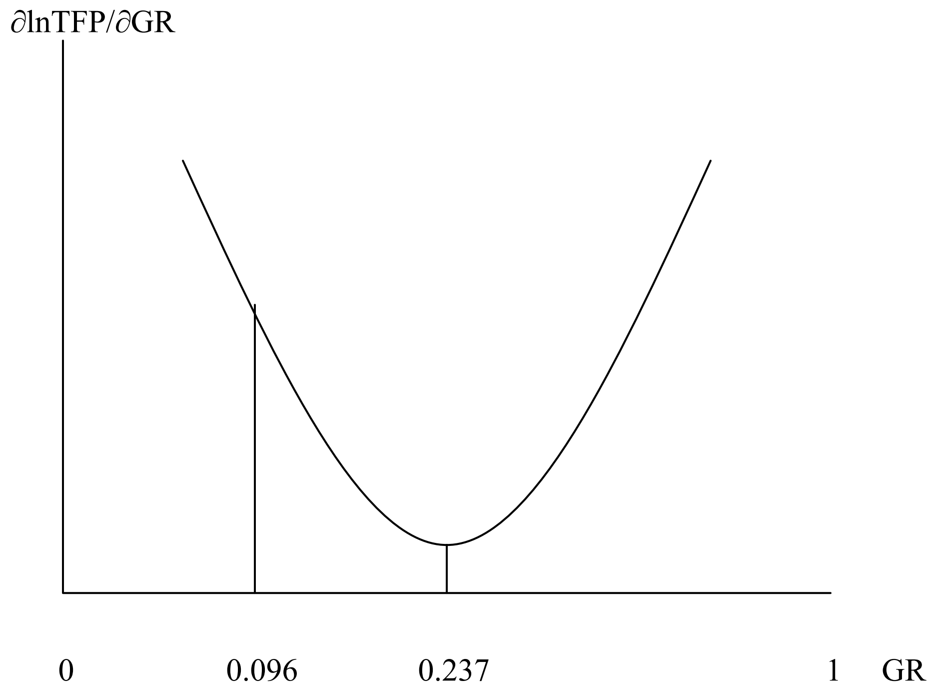

Figure 3. Marginal Effect of GR on lnTFP.

Endnotes

[1] Significant interaction effects between public and private agricultural research stocks did not exist.

[2] See Evenson (2001) and Alston and Pardey (2001) for a discussion of timing weights.

[3] Similar weights were used by Huffman and Evenson (1993). Spillover variables constructed using geo-climatic regions performed better than the regional weights limited to state boundaries which McCunn and Huffman had used.

[4] See Huffman and Evenson (2003) for a model of the determination of funding shares for the state agricultural experiment stations, i.e., making funding share endogenous.

[5] Given that the National Research Initiate Program is a national competitive program, some of the funded projects are for individuals who are not at a land grant university and hence not associated with a state agricultural experiment station. In only two cases, a state agricultural experiment station is not directly connect to a land grant university.

[6] The percentage change in PRUB and the size of the total real SAES budget in 1984 dollars is assumed to be the same.

[7] We treat this scenario as a non-marginal change, and hence, apply the difference equation (12).

[8] We have ignored the impact of the policy change on public agricultural research spillin, RPUBSPILL, because it is difficult to approximate how it would change. In addition to public agricultural research impacting state agricultural productivity, it may have other largely independent effects, including basic scientific discoveries, which are socially valuable but not related to agricultural productivity (Committee on Opportunities in Agriculture, 2003). Hence, our simulation results may not capture all of the social benefits of a re-allocation of federal funds between formula and grants and contracts.