April, 2009

Impact of local public goods on agricultural productivity growth in the U.S.[1]

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, WI, July 26-28, 2009

[1] The views expressed herein are those of the authors, and not necessarily those of the U.S. Department of Agriculture.

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Abstract

In this paper we revisit the issue on the impact of public R&D expenditure on US agricultural productivity growth. We estimate a dual cost function using a state-by-year panel data set. We construct the potential R&D "spillins" based on both geographical location and production mix. We also examine the role of the extension service, transportation network, and human capital in the process of technology dissemination. The results indicate that higher levels of local public goods, R&D spillins, extension activities, and an intensive transportation network decrease costs. The contributions to agricultural productivity from all series of R&D spillins are positive even though the social rate of return may differ.

Key words: productivity, public R&D expenditure, cost function, extension services

JEL code: O3, O4

I. Introduction

The contribution of public investment in R&D to productivity growth has been widely addressed and discussed during the last few decades (Evenson (2000)). Using different methodologies in measuring the R&D stocks or covering different products, the analysts have reached an agreement in that social returns to investments in agricultural research are high. According to Fuglie and Heisey's (2007) survey, the estimated rates of return to Federal-State investment in agricultural research are within the range of 19% to 95% (at the median). There is also strong evidence of technology "spillovers" across geographical boundaries either within one nation (such as states in the U.S.) or across countries.

Previous studies can be summarized into four main groups; first, focus on international versus domestic or regional studies; second, those that use patents versus weighted lagged R&D expenditures as a measurement of technological stock; third, a focus on individual commodities and research programs versus aggregate outputs and aggregate research expenditures; and fourth, studies that incorporate R&D stock in the estimation of the technology versus those that analyze the contribution of the R&D stock on a pre-constructed productivity index.

No matter which method has been used, the R&D stock in near by geographical locations was usually found to be as important as local (own) R&D investment due to a technology spill-in effect. A few studies have estimated rates of return to public R&D investments for the US agricultural sector. Huffman et al. (2002) reported an average marginal rate of return of 43% for the U.S. agricultural sector; Yee et al. (2002) reported a social rate of return in the range of 210% to more than 600% across U.S. states; and Plastina and Fulginiti (2008) more recently reported an average social rate of return across U.S. states in the range of 42% to 95%. In these studies it is not clear why productivity growth for some states is faster than for others in the same region or through which channels the technology was disseminated.

Therefore, the objectives of this research are three fold. First, we revisit the issue on the impact of public investment in research (R&D) on US agricultural productivity growth estimating a dual cost function and using a state-by-year panel data set. The potential spill-in effect of other states' R&D expenditures, based on both geographical location and production mix are examined. While the spill-in effect based on geographic adjacency has become the norm in the literature, we also test for spill-over effects based on production homogeneity. Second, we identify the role of the extension service, transportation network, and human capital in the process of technology dissemination. More specifically, we construct indices for extension service, public transportation network and farm labor quality and look at the interactions between the R&D stock and each of these variables. The technical diffusion effect through these alternative means allows identification of the main sources enhancing either the absorption or distribution of technology among states. Third, we compute the private (own-state) and social (inter-state spillovers) real internal rates of returns to public Agricultural Research.

II. Model

A variety of models have been presented that use an index number measuring the productivity growth rate to examine the contribution of public R&D to agriculture production. The spill-in agriculture research capital stock and the extension services were usually treated as interactive terms with local research capital (own R&D). In this study we use the production technology in its dual form—a cost function. We assume that the research capital stocks generated by other states interact with our three technical diffusion variables—extension activities (ET), farm labor quality (LQ), transportation network (RO). In this way, we determine if they act as a catalyst in stimulating the local technology diffusion or utilization. That is, are they spillover engine, speeding the absorption and dissemination of technology to local producers?

We fit a translog cost function using the state-by-year panel data set to estimate the extent of productivity growth in US agriculture. We assume that each state produces three outputs, livestock (LV), crops (CO) and farm related (FR) products using four variable inputs—land (T), hired labor (HL), materials (M), Capital (CP), and three fixed inputs, self-employed and unpaid family labor (SL), own agricultural research capital (RD), and spill-in agricultural research capital (SR). Therefore, the variable cost function can be presented in the following form:

$$\ln c = \alpha_0 + \sum_{D=1}^{48}\sum_{i=1}^{N}\alpha_{Di} Dum_D \ln w_i + \sum_{j=1}^{M}\beta_j \ln y_j + \sum_{l=1}^{L}\gamma_l \ln K_l + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\alpha_{ij}\ln w_i \ln w_j + \frac{1}{2}\sum_{i=1}^{M}\sum_{j=1}^{M}\beta_{ij}\ln y_i \ln y_j + \frac{1}{2}\sum_{i=1}^{L}\sum_{j=1}^{L}\gamma_{ij}\ln K_i \ln K_j +$$
$$\sum_{i=1}^{N}\sum_{j=1}^{M}\delta_{ij}\ln w_i \ln y_j + \sum_{i=1}^{N}\sum_{j=1}^{L}\theta_{ij}\ln w_i \ln K_j + \sum_{i=1}^{M}\sum_{j=1}^{L}\phi_{ij}\ln y_i \ln K_j + \sum_{s=1}^{T}\xi_S \ln E_s \ln K_{RD} + \sum_{s=1}^{T}\sum_{i=1}^{N}\rho_{is}\ln E_s \ln w_i + \sum_{i}^{N}\rho_{iW}\ln W \ln w_i \qquad (1)$$

where w is the input price, K is the fixed input, y is the output, E is the spillover engine, DUMs are the state dummies to capture the state specific differences in technologies, and W is the weather index.

$$w(x) \in \{T, HL, M, CP\}, y \in \{LV, CO, FR\}, K \in \{SL, RD\}, E \in \{ET, LQ, RO, SRD\} \qquad (2)$$

T is land, HL is hired labor, M is material, CP is capital, LV is live stocks, CO is crops, FR is farm-related products, SL is self-employed and unpaid family labor, RD is own R&D stock, ET is extension service, LQ is labor quality, RO is transportation network, SRD is R&D spillin.

To conserve degrees of freedom, we only introduce the state dummies in the first-order term to allow the cost shares to differ among states. To conserve degrees of freedom, we only introduce the state dummies in the first-order term to allow the cost shares to differ among states. Interaction between weather and variable input prices allows the weather variable to show up as a shock to the cost shares for individual states.

The translog form is viewed as a second-order Taylor's expansion for a more general cost function. We impose the symmetry constraints and linearity homogenous condition in prices in the estimation of parameters as follows:

symmetry constraints: $\alpha_{ij}=\alpha_{ji}$; $\beta_{ij}=\beta_{ji}$; $\gamma_{ij}=\gamma_{ji}$ (3)

homogeneity of degree one in variable input prices requires:

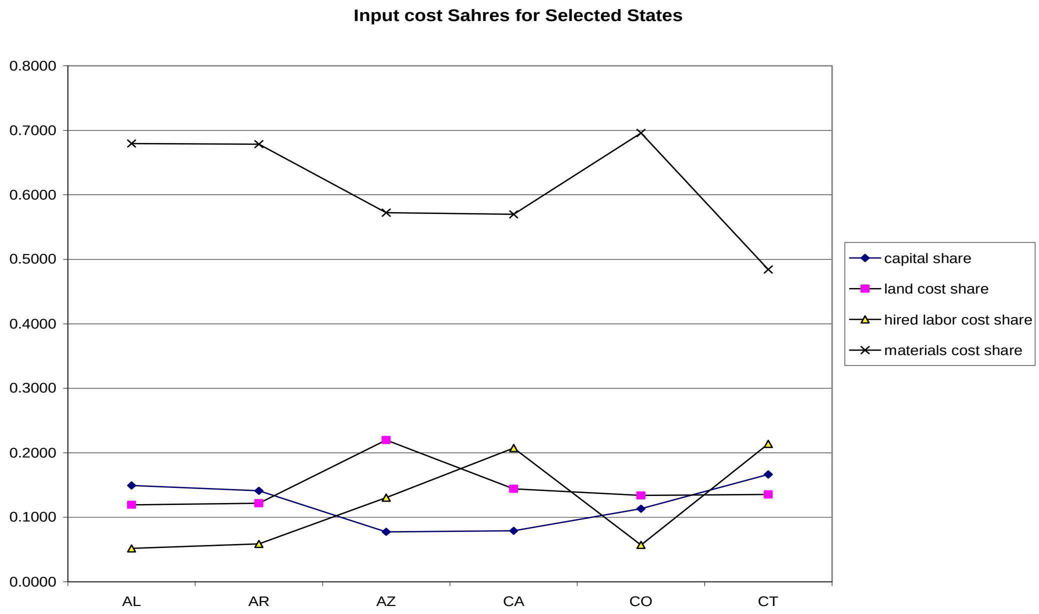
$$\sum_{i=1}^{N}\alpha_{Di}=1,\ \sum_{i=1}^{N}\alpha_{ij}=\sum_{i=1}^{N}\delta_{ij}=\sum_{i=1}^{N}\theta_{ij}=\sum_{i=1}^{N}\rho_{iS}=\sum_{i=1}^{N}\rho_{iW}=0 \tag{4}$$

Using Shephard's lemma, the cost share for input i can be derived from the first derivative of variable cost function with respect to the input price:

$$S_i=\sum_{D=1}^{48}\alpha_{Di}Dum_D+\sum_{i=1}^{N}\alpha_{ij}\ln w_j+\sum_{j=1}^{M}\delta_{ij}\ln y_j+\sum_{l=1}^{L}\theta_{ij}\ln K_j+\sum_{i=1}^{T}\rho_{is}\ln E_s+\rho_{iW}\ln W \tag{5}$$

The estimated system includes the total variable cost equation (1), and three cost input share equations (5). One cost share equation is dropped out from the estimation because the cost shares sum to unity. The parameters are estimated in the system using iterated Seemingly Unrelated Regression (ITSUR). Since the data is a pooled time series and cross sectional state level dataset, it may not be homogeneous. From Figure 1 we can see that for a sample of six states, inputs cost shares differ among states. Therefore, we introduce state dummies to the first order interactive term with input prices to capture the state-specific variance in the cost share equations.

Figure 1. Input cost shares for a sample of U.S. states.



III. Construction of variables and data sources

Outputs and Inputs

We use annual state aggregate data for the 48 U.S. contiguous states in our analysis. The time period for this research is 1980 to 2004. The agricultural production data was drawn from the USDA/ERS estimates. The output data were constructed as longitudinal indexes where indexes of real outputs across states represent the nominal values for any two states divided by their corresponding price index. Multilateral input price indexes were computed from Tornqvist indexes (see Ball et al. (1999) for a detailed description on the measurement methodology and data sources).

Own R&D

The current technical knowledge stock can be treated as an accumulation of investment of agricultural research in past periods. The methods to construct the current technical knowledge stock are numerous due to different assumptions on adoption and decay patterns. Alston et al. (2000) indicated that the most common approaches used in measuring the current technical knowledge stock were low-order polynomial, pre-constructed trapezoid, and inverted V lags. The shape and length of the lag is important as it influences the corresponding internal rate of return for one unit of investment in research (Thirtle et al. (2008)). Huffman and Evenson (1993, 1994) proposed a trapezoidal-weight pattern with a 2 year gestation period, 7 years of increasing impacts, 6 years of maturity with constant weights, and 20 years of decay with declining weights. In this study the local R&D capital stock was constructed following the methodologies used by Huffman and Evenson. The annual agricultural research expenditure data are from Huffman, McCunn, and Xu (2001) and was expanded to 2004.

R&D Spillins

Investment in public research from other states may also contribute to local production. This effect is generally referred to as "spillins" (from other regions or countries) or "spillover" (to other regions or countries). Following Khanna et al. (1994), and Cornes and Sandler (1996) we assume that knowledge capital stock generated by other states are "impure" public goods, as they are not accessible to some states than others. Most research has constructed the spillin R&D stock under a geographical correlation concept to reflect similarities in climatic and production conditions among states. Huffman et al. (2002) and Yee et al. (2002) used sum of state's R&D capital stock from one region excluding local state R&D to represent an accessible spillin R&D stock for local farmers. Plastina and Fulginiti (2008) construct a spillin R&D stock using the sum of the neighboring state's R&D.

However, dissemination of an "impure" public good from other states may not only depend on the characteristics of the region but also on the distance between states or on the similarity in production activity among states. For instance, though Virginia and Maryland belong to two different production regions (according to USDA's definition) it is possible for a farmer in Virginia to learn from producers in Maryland. Likewise, even though California and Florida are far apart, farmers in these two states can learn from each other because of their similar production activities through the help of their extension staffs or other channels. Alston et al. (2007) reported the construction of a spillin R&D stock variable based on a mix of 74 outputs.

In this study, we construct four alternative series of spillin R&D according to the concepts of production region, geographical distance, and two measures of production profile similarity. R&D spillins are a - weighted sum of R&D stocks from other states:

$$SRD_i = \sum w_{ij} RD_j \quad (6)$$

Where SRD_i is the spillin R&D stock to be constructed for state i. w_{ij} is the weight used to adjust for the contribution of the jth state's technology innovation to the ith state. RD_j is own R&D stock generated by state j. The weights for each of the four approaches used in this paper are designed as follows:

1. $w_{ij}=1$ for the spillin R&D generated by the same production region group. We use the production region group defined by USDA to account for the region spillin R&D stocks (SRRD thereafter). We assume the contribution from other states' R&D in the same region is the same as for the own state.
2. $w_{ij}=1/dist_{ij}$ for spillin R&D generated according to the geographical distance among states. We use the distance between Montana and New Mexico as the cutoff point. Any state j beyond that distance was assumed to have no impact to the state i's production.
3. $w_{ij}=1$ for spillin R&D generated by the same outputs mix cluster. We use a production profile of 14 subcategories of outputs shares for each state to account for their

production similarity. A complete linkage clustering method was applied to compile the production activity clusters. The number of clusters is determined base on the correlation between production profiles.

4. w_{ij}=1/$Tecdist_{ij}$ for spillin R&D generated according to the technical distance among states. $Techdist_{ij}$ is the technological distance based on the inverse of Spearman correlation coefficient among states. The higher the correlation relationship the smaller the technical distance among states within the same cluster.

Data used to construct the production profile is drawn form National Agricultural Statistics Service (NASS).

Extension Service

Ahearn et al. (2002) reported the series of state Extension FTEs from 1977-92 by 4 major program areas and total state full time equivalent (FTE) extension staff from 1977-97. The FTE information by program area was discontinued after 1992. We therefore use total FTEs at the state level to construct the extension capacity indexes for each state. The ET capacity index uses total FTEs as numerator and the number of farms as denominator to represent the capacity of the extension service in technology distribution. Data on FTEs by state were drawn form the Salary Analysis of the Cooperative Extension Service from the Human Resource Division at USDA.

Transportation network

A convenient transportation network can provide local farmers with an easier way to acquire new technology by attending workshops or other extension activities. It can also save on the time it takes extension staffs to contact producers around the state. We therefore construct a road density index to examine its impact on dissemination of local R&D. The road density index was constructed using total road miles excluding local miles for each state divided by total land area. We assume that the higher the road density the cheaper the dissemination of innovations and the stronger the impact of local R&D. This contributes to reductions in cost. The public transportation network was drawn from the Highway Statistics Publication.

Labor quality

Data used to construct the farm labor's quality index was drawn from the data developed by Gollop and Jorgenson and the Current Population Survey (CPS).

Weather

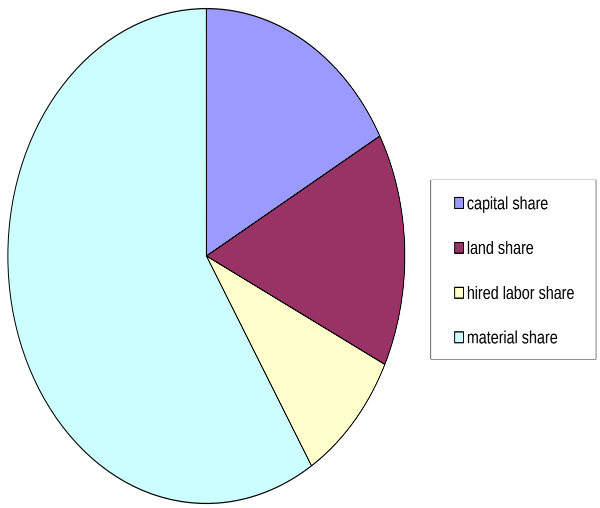
Weather is treated as a control variable in this model. We use a rainfall index drawn from a USDA/ERS dataset.

IV. Data Description and Results

Inputs Shares

According to the USDA agricultural productivity accounts, intermediate materials accounts for most of the variable cost with an average share of 59% for all 48 states form 1980 to 2004. Capital and land account for 17% and 15% respectively. Hired labor (SHL) is the smallest part of total variable inputs, with an average cost share of 9%.

Figure 2. Input shares of variable cost of production, 48 U.S. States, 1980-2004.



Trends in R&D expenditures, and Extension services

The USDA/Current Research Information System provides national summaries of gross actual expenditures of funds by source, and of actual scientist years for each fiscal year. From 1980 to 2007 the nominal total funds from different sources are shown in figure 3. The total funds were compiled from data submitted by the U.S. Department of Agriculture (USDA) research agencies, State Agricultural Experiment Stations (SAES), Forestry Schools, Colleges of 1890 and Tuskegee University, Colleges of Veterinary Medicine, and other cooperating institutions. From 1980 to 2007 the nominal research expenditures grew almost 300 percent. Once deflated using an ERS deflator and the GDP deflator, the growth rate declined to 7% and 78% respectively (Figure 3).

As to the extension activities budget approximation from USDA both the deflated extension expenditures using the GDP deflator and ERS deflator respectively have been actually declining in the 1980-2004 period (Figure 4). The extension FTEs have been declining for most of the states during the 1980 to 2004 period. (Figure 5)

Figure 3. Nominal and Real public R&D expenditures in U.S. Agriculture

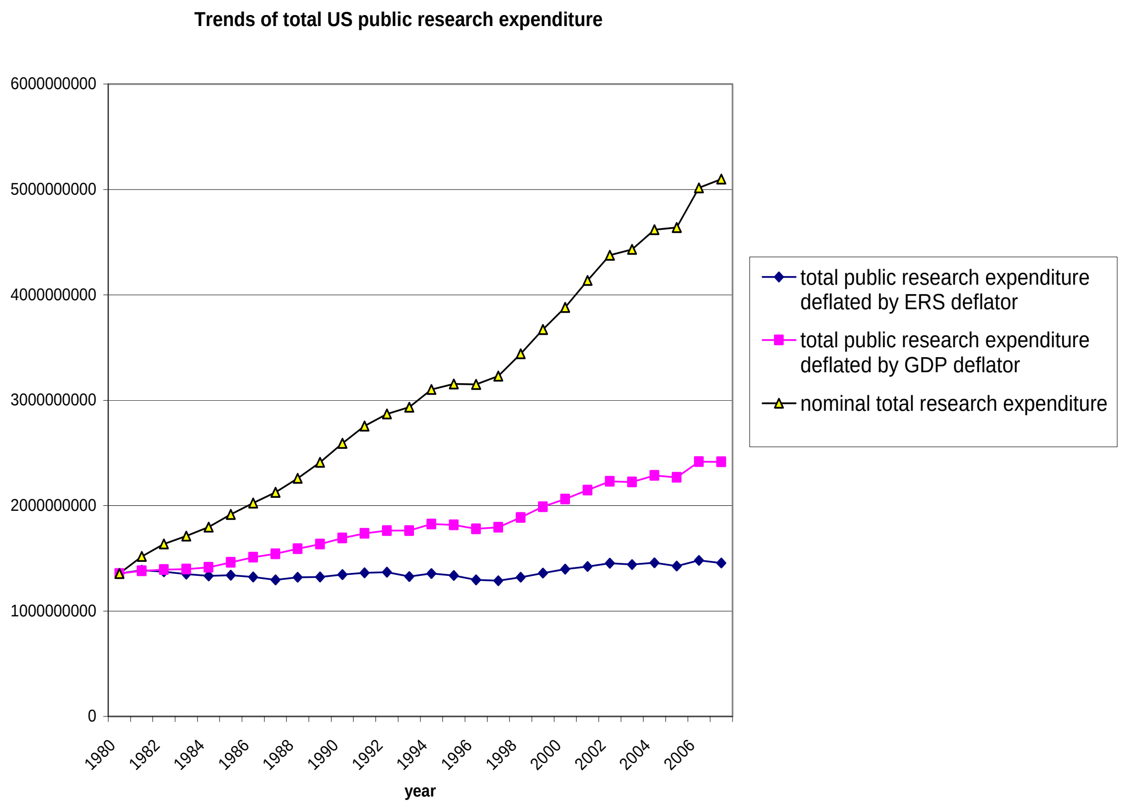


Figure 4 Nominal and Real Federal Extension expenditures in U.S. Agriculture

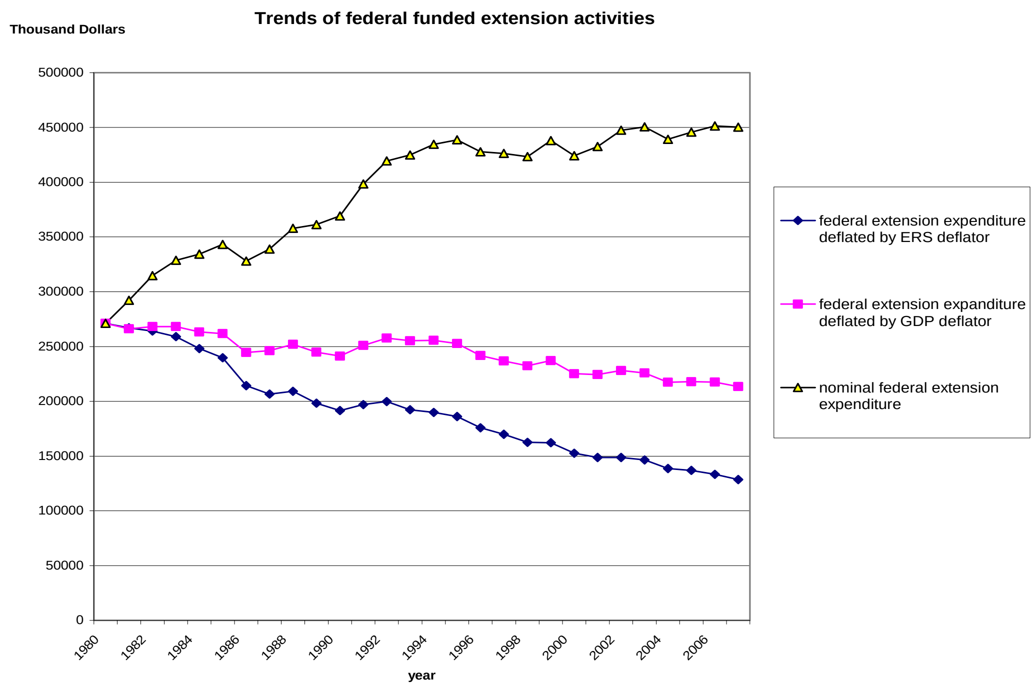
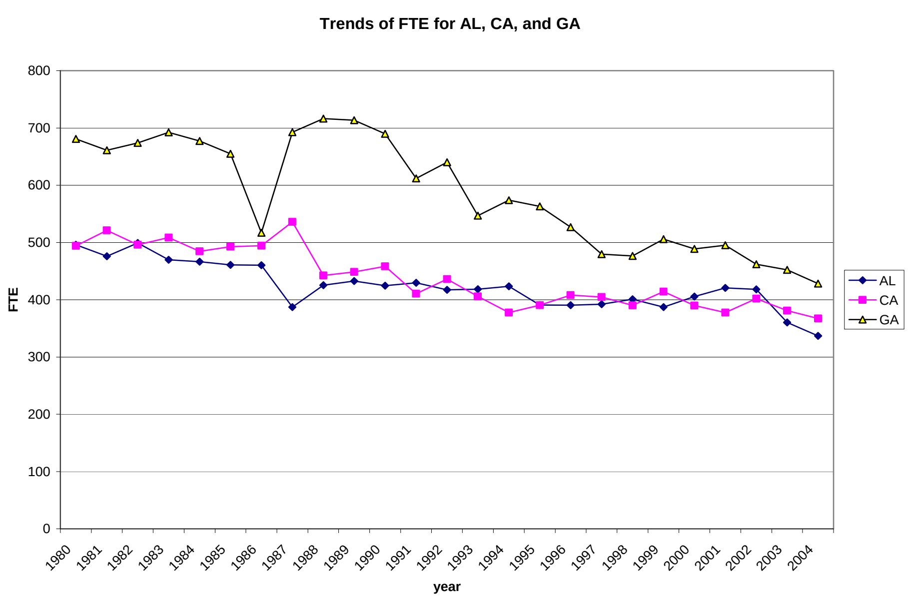


Figure 5 Extension FTEs in three U.S. states.



V. Results

Four models were estimated using different approximation of spillin R&D stocks. In total, 204 parameters were estimated using ITSUR methods and fitting the total variable cost equation (equation 1) and three cost share equations (equation 5) subject to the restrictions in equations 3 and 4. Model 1 uses a spillin R&D stock generated under the production region concept. Model 2 uses a spillin R&D stock generated under the geographical distance concept. Model 3 and Model 4 use a spillin R&D stock generated under the similarity of production profile. Model 3 uses weight adjusted spillins while Model 4 uses un-weighted spillins to construct the stock.

Table 1 presents the parameters estimated for the four models excluding the state specific interactive terms. Most coefficients are significant at the 5% level. The estimated parameters were used to calculate the corresponding input elasticities at the mean of the variables.

For a translog form the Allen partial elasticities are:

$$\sigma_{ii} = \frac{\alpha_{ii}}{s_i} + (s_i - 1), i = 1...N, \quad (7)$$

$$\sigma_{ij} = \frac{\alpha_{ij}}{s_i s_j} + 1, i, j = 1..N, i \neq j, \quad (8)$$

The price elasticities of derived demand are:

$$\eta_{ii} = s_i \sigma_{ii}, \quad (9)$$

$$\eta_{ij} = s_j \sigma_{ij}, \quad (10)$$

The fixed inputs effects as well as the effects of variables that increase dissemination and absorption of new technologies (we will refer to these as efficiency variables) are:

$$\frac{\partial \ln TVC}{\partial \ln K} \quad (11)$$

$$\frac{\partial \ln TVC}{\partial \ln E} \quad (12)$$

The impact of efficiency variables on R&D's expenditures are:

$$\left(\frac{\partial \ln TVC}{\partial RD}\right) / \partial \ln E \quad (13)$$

And the output elasticity is:

$$\frac{\partial \ln TVC}{\partial \ln Y} \quad (14)$$

The curvature condition was violated at the full sample mean for capital elasticity. However, using state level sample means the curvature condition held for most of the states. The local R&D elastiticy and the contributions of extension activities (ET), road density (RO), labor quality (LQ) and R&D spillins are the ones we focus on in this paper. All of them are cost reducing at the mean. Table 3 indicates that higher level of local public goods, R&D spillins, extension activities and an intensive transportation network decrease costs.

A comparison of the four models indicate that no matter what measure of spillin stock, we can see that all the spillin stock we use, the contributions to agricultural productivity are positive even though the social rate of return may differ.

Table 1 Empirical results

Parameters	Model 1 coefficients	Asymptotic t ratio	Model 2 coefficients	Asymptotic t ratio	Model 3 coefficients	Asymptotic t ratio	Model 4 coefficients	Asymptotic t ratio
β								
LV	1.107	3.540	0.802	2.340	0.596	1.680	0.591	1.640
CO	-0.425	-1.440	-1.037	-3.230	-0.954	-2.850	-0.931	-2.780
FR	0.850	3.140	1.084	3.680	1.020	3.280	1.035	3.340
LVLV	-0.058	-1.830	-0.056	-1.560	-0.137	-3.790	-0.138	-3.840
LVCO	0.069	3.340	0.050	2.230	0.062	2.620	0.061	2.610
LVFR	0.003	0.190	0.001	0.040	0.017	0.790	0.017	0.800
COCO	0.198	7.510	0.175	6.060	0.180	5.870	0.178	5.850
COFR	-0.172	-8.850	-0.178	-8.320	-0.163	-7.320	-0.162	-7.240
FRFR	0.141	5.930	0.195	7.540	0.181	6.670	0.181	6.680
γ								
SL	0.042	0.150	0.794	2.630	0.833	2.630	0.802	2.530
RD	0.122	0.990	0.004	0.030	0.052	0.380	0.050	0.360
SLSL	0.119	5.610	0.125	5.360	0.120	4.960	0.119	4.940
SLRD	0.029	1.830	-0.030	-1.760	-0.037	-2.100	-0.036	-2.030
RDRD	-0.015	-1.230	-0.010	-0.730	-0.022	-1.580	-0.022	-1.570
α								
TT	0.117	63.140	0.118	61.690	0.118	62.720	0.119	63.330
TM	-0.093	-44.190	-0.091	-42.430	-0.093	-43.690	-0.093	-43.680
TCP	-0.022	-11.090	-0.024	-12.110	-0.022	-11.380	-0.022	-11.490
THL	-0.003	-2.190	-0.003	-2.050	-0.003	-2.060	-0.003	-2.350
MM	0.185	38.100	0.190	38.560	0.186	37.880	0.185	37.790
MCP	-0.100	-22.150	-0.105	-23.090	-0.101	-22.280	-0.101	-22.340
MHL	0.008	3.650	0.006	2.880	0.009	4.000	0.009	4.110
CPCP	0.148	27.850	0.154	28.870	0.150	28.110	0.150	28.170
CPHL	-0.027	-15.310	-0.025	-14.080	-0.027	-15.340	-0.027	-15.160
HLHL	0.022	10.860	0.022	10.330	0.021	10.470	0.021	10.360
δ								
TLV	-0.061	-18.290	-0.061	-17.580	-0.062	-18.410	-0.062	-18.480
TCO	-0.031	-9.590	-0.028	-8.570	-0.029	-8.850	-0.029	-9.030
TFR	-0.002	-1.040	-0.003	-1.440	-0.004	-2.030	-0.005	-2.730
MLV	0.092	21.640	0.091	20.650	0.094	22.060	0.094	21.950
MCO	0.028	6.960	0.024	6.000	0.027	6.790	0.027	6.710
MFR	0.021	9.410	0.023	9.910	0.024	10.700	0.025	10.790
CPLV	-0.025	-7.930	-0.023	-7.230	-0.026	-8.290	-0.026	-8.280
CPCO	-0.017	-5.670	-0.016	-5.480	-0.017	-5.700	-0.017	-5.620
CPFR	-0.009	-5.080	-0.009	-5.140	-0.009	-5.250	-0.008	-4.780
HLLV	-0.006	-1.770	-0.006	-1.740	-0.006	-1.680	-0.006	-1.670
HLCO	0.020	5.940	0.020	5.970	0.019	5.560	0.019	5.670
HLFR	-0.011	-6.270	-0.011	-6.440	-0.012	-6.700	-0.012	-6.600

note: The spillin RD stocks are based on production region, geographical distance, correlation weithged production cluster, and nonweigheted production profile for Model 1 to Modele 4 respectively.

Table 1 (continue)

	Model 1		Model 2		Model 3		Model 4	
		Asymptotic		Asymptotic		Asymptotic		Asymptotic
Parameters	coefficients	t ratio	coefficients	t ratio	coefficients	t ratio	coefficients	t ratio
θ								
TSL	0.001	0.620	0.002	0.810	0.003	1.390	0.003	1.140
TRD	0.002	0.210	0.006	0.410	-0.025	-3.230	-0.039	-4.520
MSL	0.020	6.840	0.020	6.940	0.018	6.380	0.019	6.610
MRD	0.068	6.290	0.013	0.720	0.094	9.450	0.096	8.780
CPSL	-0.013	-5.930	-0.014	-6.400	-0.012	-5.720	-0.012	-5.620
CPRD	-0.136	-16.630	-0.070	-5.520	-0.115	-15.380	-0.107	-13.040
HLSL	-0.009	-3.660	-0.008	-3.580	-0.009	-4.020	-0.010	-4.170
HLRD	0.066	7.230	0.052	3.600	0.046	5.630	0.049	5.460
φ								
LVSL	-0.076	-3.670	-0.069	-2.990	-0.027	-1.150	-0.025	-1.070
LVRD	-0.001	-0.040	0.026	1.270	0.048	2.240	0.048	2.210
COSL	-0.110	-6.030	-0.082	-4.110	-0.099	-4.710	-0.097	-4.670
CORD	0.028	1.820	0.077	4.500	0.063	3.550	0.062	3.480
FRSL	0.054	3.260	0.034	1.890	0.017	0.890	0.015	0.790
FRRD	-0.045	-3.040	-0.071	-4.370	-0.069	-4.010	-0.069	-4.060
ξ								
TRD	-0.003	-4.670	-0.001	-1.200	-0.001	-1.600	-0.001	-1.540
LQRD	-0.008	-1.570	0.002	0.370	0.002	0.400	0.002	0.280
RORD	-0.006	-17.500	-0.006	-14.750	-0.007	-18.240	-0.007	-18.260
SRRD	-0.010	-17.570	-0.005	-7.560	0.000	-0.600	0.000	-0.140
ρ								
ETT	0.014	6.490	0.012	5.720	0.013	5.980	0.013	5.940
LQT	-0.037	-2.440	-0.041	-2.640	-0.033	-2.130	-0.032	-2.080
ROT	0.007	0.630	0.003	0.220	0.005	0.460	0.009	0.780
SRT	-0.011	-1.740	-0.016	-1.150	0.017	2.780	0.032	4.410
ETM	0.001	0.540	0.005	1.820	0.004	1.300	0.004	1.500
LQM	-0.007	-0.370	0.012	0.620	-0.003	-0.140	0.001	0.050
ROM	-0.018	-1.230	-0.014	-0.970	-0.020	-1.330	-0.021	-1.400
SRM	-0.005	-0.580	0.062	3.450	-0.031	-4.050	-0.032	-3.510
ETCP	0.003	1.300	0.000	0.140	0.001	0.350	0.001	0.310
LQCP	0.053	3.600	0.033	2.280	0.036	2.410	0.035	2.360
ROCP	0.061	5.610	0.062	5.800	0.061	5.570	0.058	5.360
SRCP	0.023	3.800	-0.054	-4.080	-0.003	-0.460	-0.013	-1.890
ETHL	-0.018	-8.310	-0.017	-8.130	-0.017	-7.900	-0.017	-8.050
LQHL	-0.008	-0.510	-0.005	-0.340	0.000	-0.030	-0.004	-0.270
ROHL	-0.050	-4.100	-0.050	-4.120	-0.047	-3.800	-0.047	-3.810
SRHL	-0.007	-1.030	0.009	0.580	0.016	2.570	0.012	1.630
WT	0.000	0.450	0.000	0.390	0.000	0.480	0.000	0.460
WM	0.001	2.230	0.001	2.160	0.001	2.060	0.001	2.120
WCP	0.000	-1.060	0.000	-0.940	0.000	-0.930	0.000	-0.950
WHL	-0.001	-2.110	-0.001	-2.100	-0.001	-2.090	-0.001	-2.120
equations	R^2	adjusted R^2	R^2	adjusted R^2	R^2	adjusted R^2	R^2	adjusted R^2
LNTVC	0.9885	0.9871	0.9863	0.9846	0.9857	0.9839	0.9856	0.9838
SM	0.9453	0.9443	0.9453	0.9443	0.9474	0.9465	0.9465	0.9455
SCP	0.9236	0.9222	0.9201	0.9186	0.9213	0.9198	0.9217	0.9202
SHL	0.9439	0.9429	0.9435	0.9425	0.9441	0.9431	0.944	0.9429

Table 2 Alternative elasticities

	Model 1	Model 2	Model 3	Model 4
Allen partial elasticities of substitution				
SE_{TT}	-0.0767	-0.0748	-0.0702	-0.0687
SE_{MM}	-0.0971	-0.0896	-0.0962	-0.0967
SE_{HLHL}	-0.6650	-0.6691	-0.6741	-0.6757
SE_{CPCP}	0.0443	0.0751	0.0548	0.0549
SE_{TM}	-0.0356	-0.0156	-0.0405	-0.0372
SE_{TCP}	0.1651	0.0807	0.1376	0.1333
SE_{THL}	0.7735	0.7822	0.7859	0.7559
SE_{MCP}	-0.0035	-0.0510	-0.0126	-0.0148
SE_{MHL}	1.1467	1.1194	1.1620	1.1665
SE_{CPHL}	-0.7493	-0.6386	-0.7591	-0.7388
Price elasticities of demand				
P_{ET}	-0.0117	-0.0114	-0.0107	-0.0105
P_{EM}	-0.0571	-0.0527	-0.0566	-0.0569
PE_{CP}	0.0075	0.0128	0.0093	0.0093
PE_{HL}	-0.0598	-0.0602	-0.0606	-0.0608
PE_{TM}	-0.0210	-0.0092	-0.0238	-0.0219
PET_{CP}	0.0280	0.0137	0.0234	0.0226
PET_{HL}	0.0696	0.0703	0.0707	0.0680
PE_{MT}	-0.0054	-0.0024	-0.0062	-0.0057
PE_{MCP}	-0.0006	-0.0087	-0.0021	-0.0025
PE_{MHL}	0.1031	0.1007	0.1045	0.1049
PE_{CPT}	0.0251	0.0123	0.0209	0.0203
PE_{CPM}	-0.0020	-0.0300	-0.0074	-0.0087
PE_{CPHL}	-0.0674	-0.0574	-0.0683	-0.0664
PE_{HLT}	0.1177	0.1191	0.1196	0.1150
PE_{HLM}	0.6744	0.6584	0.6834	0.6861
PE_{HLCP}	-0.1272	-0.1084	-0.1289	-0.1254
Fixed inputs elasticities				
FE_{RD}	-0.0851	-0.0752	-0.0976	-0.0979
FE_{SL}	0.1957	0.2315	0.2194	0.2210
FE_{ET}	-0.0541	-0.0087	-0.0158	-0.0148
FE_{RO}	-0.0939	-0.0896	-0.1135	-0.1142
FE_{LQ}	-0.1392	0.0454	0.0445	0.0345
FE_{SR}	-0.1789	-0.0814	-0.0185	-0.0162
R&D elasticities of efficiencyvariables				
E_{RDET}	-0.0034	-0.0010	-0.0013	-0.0013
E_{RDRO}	-0.0063	-0.0061	-0.0072	-0.0073
E_{RDLQ}	-0.0080	0.0021	0.0023	0.0017
E_{RDSR}	-0.0101	-0.0051	-0.0002	-0.0001
Output elasticity				
YE_{LV}	0.2866	0.3035	0.2864	0.2848
YE_{CO}	0.3252	0.3035	0.3214	0.3210
YE_{FR}	0.0656	0.0897	0.0929	0.0933

VI. Conclusion and Discussions

This paper uses new data to provide current evidence on the contributions of public research, extension service, transportation networks, and human capital to US agricultural productivity growth. This work provides information on the pattern of agricultural technology diffusion among states. The results also shed light on the impact of public investments in agricultural research and extension--both local public goods with returns not readily available from market data. We are able to discern the private or own state impact from the social or multistate impact of such local public goods. Returns to public investments can be used to help guide public decision in allocating resources to research. This is crucial given the slowing growth in public agricultural research budgets in recent years.

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