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RESEARCH ARTICLE

INFORMATION TECHNOLOGY AND ADMINISTRATIVE EFFICIENCY IN U.S. STATE GOVERNMENTS: A STOCHASTIC FRONTIER APPROACH

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Appendix A

Technical Details of Stochastic Frontier Estimation

In the first stage, we measure cost efficiency based on a multiproduct translog cost function with *n* outputs and *m* input prices, which is given by

$$\begin{aligned}\ln C_{k,t} &= \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln Y_{i,k,t} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij} \ln Y_{i,k,t} \ln Y_{j,k,t} + \sum_{i=1}^{m} \beta_i \ln w_{i,k,t} \\ &+ \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \beta_{ij} \ln w_{i,k,t} \ln w_{j,k,t} + \sum_{i=1}^{m}\sum_{j=1}^{n} \gamma_{ij} \ln w_{i,k,t} \ln Y_{j,k,t} + \varepsilon_{k,t}\end{aligned} \tag{A1}$$

where *k* and *t* are subscripts for state and year, respectively. $C_{k,t}$ is the total cost of state *k* at year *t*, $Y_{i,k,t}$ indicate the amount of outputs, and $w_{i,k,t}$ are the input prices. The interaction terms in Eq. A1 are used for estimating economies of scale or input price elasticity, which are outside the scope of our research. In estimation, the constraints for homogeneity with a degree of one in price have to be imposed (Caves et al. 1981; Ray 1982).

$$\sum_{i=1}^{m} \beta_i = 1 \quad , \quad \sum_{j=1}^{m} \beta_{ij} \ln w_j = 0 \quad \text{, and} \quad \sum_{j=1}^{n} \gamma_{ij} \ln Y_j = 0 \quad \text{for } i = 1, 2, \ldots, n \tag{A2}$$

These constraints ensure that when all input prices w_i are multiplied by *x*, the total cost *C* is multiplied by *x* as well, making the cost function homogenous with a degree of one.

In SFA, a frontier is considered to be stochastic, based on a rationale that even maximum production levels may be influenced by various unobserved factors, random shocks, or statistical noise. A model suggested by Aigner et al. (1977) and Meeusen and van den Broeck (1977) assumes that a residual $\varepsilon_{k,t}$ in Eq. A1 consists of two parts.

$$\varepsilon_{k,t} = v_{k,t} + u_{k,t} \tag{A3}$$

Here, $v_{k,t}$ represents a random error and is assumed to follow a normal distribution of $N(0, \sigma_v^2)$. $u_{k,t}$ refers to a technical inefficiency factor, which in nature is greater than or equal to zero. Here, it is assumed to follow an exponential distribution. Thus, $u_{k,t}$ is always positive. Aigner et al. explain that $v_{k,t}$ represents random factors that influence production but are outside of a firm's control. Thus, $v_{k,t}$ is thought to be part of the cost frontier. In contrast, $u_{k,t}$ is viewed as being under the firm's control and originating from such causes as mismanagement or organizational slacks. The parameters in Eq. A1 along with the standard deviation of the two residual terms ($v_{k,t}$ and $u_{k,t}$) can be estimated using maximum likelihood estimation, and the details are presented in Aigner et al.

Based on the estimated parameters (the coefficients of Eq. A1 and σ_v and σ_u), we can obtain an unbiased estimate of the inefficiency of each observation using the approach outlined in Jondrow et al. (1982). They propose the following unbiased estimator for $u_{k,t}$:

$$E(u_{k,t} \mid \varepsilon_{k,t}) = \mu_* + \sigma_* \left[\frac{\phi(-\mu_* / \sigma_*)}{1 - \Phi(-\mu_* / \sigma_*)} \right] \tag{A4}$$

where $\mu_* = \dfrac{\sigma_u^2 \varepsilon}{\sigma_u^2 + \sigma_v^2}$, $\sigma_* = \sqrt{\dfrac{\sigma_u^2 \sigma_v^2}{\sigma_u^2 + \sigma_v^2}}$, and $\Phi(\cdot)$ and $\phi(\cdot)$ refer to the cumulative and probability density function of a standard normal distribution, respectively. However, for ease of interpretation, we are more interested in estimating technical cost inefficiency (the ratio of actual cost to cost in the frontier), rather than $u_{k,t}$ itself. Since the cost function in Eq. A1 is expressed in logarithm of cost, $\exp(u_{k,t})$ represents the technical inefficiency that we are seeking to measure. Battese and Coelli (1988) suggest an estimator for the technical inefficiency $TIneff_{k,t}$ of state k at year t as follows:

$$TIneff_{k,t} = E(\exp\{u_{k,t}\} \mid \varepsilon_{k,t}) = \left[\frac{1 - \Phi(\sigma_* - \mu_* / \sigma_*)}{1 - \Phi(-\mu_* / \sigma_*)} \right] \exp\left\{ -\mu_* + \frac{1}{2}\sigma_*^2 \right\} \tag{A5}$$

In the second-stage of our estimation, we reverse $TIneff_{k,t}$ to obtain technical efficiency by taking $EFF_{k,t} = 2 - TIneff_{k,t}$ for ease of interpretation.

For output measures, we choose the four public services: education, public welfare, transportation, and public safety. Although state governments may provide a wide range of public goods and services, from an estimation perspective, it may not be feasible for us to include all of these variables in our cost function model. This is because adding more output variables (Y_i) to Eq. A1 will lead to more regressors and interaction terms, thus decreasing the degrees of freedom. In addition, beyond a threshold, we may find collinearity in state output variables, posing other challenges in the estimation. Thus, we are faced with a tradeoff between selecting output variables to comprehensively capture state government production and balancing the number of variables to manage feasibility in estimations. We decided to include the four most representative state government outputs: education, public welfare, transportation, and public safety. According to 2008 Government Employment and Payroll statistics from the U.S. Census Bureau, these four areas comprise 68.06 percent of the total state government personnel.

Note that our output measures—higher education (Y_1), Medicaid (Y_2), highway (Y_3), and correction (Y_4)—capture only public services provided solely by state governments, not by federal and local governments. Highway (Y_3) and correction (Y_4) only account for the facilities operated by state governments. Also, historically and constitutionally, education is not under the purview of the U.S. federal government (http://www.cato-at-liberty.org/education-and-the-constitution/), and local governments do not operate higher educational institutions (Kane et al. 2003). In addition, the Social Security Act of 1965, Title XIX stipulates that Medicaid is administrated by the state governments.

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Appendix B

Description of Measures

Total Cost (C) – Current Operation Expense

Operation expense is defined as "direct expenditure for compensation of own officers and employees and for supplies, materials and contractual services" (U.S. Census Bureau 2006, p. 126). From State Government Finance published by the U.S. Census Bureau, we took current operation expense, divided it by the annual population estimate, and adjusted it for 2005 dollar with the price index for GDP provided by the Bureau of Economic Accounts.

Total Cost (C) – Capital Depreciation

We referred to the "Notes to Financial Statements" section in states' comprehensive annual financial reports to obtain annual capital depreciation. Among several capital asset categories, only buildings and equipment and related asset categories such as fixtures or vehicles are considered, because states have discretion in reporting the depreciation of other types of capital assets. For example, some states categorize infrastructure as depreciable assets, while others consider it non-depreciable. We also included the asset of primary governments and excluded that of discretely presented component units because many states do not report the capital figure of such units. Per capita capital depreciation was calculated and adjusted for 2005 dollars.

Labor Price (w_1)

The State Government Employment & Payroll data published by the U.S. Census Bureau contains the monthly payroll for full-time and part-time staff employed by state governments. We took the sum of full-time and part-time payroll and divided it by the number of full-time equivalent employees.

Capital Price (w_2)

From the State Government Finances, "interest on general debt" was divided by mean debt level (the average of "debt at end of fiscal year" at the same year and that of the previous fiscal year).

IT Price (w_3)

It was obtained by the Producer Price Index (PPI) from Bureau of Labor Statistics. Specifically, we use PPI in the category of Computer and Electronic Product Manufacturing.

Education (Y_1)

From the State Higher Education Finance Survey, the number of students enrolled in public post-secondary educational institutions was divided by the population estimate.

Public Welfare (Y_2)

From Medicaid Summary Table provided by the Center for Medicare & Medicaid Services, the enrollee population was divided by population estimate.

Transportation (Y_3)

From Highway Statistics published by the Federal Highway Administration, we took the length (miles) of rural and urban roads owned and maintained by state highway agencies and divided it by the population estimate.

Public Safety (Y_4)

From National Prisoner Statistics provided by the Bureau of Justice Statistics, we divided the total number of inmates in state correctional facilities by the population estimate.

IT Intensity (IT1 and IT2)

The 2002 NASCIO Compendium of Digital Governments in States provides the actual IT budget figures in 2001 and 2002. The 2004-05 Compendium covers the actual budgets in 2003 and 2004. IT1 was calculated by dividing actual IT budget by the population estimate. IT2 was derived by dividing the IT budget by "general expenditures" from State Government Finances.

GDP and Income (z_2 and z_3)

The public economics literature argues that economic and fiscal conditions of a government affect its efficiency (Geys 2006). For instance, De Borger and Kerstens (1996) and Grossman et al. (1999) predict that higher income can be a greater tax revenue source, opening a room for inefficiency in administration. We thus include median household income (z_2) and per capita state GDP (z_3) as control variables in the second-stage estimation (Eq. 1).

Federal Grant (z_4)

The fiscal illusion hypothesis (Geys 2006; Grossman et al. 1999) suggests that a large influx of external revenues from a higher level of governments is a source of inefficiency. Hence, we also control for per capita federal government grants (z_4) to each state government in Eq. 1. From State Government Finances, "intergovernmental revenue from federal government" was divided by the population estimate.

Governor's Political Affiliation (z_5) and Party Control of Legislatures (z_6)

We include Garand's (1988) political indicators—governor's party affiliation (z_5) and party control of legislature (z_6)—because they represent political environments that affect state government efficiency. Governor (z_5) is equal to 1 if the governor is Republican and 0 otherwise. For the legislature (z_6), we calculated the ratio of Republican state representatives in state house and Republican state senator in senate, respectively, and took the sum of two. For Nebraska, which has a unicameral legislature, we multiplied the percentage of Republican by two.

Tax Complexity (z_7)

The fiscal illusion hypothesis also predicts that the more complex a state tax system, the more inefficient the state (Garand 1988). Tax complexity was measured by a Herfindahl index of seven tax categories: personal income tax, corporate income tax, property tax, sales tax, license tax, severance tax on natural resources, and other taxes. It is given by $\sum_{i=1}^{7} t_i^2$, where t_i is the ratio of tax revenues in Category i to total tax revenues. The more complex a tax system, the smaller this measure becomes.

Rural Population (m_2)

The U.S. Census Bureau defines an urban area as a densely settled core of census tracks or blocks that meet minimum population density requirements (1,000 per square mile in most cases). The rest of the areas are designated as rural. The percentage of urban population to the total population in all U.S. states is reported in the Decennial Census only in 2000 and 2010. Suppose, for example, the urban population share as a percentage in 2000 and 2010 are u_{2000} and u_{2010}, respectively. We estimate the percentage of rural population in year t between 2000 and 2010 by $100-\left(u_{2000}+\frac{(t-2000)(u_{2000}-u_{2000})}{10}\right)$. For example, the urban population percentage in Indiana in 2000 and 2010 is reported to be 70.8 percent and 72.4 percent, respectively. We calculate that the urban population share in 2002 is $70.8+\frac{(2002-2000)(72.4-70.8)}{10}=71.12\%$ and the rural population share is 100 – 71.12 = 22.88%.

Divided Government (m_3)

It was calculated by $|2z_5 - z_6|$. We multiplied z_5 by 2 because z_6 represents the sum of the ratio of Republican members in the House of Representatives and the Senate. This measure takes a value between 0 and 2, and the larger this value, the more divided the government (i.e., the more lawmakers are in the opposition party). If this value is equal to 0, all the representatives are in the same party with the governor. If it is equal to 2, the entire body of elected lawmakers are in the opposition party.

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Appendix C

Estimation with Data Envelopment Analysis (DEA)

The productivity measurement literature also widely uses DEA. Unlike SFA, a parametric model with econometric estimation, DEA assumes that the cost frontier is deterministic. Instead of imposing a functional form as in Eq. A1, it finds a cost frontier that envelops observations by solving a linear programming problem for each observation. The public sector efficiency studies also use this DEA approach. For example, Bessent et al. (1982) and Ruggiero (1996) introduce an application of DEA in analyzing productivity of public education. Ganley and Cubbin (1996) and Cook et al. (1994) illustrate use of DEA in efficiency measurement of correctional facilities and highway maintenance, respectively.

As a robustness check, we measure state government efficiency with the input-oriented variable return-to-scale DEA model put forth by Banker et al. (1984; BCC model) to check whether IT intensity is still positively associated with DEA efficiency. We adopt an input-oriented model following our assumption that state governments minimize the use of inputs given the amount of outputs to produce. As with SFA, we obtain technical efficiencies (*DEff*) for each state government observation using DEA in the first stage and regress them on IT intensity and control variables in the second-stage estimation.

$$DEff_{k,t} = g\left(\delta_0 + \delta_{IT} IT_{k,t-2} + \sum \delta_{zi} z_{i,k,t}\right) + \upsilon_k + \varsigma_t + \xi_{k,t} \qquad \text{(A6)}$$

Again, we expect the coefficient of IT intensity to be positive and significant. Details on the linear programming model are available in Banker et al. (1984).

We use the same four output variables in Table 1. We use two input variables in our DEA analysis: per capita capital depreciation and operation expenses. The correlation in efficiency measures between SFA and DEA is 0.5039. Table D10 in Appendix D demonstrates that the coefficients of IT intensity are positive and significant. We also measure state government efficiencies with a constant return-to-scale model (Charnes et al. 1978) and with an output-oriented BCC model and regress them on IT intensity and control variables (Eq. A6). Using these alternative DEA models does not change our findings substantially.

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Appendix D

Additional Estimation Results

Table D1. Granger Casualty Tests

Panel A								
Method	**System GMM Estimation** (Blundell and Bond 1998)							
Dep. Var.	log C_t		log C_t		log C_t		log C_t	
log C_{t-1}	0.9242*** (0.0686)	log C_{t-1}	0.9118*** (0.0641)	log C_{t-1}	0.9312*** (0.0611)	log C_{t-1}	0.9367*** (0.0619)	
log C_{t-2}	-0.0363 (0.1089)	log C_{t-2}	-0.0697 (0.0906)	log C_{t-2}	-0.0561 (0.0866)	log C_{t-2}	-0.0424 (0.0890)	
log C_{t-3}	0.1208 (0.0786)	log C_{t-3}	0.1495** (0.0744)	log C_{t-3}	0.1225* (0.0716)	log C_{t-3}	0.1104 (0.0718)	
log $Y_{1,t-1}$	0.2137 (0.6025)	log $Y_{2,t-1}$	0.2358 (0.2531)	log $Y_{3,t-1}$	0.2524 (0.2708)	log $Y_{4,t-1}$	0.1193 (0.2559)	
log $Y_{1,t-2}$	-0.2417 (0.5609)	log $Y_{2,t-2}$	-0.2097 (0.2509)	log $Y_{3,t-2}$	-0.2547 (0.2711)	log $Y_{4,t-2}$	-0.1263 (0.2560)	
Granger *p*-value[a]	0.5857		0.4309		0.6342		0.8330	
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$; $N = 278$; the number of states = 50; Standard errors are in parentheses; Year dummies are omitted; log C_{t-i} are instrumented by lagged values of log C. [a]*p*-value from the tests of log $Y_{i,t-1}$ = log $Y_{i,t-2}$ = 0.								
Panel B								
Method	**System GMM Estimation** (Blundell and Bond 1998)							
Dep. Var.	log $Y_{1,t}$		log $Y_{2,t}$		log $Y_{3,t}$		log $Y_{4,t}$	
log $Y_{1,t-1}$	0.9490*** (0.0556)	log $Y_{2,t-1}$	1.2024*** (0.0479)	log $Y_{3,t-1}$	0.9514*** (0.0567)	log $Y_{4,t-1}$	0.9828*** (0.0221)	
log $Y_{1,t-2}$	0.0676 (0.0714)	log $Y_{2,t-2}$	-0.2239*** (0.0695)	log $Y_{3,t-2}$	0.0914 (0.0766)	log $Y_{4,t-2}$	0.0025 (0.0107)	
log $Y_{1,t-3}$	-0.0582 (0.0513)	log $Y_{2,t-3}$	0.0038 (0.0416)	log $Y_{3,t-3}$	-0.0314 (0.0591)	log $Y_{4,t-3}$	-0.0013 (0.0106)	
log C_{t-1}	-0.1390 (0.0945)	log C_{t-1}	0.0767 (0.1428)	log C_{t-1}	-0.0075 (0.0752)	log C_{t-1}	0.1512 (0.1354)	
log C_{t-2}	0.1676* (0.1016)	log C_{t-2}	-0.0430 (0.1451)	log C_{t-2}	0.0154 (0.0772)	log C_{t-2}	-0.1483 (0.1400)	
Granger *p*-value[a]	0.2314		0.1003		0.1685		0.5265	
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$; $N = 328$; the number of states = 50; Standard errors are in parentheses; Year dummies are omitted; log $Y_{i,t-i}$ are instrumented by lagged values of log Y_i. [a]*p*-value from the tests of log C_{t-1} = log C_{t-2} = 0.								
Panel C								
Method	**System GMM Estimation** (Blundell and Bond 1998)							
Dep. Var.	log C_t		log C_t		log $w_{1,t}$		log $w_{2,t}$	
log C_{t-1}	0.9384*** (0.0672)	log C_{t-1}	0.9069*** (0.0635)	log $w_{1,t-1}$	0.9010*** (0.0581)	log $w_{2,t-1}$	0.6425*** (0.0551)	
log C_{t-2}	-0.0331 (0.0924)	log C_{t-2}	-0.0433 (0.0884)	log $w_{1,t-2}$	-0.0741 (0.0768)	log $w_{2,t-2}$	0.0716 (0.0562)	
log C_{t-3}	0.0826 (0.0803)	log C_{t-3}	0.1108 (0.0690)	log $w_{1,t-3}$	0.1885*** (0.0593)	log $w_{2,t-3}$	-0.0547 (0.0557)	
log $w_{1,t-1}$	-0.8190** (0.4250)	log $w_{2,t-1}$	0.0486 (0.0862)	log C_{t-1}	-0.0388 (0.0855)	log C_{t-1}	-0.1933 (0.5617)	
log $w_{1,t-2}$	0.8555** (0.4172)	log $w_{2,t-2}$	0.0575 (0.0919)	log C_{t-2}	0.0384 (0.0880)	log C_{t-2}	0.2704 (0.5731)	
Granger *p*-value	0.1195[a]		0.3533[a]		0.8991[b]		0.4319[b]	
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$; $N = 328$; the number of states = 50; Standard errors are in parentheses; Year dummies are omitted; log $w_{i,t-i}$ are instrumented by lagged values of log w_i; log C_{t-i} are instrumented by lagged values of log C. [a]*p*-value from the tests of log $w_{i,t-1}$ = log $w_{i,t-2}$ = 0. [b]*p*-value from the tests of log C_{t-1} = log C_{t-2} = 0.								

Following the approach of Holtz-Eakin et al. (1988, 1989) and Podrecca and Carmeci (2001) in testing causality in a panel dataset, we use a dynamic panel data estimation model (Blundell and Bond 1998) to test the hypothesis that outputs and input prices are affected by the costs. Panels (b) and (c) shows that the test of C_{t-1} = log C_{t-2} = 0 is not rejected at the 5 percent level of significance for all the four outputs and the two input prices, indicating the absence of evidence that the costs (C) affect the amount of outputs (Y_i) and input prices (w_i).

Table D2. *t*-test Results

	States in the Second-Stage Estimation (*N* = 143)	States Not in the Second-Stage Estimation (*N* = 285)	*t* Statistics (*p*-value in Two-Tail Tests)
Population (million)	5.9117 (0.5162)	6.0385 (0.4017)	-0.1940 (0.8436)
GDP (billion $)	240.3413 (22.7472)	249.5660 (17.8706)	-0.3189 (0.7500)
Total expenditures (billion $)	24.6509 (2.2087)	25.1361 (1.8052)	-0.1701 (0.8651)
Operation and capital costs (million $)	15.1734 (1.3003)	15.3983 (0.9713)	-0.1386 (0.8899)
Efficiency (*Eff*)	0.8763 (0.0097)	0.8762 (0.0075)	0.0122 (0.9903)

Standard deviations are in parentheses.

Table D3. States in the Second-Stage Estimation

Region	Division	States
Northeast	New England	Maine(3), New Hampshire(3), Vermont(2), Massachusetts(4), Rhode Island(4), Connecticut(2)
	Mid-Atlantic	New York(4), Pennsylvania(2), New Jersey(2)
Midwest	East North Central	Wisconsin(4), Michigan(4), Indiana(2), Ohio(4)
	West North Central	Missouri(4), North Dakota(4), South Dakota(4), Kansas(4), Minnesota(4), Iowa(4)
South	South Atlantic	Maryland(4), Virginia(2), West Virginia(1), North Carolina(4), South Carolina(2), Georgia(3), Florida(2)
	East South Central	Kentucky(4), Tennessee(4), Mississippi(4), Alabama(4)
	West South Central	Oklahoma(2), Texas(4), Arkansas(4)
West	Mountain	Idaho(4), Montana(4), Wyoming(2), Nevada(4), Utah(2), Arizona(4), New Mexico(4)
	Pacific	Washington(4), Oregon(2), California(2), Hawaii(3)

The number in parentheses next to a state is the number of years that the state appears in the second-stage estimation. Geographic region and division are from the 2000 U.S. Census.

Table D4. Ordinary Least Square (OLS) Regression for IT Intensity Instruments

Method	OLS Regression	
Dependent (Endogenous) Variable	IT1 (per capita IT budget)	IT2 (the ratio of IT budget to total expenditures)
	(1)	(2)
IT-Neighbor[a]	-0.2189** (0.1069)	-0.0057* (0.0029)
IT-Firm[b]	-71.6450 (99.984)	-1.3620 (2.6222)
IT-Employee[b]	-0.2589 (0.7344)	-0.0085 (0.0198)
Population	-9.7925 (8.2524)	-0.2372 (0.2305)
Income	-2.7237 (1.6560)	-0.0741 (0.0457)
GDP	-0.2258 (1.2078)	-0.0042 (0.0309)
Federal Grant	-22.7659** (10.110)	-0.5499* (0.2892)
Governor	7.2435 (10.662)	0.2593 (0.3103)
Legislature	27.5289 (36.847)	0.7060 (1.0569)
Tax Complex	206.4315 (152.532)	5.8202 (4.1148)
Controls	Year	Year
R^2	0.2743	0.2611
F	0.92	0.86
MSE	9.999	2.786
Kleibergen-Paap Rank Wald	7.21	6.72
p-value of Wald	0.0656[c]	0.0813[c]

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; $N = 142$; the number of states = 43; Standard errors are in parentheses; Year dummies are omitted. [a]Average per capita IT budget ($) in states that share geographic boundaries with the focal state. [b]The number of IT industry firms per thousand population and the number of paid employees in IT industry firms per thousand population. [c]The null hypothesis is that the equation is under-identified; that is, the IVs are not correlated with endogenous variables (IT intensity).

Table D5. OLS Regression for Hansen *J* Tests (Hansen 1982)

Method	**OLS Regression**	
Dependent Variable	**Residuals from Table 9, Column 6**	**Residuals from Table 9, Column 7**
	(1)	**(2)**
IT-Neighbor	0.0000 (0.0002)	0.0000 (0.0002)
IT-Firm	-0.0135 (0.0728)	-0.0154 (0.0739)
IT-Employee	0.0001 (0.0008)	0.0001 (0.0008)
Constant	0.0010 (0.0081)	0.0012 (0.0082)
R^2	0.0003	0.0003
F	0.01	0.02
MSE	0.0276	0.0280
NR^2	0.0402	3.1746
p-value of NR^2	0.7800[a]	0.0280[a]

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; $N = 142$; the number of states = 43; Standard errors are in parentheses. [A]The null hypothesis is that the IVs are uncorrelated with residuals (i.e., the IVs are exogenous).

We use the following instrumental variables (IVs): average per capita IT budget in states that share geographic boundaries with the focal state (IT-Neighbor), the number of IT industry firms per capita (IT-Firm), and the number of paid employees in IT industry firms per capita (IT-Employee). The IT industries include computer and electronic product manufacturing, computer systems design and related services, and information and data processing services. The correlation of IT1 (per capita IT budget) with IT-Neighbor, IT-Firm, and IT-Employ is 0.2469, -0.2044, and -0.2564, respectively.

We choose the average IT budget in neighboring states as an instrument, since the public economics literature argues that policy making in such areas as tax systems, welfare provision, and other administrative matters can be affected by decisions made by neighboring jurisdictions (e.g., Baicker 2005; Case et al. 1993). For example, Figlio et al. (1999) show that welfare policies in one state are significantly correlated with those in neighboring states, a phenomenon called welfare competition. It may be the case with IT investments. We do not expect, however, that IT spending in neighboring states will affect overall cost efficiency of the focal state.

The other instrumental variables—the number of IT firms (IT Firm) and employment (IT Employ) in local IT sectors—represent competitiveness of local IT industries. The majority of U.S. states enact state laws or policies that give preferential treatment to in-state vendors over nonlocal providers in procurement biddings.[1] For example, Ohio laws require an Ohio bidder for procurement of supplies and services, including IT, to receive a 5 percent preference. An Ohio-based vendor with the lowest bid must be selected for any service to an Ohio state agency, as long as its price is less than or equal to 105 percent of the lowest non-Ohio bids. Therefore, as the number of IT-providing firms competing for government IT procurement in one state increases (i.e., the IT industries are more competitive), the state is able to pay more competitive prices for its IT supplies and services, decreasing the state's dollar amount in IT investment. Such preferential treatment policies limit IT procurement across state boundaries, such that states that have small, noncompetitive IT industries are still required to give priority to local suppliers in IT procurement. This may be the case with IT employment. If there is a greater supply of IT workers available in the local IT job market, a state would be able to pay more competitive salaries for its IT hires, thus reducing IT spending as well. After exhaustively searching through the extant case examples and literature, we could not find any plausible evidence that IT-Firm and IT-Employ have any direct influence on state cost efficiency.

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[1] http://www.oregon.gov/DAS/EGS/PS/pages/reciprocal_detail.aspx; accessed June 3, 2013.

Table D6. The Second-Stage Estimation Results with Different Lag Effects

Fixed-Effects Estimation with Driscoll-Kraay Standard Errors

Dependent Variable – Technical Inefficiency

Lag	No Lag		One-Year Lag		Two-Year Lag		Three-Year Lag		Four-Year Lag	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Population	0.0392*** (0.0138)	0.0405*** (0.0137)	-0.0440** (0.0210)	-0.0440** (0.0209)	-0.0281*** (0.0048)	-0.0289*** (0.0047)	0.0015 (0.0061)	0.0013 (0.0061)	0.0465*** (0.0048)	0.0458*** (0.0047)
Income	0.0036 (0.0024)	0.0035 (0.0024)	-0.0045*** (0.0006)	-0.0045*** (0.0006)	-0.0063*** (0.0018)	-0.0063*** (0.0018)	-0.0045*** (0.0004)	-0.0044*** (0.0004)	-0.0010 (0.0026)	-0.0009 (0.0026)
GDP	0.0053** (0.0024)	0.0054** (0.0024)	0.0080** (0.0037)	0.0080** (0.0037)	0.0058*** (0.0019)	0.0058*** (0.0019)	0.0024** (0.0009)	0.0020** (0.0009)	-0.0083*** (0.0023)	-0.0084*** (0.0024)
Federal Grant	-0.1104*** (0.0058)	-0.1098*** (0.0056)	-0.1520*** (0.0119)	-0.1520*** (0.0119)	-0.0813*** (0.0229)	-0.0829*** (0.0223)	-0.1300*** (0.0238)	-0.1305*** (0.0236)	-0.1749*** (0.0076)	-0.1729*** (0.0071)
Governor	0.0105** (0.0046)	0.0105** (0.0046)	0.0001 (0.0043)	0.0001 (0.0043)	-0.0103 (0.0070)	-0.0111 (0.0071)	0.0106* (0.0054)	0.0109* (0.0056)	-0.0112 (0.0080)	-0.0104 (0.0078)
Legisla-ture	-0.0716*** (0.0186)	-0.0770*** (0.0190)	-0.0573*** (0.0136)	-0.0576*** (0.0138)	-0.1761*** (0.0415)	-0.1744*** (0.0412)	-0.1051*** (0.0058)	-0.1093*** (0.0064)	-0.1722*** (0.0176)	-0.1809*** (0.0172)
Tax-complex	0.0547 (0.0811)	0.0442 (0.0809)	-0.2682 (0.1792)	-0.2715 (0.1782)	-0.2167 (0.1757)	-0.2124 (0.1709)	0.3404* (0.1736)	0.3224* (0.1780)	0.1899 (0.1519)	0.1882 (0.1564)
IT1[a]	0.0000 (0.0000)		0.0000 (0.0001)		0.0004*** (0.0001)		0.0004*** (0.0001)		0.0004*** (0.0000)	
IT2[b]		0.0014 (0.0018)		0.0005 (0.0023)		0.0152*** (0.0041)		0.0124*** (0.0025)		0.0128*** (0.0010)
N	129	129	138	138	143	143	146	146	148	148
F	12.57***	13.71***	32.21***	32.92***	22.43***	23.58***	42.24***	51.34***	875.97***	1262.94***
Within R^2	0.0845	0.0845	0.2934	0.2934	0.2687	0.2675	0.2953	0.2927	0.3793	0.3754

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$, $^{\#}p < 0.1$ (one-tail test); the number of states = 44; Standard errors are in parentheses; Year dummies are omitted; AR(3) and spatial (interstate) correlation in residuals are assumed. [a]Per capita budget of the central IT function. [b]The ratio of the central IT function budget to total expenditures.

Table D7. Kumbhakar et al. (1991) One-Stage Estimation with IT1 (Per Capita IT Budget)

Stochastic Frontier Estimation (Dependent Variable: log *C*)					
Cost Function Estimation				**Estimation for Inefficiency**	
ln Y_1	31.1564*** (9.1226)	ln w_2 ln w_2	-0.0709 (0.3663)	Population	-0.3938 (0.3082)
ln Y_2	5.8325 (5.1237)	ln w_3 ln w_3	-0.5425 (0.7310)	Income	0.0015 (0.1232)
ln Y_3	0.9065 (1.6756)	ln w_1 ln w_2	-0.5028 (0.5107)	GDP	-0.0602 (0.1428)
ln Y_4	-7.1997* (3.7081)	ln w_1 ln w_3	0.0110 (0.5163)	Federal Grant	2.9867*** (1.2524)
ln Y_1 ln Y_1	-0.3305** (0.3180)	ln w_2 ln w_3	0.6744** (0.3376)	Governor	0.8066 (1.0356)
ln Y_1 ln Y_2	-0.6688*** (0.2438)	ln w_1 ln Y_1	-1.4307*** (0.4990)	Legislature	-4.4466*** (1.3807)
ln Y_1 ln Y_3	-0.1791 (0.1131)	ln w_1 ln Y_2	0.2830 (0.4104)	Tax Complex	-1.6628 (5.1681)
ln Y_1 ln Y_4	-0.3491* (0.1854)	ln w_1 ln Y_3	0.0231 (0.1792)	IT1[a]	-0.0665$^+$ (0.0409)
ln Y_2 ln Y_2	-0.1318** (0.1148)	ln w_1 ln Y_4	1.1246*** (0.3147)	Controls	Year
ln Y_2 ln Y_3	0.0634 (0.0749)	ln w_2 ln Y_1	-0.2111 (0.2363)		
ln Y_2 ln Y_4	0.2249 (0.2170)	ln w_2 ln Y_2	0.1800 (0.2587)		
ln Y_3 ln Y_3	0.0264** (0.0220)	ln w_2 ln Y_3	0.1177 (0.0773)		
ln Y_3 ln Y_4	0.0640 (0.0712)	ln w_2 ln Y_4	-0.0866 (0.2026)		
ln Y_4 ln Y_4	-0.0116 (0.0779)	ln w_3 ln Y_1	0.4358 (0.2678)		
ln w_1	-8.8803 (6.0702)	ln w_3 ln Y_2	-0.2307 (0.2386)		
ln w_2	2.6562 (3.7225)	ln w_3 ln Y_3	-0.2173*** (0.0810)		
ln w_3	7.2241 (6.7142)	ln w_3 ln Y_4	0.0122 (0.1651)		
ln w_1 ln w_1	0.4309** (0.4370)	Controls	Geographic divisions		
σ_v	0.0344*** (0.0058)	ln *L*	189.7608***	Wald χ^2	1947.82***

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ in two-tail test, $+p < 0.1$ in one-tail test; $N = 143$; the number of states = 44; Standard errors are in parentheses; Year and geographic dummies are omitted. [a]Per capita budget of the central IT function.

Table D8. Kumbhakar et al. (1991) One-Stage Estimation with IT2 (The Ratio of IT Budget to State Expenditures)

Stochastic Frontier Estimation (Dependent Variable: log C)					
Cost Function Estimation				Estimation for Inefficiency	
ln Y_1	30.5354*** (9.1868)	ln w_2 ln w_2	-0.0427 (0.3414)	Population	-0.3597 (0.3017)
ln Y_2	7.3661 (5.3018)	ln w_3 ln w_3	-0.5525 (0.7439)	Income	-0.0285 (0.1325)
ln Y_3	1.4874 (1.6945)	ln w_1 ln w_2	-0.4333 (0.4979)	GDP	-0.0484 (0.1459)
ln Y_4	-7.5908** (3.6651)	ln w_1 ln w_3	-0.0900 (0.5102)	Federal Grant	2.6808** (1.2456)
ln Y_1 ln Y_1	-0.3358** (0.3235)	ln w_2 ln w_3	0.6904** (0.3397)	Governor	0.9363 (1.0670)
ln Y_1 ln Y_2	-0.7273*** (0.2389)	ln w_1 ln Y_1	-1.3095** (0.5180)	Legislature	-4.2287*** (1.4216)
ln Y_1 ln Y_3	-0.1812 (0.1151)	ln w_1 ln Y_2	0.1795 (0.4228)	Tax Complex	-0.4542 (5.5084)
ln Y_1 ln Y_4	-0.3218* (0.1896)	ln w_1 ln Y_3	-0.0227 (0.1803)	IT2[a]	-3.0153* (1.7240)
ln Y_2 ln Y_2	-0.1343** (0.1187)	ln w_1 ln Y_4	1.1527*** (0.3098)	Controls	Year
ln Y_2 ln Y_3	0.0503 (0.0776)	ln w_2 ln Y_1	-0.1713 (0.2369)		
ln Y_2 ln Y_4	0.2199 (0.2216)	ln w_2 ln Y_2	0.1651 (0.2546)		
ln Y_3 ln Y_3	0.0250** (0.0220)	ln w_2 ln Y_3	0.0945 (0.0783)		
ln Y_3 ln Y_4	0.0524 (0.0727)	ln w_2 ln Y_4	-0.0882 (0.1992)		
ln Y_4 ln Y_4	-0.0107 (0.0750)	ln w_3 ln Y_1	0.4046 (0.2602)		
ln w_1	-9.0682 (6.1162)	ln w_3 ln Y_2	-0.2054 (0.2312)		
ln w_2	1.6923 (3.6980)	ln w_3 ln Y_3	-0.2071** (0.0825)		
ln w_3	8.3759 (6.8591)	ln w_3 ln Y_4	0.0079 (0.1622)		
ln w_1 ln w_1	0.4281* (0.4465)	Controls	Geographic divisions		
σ_v	0.0332*** (0.0065)	ln L	187.0957	Wald χ^2	1950.23***

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, +$p < 0.1$ at a one-tail test; $N = 143$; the number of states = 44; Standard errors are in parentheses; Year and geographic dummies are omitted. [a]The ratio of the central IT function budget to total expenditures.

Table D9. The Fixed-Effects Stochastic Frontier Estimation (Greene 2005)

First-Stage Fixed-Effects Stochastic Frontier Estimation				Second-Stage Fixed-Effects Estimation with Driscoll-Kraay SE		
Dependent Variable: log C				Dependent Variable: Efficiency		
$\ln Y_1$	19.894*** (6.9737)	$\ln w_2 \ln w_2$	0.0388 (0.0558)	Population	0.0146*** (0.0033)	0.0143*** (0.0030)
$\ln Y_2$	-4.1171 (2.9996)	$\ln w_3 \ln w_3$	0.0053 (0.0458)	Income	-0.0015*** (0.0005)	-0.0016*** (0.0005)
$\ln Y_3$	-2.2792 (1.7650)	$\ln w_1 \ln w_2$	0.1568 (0.1781)	GDP	0.0011 (0.0010)	0.0011 (0.0010)
$\ln Y_4$	0.0922 (2.3530)	$\ln w_1 \ln w_3$	0.6800*** (0.1334)	Federal Grant	-0.0467*** (0.0108)	-0.0476*** (0.0105)
$\ln Y_1 \ln Y_1$	-0.3469*** (0.2339)	$\ln w_2 \ln w_3$	-0.0962 (0.0662)	Governor	-0.0097** (0.0047)	-0.0096** (0.0046)
$\ln Y_1 \ln Y_2$	0.0292 (0.1421)	$\ln w_1 \ln Y_1$	0.1234 (0.4295)	Legislature	0.0534*** (0.0137)	0.0549*** (0.0139)
$\ln Y_1 \ln Y_3$	-0.1905** (0.0833)	$\ln w_1 \ln Y_2$	0.2260 (0.2328)	Tax Complex	0.0882*** (0.0299)	0.0966*** (0.0264)
$\ln Y_1 \ln Y_4$	-0.4427*** (0.1218)	$\ln w_1 \ln Y_3$	0.4341*** (0.1511)	IT1[c]	0.0001* (0.0001)	
$\ln Y_2 \ln Y_2$	0.0759*** (0.0517)	$\ln w_1 \ln Y_4$	0.5347*** (0.1897)	IT2[d]		0.0024$^+$ (0.0021)
$\ln Y_2 \ln Y_3$	-0.0206 (0.0416)	$\ln w_2 \ln Y_1$	-0.0917 (0.1057)	Controls	Year	Year
$\ln Y_2 \ln Y_4$	0.0890 (0.0559)	$\ln w_2 \ln Y_2$	0.0763 (0.0616)	N	143	143
$\ln Y_3 \ln Y_3$	-0.0018 (0.0480)	$\ln w_2 \ln Y_3$	-0.0084 (0.0278)	F	22.65***	20.34***
$\ln Y_3 \ln Y_4$	0.0821** (0.0326)	$\ln w_2 \ln Y_4$	-0.0021 (0.0586)	Within R^2	0.2029	0.1989
$\ln Y_4 \ln Y_4$	-0.0451** (0.0202)	$\ln w_3 \ln Y_1$	-0.2332*** (0.0870)			
$\ln w_1$	-30.3146*** (11.6421)	$\ln w_3 \ln Y_2$	-0.0112 (0.0466)			
$\ln w_2$	-0.4190 (2.2738)	$\ln w_3 \ln Y_3$	0.0420** (0.0233)			
$\ln w_3$	-2.9591 (1.8943)	$\ln w_3 \ln Y_4$	-0.0543 (0.0388)			
$\ln w_1 \ln w_1$	0.5201** (0.5094)	N	428			
σ_v[a]	0.0322*** (0.0025)	$\ln L$	777.4485			
σ_u[b]	0.0232*** (0.0041)	Wald χ_2	452.61***			

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ in two-tail test, +$p < 0.1$ in one-tail test; the number of states = 44; Standard errors are in parentheses; Year dummies are omitted; AR(3) and spatial (interstate) correlation in residuals are assumed in the fixed-effects estimation. [a]The variance of idiosyncratic errors ($v_{k,t}$). [b]The variance of technical inefficiency terms ($u_{k,t}$, significance from a log-likelihood test). [c]Per capita budget of the central IT function. [d]The ratio of the central IT function budget to total expenditures.

Table D10. The Second Stage Estimation with DEA Technical Efficiency

Dependent Variable	**Technical Efficiency from BCC DEA**	
Method	**Fixed-Effects Estimation with Driscoll-Kraay SE**	
	(1)	**(2)**
Population	-0.0175** (0.0088)	-0.0181** (0.0089)
Income	-0.0020 (0.0016)	-0.0023 (0.0016)
GDP	0.0048* (0.0026)	0.0049* (0.0026)
Federal Grant	-0.0308 (0.0215)	-0.0328 (0.0211)
Governor	-0.0208*** (0.0055)	-0.0205*** (0.0052)
Legislature	-0.0297 (0.0384)	-0.0267 (0.0379)
Tax Complex	-0.0946 (0.0621)	-0.0751 (0.0642)
IT1[a]	0.0002** (0.0001)	
IT2[b]		0.0033 (0.0031)
Controls	Year	Year
F	85.89***	51.80***
Within R^2	0.1355	0.1326

**p* < 0.1, ***p* < 0.05, ****p* < 0.01; *N* = 143; the number of states = 44; Standard errors are in parentheses; Year dummies are omitted; AR(3) and spatial (interstate) correlation in residuals are assumed. [a]Per capita budget of the central IT function. [b]The ratio of the central IT function budget to total expenditures

Table D11. The Second Stage Estimation with IT Intensity as the Sum of Central IT and Executive Branch IT Budgets

Dependent Variable	**Technical Efficiency**	
Method	**Fixed-Effects Estimation with Driscoll-Kraay SE**	
	(1)	**(2)**
Population	0.1263*** (0.0196)	0.1280*** (0.0222)
Income	-0.0144*** (0.0018)	-0.0144*** (0.0018)
GDP	0.0011 (0.0030)	0.0010 (0.0029)
Federal Grant	-0.1778*** (0.0167)	-0.1758*** (0.0196)
Governor	-0.0600*** (0.0150)	-0.0610*** (0.0156)
Legislature	-0.0882*** (0.0238)	-0.0832*** (0.0231)
Tax Complex	0.3407*** (0.0854)	0.3207*** (0.0801)
IT1[a]	0.0002*** (0.0000)	
IT2[b]		0.0091*** (0.0022)
Controls	Year	Year
F	26.25***	1607.62***
Within R^2	0.5321	0.5332

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$; $N = 76$; the number of states = 29; Standard errors are in parentheses; Year dummies are omitted; AR(3) and spatial (interstate) correlation in residuals are assumed. [a]Per capita total IT budget. [b]The ratio of total IT budget to total expenditures.

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