AJAE Appendix for "*Public Investment and Industry Incentives in Life-Science Research*"

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Note: The material contained herein is supplementary to the article named in the title and published in the American Journal of Agricultural Economics (AJAE).

This appendix elaborates on the selection of instrumental variables in the GMM estimation of our econometric model. We use the agricultural submodel for illustrative purposes. The medical submodel can be obtained by replacing subscript *ag* with *med* and *med* with *ag* in the following equations and vectors.

The estimating equations for the agricultural research industry can be obtained by defining the disturbances of equations (1), (2), and (9) in our article, that is

(A1) $$\mu_{ag,1t} = w_{ag,t} - [\alpha_1 + \alpha_2 h_{ag,t}],$$

(A2) $$\begin{aligned}\mu_{ag,2t} = y^{prv}_{ag,t} - [\beta_1 + (\beta_2 + \beta_5 h^{pub}_{ag,t} + \beta_6 h^{pub}_{bio,t} + \beta_7 h^{pp}_{med,t}) h^{prv}_{ag,t} \\ +0.5\beta_3 (h^{prv}_{ag,t})^2 + 0.5\beta_4 (h^{prv}_{ag,t} - h^{prv}_{ag,t-1})^2],\end{aligned}$$

where $y^{prv}_{ag,t}$ denotes medical knowledge output, and

(A3) $$\begin{aligned}\mu_{ag,3t} = \beta_2 + \beta_5 h^{pub}_{ag,t} + \beta_6 h^{pub}_{bio,t} + \beta_7 h^{pp}_{med,t} - \frac{w_{ag,t}}{p_{ag,t}} + \beta_3 h^{prv}_{ag,t} \\ + \beta_4 (h^{prv}_{ag,t} - h^{prv}_{ag,t-1}) - r\beta_4 (h^{prv}_{ag,t+1} - h^{prv}_{ag,t}).\end{aligned}$$

Stochastic Euler equation (9) and equation (A3) imply immediately that:

(A4) $$E_t \mu_{ag,3t} = 0.$$

Disturbance $\mu_{ag,3t}$ is an expectation error independent of any variable in the representative firm's information set $\Omega_{ag,t}$. And (A4) embodies the rational expectations thesis: economic agents' expectation mistakes are random errors uncorrelated with the information available. Define $z_{ag,3t} = (h^{pub}_{ag,t}, h^{pub}_{bio,t}, h^{pp}_{med,t}, h^{prv}_{ag,t}, w_{ag,t}, p_{ag,t})'$. Since each element of vector $z_{ag,3t}$ belongs to information set $\Omega_{ag,t}$, we have, by the law of iterated expectation, the following moment conditions for equation (A3):

(A5) $$E(z_{ag,3t} \otimes \mu_{ag,3t}) = 0.$$

The disturbance term in supply equation (A1) can be interpreted as an input supply shock. Instruments must be found for equation (A1) that are demand shifters but not supply shifters. Candidates include knowledge output price $p_{ag,t}$, public-sector biological research investment $h^{pub}_{bio,t}$, and total agricultural R&D investment $h^{pp}_{med,t}$. While knowledge output price unequivocally shifts demand and not supply, biological and agricultural R&D investments may to some extent be substitutable for medical R&D investments and hence shift the supply of, and so be correlated with, medical research inputs. Hence, we define two instrument sets for (A1): $z^1_{ag,1t} = (1, p_{ag,t})'$ and $z^2_{ag,1t} = (1, p_{ag,t}, h^{pub}_{bio,t}, h^{pp}_{med,t},)'$. The moment conditions for (A1) are therefore one of the following two equations:

(A6) $$E(z^k_{ag,1t} \otimes \mu_{ag,1t}) = 0, \quad k = 1, 2.$$

The disturbance term in production function (A2) can be interpreted as a technological shock in knowledge production. Because knowledge output is measured by patent numbers, the disturbance also may be interpreted as a change in the frequency with which a patent application is awarded or a change in the firm’s propensity to patent. The independent variables in production function (2) are chosen to be equation (A2)’s instrumental variables:

$$z^1_{ag,2t} = (1,\ h^{prv}_{ag,t},\ h^{pub}_{ag,t}h^{prv}_{ag,t},\ h^{pub}_{bio,t}h^{prv}_{ag,t},\ h^{pp}_{med,t}h^{prv}_{ag,t},\ 0.5(h^{prv}_{ag,t})^2,\ 0.5(h^{prv}_{ag,t} - h^{prv}_{ag,t-1})^2\ )'.$$

Because of (A2)’s quadratic specification, the disturbance term can shift the production function up or down but cannot affect its curvature. Consequently, R&D investment demand obtained from the first-order condition of the profit optimization problem is independent of the disturbance term in the production function. This justifies the use of private medical research $h_{ag,t}^{prv}$, and other explanatory variables that depend on it, as instruments for (A2).

Finally, for the assumption that the disturbance term in equation (A2) is independent of output price $p_{ag,t}$ and input price $w_{ag,t}$, the following alternative sets of instruments may be postulated:

$$z_{ag,2t}^{2} = (1, h_{ag,t}^{prv}, h_{ag,t}^{pub}h_{ag,t}^{prv}, h_{bio,t}^{pub}h_{ag,t}^{prv}, h_{med,t}^{pp}h_{ag,t}^{prv}, 0.5(h_{ag,t}^{prv})^2, 0.5(h_{ag,t}^{prv}-h_{ag,t-1}^{prv})^2, p_{ag,t}, w_{ag,t})' .$$

Moment conditions for production function (A2) consequently would be one of the following two equations:

(A7) $$E(z_{ag,2t}^{k} \otimes \mu_{ag,2t}) = 0, \quad k = 1, 2 .$$

Altogether, we have four instrument sets for the three equations (A1 - A3):

$\{z_{ag,1t}^{1}, z_{ag,2t}^{1}, z_{ag,3t}\}$, $\{z_{ag,1t}^{2}, z_{ag,2t}^{1}, z_{ag,3t}\}$, $\{z_{ag,1t}^{1}, z_{ag,2t}^{2}, z_{ag,3t}\}$, $\{z_{ag,1t}^{2}, z_{ag,2t}^{2}, z_{ag,3t}\}$.

In both agriculture and medicine, our estimates from instrument set $\{z_{ag,1t}^{2}, z_{ag,2t}^{1}, z_{ag,3t}\}$ generated the smallest mean squared prediction error and our discussion in the article uses results from this instrument set.

Below are time series plots of the key variables in table 1 of the text, including research output and input in both medical and agricultural research.

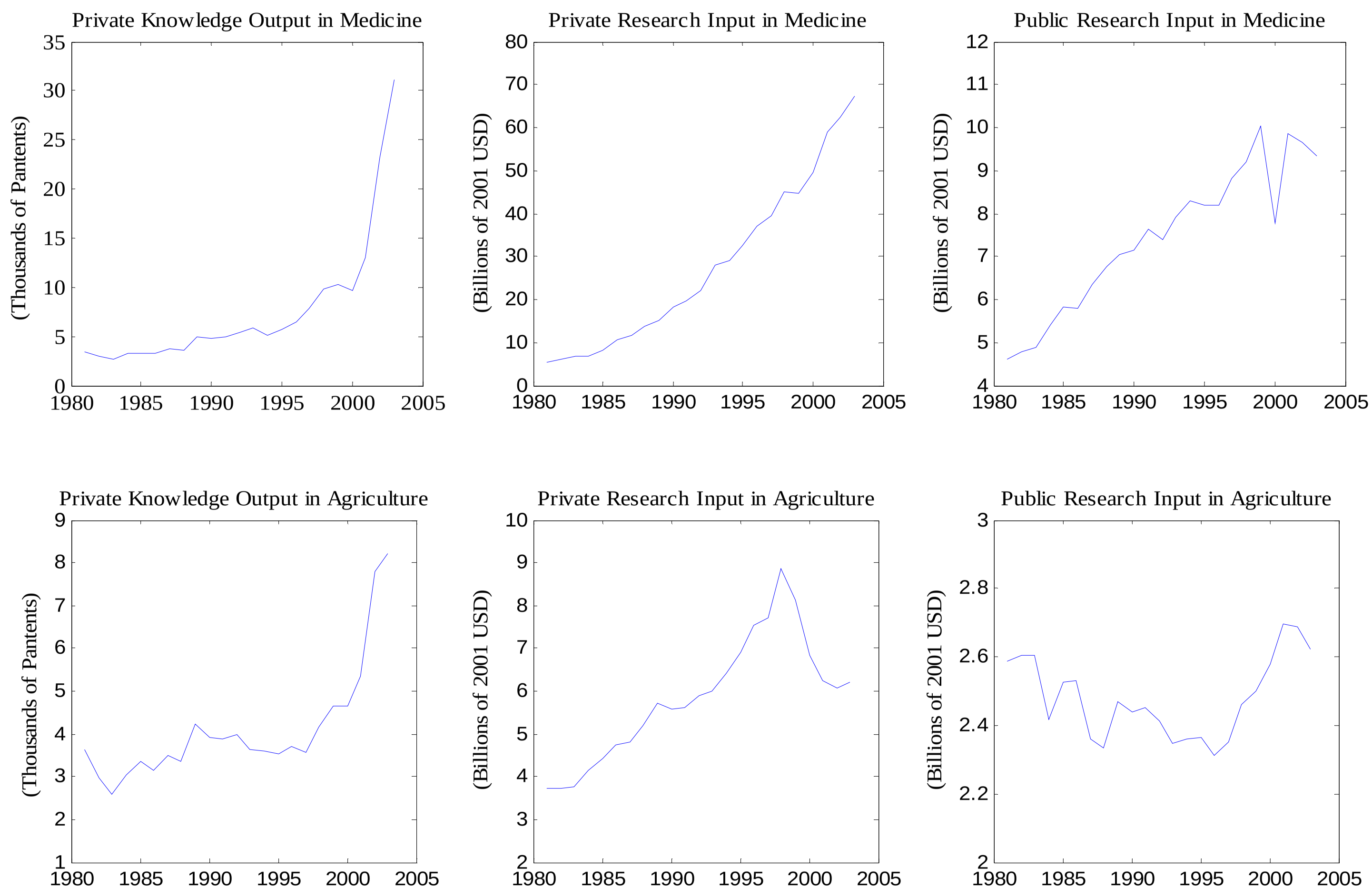

Figure 1. Time-Series Plots of Research Input and Output in Medical and Agricultural Research