DETERMINANTS OF STATE ECONOMIC GROWTH: COMPLEMENTARY RELATIONSHIPS BETWEEN R&D AND HUMAN CAPITAL

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ABSTRACT

According to a recent Cleveland Federal Reserve Study, economic growth is a function of education, innovation (measured by patent statistics), and industry specialization. In another Cleveland Federal Reserve study, Bauer et al. find both the percent of the population with a college degree and the percent of the population with a high school diploma to be highly significant in determining economic growth rates. We wish to use these findings as an empirical baseline to guide our own research and determine the importance of research and development in economic growth rates. Using data from the National Science Foundation's (NSF) annual surveys of government, academic, industry and non-profit R&D expenditures, the U.S Bureau of Economic Analysis determined R&D contributed 6.5 percent to economic growth between 1995 and 2002. (NSF 2006). In our study, we will substitute research and development expenditures for patents as the innovation variable as R&D is more easily controlled from a policy standpoint. Our hypothesis will be that it should produce results similar to the patent variable used by the Fed. We anticipate that R&D will complement college education. We hope to find a correlation between the states with higher per capita incomes and the states that partake more in research and development.

MOTIVATION

Many studies have linked innovation to the lack of complete per capita income convergence within the United States through patent data. We have chosen to instead look at the amount of money spent within a state on research, and then to break that down into money spent by the federal and state governments, the industrial or private sector, and academic institutions. States that host a large degree of research, be it applied or basic, tend to attract a higher percentage of educated people who will draw higher salaries than people who are less educated. This in turn will increase the per capita income of the research-heavy state (Barro et al. 1991).

Patents measure the creative output of research and development, but they do not reflect the differing amounts of capital that go into producing them. Also, patents cannot entirely measure basic research; they are better indicators of applied research, which often depends on the foundations established by basic research. So while patents are a reasonable measure of inventive output, they fall short as a measure of innovative inputs. However, since most studies focus more heavily on patent statistics, we have chosen to look more stringently at the amount of money involved and use research and development data. (Grilches 1990).

Characteristically, much of the R&D in the United States occurs at universities across the country, which is why we expect an education compliment. Universities are linked to overall research and development not only in the sense that a great deal of the actual research transpires at them, but also because they train students and give them the skills necessary to excel in science and engineering, which are often imperative for new research and innovation. A 2006 study looked at the percentage of patents that listed inventors who had an advanced degree in engineering or in the natural or life sciences; an indicator of an extensive training period. In 1985, 6.9 percent of inventors had an advanced degree, while only twelve years later that number had risen to 14.7 percent (Kim and Marschke, 2006). Often, companies or firms will pay universities to perform applied research, or to investigate a specific problem and find a solution. Knowledge spillover is also an important aspect of the close proximity of academia and industry (Foray, 101).

METHODS AND RESULTS

In our study, we looked at the effects of total R&D expenditures on growth rates from 1980-2005, growth rates from 1995-2005 and income levels in 2005. We then multiplied variables together in order to determine interaction results and ran the new variables in the same regressions. We had significant findings in all three categories, so we will describe the regression results in detail.

Income Levels

One of the first things we wanted to examine was the idea that differences in total R&D spending explain the differences in income levels across the United States. In order to do this, we used Per Capita Personal Income for 2005 as the dependent variable and 1999 tax rates, 1999 business failure rates, 1999 college graduation rates, and total per capita research and development expenditures for the independent variables. These variables were used in the Cleveland Federal Reserve study, which we used as a baseline for our regression. Both total per capita research and development and college graduation rates were significant above the 1% level. The R&D variable had a T-Score of 2.83. We then added an additional independent variable: 1999 high school graduation rates. Even with this extra variable, both college and total per capita R&D were still significant at the 1% level, and the R&D variable actually had a stronger T-Score (2.99).

Economic Growth Rates 1980-2005 and 1995-2005

We expected to get roughly the same results as the Cleveland Federal Reserve Bank when we ran regressions with the growth rates as the dependent variable, since we used their data for some of the independent variables and replicated their study as closely as possible. Using the 1999 tax rate, the 1999 business failure rate, the per capita research and development variable and 1999 college graduation rates either produced negative T-Scores for research and development or positive and insignificant T-Scores. The same results were true when high school graduation rates were added. Also, when we took out the research and development variable, and put in the patent statistics that the Cleveland Fed used in their original papers, the patent statistic T-Scores were negative as well, which is not at all what they found. Possibly because the Cleveland Federal Reserve used a panel data set, while we only used data from one year and did an OLS linear regression. We did not control for as many variables as the Federal Reserve did, which may have made a difference in our results.

Interaction Effects

The most significant results that we found were regarding interaction effects. We created three new variables using our data. These are: the product of college graduation rates and total per capita R&D, the product of per capita patents and total per capita research and development, and the product of college grad. rates, total per capita R&D and per capita patent statistics.

We have found an instance of highly complimentary variables in our study, in terms of both growth rates and income levels. When the three new variables were added to the income level regressions, each new variable was statistically significant, and in only one regression was the new variable not significant at above the 1% level. This indicates that a college education, patent statistics, and research and development are highly complimentary and that each is needed in order to achieve a high-income level.

When the new variables were added to the growth rate regressions, most of the results were highly significant as well, showing that the multipliers for the new variables are all necessary for economic growth, as well as for high income levels. These regression results can be found in the following tables.

PER CAPITA INCOME GROWTH RATES 1985-1995

P.I.G. 1980-2005	1	2	3	4	5	6	7
Per Capita	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**
Income 1980	**-2.82**	**-2.68**	**-3.18**	**-3.24**	**-2.76**	**-3.4**	**-3.57**
Tax Rates	-1.392	-1.386	**-1.414**	**-1.483**	**-2.188**	**-1.617**	**-1.678**
	-1.61	-1.57	**-1.70**	**-1.76**	**-2.36**	**-1.91**	**-2.02**
Business	**-9.419**	**-9.423**	**-8.168**	**-7.936**	-6.064	**-7.742**	**-7.29**
Failure Rates	**-2.53**	**-2.51**	**-2.26**	**-2.17**	-1.51	**-2.12**	**-2.03**
Total Per	.0245	.0240	**-.1978**	-.2222	-.015	-.056	-.037
Capita R&D	1.05	.97	**-1.83**	-1.96	-.38	-1.41	-1.17
College Grad.	**.0098**	.0098	.0023	.0001	X	**.0099**	**.0064**
Rates	**3.48**	3.1	.51	.03		**3.28**	**2.00**
High School	X	-.0001	X	.0021	.0045	.0008	.0014
Grad. Rates		-.06		.74	1.62	.30	.55
Patents Per	X	X	X	X	-.212	**-.246**	**-.158**
Capita					-1.53	**-1.97**	**-1.76**
R&D x	X	X	**.0087**	**.0099**	X	X	X
College			**2.11**	**2.22**			
R&D x	X	X	X	X	**.2858**	**.2964**	X
Patents					**2.17**	**2.51**	
R&D x	X	X	X	X	X	X	**.0087**
Patents x College							**2.85**

PER CAPITA INCOME GROWTH RATES 1995-2005

P.I.G. 1995-2005	1	2	3	4	5	6	7
Per Capita	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**
Income 1995	**-1.73**	**-1.85**	**-1.96**	**-2.41**	**-1.87**	**-2.48**	**-2.53**
Tax Rates	-.5711	-.6159	-.6227	-.7241	-.8483	-.739	-.7833
	-.89	-.99	-.97	-1.2	-1.38	-1.24	-1.30
Business	-.9298	.6589	1.206	1.068	1.922	-.9702	-1.056
Failure Rates	-.36	-.26	.46	.43	-.79	-.41	.44
Total Per	-.0017	.0059	-.0806	-.1452	-.0267	**-.2236**	-.0245
Capita R&D	-.10	.34	-1.05	-1.8	-.98	**-2.60**	-1.08
College Grad.	**.0057**	.0036	.0029	-.0019	X	**.0043**	.0022
Rates	**2.68**	1.57	.89	-.54		**1.98**	.97
High School	X	**.0037**	X	**.0049**	**.0060**	**.0044**	**.0048**
Grad Rates		**1.97**		**.2.55**	**3.50**	**2.46**	**2.58**
Patents Per	X	X	X	X	**-.203**	**-.2237**	**-.1449**
Capita					**-2.30**	**-2.60**	**-2.28**
R&D x	X	X	.0034	**.0061**	X	X	X
College			1.05	**1.91**			
R&D x	X	X	X	X	**.1918**	**.2100**	X
Patents					**2.25**	**2.53**	
R&D x	X	X	X	X	X	X	**.0054**
Patents x							**2.41**
College							

PERSONAL INCOME LEVELS IN 2005

P. I. Levels 2005	1	2	3	4	5	6	7
Tax Rates	**-104593**	**-105796**	**-102375**	**-103969**	**-139527**	**-110527**	**-112213**
	-2.56	**-2.59**	**-2.65**	**-2.79**	**-3.56**	**-3.02**	**-3.15**
Business	**-115297**	-124134	-60082	-63103	28986	-61647	-44022
Failure Rates	**-.66**	-.71	-.36	-.39	-.17	-.39	-.29
Total Per	**3029**	**3285**	-9633	**-12339**	-378.52	-2164	-992.19
Capita R&D	**2.83**	**2.99**	-1.86	**-2.37**	-.2	-1.19	-.68
College Grad.	**525.8**	**450.8**	90.69	-163.34	X	435	224.51
Rates	**3.95**	**2.95**	.42	-.67		3.16	1.55
High School	X	131.8	X	**253.26**	**327.58**	152.6	186.09
Grad. Rates		.99		**1.99**	**2.75**	1.26	1.57
Patents Per	X	X	X	X	**-12490**	**-13670**	**-8141**
Capita					**-2.02**	**-2.44**	**-2.02**
R&D x	X	X	**492.28**	**616.5**	X	X	X
College			**2.49**	**3.06**			
R&D x	X	X	X	X	**17855**	**17869**	X
Patents					**3.12**	**3.45**	
R&D x	X	X	X	X	X	X	**513.31**
Patents x							**3.86**
College							

Summary

Each year, billions of dollars are spent on research and development in the United States. Is it worth it? Do states benefit? If so, do they benefit more from research and development than they would if the money were spent on infrastructure or education? In 2006, the Cleveland Federal Reserve Bank published a study that examined five variables that impact economic growth rates. This study found that the largest factor causing income differences across states is innovation (proxied by patent statistics), followed by education and industry specialization, while tax policy and public infrastructure are not significant. These results are new and striking. We have used this Fed study as our baseline. However, while patent stats are certainly important, we decided to focus on R&D as this variable can be influenced directly by public policy.

Through regression analysis we found positive effects from total R&D expenditures on income levels. Our paper is innovative in showing "complementarities" between R&D and college education and patents. These joint effects are very strong. States can significantly increase their growth rates by investing more in universities and innovation. The empirical results confirm the intuition that college education by itself will not fully generate innovation. Similarly, benefits of research and development do not occur without first investing in higher education. Education and R&D complement each other.

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