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Regional Economic Impacts of Federal Research and Development Spending, and City Size

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<Contents>

Ⅰ. Introduction

Historically, federal research and development (hereafter, R&D) spending in the United States have been concentrated in a small number of large urban areas. (Malecki, 1982: 20). For example, 20 metropolitan areas received 90.2 percent of total federal R&D funds in 1965, and 87.3 percent in 1977 (Ibid: 29). During FY 1986 - 1988, 39 metropolitan areas received more than 76 percent of federal contract R&D funds. For the most part, federal R&D funds have been distributed directly to performers that are judged possess the infrastructual and institutional capabilities necessary to pursue the objectives of the R&D agendas. As a result, the disbursement of federal R&D funds inevitably yields spatial concentration. Even if federal

R&D investment has never been viewed as a primary policy instrument for promoting regional economic development, federal R&D investment flows into a region may help to sustain the economic base as providing direct income source and stimulating the industrial technology base of the region.

This study proceeds by drawing on what is known about both the distributional and locational features of R&D spending. It then tests a series of models in an effort to detect and identify income and employment impacts associated with federal contract R&D spending and with city size. Finally, it concludes by examining in detail the apparent non-linear relationship between city size and economic impacts.

Ⅱ. Locational Constraints of R&D Activities

Malecki (1979: 310) and Buswell (1983: 15) indicate that R&D activities in general tend to agglomerate in large urban areas where research universities, R&D workers, and manufacturing are present. R&D activities also tend to be near or at the location of corporate headquarters, also typically in large urban areas. This pattern is thought to reflect the fact that R&D activity is an expression of overall corporate strategies and is more likely to be hosted in decision making centers than in locations that host more routinized individual production activities (Malecki, 1979: 310; 1983: 102).

Locational preferences of R&D personnel are also a major locational constraint of R&D activities. It is generally accepted that R&D staffs prefer to live in large urban areas because they provide access to good schools, a wide range of housing choices, future employment opportunities and other environmental amenities (Buswell, 1983: 15; Malecki, 1983: 107; 1987: 212).

The presence of research universities and R&D laboratories is also deemed an important locational determinant for R&D activities. Such institutions provide not only physical facilities but also pools of highly qualified researchers and successive cohorts of graduate students who comprise future employment pools. The location of government R&D laboratories is likewise regarded as a major locational constraint for certain firms that rely on government contract R&D funding (Malecki, 1979: 310; 1988: 387). Since new product manufacturing which results from R&D requires skilled labor forces until the production line can be routinized, the location of R&D activities may also be related to the location of manufacturing centers (Malecki, 1979: 310).

The major factors thought to influence the geographical concentration of federal R&D funds include the presence of established federal R&D laboratories, regional specialization, agglomeration, and political influences (Malecki, 1982: 23). According to Malecki, agglomeration which can develop from a local specialization is one of most important factor influencing the regional concentration of federal R&D spending (Ibid).

Although the importance of each of those locational constraints can differ by industry sector and the characteristics of individual R&D projects, the majority of studies have confirmed that R&D activities primarily takes place in urban areas (Buswell, 1983: 15).

Ⅲ. Regional Economic Impacts of R&D Investment: Theoretical Approaches

The major theoretical studies on the regional economic effects of R&D investment indicate that the regional economic impacts of R&D investment are come through two different main mechanisms: 1) direct income and employment effects; and 2) indirect economic effects which operate through the agglomeration of local R&D capacities (U. S. Department of Commerce, 1967; NAS, 1969; Malecki, 1981a, 1981b, 1982).

(1) Direct income and employment effects. R&D investment in a region generates direct employment of R&D personnel. The purchasing by local R&D institutions and spending by R&D employees in turn generate multiplier effects in the regional economy. The spending tied to payrolls associated with the employment and purchasing of the R&D institutions create additional local employment and income sources.

(2) Indirect economic effects. In this category, R&D investment can generate regional economic effects through the improved functioning of local R&D organizations. This, in turn, strengthens the larger regional economic infrastructure. To a large extent, there are two different ways that local R&D organizations can benefit the regional economy through its functions: 1) the results of the R&D performed in the region; and 2) the industrial/commercial spin-offs stimulated by the local R&D agglomeration process.

Local R&D capabilities can influence a regional economy positively through the results of its R&D activities in the long term (Thwaites, 1982, 1983). The outcomes of R&D activities can typically be expressed in terms of either new ideas or knowledge, new products, or new production process. New ideas or knowledge can expand and/or deepen a firm's technology base. A new production process can lower costs of production, and new products may help a firm maintain its existing consumers and create new markets (Oakey, 1983: 61). Therefore, the adoption of new technology by a local firm can improve the firm's competitive position within its industry, and consequently, it is in a position to generate additional job opportunities and income sources for the region which hosts it (U. S. Department of Commerce: 12).

The bane of this perspective on regional economic development, on the other hand, is that the gains associated with the production of new products and its associated diffusion are not necessarily appropriable by a specific region. However, since experimentation that results in innovation requires skilled labor and special regional infrastructures, in the early stage of producing new products, production activities and technology diffusion are more likely to occur within the region where the R&D performing organizations are located. In this context, the results of R&D can generate additional local income and employment (Lonsdale and Seyler, 1979: 58-60; Rees, 1979: 48-51).

Indirect economic effects of R&D investment are also tied to the agglomeration process that tends to cluster and leverage local R&D organizations and downstream results of the industrial spin-off process. Several studies indicate that new firm spin-offs occur where the new entrepreneurs learned necessary skills from a former employer (Garvin, 1983; Malecki, 1981b, 1981c. 1982; Oakey, 1983). Malecki and Oakey have defined organized R&D as a potential source of industrial spin-offs, as start-up firms can obtain necessary information, data, R&D personnel and facilities from local R&D organizations (Malecki, 1981b, 1981c, 1982, 1984; Oakey, 1983, 1984). Alternatively, R&D investment can result in indirect regional income and employment by providing sources of industrial spin-offs through the local R&D-performing organizations.

Concentration of R&D activities in a region and the results of industrial spin-off within a region also generate further local agglomeration of industry and R&D activities (Malecki, 1981b: 123). According to Malecki, agglomeration in R&D results from the locational preferences of R&D personnel. These include major metropolitan areas, attractive environmental amenities apart from city size, and existing R&D labor pools that can sustain new rounds of corporate research growth (Ibid). Agglomeration in R&D is a stimulus for new industry within a region, especially start-up firms, resulting in new industrial growth. As a result, agglomeration in R&D leads to further agglomeration of industry.

Regionally distributed federal R&D investment can generate direct income and employment effects, and it also can bring additional benefits to the economies through the complementary roles played by R&D performers as described above, although it is suspected that commercial spin-offs from government R&D are infrequent (Malecki, 1981a: 7). In addition to these more "natural" processes, federal R&D has been subject to attempts to induce spin-off. Among more recent ones is an Executive Order dated March, 1983 intended to stimulate the flow of the results of work performed in federal laboratories into commercial applications in the private sector. The mechanism embodied in this document granted permission for all businesses to retain rights to results of federally funded research (Congressional Budget Office, 1984: 86). The stated purpose of this policy shift, of course, was to simulate the commercial application of the results of federally-funded R&D. However, the longer-term - and unstated aim - was to stimulate additional income and employment for the nation, if not necessary the host region.

The regional economic impact of R&D investment, on the other hand, may differ with the population size of the host region. Spatial concentration of R&D activities can generate agglomeration effects, and R&D activities are tend to agglomerate in large urban areas as discussed above. Many theoretical and empirical studies on agglomeration economies indicate that large cities have advantage in innovative activities over small cities since large cities can provide a stable, diversified and progressive economic structure (Hoch, 1972; Richardson, 1973; Malecki and Varaiya, 1986; Montgomery, 1988). Dieperink and Nijkamp (1988), however, found that medium-size towns have more innovation potential than large cities in the case of Netherlands cities. R&D investment is the key input of innovative activities, and innovative capability of a regional or national economies are the key factor that influence the economies. In this research, I intend to investigate how the regional economic effects of federal contract R&D spending differ with the size of the host cities.

Ⅳ. Metro-Regional Income and Employment Effects of Federal Contract R&D Spending

There exist a number of empirical studies on the relationship between industrial R&D activities and regional economic growth. In general, they tend to show that regions with more R&D activities or innovation resources have a comparative advantage over other regions in terms of technological change, the creation of new products and new industries which consequently contribute to regional economic growth (Clark, 1972; Meyer-Krahmer, 1985; Norton and Rees, 1979; Rees, 1979; Oakey, 1984; Thwaites, 1982, 1983).

Few studies, however, have examined the effects of federal R&D spending on regional economies. None of the studies attempted to examine cross-sectional and longitudinal income and employment effects of federal R&D funds at the level of metropolitan areas. In this research, the regional income and employment effects of federal contract R&D spending are examined through cross-sectional and pooled analyses with simultaneous equation estimation and weighted least squares estimation techniques.[1] Annual average employment rate and real

[1]To estimate the coefficients of the simultaneous equations, the 2-stage least squares (2SLS) estimation technique is used. Since the regional distribution of federal contract R&D funds has been concentrated in a small number of urban areas, heteroskedastic error may be presented in the data set. Hence, I also used the weighted least squares (WLS) estimation technique to obtain less biased parameter estimates after conducting the White's test for heteroskedasticity.

annual average wage level are used to measure the regional income and employment effects of federal contract R&D spending.[2]

In this empirical study, the unit of analysis is Metropolitan statistical Area (MSA). Three different sample populations are employed to test the models - all MSAs, largest 39 MSAs and all MSAs excluding the 39 MSAs whose selection was based on their 1980 population size.[3] Federal contract R&D data for all MSAs are available for only a three-year period -- FY 1986 to 1988, while the data for the largest 39 MSAs are available for FY 1982, 85, 86, 87, and 88. The following simultaneous equation models are formulated under the assumption that employment rate and wage level have bidirectional feedback and they are common to the models tested.

$$ER_i = f(AAW_i, PFR_i, POP_i, PME_i, PSE_i, DR1, \ldots, DR8) \;\ldots\ldots \quad (1)$$

$$AAW_i = f(ER_i, PFR_i, POP_i, PMI_i, PSI_i, DR1, \ldots, DR8) \;\ldots\ldots \quad (2)$$

ER_i is the annual average employment rate in ith Metropolitan Statistical Area (MSA). AAW_i is the real annual average wage in ith MSA. PFR_i is real per capita federal contract R&D funds[4] in ith MSA. POP_i is the population size in thousand in ith MSA. PME_i is the percentage of manufacturing sector to total employment in ith MSA. PMI_i is the percentage of manufacturing sector income to total income in ith MSA. PSE_i is the percentage of producer service sector employment to total employment in ith MSA. PSI_i is the percentage of producer service sector income to total income in ith MSA. Regional dummies representing

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[2]Real annual average wage levels for each metropolitan areas are obtained by dividing real total annual wage by total annual average employment. To control living cost differences among MSAs and inflation rate, cost of living index and a GNP deflator (1985 = 100) are used. This study confined the analysis to nonagricultural private sector activities only.

[3]The population size of the largest 39 MSAs is at least 1 million in 1980.

a geographical characteristics of MSAs which categorized based on the census divisions.[5]

V. Model I: Regional Income and Employment Effects for All MSAs

Cross-sectional analyses consistently indicate that federal contract R&D funds affected regional annual average employment rates and real annual average wages positively. The signs of the per capita federal contact R&D funds coefficients (PFR) in both employment (ER) and real annual average wage (AAW) equations are positive in all cross-sectional analyses and are statistically significant except in the case of the FY 1988 ER equation.

Since large cities command a large proportion of total federal contract R&D funds, it is suspected that heteroskedastic error terms might exit in the data sets. This may have resulted even though the population size variable is included in the all equations and standardized most variables by population size to control error variances. To detect heteroskedasticity, White's test was conducted and heteroskedasticity was found in the FY 1987 ER and AAW equations. Thus, a two-step weighted least squares (WLS) technique was used to obtain more efficient estimates. The results of WLS and 2SLS for the FY 1987 ER and AAW equations are more significant than the parameter estimates produced by 2SLS. The signs of AAW and ER in the respective equations, on the other hand, are negative in all sets of cross-sectional analyses. This indicates, as expected, that metro-regional employment rates and annual average wages exhibit a negative bidirectional relationship with one another.

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[4]To obtain real per capita federal contract R&D funds, I used GNP deflator only.

[5]DR1 = 1 if Middle Atlantic; DR2 = 1 if East North Central; DR3 = 1 if South Atlantic; DR4 = 1 if South Atlantic; DR5 = 1 if East South Central DR6 = 1 if West South Central; DR7 = 1 if Mountain; and DR8 = 1 if Pacific. For purposes of the dummy variable analysis, the New England division is omitted. As none of the largest 39 MSAs is located in East South Central Division, there are only 7 regional dummies for the 39 largest MSAs model, and DR6 represents the West South Central Division and DR7 represents the Mountain Division. As the number of regional dummy variables in the two different sample populations (top 39 MSAs vs. 270 MSAs) are not same, it is not possible to conduct an F-test to examine whether the coefficients for R&D funds came from two different sample populations are significantly different.

In order to obtain more efficient parameter estimates, cross-sectional and time-series data were combined[6], and a pooled model with dummies was used. In this pooled model, two time dummies were added to the equations.[7] The results yield more efficient parameter estimates than obtained in the cross-sectional analyses. As indicated in Table 1, each dollar of per capita federal R&D was associated with an increase of 0.0019 percent in the regional employment rate, as well as with an increase of 3.04 dollars in real annual average wage. The magnitude of the coefficients of PFR variables seem to be small. However, when we consider the absolute size of federal contract R&D spending, the potential for a substantial impact of federal R&D spending on regional economies simply cannot be ignored.

The signs of all the estimates of major control variables are positive and are statistically significant except the producer services share of total regional income variable (PSI) in the annual average wage (AAW) equation. These results indicate that city size, and manufacturing and producer service shares of total regional employment and income are positively associated with regional economic growth. The estimates of regional dummies further indicate that the Mountain division had the lowest annual average employment rate and wage level of all census divisions, while the Middle Atlantic division had the highest annual average employment rate and wage level during the period. The time dummies indicate that by inference FY 1988 was a recovery year for the economy.

An examination of the error terms in the pooled data set for heteroskedasticity using White's procedure indicated that the variances of the error terms were not constant. Therefore, the WLS technique was used to gain more efficient parameter estimates. As shown

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[6]To examine whether the parameter estimates of simultaneous equations are consistent over time and over cross-section unit, i.e., whether the cross-section and time-series data can be pooled, the Likelihood Ratio (LR), or Wald (W) or Lagrangian Multiplier (LM) tests are generally used. For these tests, we need the Maximum Likelihood (ML) estimates from both restricted and unrestricted maximization of the likelihood function (Maddala, 1988: 84-86). Since I used 2SLS technique to obtain the parameter estimates of the simultaneous equations in this study, I was not able to test whether the parameter estimates are consistent over time and over cross-section unit. The regression analyses in this study, however, yielded consistent parameter estimates in most cases.

[7]DY86 is the time dummy for FY 1986 and DY87 is the time dummy for FY 1987.

TABLE 1: POOLED ANALYSIS WITH TIME DUMMIES (MODEL I)
ALL MSAs
POOLED DATA FROM FY 1986 TO FY 1988

	ER (EQ1)	AAW (EQ2)	ER (EQ1)	AAW (EQ2)
VAR.	2SLS ESTIMATES		2SLS AND WLS ESTIMATES	
INT.	96.2445	81079.5754	96.8352	104462.33
	(67.47)	(4.78)	(82.92)	(10.87)
AAW	-0.00036	.	-0.00029	.
	(-4.30)	.	(-5.23)	.
ER	.	-710.0861	.	-965.27979
	.	(-3.85)	.	(-9.26)
PFR	0.00187	3.0431334	0.00177	3.33041663
	(4.10)	(5.93)	(5.84)	(12.97)
POP	0.00042	0.7676483	0.00051	0.93607767
	(4.77)	(8.04)	(6.91)	(16.09)
PME	0.0595	.	0.0308	.
	(4.86)	.	(3.23)	.
PSE	0.0872	.	0.0434	.
	(4.51)	.	(2.80)	.
PMI	.	59.6527105	.	57.6850847
	.	(6.56)	.	(8.46)
PSI	.	10.7706372	.	17.4016055
	.	(0.52)	.	(1.23)
DY86	-1.4516	-1013.2478	-1.3283	-1243.0788
	(-8.25)	(-2.99)	(-9.72)	(-6.73)
DY87	-0.6359	-312.7646	-0.5806	-340.96770
	(-3.62)	(-1.32)	(-4.65)	(-2.51)
DR1	2.5734	1216.4308	2.2448	2391.08393
	(5.95)	(1.68)	(8.11)	(5.85)
DR2	1.2357	1251.5635	1.2749	1535.64370
	(4.45)	(3.32)	(4.97)	(5.65)
DR3	0.8005	2087.2942	0.5590	2240.13607
	(2.45)	(7.21)	(2.13)	(11.07)
DR4	1.9178	1828.8693	1.7153	2000.35104
	(6.08)	(3.93)	(7.09)	(7.11)
DR5	1.2789	785.2657	1.2768	1446.38562
	(4.95)	(2.19)	(6.07)	(6.36)
DR6	-0.5993	-469.5576	-0.5888	-315.25241
	(-1.74)	(-1.19)	(-1.97)	(-1.26)
DR7	-1.5051	-564.3579	-1.7481	1088.45128
	(-5.29)	(-1.21)	(-5.96)	(-3.76)
DR8	0.0663	396.2178	-0.1717	247.51349
	(0.19)	(1.03)	(-0.67)	(1.21)
F-VALUE	33.537	24.253	35.876	37.554
R-SQUARE	0.3528	0.2827	0.3683	0.3897
ADJ. RSQ.	0.3422	0.2711	0.3580	0.3798
N = 939				

Note: T-ratios in parentheses.

in Table 1, more efficient parameter estimates are obtained after correcting for heteroskedasticity. The signs of all variables are the same as before the correction of heteroskedasticity, but there are slight changes in the magnitudes of the coefficients. The significance of proportion of producer service sector income variable (PSI) is also improved, but yet it is not significant enough at 0.1 critical level.

VI. Model II and III: The Differences in Regional Income and Employment Effects by City Size: The Largest 39 MSAs vs. The Rest Smaller size MSAs

In the results of both cross-sectional analyses for tow different sample populations, the signs of PFR variables consistently indicate that federal contract R&D spending positively affected the regional real annual average wage and employment rate. In case of the largest 39MSAs the PFR variables in most cases are not statistically significant, which may be due mainly to the small number of observations. In case of the sample population of smaller size MSAs, by contrast, the PFR variables are significant at least at the 0.1 critical level with the exception of ER equation in FY 1987. The estimated coefficients of PFR variables in the 39 MSAs, however, are larger than those of the PFR variables for the rest MSAs in all cross-sectional analyses except in ER equation for FY 1987.

To obtain more efficient parameter estimates by increasing the number of observations, the cross-sectional and time-series data were combined and pooled analysis with time dummies was used. The regression results of the pooled data from FY 1986 to FY 1988 for the top 39 MSAs are presented in Table 2. In Table 3, the regression results for all MSAs excluding the top 39 MSAs are provided.

In all cases, more significant parameter estimates than were yielded by the cross-sectional analyses were obtained. The results of all three cases indicate that federal contract R&D funds affected the regional economies positively. If we compare the estimates of the PFR variable in the two different sample populations, the results offer evidence that the larger cities leveraged the federal contract R&D funds more efficiently in terms of experiencing increasing

TABLE 2: POOLED ANALYSIS WITH TIME DUMMIES (MODEL II)
THE LARGEST 39 MSAs
POOLED DATA FROM FY 1986 TO FY 1988

	ER (EQ1)	AAW (EQ2)	ER (EQ1)	AAW (EQ2)
VAR.	2SLS ESTIMATES		2SLS AND WLS ESTIMATES	
INT.	106.5352	95844.2685	105.6953	123627.76
	(22.53)	(2.43)	(65.88)	(11.54)
AAW	-0.00065197	.	-0.00069042	.
	(-2.44)	.	(-7.89)	.
ER	.	-817.4477	.	-1104.9480
	.	(-1.99)	.	(-9.90)
PFR	0.00247039	3.5375295	0.00246950	4.1316666
	(2.48)	(3.60)	(6.70)	(29.19)
POP	0.00014819	0.3146971	0.00014793	0.3163771
	(1.28)	(3.05)	(3.25)	(12.36)
PME	0.0580486	.	0.0815888	.
	(1.22)	.	(6.09)	.
PSE	-0.0475343	.	-0.0183058	.
	(-0.73)	.	(-0.65)	.
PMI	.	40.5382838	.	36.3335930
	.	(1.11)	.	(4.76)
PSI	.	-84.2318839	.	-106.0597
	.	(-1.41)	.	(-6.03)
DY86	-1.2464926	-1102.7368	-1.3452217	-1557.9839
	(-3.78)	(-1.86)	(-18.77)	(-9.93)
DY87	-0.5831567	-448.2882	-0.4366072	-516.4141
	(-1.81)	(-1.01)	(5.62)	(-6.30)
DR1	0.1179128	-1411.7453	-0.4700040	-1518.0558
	(0.09)	(-0.99)	(-0.99)	(-1.13)
DR2	0.7379092	609.7116	0.9134469	474.2769
	(1.61)	(1.02)	(5.93)	(2.72)
DR3	0.4167382	1096.6509	0.6408196	1298.5477
	(0.62)	(1.66)	(2.83)	(8.35)
DR4	1.8185968	2003.6151	2.4666507	2639.3565
	(2.32)	(2.25)	(7.30)	(19.77)
DR5	1.3081089	1468.3970	1.7984002	1650.0484
	(2.50)	(2.14)	(9.74)	(7.29)
DR6	-1.6212168	-696.6660	-1.2962117	-1524.2134
	(-2.22)	(-0.52)	(-4.47)	(-4.29)
DR7	-0.3350827	-225.7037	0.0425698	-335.7705
	(-0.47)	(-0.25)	(0.16)	(-2.94)
F-VALUE	6.498	5.175	13.808	13.519
R-SQUARE	0.4714	0.4153	0.6546	0.6498
ADJ. RSQ.	0.3989	0.3350	0.6072	0.6017
N = 117				

Note: T-ratios in parentheses.

TABLE 3: POOLED ANALYSIS WITH TIME DUMMIES (MODEL III)
ALL MSAs EXCLUDING THE LARGEST 39 MSAs
POOLED DATA FROM FY 1986 TO FY 1988

	ER (EQ1)	AAW (EQ2)	ER (EQ1)	AAW (EQ2)
VAR.	2SLS ESTIMATES		2SLS AND WLS ESTIMATES	
INT.	96.9754	121182.56	97.7067	139397.44
	(63.33)	(5.25)	(84.79)	(14.41)
AAW	-0.00046	.	-0.00043	.
	(-4.91)	.	(-7.04)	.
ER	.	-1165.2112	.	-1358.0593
	.	(-4.61)	.	(-12.74)
PFR	0.00172	2.9017441	0.00147	2.9035776
	(3.16)	(3.97)	(6.74)	(15.78)
POP	0.00262	4.2095198	0.00248	4.2144978
	(6.96)	(6.74)	(12.05)	(17.41)
PME	0.0643	.	0.0351	.
	(4.96)	.	(4.08)	.
PSE	0.0770	.	0.0388	.
	(3.74)	.	(2.85)	.
PMI	.	70.9689503	.	60.3988782
	.	(5.92)	.	(7.38)
PSI	.	39.4053073	.	26.0487068
	.	(1.43)	.	(1.51)
DY86	-1.4906	-1714.3259	-1.2835	-1677.3289
	(-7.64)	(-3.61)	(-10.54)	(-8.93)
DY87	-0.6205	-630.5261	-0.5532	-517.6757
	(-3.18)	(-1.94)	(-4.69)	(-3.77)
DR1	3.1092	3505.6610	3.6024	4135.0948
	(6.60)	(3.31)	(13.00)	(9.46)
DR2	1.4401	2002.5705	1.9640	2738.1557
	(4.44)	(3.71)	(7.56)	(9.47)
DR3	1.4775	2761.1710	1.5421	2894.8755
	(3.79)	(6.66)	(4.91)	(15.05)
DR4	2.5792	3469.1623	2.6815	3634.0016
	(7.21)	(4.85)	(10.83)	(12.22)
DR5	1.4878	1622.6460	1.7393	2104.8758
	(5.01)	(3.10)	(6.89)	(9.78)
DR6	-0.2429	-249.1741	-0.0115	119.8356
	(-0.65)	(-0.50)	(-0.04)	(0.64)
DR7	-1.1093	-977.6613	-0.7086	-891.7957
	(-3.43)	(-1.65)	(-2.13)	(-3.72)
DR8	0.4492	849.3935	0.7376	1065.3262
	(1.11)	(1.58)	(2.96)	(4.40)
F-VALUE	30.488	15.109	35.457	40.520
R-SQUARE	0.3652	0.2221	0.3801	0.4336
ADJ. RSQ.	0.3532	0.2074	0.3684	0.4229
N = 810				

Note: T-ratios in parentheses.

annual average employment rate and wage levels.

The magnitude of the coefficients for PFR in both equations for the 39 largest MSAs exceeds that of the same coefficients for the rest of the MSAs. This might well indicate that these regions constitute major industrial capital arrangements especially well suited to attracting and leveraging the federal contract R&D funds received. Moreover, the regions are of such scale and scope that they are able to capture the bulk of the employment and income gains from these federal expenditures. Since the number of regional dummies is different in two different sample populations, it is not possible to test whether the magnitude of the coefficients is significantly different across the sample populations. The signs of all control variables for the 270 MSAs are positive and significant with exception of the PSI variable in the AAW equation. These results are the same as those in the pooled analyses for all MSAs. In the case of the 39 largest MSAs, by contrast, the signs of producer services employment and income share (PME and PSE) variables are negative although statistically insignificant. The negative signs of PSE and PSI variables indicate that as a large metropolitan area becomes more specialized in producer services, its economy may begin to decline in terms of aggregate well-being.

White's test was conducted to detect heteroskedasticity for both sample populations and found heteroskedasticity in both cases. Hence, the models were reestimated using WLS and 2SLS techniques to gain more efficient results. The WLS and 2SLS estimates for the top 39 MSAs for the time period of FY 1986-88, and for the rest of MSAs are provided in Table 2 and 3, respectively.

The regression results in all three cases are more significant than 2SLS estimates, and there is significant improvement in the overall significance and explanatory power of the models. The results further confirm that the 39 larger MSAs have advantages over smaller size MSAs in terms of leveraging the federal contract R&D funds. As a matter of fact, the difference in the estimated coefficients for the PFR variable in the two different sample populations is larger than the coefficient estimated by 2SLS. Therefore, the regression results of Model II and III confirm that large size cities have more efficient infrastructure for innovative activities than do small size cities, which represents positive externalities of large size cities or agglomeration effects.

The PSE and PSI variables for the sample population of the top 39 MSAs, on the other hand, are significant and still negative. This suggests that experiencing large increases in producer services in a large metropolitan area may result in a regional economic decline.

VI. Model IV: The Non-linear Relationship between Population Size, and Real Annual Average Wage and Employment Rate

The non-linear relationship between population size and both regional annual average employment rates and real annual average wages was examined by including quadratic and cubic terms for population size in the equations. The sign of the quadratic term for population size is negative in both ER and AAW equations in all cases of the cross-sectional analyses, while the sign of cubic term of population size is consistently negative. They are significant at least at 0.01 critical level.

The cross-sectional and time-series data were combined to obtain more efficient estimates. The results confirm that population size, and the annual average employment rates and wage levels have inverse U-shaped relations up to certain point, after that point, they have U-shaped relationships. To measure the turning points of population size, the model was regressed without dummy variables. The parameter estimates, as shown in Table 4, are obtained under the assumption of the same intercept for all MSAs. With those estimates, I further found that the annual average employment rate and real annual average wage increased until a population of around 3 million, then decreased to 7 million. The annual average employment rate and real annual average wage increased again beyond a population of 7 million. As shown in Figure 1 and 2, at population of approximately 3 million the annual average employment rate reaches 94.86%, and the real annual average wage increases 71.4 thousand dollars. Then, the employment rate and the wage level decline to 92.92% and 70.09

thousand dollars when the population size is near 7 million. Finally, beyond a population of approximately 7 million, both employment rate and the wage level increase again.

These findings are closely related with the relationship between population size and both regional economic diversity and stability in U. S. metropolitan areas. Kim (1990) found that industrial specialization increased until a population of around 3 million, then industrial diversification increased to 8 million. Beyond a population of around 8 million, industrial specialization resumed again. His findings further indicate that regional economies are more stable at the extremes of industrial specialization and diversification than they are in the middle range. The findings of this study does not provide indicators of regional economic stability. However, if we link Kim's findings to the findings of this study, we may conclude that the cities whose population is around 3 million has the highest real annual average wage and employment rate, and its regional economic structure is highly specialized. The findings of this study also strongly support the findings of Carlino (1982) and Kawashima (1975)'s findings on that the agglomeration effects in manufacturing industries are peak at city sizes in the range of 3 million in the United States.

TABLE 4: NON-LINEAR RELATIONSHIPS BETWEEN POPULATION SIZE AND REAL ANNUAL AVERAGE WAGE AND ANNUAL AVERAGE EMPLOYMENT RATE POOLED ANALYSIS WITHOUT DUMMIES: POOLED DATA FROM FY 1986 to FY 1988 TWO-STAGE LEAST SQUARES ESTIMATES

	DEP. VARIABLE: ER			DEP. VARIABLE: AAW		
VAR.	COEFFICIENTS	T STAT.	PROB > |T|	COEFFICIENTS	T STAT.	PROB > |T|
INT.	92.34655259	72.642	0.0001	67442.77951	5.614	0.0001
AAW	-0.000376619	-4.925	0.0001	.	.	.
ER	.	.	.	-587.42312	-4.324	0.0001
PFR	0.001129716	2.446	0.0146	1.55718631	3.464	0.0006
POP	0.002346300	6.034	0.0001	3.20226156	7.440	0.0001
PME	0.10850100	8.741	0.0001	.	.	.
PSE	0.17198501	8.905	0.0001	.	.	.
PMI	.	.	.	98.17114055	10.176	0.0001
PSI	.	.	.	41.89558721	1.771	0.0768
POPS	-6.38215E-07	-4.050	0.0001	-0.000797664	-4.832	0.0001
POPC	4.49581E-11	3.130	0.0018	5.63243E-08	3.858	0.0001
F-VALUE		26.663			46.800	
R-SQUARE		0.1617			0.2603	
ADJ. RSQ.		0.1554			0.2547	
N = 919						

Figure 1 : Non-linear Relationship : Population Size and Employment Rate
Pooled Data (FY 86-88)

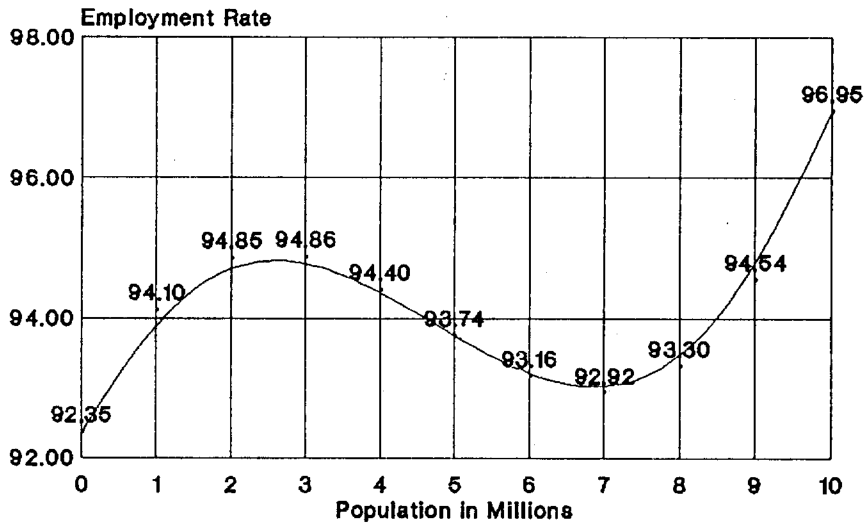
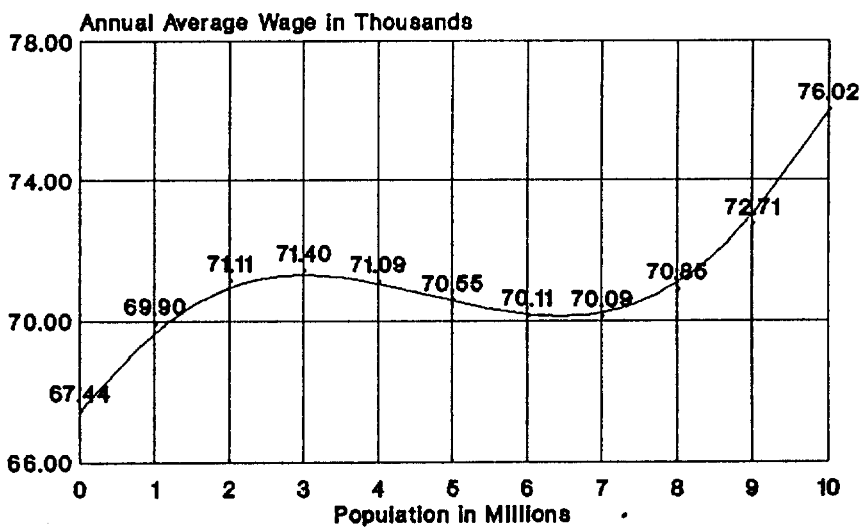


Figure 2 : Non-Linear Relationship :
Population Size and Annual Average Wage
Pooled Data (FY 86-88)



SUMMARY

In summary, the empirical findings of this study indicate that federal contract R&D spending have positive impacts on both the real annual average wage level and annual average employment rate of U. S. metropolitan areas. The findings of this study appear to indicate that the employment and income returns to federal R&D investment tend to be greater for large size cities than small ones. These findings reflect that large size cities have more efficient infrastructure for innovative than do small ones, which may results from agglomeration effects. Finally, it was found that both real annual average wage and annual average employment rate are peak around a population size of 3 million and decrease to 7 million, and they resume again beyond the population size of 7 million. These findings of non-linear relationship between population size, and wage level and employment indicate further that cities whose population size is around 3 million have the highest real annual average wage and annual average employment rate among all size of cities, and they have highly specialized industrial structure. These findings also strongly support the findings of Carlino and Kawashima's findings which are the agglomeration effects in manufacturing industry sector are peak at the city sizes of 3 million in the United States.

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