Productivity and City Size: Some Historical Evidence

Thomas Hyclak*

I. INTRODUCTION

A number of recent studies have found a positive relationship between population size and total factor productivity in production function regressions estimated for cross-MSA data from the late 1960s and early 1970s.¹ These results have been interpreted as evidence that there are net agglomeration economies associated with city size or, alternatively worded, that Hicks-neutral productivity is positively associated with city size. The results of these statistical studies have also been viewed as supporting the central role of agglomeration economies in theories of urban growth.

Although the positive relationship between city size and Hicks-neutral productivity has been widely incorporated, some questions have been raised regarding the size of the estimates of the effect of population on productivity. Moonaw (1981b) presents evidence that earlier studies by Sveikauskas (1975) and Segal (1976) overestimated the extent to which productivity rises with city size. Moonaw traces the source of this upward bias to difficulties stemming from the complete absence of a capital stock variable in Sveikauskas' model and from Segal's method of estimating aggregate capital stocks. In his findings, Moonaw (1981a, 1981b) estimated that a doubling of city size in 1967 was associated with only a 1.8% to 2.7% rise in Hicks-neutral productivity for urban manufacturing, which contrasts sharply with Sveikauskas' calculation of 6.0%. And in a similar study based on 1977 manufacturing data, Moonaw (1983) also found that, on average, a doubling of population resulted in a 1.8% rise in Hicks-neutral productivity.

This paper undertakes to cast some historical perspective on this issue by examining the effect of city size on manufacturing productivity using data from the 1905 Census of Manufactures. It seems quite reasonable to expect that larger cities generated greater agglomeration economies at the turn of the century in an economy with much more primitive communication and transportation systems than the same sized cities would today. Thus a comparison of agglomeration economies in different time periods might yield interesting information on the role of such economies in the evolution of the U.S. system of cities.

There are two advantages to using 1905 data to test the general hypothesis that productivity rises with city size. First, the Census reports data are derived from a survey of businesses, and relate to the aggregate book value of land, buildings and machinery and the value at the end of the year of working capital, such as bills receivable, stocks and cash on hand (U.S. Bureau of the Census, 1907a, p. 1xiii). These data are used below to construct measures of the aggregate capital stock in

*Economics Department, Lehigh University, Bethlehem, Pennsylvania 18016
manufacturing in each city in our sample. As Movchan (1981a) demonstrates, capital stock data are necessary to accurately estimate agglomeration economies related to city size. While the census tabulates did list several problems with this capital stock data, they nevertheless concluded that "...it is doubtful if more nearly accurate totals could be secured by the use of any other series." (U.S. Bureau of the Census, 1980a, p. 4xv).

The second advantage to using 1905 Census of Manufacturers to test the productivity—city size hypothesis is that data are reported for a total of 520 cities, ranging in size from 8,000 to over 3 million inhabitants. This contrasts favorably with studies based on more recent data that are generally limited to relatively small samples of fairly large SMSAs, usually those over 250,000 in population.

II. THE MODEL AND RESULTS

The generalized form of the production function suggested by previous studies of the city-size productivity relationship is given by:

\[ V = g(A) f(K, L) \]

where \( g(A) \) expresses Hicks-neutral productivity as a function of area characteristics, primarily the net agglomeration economies under study. In this study, as in most previous analyses in this literature, the specific form of the function \( g(A) \) is written as:

\[ g(A) = C N^{\eta} \left( 1 - D \right) \]

where \( N \) is the population of the \( i \)th city, \( C \) is a constant term and \( D \) is a dummy variable indicating the region in which the \( i \)th city is located.

Equation (2) is combined with an unrestricted Cobb-Douglas production function to yield the specific form of equation (1) that is used in the empirical work in this study. Written in logarithmic form, the production function is:

\[ \ln V_i = \ln C_i + a_1 \ln L_i + a_2 \ln N_i + a_3 SA_i + a_4 SC_i + a_5 ST \]

where \( V_i \) is value added in manufacturing in the \( i \)th city divided by the number of manufacturing establishments in the city, \( C_i \) is a constant term, \( L_i \) is the population of the \( i \)th city, and SA, SC and ST are dummy variables equal to one for cities located in the respective region and zero otherwise. \( K_i \) is the value of capital used in manufacturing in the \( i \)th city divided by the number of manufacturing establishments in the city. Two measures of capital are employed here. \( K_1 \) equals the value of land, buildings and machinery used by manufacturing firms and \( K_2 \) adds to this the value of cash, inventories, and other forms of working capital used by manufacturers in area 1.3

Three separate labor input variables are used to try to control for differences in the quality of labor from area to area. \( L_{S1} \) is the number of salaried officials and clerks per manufacturing establishment; \( L_{M1} \) is the number of male wage earners over 16 per establishment; and \( L_{W1} \) is the number of female wage earners over 16 plus the number of male and female wage earners under 16 per establishment in area 1. Female and young workers are aggregated into one labor input category largely because of the small number of youths employed in most of the areas. Also, Grant and Hamersh (1983) have demonstrated that there is a very high degree of substitutability between female and youth workers in cross-section data for 1969.

Both in disaggregating labor by type and specifying the production function on a per-establishment basis, this study follows Hildebrand and Liu (1985). The main hypothesis we examine, then, is whether Hicks-neutral productivity in the average manufacturing plant in an area rises as the population of the area rises.4

Table 1 presents the ordinary least squares estimates of the coefficients of equation (3) for the alternative capital measures along with the means and standard deviations of the variables. These estimates are derived from total manufacturing data drawn from a sample of 520 cities in 1905. The regression results indicate that the model fits the data quite well. The regressions explain better than 75% of the variance in the dependent variable and all but two of the independent variables have coefficients that are statistically different from zero at the .05 level of significance. The coefficients of these two variables, the regional dummy variables NC and SC in regression 2, are statistically significant at the .10 and .15 levels, respectively.

City size has a statistically significant positive effect on output per manufacturing firm, holding constant the other variables in the model. Thus, these cross-city results on 1905 data corroborate the findings of studies using more recent data. A doubling of city size, ceteris paribus, would result in a 3.8% increase in Hicks-neutral productivity according to the results in Table 1. This estimate of the marginal effect of a change in population on output per manufacturing firm is not sensitive to the definition of capital and is not inconsistent with Movchan's recent estimates that doubling of city size in 1905 was associated with a 1.8% to 2.7% increase in Hicks-neutral productivity. It seems reasonable that the net productivity advantage of larger cities could have declined from 1905 to 1969 as transportation and communication innovations over time may have reduced the benefits derived from locating in larger cities while the congestion costs associated with population size have apparently risen. The decentralization of population and economic activity that has occurred in the decade of the 1970s is apparent evidence of a reduced net advantage to city size.

In addition to the city size effects, the 1905 data yields some interesting regional comparisons. The pattern of estimated coefficients on the regional dummy variables in the production function regressions indicates that, ceteris paribus, value added per firm was higher in Western cities than in cities located in the Northeast, whereas value added per firm was greater in Northeastern cities than in cities in the North Central, South Atlantic and South Central regions of the country. This ranking of productivity differences by region in 1905 is generally consistent with the results of studies on data from the 1950s, except for a reversal of the North Central and Northeastern regional effects. Studies using data from
more recent periods find that value-added productivity is higher in North Central cities than in urban areas in the Northwest. This difference between 1905 and the 1960s may be due to the growth of the automobile and auto-related industries, which has had its greatest relative effect on the economies of the North Central states.

Although Peterson and Muller (1980) and Moonaw (1981) conclude that the significance of regional dummy variables in production function regressions is evidence for substantial regional variations in productivity, the fact that the dependent variable is value-added makes it impossible to separate the regional differences into differences in output per plant versus differences in regional price levels. For example, Mieszowski (1975) presents data on the relative cost of living by region in 1920 in which the ranking of regions is the same as the ranking of regions in terms of value-added per plant found in our study of 1905 data. Thus, at least some of the regional effects shown in this study are most likely due to regional price differentials which affected the costs and prices of manufactured products in each region in 1905.

With regard to the remaining production function variables, the coefficients of the capital and labor variables sum to 1.01 in regression 1 and .97 in regression 2. Thus, it appears that approximately constant internal returns to scale prevailed in urban manufacturing in 1905. This finding is not uncommon in empirical production functions.

III. CONCLUSION

This paper presents estimates of a manufacturing Cobb-Douglas production function using 1905 data for a sample of 500 cities in order to test the hypothesis that Hicks-neutral productivity is positively related to city size. Although several tests of this hypothesis using recent census data have been carried out, the historical data used here have several advantages: capital stock data are available and other pertinent data exist for a wide range of city sizes. The results show that, controlling for capital, labor, and region, value added per manufacturing firm rose with city size in 1905, such that a doubling of city size led to a 4.5% rise in value added per firm. When this is compared to Moonaw’s estimates for SMSAs in 1969, it would appear that the productivity advantage of larger urban areas has been reduced by about half in the period from 1905 to 1969.

FOOTNOTES

*The author wishes to thank Vine Cunly and Eill Schwartz for helpful comments. Research on this paper was supported in part by a grant from the Union Bank and Trust Company, Bethlehem, PA.


2. The reference region is the Northeast which consists of the following states: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont. NC is a dummy equal to one for cities in the North Central States of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin. SC is a dummy equal to one for cities in the South Atlantic States of Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. SC is a dummy equal to one for cities in the South Central States of Alabama, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas. Finally, NDT is a dummy equal to one for cities in the Western States of California, Montana, Oregon, Utah, Washington and Wyoming.

3. Difficulties in data collection make the information on working capital, and hence N2, less reliable than the other capital stock information. (See U.S. Bureau of the Census, 1907a, p. 116). Both capital variables are included in an attempt to fully control for capital in the regressions and to check for the robustness of the coefficient estimates on population size to different model specifications.

4. A statistical advantage of using data that is expressed on a per establishment basis is that it substantially reduces the degree of collinearity between the independent variables. For example, the correlation coefficient between lnK and lnN2 is .770 while the correlation coefficient between lnK and the logarithm of the aggregate capital stock K2 is .792.

5. The American Productivity Center (1980) has calculated that in 1972 value-added per worker was 22% higher in the West, 12% higher in the North Central States and 11% greater in the Northeast than in the South. See also, Moonaw (1981a).

REFERENCES


Table 1: OLS Estimates of the Coefficients of the Manufacturing Production Function Across 520 Cities in 1965.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Regression 1</th>
<th>Regression 2</th>
<th>Mean</th>
<th>S.D.</th>
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<tr>
<td>lnC</td>
<td>.9893 (7.62)</td>
<td>.58178 (4.25)</td>
<td>-</td>
<td>-</td>
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<td>lnW</td>
<td>.04653 (2.45)</td>
<td>.04444 (2.50)</td>
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<td>NC</td>
<td>-.10452 (-2.74)</td>
<td>-.06869 (-1.70)</td>
<td>.3658</td>
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<td>BA</td>
<td>-.2565 (-4.24)</td>
<td>-.20526 (-3.40)</td>
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<td>.2757</td>
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<tr>
<td>SC</td>
<td>-.4291 (-2.08)</td>
<td>-.0856 (-1.49)</td>
<td>.0855</td>
<td>.2642</td>
</tr>
<tr>
<td>WST</td>
<td>.23612 (2.77)</td>
<td>.20808 (2.55)</td>
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<td>.2141</td>
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<td>lnK1</td>
<td>.13591 (3.09)</td>
<td>.35213 (.79)</td>
<td>.7746</td>
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<tr>
<td>lnK2</td>
<td>.32444 (8.15)</td>
<td>.2012 (1.79)</td>
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<td>lnL</td>
<td>.33908 (7.14)</td>
<td>.22868 (4.77)</td>
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<td>.5690</td>
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<td>lnM</td>
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<td>.38351 (6.71)</td>
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<td>lnMC</td>
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<td>R²</td>
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<td>.7716</td>
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<td>F</td>
<td>172.78</td>
<td>195.86</td>
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* t statistics in parentheses. The mean of the dependent variable is 3.5689, with a standard deviation of .7336.