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LOCAL INPUT AND PRODUCTIVITY GROWTH IN U.S. MANUFACTURING: 1972–2002*

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ABSTRACT. This research analyzes manufacturing growth and decline across metropolitan and nonmetropolitan regions during the 1972–2002 period. We decompose real value added growth across local labor market areas in the lower 48 U.S. states into contributions from labor, capital, and total factor productivity. We then estimate a model describing the long-run growth of labor, capital, and productivity and find that increased productivity increases the growth of labor and capital, as well as a positive correlation between labor and capital stock growth. We also find evidence that human capital investment and agglomeration economies encourage productivity growth, while unionization discourages it.

1. INTRODUCTION

Manufacturing remains a critical sector of the U.S. economy. Indeed, in 2006 manufacturing accounted for 11.7 percent of U.S. GDP, 8.3 percent of employment, and 14.0 percent of labor earnings, according to the U.S. Bureau of Economic Analysis. Furthermore, these shares do not account for interindustry linkages, such as purchases of raw materials, as well as accounting, management, legal, and other services, through which manufacturing activity generates output, jobs, and income beyond its own narrow industry classification. Summarizing these linkages using 2007 IMPLAN output multipliers, we find that manufacturing has the largest multiplier of any North American Industry Classification System (NAICS) supersector.[1] In addition, innovation tends to be higher in regions with large levels of manufacturing activity (Feldman and Florida, 1994). Thus, manufacturing performance remains of critical concern to policymakers because of its direct impact, its spillover impacts on related sectors, its ability to influence innovation, and thus its influence on the tax base.

U.S. manufacturing output has expanded during the past 30 years, although its share of output has fallen from 22.1 percent in 1972. According to our data for the 1972–2002 period, real manufacturing value added grew at an average annual rate of 3.1 percent per

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[1]We calculate supersector multipliers by averaging the unweighted subsector multipliers available from IMPLAN. The 2007 IMPLAN output multiplier for manufacturing is 2.13. Guo and Planting (2000) report similar results using national input–output tables.

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year nationally. In addition, output growth varied significantly across geographic regions of the country and across metropolitan and nonmetropolitan labor markets during the period. Indeed, annual real value added growth in the West and South Census regions was 4.1 percent and 4.0 percent, respectively. These rates were far above the growth rates posted by the Northeast and Midwest region, at 1.8 percent and 2.7 percent, respectively. These growth differentials represent the continuation of a trend found in the value added data extending back into the early 1950s and represent a further major reallocation of economic activity across regions of the country, with important social and economic impacts.

Most manufacturing activity takes place in metropolitan labor markets, but nonmetropolitan labor markets became more attractive locations for activity during the period. Indeed, during the 1972–2002 period, real value added growth in metropolitan labor markets averaged 3.0 percent per year, compared to 3.9 percent for nonmetropolitan labor markets. That translates into nonmetropolitan growth 30.0 percent faster than metropolitan growth during the period.

We address two goals in this paper. First, we provide new estimates of the sources of manufacturing value added growth in the lower 48 U.S. states using a growth accounting framework and a mutually exclusive and exhaustive set of metropolitan and nonmetropolitan labor market areas (LMAs). We provide these estimates for three time periods: 1972–1992, 1997–2002, and 1972–2002. Second, we develop and estimate a model describing the long-run growth of labor, capital, and total factor productivity, which accounts for the endogeneity in the choice of capital and labor, as well as the residual correlation across equations.

Previous researchers (for instance, Moomaw and Williams, 1991; Mullen and Williams, 1990; Beeson, 1990; Mullen and Williams, 1987; and Hulten and Schwab, 1984) documented a reallocation of manufacturing activity within the United States toward the South and West during the 1950s, 1960s, and early 1970s using a growth accounting approach. We expand this analysis through the 1970s, 1980s, 1990s, and early 2000s, accounting for growth in capital stock, labor, and total factor productivity within the metropolitan and nonmetropolitan regions of the country. Our decomposition of growth across Census regions and metropolitan and nonmetropolitan regions is more regionally detailed and more timely than any previously available in the literature.

We also develop a regional model of the long-run development of the manufacturing sector that demonstrates the role of total factor productivity in encouraging growth in capital and labor inputs, and reflects the simultaneous nature of capital formation and employment growth within regional economies. We then use the model to examine the impact of a broad range of policy variables and regional characteristics on the development of the local manufacturing sector, including regional amenities, human capital formation, public investment, taxes, unionization, and energy costs. Most previous research has focused on individual components of manufacturing growth, such as total factor productivity (Beeson, 1987; Williams and Moomaw, 1989; Mullen and Williams, 1990; Moomaw and Williams, 1991; Weber and Domazlicky, 1999), employment (Wheat, 1986), and the capital stock (Garofalo and Fogarty, 1987), without much attention devoted to the interrelationships between sources of growth. This paper advances the growth accounting approach by being the first to carefully investigate the interrelationships between the components of growth.

We find that the relatively strong output growth in the West and South Census regions, compared to the Northeast and Midwest, was driven by faster input growth during the 1972–2002 period. We also find strong total factor productivity growth in the Midwest, South, and West, but the Northeast posted the strongest productivity gains during the period. We find relatively strong output growth in nonmetropolitan regions, compared to metropolitan regions, and that this was primarily driven by relatively strong growth in labor and capital stock growth.

Our econometric results suggest that total factor productivity growth contributed positively to labor and capital stock growth during the period and that the correlation between labor and capital stock growth is positive. We find that human capital investment encourages regional manufacturing productivity growth. Furthermore, our focus on local (rather than state) economies allows us to contribute to the manufacturing productivity literature by more clearly establishing the positive relationship between agglomeration and productivity growth, as well as the negative relationship between unionization and productivity growth. We also find that higher tax rates tend to discourage both labor and capital stock growth.

This paper proceeds as follows: Section 2 presents and discusses our decomposition of output growth during the 1972–2002 period into three sources: labor, capital, and total factor productivity growth. Section 3 presents the model used to motivate our empirical work. Sections 4 and 5 contain descriptions of the data and the regression results. The paper concludes with Section 6.

2. DECOMPOSITION OF OUTPUT GROWTH: 1972–2002

We begin by decomposing local manufacturing output growth into contributions from input growth and total factor productivity. We employ a growth accounting framework using U.S. regional data, following Moomaw and Williams (1991), Beeson (1990), Mullen and Williams (1987), and Hulten and Schwab (1984), among others. As in these previous efforts, we focus on labor and capital as the two inputs used in production. We assume that production is characterized by constant returns to scale and Hicks neutral technological change.

We can express the decomposition algebraically as

$$\text{(1)} \qquad \ln VA_{it} - \ln VA_{it-1} = e_{iK}\,(\ln K_{it} - \ln K_{it-1}) + e_{iL}\,(\ln L_{it} - \ln L_{it-1}) + \Delta \ln TFP_{it},$$

where VA_{it} in Equation (1) is real value added at time t in labor market i, K_{it} is the real capital stock, L_{it} is labor input, TFP_{it} is total factor productivity, and e_{iK} and e_{iL} are the output elasticities of capital and labor. If labor and capital are paid according to their marginal products, then their output elasticities are equal to their cost shares. Under the assumptions outlined so far we can calculate TFP_{it} as follows in Equation (2):

$$\text{(2)} \qquad \Delta \ln TFP_{it} = (\ln VA_{it} - \ln VA_{it-1}) - e_{iK}\,(\ln K_{it} - \ln K_{it-1}) - e_{iL}\,(\ln L_{it} - \ln L_{it-1}),$$

where e_{iL} is the labor share of income and e_{iK} is the capital share of income.

Previous studies utilizing growth accounting for the U.S. manufacturing sector have used data for multistate regions (Hulten and Schwab, 1984), states (Beeson, 1987; Williams and Moomaw, 1989; Moomaw and Williams, 1991; Weber and Domazlicky, 1999), and selected large metropolitan statistical areas (Mullen and Williams, 1987; Mullen and Williams, 1990) along with data outside these selected metropolitan areas (Beeson, 1990). We contribute to the literature through our use of county data aggregated to 719 LMAs (256 metropolitan and 463 nonmetropolitan) in the lower 48 U.S. states, which provides a more regionally disaggregated data set than previous research. These mutually exclusive and exhaustive local labor markets were developed by the U.S. Department of Agriculture's Economic Research Service to capture commuting zones in nonmetropolitan as well as metropolitan areas (Tolbert and Sizer, 1996). We also contribute by developing estimates for three time periods: 1972–1992, 1997–2002, and 1972–2002.

We calculate $\Delta \ln TFP_{it}$ using data available from the *Census of Manufactures* for 1972 and 2002 for value added, labor hours, and wages for U.S. counties. County values are aggregated to LMA values. Due to data constraints, we use value added data as our measure of manufacturing output, which requires the assumption that inputs are separable from materials. Norsworthy and Malmquist (1983) present evidence against this separability. However, while gross output data might be preferable, it is not available at the local level. We follow the previous literature in our use of value added data.

As previous research has noted, Census value added incorrectly includes purchased business services. Previous research corrects for this using the ratio of national gross product originating in manufacturing from the U.S. Bureau of Economic Analysis to Census value added. We follow their example. Value added is adjusted for inflation using the national deflator for value added in manufacturing from the U.S. Bureau of Economic Analysis.

Manufacturing capital stock is the cumulative sum (adjusting for depreciation) of gross annual capital investment in the LMA in each year beginning in 1954. We utilize average annual gross investment by the manufacturing industry, and statewide capital depreciation rates for the appropriate state. Manufacturing investment is reported for counties each five years in the Census of Manufactures. The Census of Manufactures also is the source for data on state depreciation rates.[2] In three small nonmetropolitan LMAs, there was no capital investment reported before 1972 or no employment reported in 2002, so we cannot report results for them. The capital stock data are adjusted for inflation using the national deflator for nonresidential fixed investment.

Our measure of labor input is hours worked in manufacturing. Data on labor hours for production workers are published in the Census of Manufactures. We estimate labor hours for nonproduction workers by multiplying the number of nonproduction workers by 2,000 hours. We calculate the labor share of income using total payroll divided by value added for each county.

Table 1 summarizes our results for three periods: 1972–1992 (on an SIC basis), 1997–2002 (on a NAICS basis), and for the full 1972–2002 period. Since our primary interest is long-run trends in manufacturing growth, we begin with the results for the full 30-year period. U.S. real value added growth in manufacturing averaged 3.1 percent per year during the 1972–2002 period, with that growth driven primarily by gains in the real capital stock (1.3 percent) and total factor productivity growth (2.3 percent) because labor input declined by 0.5 percent per year.

Table 1 also shows the major reallocation of manufacturing across Census regions during the period, with real output growth much faster in the West and South than in the Northeast and Midwest. Indeed, as a share of U.S. value added the Northeast and Midwest shares dropped from 26.1 percent and 33.9 percent, respectively, in 1972 to 17.5 percent and 29.9 percent by 2002. In contrast, the West and South posted increases in their respective shares of U.S. activity, rising from 13.3 percent and 26.8 percent in 1972 to 17.9 percent and 34.7 percent by 2002. Slow output growth in the Northeast and Midwest, in turn, arose primarily from labor declines and from slow growth in the capital stock. These regional reallocations are similar to trends observed by Hulten and Schwab (1984) and Moomaw and Williams (1991) for the mid 1950s through mid 1970s.

Our data also suggest that nonmetropolitan regions posted faster output growth during the period than did metropolitan regions, with annual real value added growth in nonmetropolitan regions 30.0 percent higher than in metropolitan regions. This implies that nonmetropolitan regions accounted for a larger share of national output in 2002 than 1972 and indeed that share rose from 9.3 percent in 1972 to 11.7 percent in 2002.

[2]Data from 1954 to 1992 are on an SIC basis, while data for 1997 and 2002 use the NAICS classification system. This change may distort the results due to differences in classification schemes, particularly the exclusion of headquarters operations from the manufacturing sector under NAICS.

TABLE 1: Sources of Growth in U.S. Manufacturing (Average Annual Growth Rate)

	1972–1992[a]				1997–2002[b]				1972–2002[c]			
	ΔlnVA	ΔlnL	ΔlnK	ΔlnTFP	ΔlnVA	ΔlnL	ΔlnK	ΔlnTFP	ΔlnVA	ΔlnL	ΔlnK	ΔlnTFP
United States	2.5	−0.1	1.1	1.5	2.8	−1.8	1.3	3.3	3.1	−0.5	1.3	2.3
Metro	2.4	−0.2	1.0	1.5	2.7	−1.8	1.3	3.2	3.0	−0.6	1.3	2.3
Nonmetro	3.1	0.4	1.4	1.2	3.8	−1.7	1.7	3.8	3.9	0.1	1.6	2.2
Northeast	1.1	−1.3	0.6	1.8	3.0	−2.1	0.8	4.4	1.8	−1.5	0.8	2.5
Metro	1.0	−1.3	0.6	1.8	3.0	−2.1	0.8	4.4	1.7	−1.6	0.8	2.5
Nonmetro	2.1	−0.5	0.8	1.8	3.7	−2.2	1.0	4.9	2.8	−0.7	1.0	2.6
Midwest	1.7	−0.4	0.8	1.3	3.1	−1.7	1.2	3.6	2.7	−0.6	1.0	2.2
Metro	1.5	−0.5	0.8	1.3	2.8	−1.8	1.0	3.6	2.5	−0.8	1.0	2.3
Nonmetro	3.0	0.5	1.3	1.2	4.5	−1.1	2.1	3.6	4.1	0.4	1.7	2.0
South	3.6	0.4	1.7	1.5	2.8	−1.8	1.5	3.1	4.0	−0.1	1.8	2.2
Metro	3.6	0.4	1.7	1.5	2.6	−1.8	1.5	2.9	3.9	−0.1	1.8	2.3
Nonmetro	3.5	0.5	1.7	1.2	3.4	−2.1	1.6	3.9	4.0	0.0	1.8	2.2
West	3.8	1.2	1.3	1.4	2.1	−1.5	1.7	1.9	4.1	0.4	1.6	2.1
Metro	3.9	1.2	1.3	1.4	2.1	−1.6	1.7	1.9	4.2	0.4	1.6	2.1
Nonmetro	2.4	0.4	1.0	1.0	2.8	−0.7	1.1	2.4	2.9	0.0	1.1	1.8

[a]Data on an SIC basis; [b]Data on a NAICS basis; [c]Data both SIC and NAICS.

Northeast (CT, ME, MA, NH, NJ, NY, PA, RI, VT), Midwest (IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI), South (AL, AR, DC, DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV), and West (AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY) are Census-defined regions.

For the United States as a whole, faster growth in nonmetropolitan regions was driven by stronger growth in inputs, because our estimates of total factor productivity suggests similar growth for nonmetropolitan and metropolitan regions.

While we find a continuation of the interregional shift in manufacturing activity observed for the 1950s through 1970s, we also find large intraregional variation across metropolitan and nonmetropolitan labor markets. For instance, in the Northeast, nonmetropolitan regions posted faster growth than metropolitan regions, with annual real value added growth more than 50 percent above the metropolitan rate. This resulted in an increase in the nonmetropolitan share of regional output from 2.5 percent to 3.4 percent. This was due to both slower losses in labor hours and faster growth in the capital stock in nonmetropolitan regions. We observe a similar pattern in the Midwest, with nonmetropolitan regions posting output growth more than 50 percent above the metropolitan rate. This generated an increase in the nonmetropolitan share of regional output from 9.7 percent in 1972 to 14.8 percent in 2002. This was due to faster input growth in nonmetropolitan regions.

However, for the South and West, the story is quite different. Metropolitan regions in the South grew at about the same pace as nonmetropolitan regions (3.9 percent vs. 4.0 percent), with similar gains in inputs and productivity. Metropolitan regions in the West far outpaced growth in nonmetropolitan regions (4.2 percent vs. 2.9 percent) and increased their share of regional output from 92.8 percent in 1972 to 95.0 percent by 2002. This relative growth advantage was fueled by faster input and productivity growth in metropolitan regions.[3]

Our results suggest that value added by manufacturing in large metropolitan areas, as defined in Beeson (1990), grew more slowly during the 1972–2002 period (2.8 percent)

[3]Western LMAs tend to be large compared to their counterparts in the Northeast, Midwest, and South. This may mean that we get a less clear breakdown between metropolitan and nonmetropolitan in the West, which in turn may contribute to the contrasting results we observe.

than during 1959–1978 (3.2 percent). However, the growth slowdown was more dramatic for the remaining labor markets, where growth slowed from 4.8 percent to 3.3 percent during the 1972–2002 period. The relatively dramatic slowdown outside of the large metropolitan areas was driven by slower gains in labor and the capital stock during the more recent period.

Our results also show that growth in national manufacturing output accelerated slightly during the 1997–2002 period, compared to the 1972–1992 period.[4] However, the sources of growth shifted radically, with declines in labor input becoming much larger and productivity growth more than doubling.

We also observe a shift in output growth across Census regions during the more recent period, with the Northeast and Midwest posting large output gains, which were driven by accelerations in productivity growth that offset large declines in labor input. Both the South and the West post slower output growth in the more recent period, again driven by labor input declines.

Our results also suggest that the surge in productivity growth observed by Jorgenson et al. (2008) for the United States during the 1990s was reflected in the manufacturing sector, but not evenly distributed across regions. Indeed, we see large accelerations in productivity growth in the Northeast, Midwest, and South during the late 1990s, with a much more modest gain in the West. The slow productivity growth in the West, in turn, originates in the Mountain states, which posted negative productivity growth during the five-year period. Furthermore, while both metropolitan and nonmetropolitan regions generated large increases in productivity during the 1997–2002 period, the acceleration was much larger in nonmetropolitan regions (where productivity gains more than tripled). Overall, our results show the rich diversity in manufacturing input and productivity growth across the lower 48 U.S. states, both across Census regions and across metropolitan and nonmetropolitan labor markets. We now turn to the influences on long-run regional input and productivity growth (during the past 30 years) using a structural factor market model, along the lines of Carlino and Mills (1987).

3. MODEL

We utilize a model of the manufacturing industry with multiple factors of production and begin with a constant-returns-to-scale production function with Hicks neutral technological change for firms in a subnational region i. In Equation (3), we assume a Cobb–Douglas production technology in a single good economy where output (Q_{it}) is a function of productivity (TFP_{it}), private capital (K_{it}), and labor (L_{it}) in region i at time t

$$Q_{it} = TFP_{it} K_{it}^{a} L_{it}^{b}. \tag{3}$$

Manufacturing firms maximize profits by utilizing the amount of capital and labor at which the marginal productivity of labor equals the wage requirements of workers and the marginal productivity of capital equals the required rate of return on capital. Given a regional price net of taxes for private capital (r_{it}) and labor (w_{it}) in region i and time t, the regional tax rate on private capital (BT_{it}) and labor (HT_{it}), and the price of the final good (P_t) in the economy at time t, the first order conditions are

$$L_{it}^{*} = \left[\frac{P_t b TFP_{it} K_{it}^{a}}{w_{it}(1+HT_{it})}\right]^{1/(1-b)}, \tag{4}$$

[4]Our results for regional variation in total factor productivity growth during the 1972–1992 period are similar in some ways to those of Weber and Domazlicky (1999) for the 1977–1989 period, with stronger productivity gains in the South and West than in the Midwest.

$$K_{it}^{*} = \left[\frac{P_t aTFP_{it}L_{it}^{b}}{r_{it}(1+BT_{it})}\right]^{1/(1-a)}. \tag{5}$$

Following Glaeser, Scheinkman, and Shleifer (1995), we assume a utility function of the following form:

$$U_{it} = A_i^{\gamma} w_{it} H_{it}^{-\delta}, \tag{6}$$

where A_i in Equation (6) represents natural amenities, w_{it} is wage net of taxes in region i at time t, and H_{it} is a measure of house prices. We assume that $H_{it} = A_i^{\sigma}$, so that house prices rise with regional amenities. Given that in equilibrium utility in all regions must be equal (and using our relationship between house prices and amenities), the following relationship would hold between any region i and a "composite" U.S. region:

$$w_{it} = A_{us}^{\gamma} w_{ust} H_{ust}^{-\delta} A_i^{\sigma\delta-\gamma}. \tag{7}$$

Setting A_{us} equal to 1 in the composite region, and substituting (7) into (4) yields

$$L_{it}^{*} = \left[\frac{P_t bTFP_{it}A_i^{\gamma-\sigma\delta}K_{it}^{a}H_{ust}^{\delta}}{w_{ust}(1+HT_{it})}\right]^{1/(1-b)}. \tag{8}$$

The regional rental rate of capital net of taxes would equal the national rate net of taxes (r_{ust}), so that substituting into (5) yields

$$K_{it}^{*} = \left[\frac{P_t aTFP_{it}L_{it}^{b}}{r_{ust}(1+BT_{it})}\right]^{1/(1-a)}. \tag{9}$$

As the study examines growth in labor and capital stock, as well as total factor productivity, over time, we take the log of both sides of (8) and (9) and put each in terms of the change between time $t-1$ and t ($\Delta \ln L_i$ and $\Delta \ln K_i$, respectively).

$$\Delta \ln L_i = \frac{1}{1-b}[\Delta \ln(Pb) + \Delta \ln TFP_i + (\gamma - \sigma\delta)\Delta \ln A_i + a\Delta \ln K_i + \delta\Delta \ln H_{us} - \Delta \ln w_{us} - \Delta \ln(1+HT_{us})], \tag{10}$$

$$\Delta \ln K_i = \frac{1}{1-a}\left[\Delta \ln(Pa) + \Delta \ln TFP_i + b\Delta \ln L_i - \Delta \ln r_{us} - \Delta \ln(1+BT_i)\right]. \tag{11}$$

Note that the change in labor hours is a function of the change in total factor productivity, the change in capital stock, and the change in household taxes, and amenities. The change in capital stock is a function of the change in total factor productivity, the change in labor hours, and the change in business taxes.

We assume that the change in output price (and therefore, $\Delta\ln(Pb)$ and $\Delta\ln(Pa)$) is the same in all regions, as are $\Delta\ln r_{us}$, $\Delta\ln w_{us}$, and $\Delta\ln H_{us}$. All of these variables are dropped from the cross-section regression. We use three specific amenity variables for A_{it} (Huang et al., 2002; Hammond and Thompson, 2008): the ruggedness of the terrain (Rugged_i) and its square, the mean July temperature (Jul_i) and the presence of water (WA_i). These amenities do not change over time and are presented in level form in the equation. However, as normal goods, the value of fixed regional amenities to households should rise over time as incomes rise. Thus, manufacturing labor would be expected to grow over time with a warmer climate, a more rugged terrain that offers scenic and recreation opportunities, and a greater water amenity.

We include three additional demand factors for capital: the presence of a four-lane interstate highway in the region (HWY_i), energy costs (PNG_{it-1}) and population density (D_{it-1}). We expect the presence of a four-lane interstate highway to encourage capital investment in the manufacturing sector in local areas (Chandra and Thompson, 2000) while higher energy costs discourage it (Garofalo and Fogarty, 1987). We anticipate that population density would discourage investment to the extent that there is a higher cost of land and other inputs in more densely populated areas (Carlino, 1985). We focus on initial period values for effective tax rates, energy costs, and population density to minimize possible endogeneity problems.

We also include dummy variables for the Midwest (MW), South (S), and West (W) Census regions, with the Northeast as the omitted region. Coefficients for the Census dummy variables will indicate whether growth rates differ by region of the country in ways that are not captured in our model.

These changes yield (12) and (13)

$$(12)\quad \Delta \ln L_i = c_1 + c_2 \Delta \ln TFP_i + c_3 \Delta \ln K_i + c_4 \Delta \ln(1 + HT_{it-1}) + c_5 \ln Rugged_i + c_6 \ln Rugged_i^2 + c_7 \ln Jul_i + c_8 \ln WA_i + c_9 MW + c_{10} S + c_{11} W + u_i,$$

$$(13)\quad \Delta \ln K_i = c_{12} + c_{13} \Delta \ln TFP_i + c_{14} \Delta \ln L_i + c_{15} \Delta \ln(1 + BT_{it-1}) + c_{16} HWY_i + c_{17} \Delta \ln D_{it-1} + c_{18} \Delta \ln PNG_{it-1} + c_{19} MW + c_{20} S + c_{21} W + v_i.$$

In Equations (12) and (13), manufacturing capital stock and manufacturing employment are determined simultaneously, and growth of one should encourage growth of the other within regions. Labor and capital are gross complements at the regional level, similar to what was found by Crihfield and Panggabean (1996a; 1996b). Growth in total factor productivity also is expected to lead to faster growth in both manufacturing capital and labor.

We also are interested in the determinants of total factor productivity growth and rely on the previous research for our choice of variables. In Equation (14), growth in total factor productivity is modeled as a function of initial per capita human capital (S_{it-1}), the number of four-year colleges and universities in the region (COL_{it-1}), the initial level of population density (D_{it-1}), and the initial level of unionization ($U_{\mathrm{it}-1}$). We focus on initial period values in the growth regression in order to minimize possible endogeneity problems.

$$(14)\quad \Delta \ln TFP_i = c_{22} + c_{23} \ln S_{it-1} + c_{24} \ln COL_{it-1} + c_{25} \ln D_{it-1} + c_{26} \ln U_{it-1} + c_{27} MW + c_{28} S + c_{29} W + z_i.$$

Human capital investment has often been used to explain regional productivity differences, as higher levels of education translate into a more effective and productive workforce. For instance, Moomaw and Williams (1991) find that growth in educational attainment in states is related to faster growth in total factor productivity. In addition, Mullen and Williams (1990) also find a positive correlation between education growth and productivity for a sample of 29 Standard Metropolitan Statistical Areas (SMSAs). Beeson and Husted (1989) focus on education levels at a point in time and find a positive correlation with productivity growth. In addition, to the extent that high concentrations of human capital encourage the development of regional information technology clusters, we expect that productivity growth will accelerate along the lines proposed in Jorgenson (2001).

The presence of more colleges and universities also increases the ability of local areas to build human capital stock, as found in Hammond and Thompson (2008), through retaining and attracting educated workers. This also would be expected to contribute to the growth of manufacturing factor productivity.

Greater unionization is another factor that can influence the growth in total factor productivity. In particular, union rules can limit the ability of managers to efficiently organize production and to rapidly respond to changing market conditions. Moomaw and

TABLE 2: Summary Statistics for Regression Data

Variable Name	Variable Description	Means All LMAs	Means Metro LMAs	Means Nonmetro LMAs
Δln K	Change in the log of manufacturing capital stock 1972–2002[a]	1.321	1.326	1.318
Δln L	Change in the log of manufacturing labor hours 1972–2002[a]	0.088	−0.019	0.147
Δln TFP	Change in the log of total factor productivity 1972–2002[a]	0.615	0.637	0.604
Property tax 1972	State and local property taxes as share of income (%)	3.997	3.686	4.168
Other tax 1972	Other state and local taxes as share of income (%)	6.405	6.645	6.272
July temperature	Average July temperature	75.379	76.240	74.904
Percent water	Percent of surface area covered by water (%)	4.506	6.395	3.464
Ruggedness	Topographic scale (1 = plains, 21 = high Mountains)	9.280	8.629	9.639
Highway access	Interstate highway in labor market area (= 1 if present, else 0)	0.628	0.910	0.472
Price of natural gas	Avg. price of natural gas 1972–1992 (dollars per mil. BTU)	0.470	0.515	0.445
Population density 1970	Density (persons/square mile) 1970	77.379	172.529	24.882
Δ% High school graduates	Growth in pop. share with HS attainment, 1960–1970 (%)	25.141	24.896	25.276
Unionization	Labor union membership share 1972 (%)	21.746	22.944	21.084
Four-year Colleges	Four-year colleges in labor market area	2.757	6.715	0.573

[a]Since these means are unweighted averages, they are not directly comparable to Table 1, which provides weighted averages.

Williams (1991), Mullen and Williams (1990), and Beeson and Husted (1989) use the level of unionization as one determinant of growth in total factor productivity. Contrary to our expectation, Moomaw and Williams (1991) and Beeson and Husted (1989) find a positive correlation between unionization and productivity growth for states, while Mullen and Williams (1990) find no consistent significant correlation for a sample of SMSAs.

Finally, Moomaw and Williams (1991), Mullen and Williams (1990), Williams and Moomaw (1989) and Beeson (1987) also examined the influence of population concentration on total factor productivity in states. Previous studies utilized the size of metropolitan areas as a measure of agglomeration. These studies failed to find consistent evidence that the size or share of metropolitan population within states was related to total factor productivity growth. We utilize initial population density of the LMA, as measured by the population per square mile, as our measure of population concentration. This is similar to the approach of Ciccone and Hall (1996) for state data.

4. DATA

In this section, we provide brief descriptions and summary statistics (in Table 2) of our data. Our measures of the manufacturing capital stock, labor hours, and total factor productivity are the same as those discussed in Section 2.

Following Crihfield and Panggabean (1995; 1996a; 1996b), the effective state and local tax rate on property is a measure of business taxes. Property tax rates are used because manufacturers have a large capital stock and pay high levels of real and personal property tax. The effective tax rate is state and local property tax revenue divided by nontransfer income. All other state and local taxes, including sales and income taxes, are used as the measure of household taxes. In the estimation of (12) through (14), we utilized the initial level of effective household and business tax rates rather than the change in state and local tax rates over time. This was done because effective tax rates are taxes paid as a share of income, and income growth would be expected to be influenced by growth in the manufacturing sector, so that growth in the effective tax rate could be endogenous in a manufacturing growth equation. Data on state and local tax revenue are gathered from the 1972 Census of Government at the county level and aggregated to the LMA. Effective state taxes are assigned to the LMAs in each state, and were weighted by population in cases where an LMA is located in two or more states.

Household amenity variables include the ruggedness of the terrain, the average July temperature and the percentage of surface area that is covered by water. For the ruggedness variable, all areas are rated on a scale from 1 (plains) to 21 (high mountains). The scenic and recreation amenity value would be expected to rise with ruggedness, although it could decline for the highest levels of ruggedness. For this reason, both the level and square of ruggedness are included in the regression model. The amount of surface area covered by water is critical since it reflects access to recreational opportunities on rivers, lakes, and the shoreline of oceans. Data for the ruggedness, climate, and water access variables came from the Economic Research Service (ERS) of the U.S. Department of Agriculture, see McGranahan (1999).

Data on highway presence in each county was provided by the Federal Reserve Bank of Kansas City. County data on whether a four-lane interstate highway was present in each county were used to determine whether a highway was present in each LMA. Population density is population per square mile in each LMA in the Census year of 1970. We again utilize data from the initial year, given that growth in the manufacturing sector would be expected to lead to growth in population in LMAs. Following Wheat (1986), we utilize natural gas prices as our measure of energy costs. Average 1972 natural gas rates for industrial users by state come from the U.S. Department of Energy. State data are allocated to counties, then counties are aggregated to ERS regions based on the relative size of component counties within the region.

The human capital variable was defined as growth from 1960 to 1970 in the percent of residents age 25 and older with a high school degree or higher. These data are drawn from the 1960 and 1970 Census of Population. County data were aggregated up to the LMA. We focus on growth in the earlier period in order to minimize possible endogeneity problems with this indicator.

Data on the number of four-year colleges and universities in each LMA in 1980, the earliest year for which the data were available, were gathered from the National Center for Education Statistics. Data on union membership as a share of nonfarm employment in 1972 were taken from the U.S. Bureau of Labor Statistics. State data are allocated to counties, then counties are aggregated to ERS regions based on the relative size of component counties within the region, based on population. Thus, a populous county will contribute more to a region's unionization level than a sparsely population county.

5. RESULTS

We estimate Equations (12), (13), and (14) utilizing three-stage least squares. This allows us to account for the endogeneity of the choice of capital and labor, as well as the residual correlation across the labor, capital, and total factor productivity equations.

We have at least three excluded exogenous variables from each equation, so that they are identified via the order condition.[5] Our procedure is broader in scope and uses more regionally disaggregated data than available in previous literature. Results of the model estimation are reported in Table 3 for all LMAs. As tests reject at the 1 percent level, the pooling of data from metropolitan and nonmetropolitan LMAs, model results also are reported separately for metropolitan and nonmetropolitan areas. However, for many variables, the results are similar for these geographical breakdowns. In particular, in both metropolitan and nonmetropolitan areas, and overall, results suggest a positive relationship between increases in total factor productivity and the expansion of factors of production within LMAs. We also find a positive relationship between labor and capital growth, which suggest that they are gross complements at the regional level.[6]

Growth in Total Factor Productivity

Results in Table 3 suggest that greater population density, more four-year colleges and universities, higher human capital investment, and lower levels of unionization encourage growth in total factor productivity. The link between population density and total factor productivity growth arises from the interplay between opposing forces from agglomeration and congestion. A positive relationship between density and productivity growth would occur if agglomeration dominates. As seen in Table 3, we find a positive and statistically significant relationship between population density in 1970 and subsequent growth in total factor productivity from 1972 to 2002 in metropolitan LMAs and all LMAs. The coefficient estimate for population density was positive but smaller in nonmetropolitan areas and was not statistically significant at the 10 percent level.

In the all LMA results, our estimated coefficient implies that a 10 percent increase in population density generates a 0.7 percent (relative to mean productivity growth) increase in total factor productivity in the long run. Our model then allows us to estimate the subsequent impact on labor and capital growth. In the all LMA results, we find that a 10 percent increase in population density, working through its impact on total factor productivity, ultimately generates a labor growth impact of +0.58 percentage points over the 30-year period and a capital stock growth impact of +1.03 percentage points. Compared to the mean labor growth across all regions of 8.8 percent from 1972 to 2002, the labor growth impact translates into a 6.6 percent increase. The labor growth impact, relative to the mean, appears to be relatively large. The impact is magnified by the very low labor growth during the period. For capital stock growth, the population density impact translates into a 0.8 percent increase, relative to average growth across all regions.

The positive correlation between population density and productivity growth is similar to results in Ciccone and Hall (1996) for states and Mullen and Williams (1990) for a sample of SMSAs, but is at odds with previous research for states, which found no consistent relationship between SMSA population and growth in total factor productivity (Beeson, 1987; Beeson and Husted, 1989; Moomaw and Williams, 1991). Our ability to examine the impact of density within local economies rather than in larger political subdivisions such as states probably helps to identify the expected link between agglomeration and productivity growth.

[5] F-tests show that the first-stage instruments pass a joint exclusion test in all but one case. The exception is the nonmetropolitan labor hours equation, which indicates that the results of this equation may be less reliable. However, the results from this equation tend to be similar to those from the all LMA labor hours regression and (at least with respect to the sign of the other tax variable) to the metropolitan labor hours equation.

[6] Our regression results are similar using SIC data for the 1972–1992 period. These results are available upon request.

TABLE 3: Three-Stage Least Squares Regression Results for Equations (12)–(14)

	All LMAs			Metro LMAs			Nonmetro LMAs		
Variable	Δln L	Δln K	Δln TFP	Δln L	Δln K	Δln TFP	Δln L	Δln K	Δln TFP
Constant	0.166	0.711***	0.213*	−2.067*	0.456	0.215	2.280	1.029***	0.092
Δln Capital	0.778***			0.993***			0.360*		
Δln Labor		0.779***			0.719***			0.201	
Δln TFP	−0.550**	0.993***		−1.131***	1.692***		0.380	0.609**	
ln (1 + property tax 1972)		−4.488***			−0.403			−9.678***	
ln (1 + other tax 1972)	−5.424***			−0.989			−13.394***		
ln (July temp)	−0.097			0.376			−0.474		
ln (Percent water)	0.001			0.023**			−0.013		
ln (Ruggedness)	−0.009			−0.102**			0.169		
(ln (Ruggedness))^2	−0.007			0.034**			−0.072		
Highway access		0.023			0.002			0.061	
ln (Price Ngas 72)		−0.104			−0.029			−0.188	
ln (Pop density 70)		−0.010	0.043***		−0.086***	0.055***		0.004	0.033
Δln (%HS gds 1960–70)			0.393**			0.205			0.626***
ln (Union 1972)			−0.152***			−0.141***			−0.212***
ln (Four-year colleges)			0.001			0.005**			0.000
Midwest	0.098	0.009	−0.054	−0.021	0.160	−0.085	0.035	0.199	−0.046
South	−0.089	0.119	−0.141**	−0.199**	0.267**	−0.140**	−0.047	0.015	−0.146
West	0.189*	−0.052	−0.019	0.086	0.094	−0.056	0.093	0.009	−0.007
R^2	0.646	0.526	0.195	0.641	0.461	0.284	0.672	0.329	0.190
N	719	719	719	256	256	256	463	463	463
Estimation period: 1972–2002.									

*Significant at 10 percent level; **Significant at 5 percent level; ***Significant at 1 percent level.

We find a negative relationship between unionization and productivity growth during the 1970s, 1980s, 1990s, and early 2000s in the results for all LMAs, metropolitan LMAs, and nonmetropolitan LMAs. This suggests that workplace regulations agreed to in collective bargaining, including factors such as work rules and seniority, which limit the ability of employers to recombine capital and labor in the workplace, may reduce productivity gains. This result differs than the findings of previous research on the effect of unionization. Moomaw and Williams (1991) and Beeson and Husted (1989) found a positive relationship for states, and Mullen and Williams (1990) found no consistent effect for SMSAs. This may be due to our emphasis on more recent time periods (previous research along these lines used data current through the 1970s). Increasing competitive pressure in the 1980s and 1990s may well have intensified the negative impact of unionization on productivity growth, as heavily unionized organizations had difficulty responding to rapidly changing market conditions. Furthermore, our focus on an exhaustive set of LMAs (as opposed to a subset of metropolitan areas) may also contribute to the precision of our results. Our point estimates for all LMAs suggest that a 10 percent increase in unionization generates a 2.4 percent decrease in productivity growth (relative to the mean). The impact on productivity growth generates a decrease in capital stock and labor growth of 3.6 percentage points and 2.8 percentage points, respectively. Evaluated relative to their respective means, these impacts translate into declines of 3.6 percent for capital stock growth and 32.2 percent for labor growth.[7]

Results in Table 3 further show support for the role of human capital investment in the growth in total factor productivity. Specifically, improvements in human capital were significant for faster total factor productivity growth in the all LMA results. Our coefficient estimates imply that a 10 percent increase in the growth rate of human capital generates a 1.6 percent increase in total factor productivity growth for all regions, with subsequent increases in capital stock and labor input growth of 2.5 percentage points and 1.9 percentage points, respectively. Evaluated relative to their respective means, these impacts translate into increases of 1.9 percent for capital stock growth and 22.0 percent for labor growth.

These findings for human capital are consistent with Mullen and Williams (1990) for SMSAs, as well as Moomaw and Williams (1991) and Beeson and Husted (1989) for states. These results also likely reflect the importance of the information technology sectors in driving productivity growth (Jorgenson, 2001), as regions with high levels of human capital are better able to attract growth in high-technology sectors, including manufacturing.

We also find that human capital investment may have a bigger payoff for productivity growth in nonmetropolitan regions than for metropolitan regions. We find that a 10 percent increase in human capital investment generates a 2.6 percent increase (relative to the mean) in productivity growth in nonmetropolitan regions, but has no significant impact for metropolitan areas.

We find a positive relationship between the number of colleges and universities in an LMA and productivity growth in manufacturing for metropolitan areas. This suggests that the capacity of the labor market to generate human capital may be important, consistent with results on long-run county growth presented in Beeson et al. (2001).

Taken together, our results provide evidence that general efforts to improve the productivity of the area economy through investments in education and through less unionization can generate stronger total factor productivity growth.

[7]Keep in mind that the impact on the labor growth rate relative to the mean seems large in part because the average growth rate during the 30-year period is very low.

Finally, while our model in Equations (12) through (14) did not suggest that growth in capital and labor would encourage growth in total factor productivity (by contrast, it did indicate that growth in total factor productivity would encourage growth in capital and labor inputs), we do note that Moomaw and Williams (1991) and Mullen and Williams (1990) include contemporaneous output growth in their productivity regressions. In the context of our model, this suggests that labor and capital growth may influence total factor productivity gains. To test this, we included labor and capital growth in our productivity regression and reestimated the system. The results suggested that labor and capital growth do not generally significantly influence productivity growth in our sample of regions.

Capital and Labor Formation

Results from the factor growth equations show a positive and statistically significant relationship between growth in manufacturing labor hours and growth in manufacturing capital stock. Thus, we find that labor and capital are gross complements at the regional level, similar to Crihfield and Panggabean (1996a; 1996b).

Results from the factor growth equations also support the expected positive relationship between growth in total factor productivity and growth in capital stock and labor. The coefficient on growth in total factor productivity is positive and significant in the capital stock equation in the all LMA, the metropolitan LMA, and the nonmetropolitan LMA results. Furthermore, while the coefficients for growth in total factor productivity are not significant or even negative for the labor equation, growth in factor productivity still increases utilization of these factors. To see this, take the example of the all LMA results. Growth in total factor productivity directly increases capital stock. Further total factor productivity growth will still have a positive, but indirect, effect on labor utilization, due to the complementary relationship between growth in manufacturing capital and labor. Therefore, as growth in total factor productivity increases capital formation, it indirectly increases labor utilization. The net effect of total factor productivity growth working through both equations is to increase capital stock (significant at the 1 percent level), and labor utilization (significant at the 22.7 percent level). We also test for these net impacts in both metropolitan and nonmetropolitan regressions and find positive and significant impacts for total factor productivity growth on capital stock and labor hours growth (at the 10 percent or better significance level).

Regression results in Table 3 also indicate that taxes are a key factor in capital and labor formation. Indeed, our results in the all LMA regression imply that a 10 percent increase in property taxes as a share of nontransfer income generates a 4.4 percentage point decrease in the 30-year growth rate of capital and a 3.4 percentage point decrease in the 30-year growth rate of labor hours, after taking into account the interdependence of labor and capital.[8]

Furthermore, a 10 percent increase in other taxes as a share of nontransfer income generates an 8.2 percentage point decrease in labor hours growth over a 30-year period and a 6.4 percentage point decrease in capital growth. Taxes seem to be most important for nonmetropolitan areas, as these coefficients were not significant in metropolitan LMAs.

Among other factors, higher energy prices and the presence of highways were not found to discourage capital investment within the manufacturing sector in the all LMA,

[8]Mark et al. (2000) estimate the response of total county employment growth in the Washington metro area to tax measures, including the effective property tax rate. Our results suggest a lower response than that found by Mark et al. (2000). This is likely due to the fact that they work with intermetropolitan responses, while we work with intrametropolitan responses.

metropolitan LMA and nonmetropolitan LMA regression results. Furthermore, holding total factor productivity constant, greater population density discouraged capital formation in metropolitan areas. This may reflect the impact of higher costs for land or other inputs in more densely populated metropolitan areas.

Household amenities primarily influenced growth in the labor input in metropolitan LMAs. More access to lakes, rivers, or oceans was associated with faster growth in manufacturing labor. A rugged topography was associated with slower growth in manufacturing labor, though at a declining rate as topography increased. The climate amenities, however, were insignificant.

None of the amenity variables were significant in the nonmetropolitan LMA results. This suggests that taxes rather than amenities were the key supply-side variable for manufacturing labor in nonmetropolitan areas.

6. CONCLUSION

We have shown that there were large differences in the growth rates of labor hours, the capital stock, and productivity among the Census regions during the past 30 years. Our econometric results imply that such differences can be predicted in part by policy variables (tax rates and unionization) and regional characteristics (population density, amenities, educational attainment, natural gas prices, colleges and universities).

We note that real output growth during the past 30 years was particularly strong in the West and South Census regions. In turn, our results suggest that this was primarily due to relatively strong input accumulation during the period, as the West was the only region to generate growth in labor hours and the South posted the fastest rate of capital stock growth. Our econometric results suggest that taxes played an important role in input growth during the 1972–2002 period. Specifically, we find that nonproperty taxes (which influence growth in labor hours in our model) tended to be relatively low in the West, while property taxes (which influence growth in the capital stock) tended to be relatively low in the South. Thus, our results suggest that the relative influence of tax rates accounts for part of the geographic variation in manufacturing performance within the United States.

Overall, our results support the expectation that LMAs can attract both capital and labor through improving total factor productivity. These results also demonstrate that local areas have a variety of policy options to capture growth in the manufacturing industry as it continues to churn and reallocate within the U.S. economy. Furthermore, the policies that encourage growth in manufacturing may be the same policies that improve the overall strength of the local economy such as improved education and lower taxes. Targeted policies to encourage manufacturing also were found to be effective. In particular, reduced levels of unionization also encourage growth in the manufacturing sector.

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