

# Determinants of Labor Productivity for Detailed Manufacturing Industries

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## ABSTRACT

Labor productivity is a crucial determinant of an economy's competitiveness, and it varies dramatically across American metro areas. This paper attempts to explain why productivity varies so much, using a select set of 5-digit manufacturing industries. It explores reasons for this variation, examining the impact of education, investment in physical capital, human capital, public capital, agglomeration economies (both urbanization and localization), patents, and other possible determinants. It concludes with insights for the individual industries, as well as some broader patterns.



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## I. Introduction

This paper continues a stream of research that has explored the determinants of productivity differences in manufacturing industries across American metro areas. The stream began (Kurre, 2004) by documenting the huge differences in manufacturing productivity across metro areas in the manufacturing supersector—more than 22 fold from the top to the bottom MSA in 1997—and exploring some potential determinants. The series has worked its way down the NAICS hierarchy through durables vs. nondurables (Brunot and Kurre, 2012) to the three-digit level (Kurre and St. Andrews, 2013) until it arrives at the 5-digit level with this paper. This is probably the limit of industrial disaggregation in the manufacturing sector since confidentiality restrictions lead to unworkably small sample sizes at the 6-digit level.

One key finding of this stream of research is that there seem to be some over-arching, broad patterns in terms of manufacturing productivity determinants, but there are also differences among industries. Of course, this fits with a priori expectations. Some industries require high skill levels of their workers while others focus more on the capital input or economies of scale. That leads to the conclusion that it is important to examine patterns among detailed industries; the more homogeneous the industry categories used, the better. Hence this study.

While there were 184 5-digit NAICS manufacturing categories in 2007, we found that only about a half dozen industries have enough data available at the metro level for both the dependent variable and the set of independent variables that we think are important, to allow meaningful regression analysis.

It is clear that productivity varies significantly across industry categories within manufacturing. Table 1 shows 2007 productivity, measured as value added per production worker hour, at the national level for the manufacturing supersector and its three-digit components. The variation is quite striking, from a low of only \$48.86 per production worker hour in apparel manufacturing (NAICS 315) to \$828.16 an hour in petroleum and coal products (NAICS 324)—nearly 17 times as much. The key question is “why?”

Table 1  
2007 Productivity in Manufacturing Industries Nationally

NAICS	Industry	Value added per production worker (\$)	Value added per production worker hour (\$)
31-33	<b>Manufacturing, United States</b>	<b>253,868</b>	<b>126.12</b>
311	Food mfg	211,596	105.60
312	Beverage and tobacco product mfg	913,382	458.20
313	Textile mills	122,302	60.86
314	Textile product mills	118,700	60.16
315	Apparel mfg	87,541	48.86
316	Leather and allied product mfg	101,364	53.91
321	Wood product mfg	98,451	49.18
322	Paper mfg	253,882	120.05
323	Printing and related support activities	138,990	71.94
324	Petroleum and coal products mfg	1,837,947	828.16
325	Chemical mfg	782,254	384.93
326	Plastics and rubber products mfg	150,362	73.75
327	Nonmetallic mineral product mfg	197,952	94.78
331	Primary metal mfg	254,536	120.40
332	Fabricated metal product mfg	156,701	77.07
333	Machinery mfg	222,017	110.04
334	Computer and electronic product mfg	460,121	230.30
335	Electrical equipment, appliance, and component mfg	209,276	104.23
336	Transportation equipment mfg	261,736	131.12
337	Furniture and related product mfg	120,057	60.60
339	Miscellaneous mfg	228,766	118.06

Source: 2007 Economic Census

## II. The Model: Economic Logic and the Data to Test It

This paper is part of an ongoing research stream, building on the work that has gone before. As such, it repeats some of the core explanation in those earlier papers such as Kurre and Miseta (2008), Brunot and Kurre (2012), and Kurre and St. Andrews (2013), and then extends it.

The model tested in this paper for each individual industry is:

Productivity<sub>i</sub> = f (physical capital<sub>i</sub>, human capital<sub>i</sub>, public capital<sub>i</sub>, economies of scale<sub>i</sub>, innovation<sub>i</sub>, government influence<sub>i</sub>, entrepreneurship<sub>i</sub>)

where: Productivity = value added per production worker hour in manufacturing,  
i = metropolitan statistical areas (MSAs),  
and the other variables are as explained below.

Entrepreneurship (measured as proprietorship rates) and public capital are new to the model from previous pieces in this stream of research. Other previously included variables, such as education and age, have been categorized into “human capital.” Some of these variables, such as human capital and economies of scale, have subcategories, each of which will be tested as a determinant. So the model as tested has more detailed variables than the model listed above.

### A. Productivity

#### i) Productivity Basics

Most fundamentally, productivity is “some measure of output per some measure of input.” We choose to measure productivity as value added per hour worked by production workers in manufacturing industries. In their study of regional comparative advantage, Hill and Brennan (2000) use a similar measure. We opt

not to use a measure of the value of goods sold, such as value of shipments, since that would involve double-counting of inputs. As the Census Bureau says:

“Data for cost of materials and value of shipments include varying amounts of duplication, especially at higher levels of aggregation. This is because the products of one establishment may be the materials of another. The value added statistics avoid this duplication and are, for most purposes, the best measure for comparing the relative economic importance of industries and geographic areas.”<sup>1</sup>

A metro area that produces steel sheets, steel fabrication (turning the steel sheets into fenders), and automobiles would have a total value of shipments that double-counts the steel fabrication and triple-counts the steel itself. Thus the value of shipments is inflated compared to the true value produced—the final product, the car. Using value added at each step in the production process will avoid this problem.<sup>2</sup>

And we focus on the productivity of a single input, labor, rather than other factors of production. One reason why this is appropriate is that labor costs account for the lion’s share of costs for most businesses. And labor is the source of most income for most Americans. Nationally, employee compensation accounted for 63.4% of national income in 2007, compared with 12.2% for corporate profits, 8.8% for proprietors’ income, 5.9% for net interest income, and 1.2% for rental income.<sup>3</sup> And employment is a key focus of government policy, both at the national and the local level. This is certainly not to say that the other factors of production aren’t important; we just choose to focus on this specific factor.

For this paper we measure productivity using hours of work by production workers as the denominator. It would have been possible to calculate productivity as output per worker instead of per hour of labor, but that would be a less accurate measure since not all workers work full time. To the extent that an area’s industries tend to use more part time workers or to use overtime labor, their measures of labor input (hours of work) may not correlate closely with employment. For example, if area A’s firms only hire workers who work 20 hours a week, while area B’s firms only hire workers who work 40 hours a week, area A would need twice as many workers to produce the same output as B, although they use the same amount of labor input (hours of labor). Clearly, use of output per worker data to measure productivity could be misleading. For that reason, we elect to use output per hour as our measure of productivity.

In fact, measures of productivity per worker and productivity per hour are highly correlated across metro areas. Kurre (2004) found a correlation of .991 across 327 metro areas in the 1997 Economic Census, and similar results obtained for both the “hours” and the “workers” measures in that regression analysis, suggesting that either approach is acceptable. 2002 Economic Census data yielded a correlation coefficient of 0.994 for value added per production worker and value added per production worker hour across 273 metro areas (Kurre and Miseta, 2008). And the data from 2007 for the manufacturing supersector (Brunot and Kurre, 2012) yielded a correlation of 0.995 between productivity per production worker hour and per production worker across 332 MSAs. Although this suggests that employment may be an acceptable proxy, we prefer to use “hours worked” since that is more appropriate on a theoretical level.

Hammill (2002) explored possible data sources for metro-level productivity, concluding that the Geographic Area Series of the Economic Census is the preferred source. It provides data for all metro areas for a single point in time from a single data source, permitting the kind of cross-sectional study that we wish to do. The Census Bureau has a well-earned reputation for the quality of its data, and this is an

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<sup>1</sup> U.S. Bureau of the Census, *2007 Economic Census Methodology: Manufacturing (sector 31-33)*, page 6. Available online at: [http://www.census.gov/econ/census07/pdf/meth/meth\\_31.pdf](http://www.census.gov/econ/census07/pdf/meth/meth_31.pdf).

<sup>2</sup> There is a correlation of .976 between the Value Added and the Value of Shipments data across the 329 MSAs for which there were data for both variables for the manufacturing supersector in the 2007 Census of Manufactures, but this is largely driven by the simple size of the MSAs. The correlation between the productivity measures using those two variables is .753.

<sup>3</sup> Calculated from U.S. Bureau of Economic Analysis: NIPA Table 1.12. National Income by Type of Income, available online at <http://www.bea.gov/national/nipaweb/SelectTable.asp?Selected=N>. The other 8.5% is composed of taxes less subsidies, business transfer payments, and the deficit of government enterprises.

important factor for any database. Along with productivity data, the Economic Census also provides data on capital stock additions for metro areas, an important variable in the model.

Of course, the Economic Census is not a perfect database. We would prefer to have data for as recent a period as possible, but the Economic Censuses are taken only every five years. As of this writing, the most recent data are for 2007 and the manufacturing portion of the Geographic Area Series were released in early 2010, a lag of over two years from the data point. But what the Economic Census lacks in timeliness, it makes up for in data coverage and detail. Specifically, it is one of the few sources with input and output data by industry at the metropolitan level.

The most recent Economic Census data are for 2007, but is this year atypical in some way, so that the relationships in the 2007 data are not representative of other times? Does our time point bias the results somehow?

Productivity is generally thought to be procyclical (OECD, 2001), although this is not universally accepted (Baily et al. 1996; Estrella, 2004.) Estrella (2004) points out that while there is evidence of pro-cyclical productivity changes, some models (specifically Keynesian ones) predict that productivity should be countercyclical. If productivity varies with the business cycle, regardless of how, the cyclical characteristics of the time period used may affect the generalizability of results. Specifically, if different metro areas have different timing relative to the national business cycle and the cycles of other metro areas, productivity may be higher or lower in those areas due just to cyclical effects rather than due to the hypothesized determinants. An attempt to explain productivity differences across those metro areas based on characteristics of the areas, such as this paper attempts to do, will have a harder time in such a situation. The implication is that it would be better to stay clear of cyclical turning points in an analysis such as this.

So where does 2007 fall in relation to the business cycle? Figures 1 and 2 show data for real national GDP from 2000 through the second quarter of 2012, with the four quarters of 2007 identified.<sup>4</sup> The National Bureau of Economic Research identifies December 2007 as a cyclical peak followed by a trough in June of 2009.<sup>5</sup> This means that the Economic Census's 2007 data point covers the tail end of the expansion, just before the start of the Great Recession. If some MSAs lead the national economy, as seems likely, by 2007 some of them most likely had already tipped over into recession, with the resulting impact on productivity numbers. At the same time, other metro areas that lag the national economy were still riding high. So the timing of the data may introduce some noise into the productivity analysis. We'd prefer that this study be based on data from the midpoint of an expansion, but like other researchers we work with the data that we have.

Figure 1: Real GDP

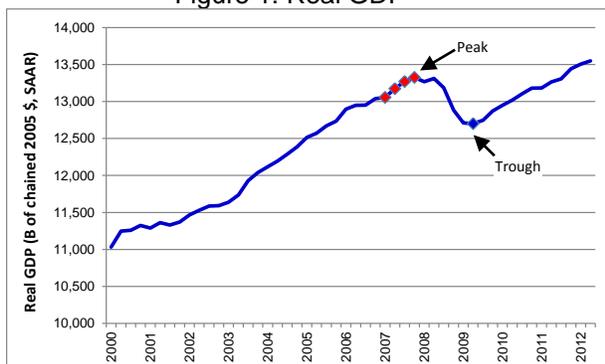
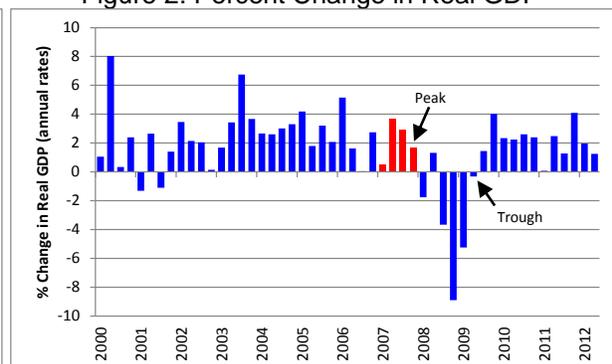


Figure 2: Percent Change in Real GDP



<sup>4</sup> Data are from the U.S. Bureau of Economic Analysis at: [http://www.bea.gov/iTable/index\\_nipa.cfm](http://www.bea.gov/iTable/index_nipa.cfm).

<sup>5</sup> National Bureau of Economic Research, US Business Cycle Expansions and Contractions, online at: <http://www.nber.org/cycles/cyclesmain.html>.

## ii) Productivity Data

We chose the Economic Census as the source for the key data for this study since it gives value added and production worker hours, for detailed manufacturing industries, by metro area. But as with all spatial and industrial data, there are tradeoffs between coverage and detail.

Geographically, we selected Metropolitan Statistical Areas (MSAs) as the unit of analysis since metro areas are defined to be small economies—labor markets. Lobo and Rantisi (1999) point out the advantages of studying metropolitan economies in the U.S., citing their economic openness and the fact that they are less arbitrary than countries, regions, or states. They add that a metropolitan area constitutes a single labor market, unlike states which are too large or cities which are too small (p 107).

Not all MSAs are independent economies; there is undoubtedly some interdependence among MSAs that are adjacent to other MSAs--which is the reason for designation of Combined Statistical Areas (CSAs), after all. However, MSAs are generally more logical geographical units for economic analysis than counties (one level down the geographical spectrum) or states (one level up), both of which use historical political boundaries that often do not reflect current economic forces. The Economic Census presents data at the MSA level, making it a logical choice as a data source.

The 2007 Economic Census uses MSA definitions as of December 2006 from the Office of Management and Budget.<sup>6</sup> All 363 officially-defined MSAs were included in the 2007 Census of Manufactures. The eight MSAs in Puerto Rico were excluded from the analysis as being different in kind from the others, and not all MSAs had data for all the variables needed for this study. And, of course, not all industries exist in all MSAs. And when an MSA had a small number of firms in one industry, the data were not disclosed. That led to varying numbers of observations for different industries.

One key goal of this project was to test the model using more industrially disaggregated data than previous papers. For this paper, we used 5-digit industries. Table 2 shows the number of observations for each 5-digit NAICS category. Only the top group of 5-digit NAICS codes is shown because, as can be seen, in the first 20 industries we have already gotten to numbers too low for regression analysis. The last column of Table 2 shows how many MSAs have all four variables necessary for this study within a given 5-digit industry.

The model will be applied to the five selected industries listed below. These industries cover a broad range of manufactured goods, some more detailed than others.

-32619—Other plastics manufacturing

“This industry comprises establishments primarily engaged in manufacturing resilient floor covering and other plastics products (except film, sheet, bags, profile shapes, pipes, pipe fittings, laminates, foam products, and bottles).”

-33231—Plate work and fabricated structural product manufacturing

“Establishments primarily engaged in manufacturing one or more of the following: (1) prefabricated metal buildings, panels and sections; (2) structural metal products; and (3) metal plate work products.”

-33232—Ornamental and architectural metal products manufacturing

“This industry comprises establishments primarily engaged in manufacturing one or more of the following: (1) metal framed windows (i.e., typically using purchased glass) and metal doors; (2) sheet metal work; and (3) ornamental and architectural metal products.”

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<sup>6</sup> Executive Office of the President, Office of Management and Budget. “Update of Statistical Area Definitions and Guidance on Their Uses” OMB Bulletin 07-01. December 18, 2006. Available at: <http://www.whitehouse.gov/sites/default/files/omb/assets/omb/bulletins/fy2007/b07-01.pdf>.

Table 2. Data Availability for 5-digit Industries (First 20)

5-digit NAICS Industry	Data for # Establishments	MSAs w/ Data for Value Added	MSAs w/ data for production worker hrs	MSAs w/ Data for Capital	MSAs w/ All Four Variables Available
Machine shops	156	74	130	107	63
Plate work and fabricated structural product manufacturing	142	46	98	76	37
Other plastics product manufacturing	186	56	103	74	37
Ornamental and architectural metal products manufacturing	131	44	93	69	34
Turned product and screw, nut, and bolt manufacturing	76	31	57	51	30
Coating, engraving, heat treating, and allied activities	89	36	64	54	29
Medical equipment and supplies manufacturing	141	34	97	61	28
Forging and stamping	73	26	44	35	20
Metalworking machinery manufacturing	93	24	66	47	20
Printing	206	23	95	66	16
Ready-mix concrete manufacturing	72	27	45	30	15
Commercial and service industry machinery manufacturing	70	17	34	26	14
Veneer, plywood, and engineered wood product manufacturing	72	17	34	25	13
Wood kitchen cabinet and countertop manufacturing	93	20	61	40	13
Sign manufacturing	67	18	49	29	12
Animal slaughtering and processing	145	20	54	40	12
Millwork	85	16	48	27	12
Other concrete product manufacturing	64	21	37	24	12
Support activities for printing	38	11	26	20	11
All other general purpose machinery manufacturing	93	15	42	28	11

Source: 2007 Economic Census

#### -33271—Machine shops

“This industry comprises establishments known as machine shops primarily engaged in machining metal and plastic parts and parts of other composite materials on a job or order basis. Generally machine shop jobs are low volume using machine tools, such as lathes (including computer numerically controlled); automatic screw machines; and machines for boring, grinding, and milling.” This definition foreshadows some of the results. By pointing out that machine shops are generally low volume, it is fair to say economies of scale are an unlikely determinant for this industry.

#### -33911—Medical equipment and supplies manufacturing

“This industry comprises establishments primarily engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, ophthalmic goods, dentures, and orthodontic appliances.”

## B. Independent Variables

### i) Physical Capital

The productivity of a worker will obviously be related to the quantity and quality of capital with which he or she works. More capital and more modern technology should translate to greater output; a worker with a brace and bit will get a lot fewer holes drilled per hour than one controlling a battery of computer-assisted drill presses. This means that we must include a measure of capital stock in each metro area as an important variable in our model. It is not surprising that most studies of productivity focus on capital as a crucial determinant of output. Indeed, it would be surprising if capital *didn't* play a key role. For example, Kitson, Martin, and Tyler (2004) emphasize the role of physical capital in building regional competitiveness (p. 995). Schreyer and Pilat (2001) identify capital as one of the required variables for measuring productivity (p. 142). Audretsch and Keilbach (2005) found capital—both physical and entrepreneurial—

to play an important role in German regions, and Christopolous and Tsionas (2004) found it important in Greek regions. Deno (1988) documented the impact of public capital in 36 American metro areas, and Ezcurra et al (2005) found similar results for Spain. Primont and Domazlicky (2005) measured the importance of private capital across American states. And Abel and Gabe (2010) found capital to be an important determinant of productivity for 290 U.S. metro areas, although they found equipment to play a larger role than structures. In the current research stream, Kurre (2004), Kurre and Miseta (2008), Brunot and Kurre (2012), and Kurre and St. Andrews (2013) all found capital to play a significant role in explaining productivity across metro areas.

Unfortunately there appears to be no good measure of capital stock at the metro level. However, the Economic Census itself includes data on total capital expenditures—i.e., investment—in 2007. While this flow measure is not the variable that we would most prefer (total capital stock), it does give us at least a proxy for the effects of capital on output. The data on investment from the Economic Census cover expenditures on new and used capital, including buildings and equipment, at existing operations and plants under construction.

Since the dollar amount of the 2007 capital expenditure will vary with the scale of the metro area, we chose to use “change in capital stock per production worker hour” as the variable in our models to eliminate the scale effect. (Effects of scale on productivity will be included in the population variable, as explained below.) Without this adjustment, we would be testing whether places with more capital in total are more productive, rather than asking whether places with more capital *per unit of labor* (per worker hour) are more productive—and the latter question is the more appropriate one. And, as explained above, we think it makes more sense to focus on production worker hours in a study of manufacturing productivity than simple numbers of workers without regard for their type (production, nonproduction) and how many hours per week they work.

## **ii) Human Capital**

Just as important to production as physical capital is human capital. The literature emphasizes this often. For instance; Bronzini and Piselli (2009) use human capital as an independent variable for measuring total factor productivity and find a significant positive relationship (p.193). Education is commonly used as a measure of human capital, the argument being that education increases the skills of laborers and their ability to adapt. This drives growth as workers make better use of existing technology and implement new technologies. While human capital may be developed in other ways, education is easily measured and commonly considered the most important part of human capital.

Many studies of productivity include discussion of the effects of education. At the sub-national level, Beeson (1987), Beeson and Husted (1989), Moomaw and Williams (1991) and Brock (2001) all introduced education variables into their state-level studies of productivity differences, and education was the primary focus of Iranzo and Peri (2006). Gottlieb and Fogarty (2003) focus on the crucial contribution of education to productivity and its subsequent effect on the growth rates of metro areas. Hunter and Kurre (2003), Kurre (2004), Kurre and Miseta (2008), Brunot and Kurre (2012), and Kurre and St. Andrews (2013) all found education to be an important determinant of productivity at the metro level. And Abel and Gabe (2010) found educational attainment to play a larger role than physical capital or agglomeration economies in their study of 290 metro areas.

While these studies used various measures of education, the variable that showed most promise was percent of the metro area’s population that have attained various levels of education: associate’s degree, bachelor’s degree, and graduate/professional degrees. Data from the Census Bureau’s American Community Survey, three year estimates for 2006-2008, Table S1501, were used for these variables.

Correlation analysis across the 363 MSAs indicates that places with a higher percentages of college graduates also tended to have a higher percentage of those with graduate degrees ( $r = 0.795$ ), but there was very little correlation with percent having an associate degree ( $r = 0.085$ ). In fact, percent with an

associate degree was mostly uncorrelated with “% grad degrees” ( $r = -0.050$ ) and with “% bachelor’s or higher” ( $r = 0.023$ ).

Our working hypothesis is that areas with a greater proportion of residents with a bachelor’s degree or higher will tend to have higher levels of productivity.

Kurre and St. Andrews (2013) point out that the skill of a worker is not always reflected by education. There may be workers who have plenty of education but little practical skills, or workers with little education but plenty of skill. Demographic variables may capture some of these effects. The percent of workers in certain age ranges (such as the 25-34 range) may be correlated with productivity. Kurre and St. Andrews find a significant positive relationship between this variable and productivity in their study of regional productivity (pp. 14-16). To address the two different forms of human capital discussed here, both education levels and the percent of the population that is in different age ranges will be tested as determinants for productivity.

One approach may be to use age of workers as a proxy for experience, and perhaps skill. For this project we considered those at each end of the age spectrum: those in the 25-34 age group, not long out of school, and those in the 55-64 age group, those contemplating retirement.

Signs reflecting the impact of these variables on productivity are not immediately clear a priori. For the younger group, we might expect them to have higher productivity because they are not long out of school where, if they made good education choices, they learned the latest techniques. They can bring a fresh viewpoint to old problems, along with the vigor and enthusiasm of youth and a greater integration of technology into their worklives. On the other hand, they are probably inexperienced and will have to suffer through beginner’s mistakes as they engage in some amount of on-the-job training. And just maybe they spend more work-time on their personal digital devices. These competing forces can have opposite impacts on productivity.

For the older group, the opposite story can be told. These workers have a lot of years under their collective belt, and have learned their craft through decades of applied training. They literally know the tricks of the trade, and that helps them be productive. But they may or may not have kept up with the newest techniques and software, and they may be winding down a bit physically compared to their earlier days, which may have the opposite effect on their productivity.

We have no a priori theoretical expectation about the signs of these two variables, but previous work for the whole manufacturing supersector found the older workers to have a positive and significant effect on productivity, while the younger worker variable exerted a negative—though not statistically significant—effect (Brunot and Kurre, 2012). We might expect this effect to vary by industry though. In the higher-tech industries, recent education and technological savvy might have a major effect on output, while a less-technical old-line industry may rely on skills won through decades of hands-on experience.

Data for the age variables came from the American Community Survey, Table S0101, using the 3-year estimates covering 2006-08. The two age variables reflect the percent of total population in the 25-34 or 55-64 age groups. The percent of younger workers averaged 13.3% over the 363 MSAs, and varied from 10.1% in Punta Gorda FL and Weirton-Steubenville WV-OH to 18.6% in Hanford-Corcoran, CA. The percent of older workers averaged 10.9% and ranged from 6.0% in Hinesville-Fort Stewart GA and Provo-Orem UT to 14.4% in Grayer Santa Fe NM. The two variables are inversely correlated ( $r = -0.702$ ) across the 363 MSAs, so metro areas with a higher percentage of 25-34 year-olds tend to have fewer 55-64 year-olds.

## **ii) Public Capital (Infrastructure)**

Physical capital and human capital are both provided by firms, but industries often make use of publicly provided capital, or infrastructure. The usefulness of roads, bridges, and other means of transport can

make a big difference in an industry's productivity and is especially pertinent in comparing productivity across MSAs, since the public capital will be shared by firms within an MSA and vary between MSAs.

Infrastructure is cited by Kitson et. al (2004, p. 995) as a one of the key factors in regional competitiveness. While Bronzini and Piselli (2009) point out that some debate in this field exists, they find a link between public capital and regional productivity (pp. 188-189). Lobo and Rantisi (1999) examine public capital as a production function shifter. While they do not confirm a relationship between the level of public infrastructure and the level of productivity, the study does find a positive relationship between the growth rates of public investment and regional productivity (pp.118-123).

Public capital is another area where data availability presents a problem in testing the theory. A good measure of the level of infrastructure in MSAs is unavailable. So we have to turn to proxies, but the results are much less likely to match our expectations. For this study, the level of state and local government spending will be used as a proxy for public infrastructure. This proxy has a couple of flaws. Conceptually, it parallels our (private) capital proxy in that it only measures spending in the year observed instead of the overall stock. Also, not all of the government spending is on infrastructure or public capital, clearly. A lot of local spending may be on services or transfers that are unrelated to productivity. Some may even argue that this variable should have a negative relationship with productivity due to government interference causing inefficiency. Federal government spending was omitted to try to narrow the scope and avoid transfer payments, but the proxy variable still has flaws.

#### **iv) Economies of Scale—Internal and External**

Greater productivity might also spring from economies of scale, either internal or external. A better scale yields lower average cost, and thus higher value added per unit of labor. There are several possible effects here, so we will divide them into separate categories.

##### **a) Internal Economies of Scale**

Firms may experience internal economies of scale to different degrees in different industries. This implies that an area that tends to have smaller plants in an industry may experience lower productivity than an area with larger plants. Or if diseconomies set in early for the industry, areas with smaller plants may have greater productivity.

How can we measure this effect? Ideally it would involve plant-level data, which we do not have. In lieu of that, we will use a measure of the average size of plants in each area. The Economic Census offers data on the average number of employees per establishment.

This is certainly not a perfect formulation of the concept, but perhaps it can work as a reasonable proxy for internal economies. For one reason, it is an input measure rather than an output measure. Previous work found this variable to be statistically significant for the overall manufacturing industry in 2007 (Brunot and Kurre 2012) and for selected manufacturing industries in 2002 (Kurre and Miseta 2008). In all these cases, larger average plant size meant higher productivity, although the 2002 data for both the manufacturing supersector and the individual industries exhibited a diminution of the effect as the plant got larger.

Since we do not have specific knowledge of the nature of economies of scale in the individual industries in this study, we do not have a strong hypothesis about the effect of the employees per establishment variable on productivity.

##### **b) External Economies of Scale**

Following Hoover's taxonomy, external economies may take the form of localization or urbanization economies. Localization economies are "...economies for all the firms in a single industry at a single location, consequent upon the enlargement of the total output of that industry at that location." (Hoover,

1937, pp. 90-91). Agglomeration of a single industry in space can result in that industry becoming large enough locally to support firms that supply specialized transport, warehousing, and other infrastructure important to that industry. The industry may become large enough to cause the local educational system--secondary, technical, or post-secondary--to introduce programs that train workers for the industry, lowering firms' training costs and increasing productivity of workers. Larger size of the industry can lead local financial institutions to become more proficient in finding or creating financial instruments to meet the industry's special needs. All of these are examples of benefits from localization that would reduce costs and increase value added, and thus productivity. Of course, there could be diseconomies too; as the industry grows it is possible that it might drive up the price of specialized inputs that are in limited supply, causing higher costs for the firm.

It would be possible to test for localization economies by using the amount of the relevant activity, in this case a measure of activity in 2007 in the individual manufacturing industries, such as total employment or output. But just where to draw the line on localization economies is not clear-cut. It may be the case that a local concentration of other manufacturing firms has a beneficial effect on productivity, too, even if those firms are not in the same industry. It is not hard to imagine technology spillovers from firms in other industries that use similar production processes or inputs. For that reason, it makes sense to also test the effect of total manufacturing employment, as well. As with internal economies of scale, we presume that these external economies might also be nonlinear, so we need to apply a quadratic form in our tests to allow diseconomies to register.

Urbanization economies are "economies for all firms in all industries at a single location, consequent to the enlargement of the total economic size...of that location, for all industries taken together." (Hoover, 1937, p. 91). While localization economies refer to benefits from a single industry agglomerating in space, urbanization economies refer to benefits from a broad range of economic activities agglomerating in space. Locating in a large agglomeration of various economic activities may benefit the firm by providing a broader range of possible suppliers who may be able to produce the firm's inputs more cheaply, leading to lower input costs and higher value added. Locating in a larger agglomeration can also lessen the chance that growth of this industry will drive up input costs, since it is more likely that larger pools of inputs exist there, and the broader range of activities may generate more substitutes for inputs that are beginning to experience tight supply and higher prices. This suggests that it would be logical to include some measure of activity linked to the industry under study, perhaps the presence of appropriate clusters for each industry. But these are scale measures, and tend to be highly correlated with other measures of metro size.

A broader approach to measuring the effect of urbanization economies is to use a simple measure of the size of the place, such as metro population. Previous research for manufacturing as a whole (Kurre 2004, Brunot and Kurre 2012) found population to be a statistically significant and positive factor for productivity. But tests of similar models for individual 3-digit manufacturing industries found population to be marginally significant, at most (Kurre and Miseta 2008). Rice et al (2006) found that productivity varies positively with access to "economic mass." They point out that this can be due to: 1) technological/knowledge spillovers; 2) access to a broader labor supply; and/or 3) better access to customers and/or intermediate inputs. Sedgley and Elmslie (2004) found that benefits of agglomeration outweighed congestion costs at the state level with respect to knowledge spillovers.

Alternatively, Abel and Gabe (2010) used population density (not absolute size) as a measure of agglomeration economies, and found that it was positively related to GDP per capita across 290 metro areas. In their study of three manufacturing industries, Drucker and Feser (2012) found that population density had a positive effect on productivity in five of eight models they tested, noting that urbanization economies outweighed congestion costs. They also noted that the effect, while statistically significant, was small in absolute value. And they do not find significant impacts of agglomeration for labor pooling, although they do for knowledge spillovers. Sparber (2010) also found employment density to have a significant positive impact on productivity.

To test for urbanization economies, we chose to use population as the measure of a metro area's size (Moomaw 1986). Given the work of Abel and Gabe (2010) and Drucker and Feser (2012), we will also

explore the impact of population density on productivity. Population data for 2007 came from the Census Bureau's Population Estimates Program.<sup>7</sup> Land area data for counties came from the U.S. Census Gazetteer for 2010, and were aggregated to reflect the December 2006 metro area definitions.

So this project will measure the influence of economies of scale on productivity using the number of firms, number of employees per firm, number of overall employees, and the share of employment and firms in the industry being studied. Population and population density are also included in the model to test urbanization effects.

## **v) Innovation**

To the extent that increased productivity comes from adoption of new, improved techniques in production, it would be logical to conclude that places that are active in creating new techniques would also be beneficiaries in the form of higher productivity. Freeman (2002) emphasizes the importance of innovation systems of sub-national regions. Freeman refers to an area's ability to institute change and implement new technologies as a key determinant of regional productivity. This argues for inclusion of some measure of creative activity relevant to production. One obvious candidate is the number of patents issued to residents of the metro area.

The patent data are from the U.S. Department of Commerce, United States Patent and Trademark Office. We used data for "utility" patents, the most common kind of patent.<sup>8</sup> The Patent Office issues reports on the residence of the first named patent holder, which adds the spatial dimension needed for this study. They note that this is probably an imperfect indicator of the location where the patent work was actually done, since in some cases the first-named patent holder might live in a different place than the location of his/her employer where the work was actually done. But given that this study uses metro areas as the basic geographic unit, and metro areas are intended to be labor markets, this is not expected to be a major problem. We do recognize that more people are telecommuting, however, and that could introduce some error into the analysis. But perhaps this is less important for research and development, where a lab may be required.

The patent reports that provide location data are issued only on an irregular basis. The Patent Office issued such a report in 2010; the previous one was in 1999. The 2010 report gives data for the years 2006 through 2010, so our target year of 2007 is included. However, they use the 2009 MSA definitions to aggregate the data, and these vary somewhat from the December 2006 MSA definitions that are used for the other variables in the study. To rectify this problem, we aggregated their county-level patent data to the December 2006 MSA definitions.

To prevent this variable from being a scaling variable (larger places will naturally have more patents than smaller places, *ceteris paribus*), we use patents per 100,000 residents as the explanatory variable here, using 2007 population of the metro area as the denominator. In 2007 patents averaged 22 per 100,000 residents across the 363 metro areas, but varied from zero in three small MSAs (Danville IL, Goldsboro NC, and Hinesville-Fort Stewart GA) to 399.7 per 100,000 in innovative San Jose-Sunnyvale-Santa Clara, CA.

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<sup>7</sup> Online at <http://www.census.gov/popest/data/historical/2000s/index.html>. These estimates were taken from the 2007 Vintage estimates since they use the December 2006 MSA definitions, which is consistent with the Economic Census data. We deemed this preferable to the American Community Survey data for 2006-2008.

<sup>8</sup> Technically, utility patents are "issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof, it generally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing, subject to the payment of maintenance fees. Approximately 90% of the patent documents issued by the Patent and Trademark Office in recent years have been utility patents, also referred to as "patents for invention". Definition from the Patent and Trademark Office at: <http://www.uspto.gov/web/offices/ac/ido/oeip/taf/patdesc.htm>. The data are available online at: [http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cls\\_cbsa/allcbsa\\_gd.htm](http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cls_cbsa/allcbsa_gd.htm)

Of course, patent data are not the only way to measure innovation. Bronzini and Piselli (2009) point to a slightly different idea of innovation--examining the importance of research and development spending in regional productivity. That study finds a positive relationship between research and development and regional productivity in Italian sub-national regions. Audretsch and Keilbach (2005) use the number of employees engaged in research and development. In their study of three manufacturing industries, Drucker and Feser (2012) explore use of both R&D expenditures and patents per capita. They find mixed results for the former, but find patents to have an important positive impact in all three industries. In fact, they say the effect is large enough to consider it as “a possible route for local or regional policy measures to influence productivity.” (p. 7)

Our working hypothesis is that more patents issued per capita in a metro area will lead to greater productivity there.

#### **vi) Government**

Begg (1999) points out how governance and policy can both hinder and support a region’s productivity. With wise investments in infrastructure, a government can improve productivity in its jurisdiction. This would be captured in the public capital determinant discussed earlier. On the other hand, by having high corporate taxes or making it difficult to open or operate a business through over-regulation, a government can hinder its region’s productivity. Begg (1999) points to ownership of decision-making power as a factor in competitiveness. By measuring corporate taxes, or the cost to open a business, or number of days it takes to open a business, it may be possible to examine the effects of regulation on regional productivity. The proxy variable discussed for public capital may capture some of these effects, as well as variables to measure business taxes.

Our working hypothesis is that the higher the tax rate per worker in a metro area’s state, the lower the productivity in that metro area.

#### **vii) Entrepreneurship**

Begg also points to rapid start-up rates as a desirable characteristic for a city to foster competitiveness. Following this idea, it is possible that proprietorship rates, or the share of income gathered by proprietors, are related to productivity (p.8). Having firms that are locally owned shows entrepreneurial tendencies and could make an MSA more productive, if it has successful proprietor-owned businesses. Carree and Thurik (2002) point to a number of reasons why entrepreneurship brings economic benefits to a region. By providing “flexible specialization,” “creative destruction” and increased competition between firms, entrepreneurship both forces and allows firms to be more productive and economies to grow. However, larger firms with distant ownership may benefit from economies of scale, so the impacts of this variable are not immediately obvious. Proprietorship rates are included as a proxy variable to test this. Both the share of income and employment attributed to proprietorships are tested in the model. Table 3 shows the list of variables that will be tested.

### **III. Results**

The results of the regression analysis vary by industry, but common themes emerge from the data. Both of these will be addressed—first by examining the results by industry, then by exploring common trends that permeate different industries. Table 4 shows the regression results, organized by industry.

Table 3. List of Variables

Concept	Variable	Unit of Measure	VarName	Count <sup>1</sup>	Average	Min	Max	MSA Defns <sup>2</sup>	Source
Productivity	Value Added per Production Worker Hour	\$ per hour	Prod					12/06	Econ Census 2007
Capital per worker	Capital Expenditures per Production Worker Hour	\$ per hour	KpHr					12/06	Econ Census 2007
Education	% of Population with Associate Degree	Percent	%Assoc	363	7.87	3.60	13.00	11/07	ACS 3-yr estimates, 2006-08
	% of Population with Bachelor's Degree	Percent	%BA	363	15.90	7.50	31.70	11/07	ACS 3-yr estimates, 2006-08
	% of Population with Graduate Degree	Percent	%Grad	363	9.09	3.30	28.90	11/07	ACS 3-yr estimates, 2006-08
	% of Population with Bachelor's or Higher	Percent	%BA+	363	24.99	11.00	55.90	11/07	ACS 3-yr estimates, 2006-08
Innovation	Utility Patents per 100,000 Residents	Patents per 100,000 residents	PATSpC	363	22.053	0.000	398.693	12/06	U.S. Patent & Trademark Office
Internal Economies	Average Empt of Mfg Establishments	Employment	AvgMfgEmpt	355**	44.49	6.41	149.85	12/06	Econ Census 2007
	Percent of MSA Employment Within the Industry	Percent of Total Employment	%EMP3****					12/06	Econ Census 2008
	% of Establishments with > 20 Employees	Establishments	%MfgEst20	363	31.4	4.7	53.4	12/06	Econ Census 2007
	Avg Empt of Establishments in This 5-Digit Industry	Employment	AvgEmp3****					12/06	Econ Census 2007
Localization Economies	Total Mfg Empt in the MSA	Employment	MfgEmpt	355**	29,619	430	628,771	12/06	Econ Census 2007
	# of Mfg Establishments in the MSA	Establishments	#MfgEst	363	748	19	20,509	12/06	Econ Census 2007
	Percent of Total Establishments in Manufacturing	Percent of Total Establishments	%MfgEst					12/06	Econ Census 2008
	Total Empt in This 5-Digit Industry	Employment	Emp3****					12/06	Econ Census 2009
	# of Establishments in This 5-Digit Industry	Establishments	Est3****					12/06	Econ Census 2010
	Share of Total Establishments in 5-digit Industry	Percent of Total Establishments	%Est3****					12/06	Econ Census 2011
Urbanization Economies	Total Population of the MSA	People	Pop07	363	693,891	54,939	18,815,988	12/06	Census Bureau's Population Estimates
Density	Population Density	People per square mile	Density	363	283.5	6.8	2,814	11/07	Census Bureau's Population Estimates
Age	% of Population 25-34 Years of Age	Percent	%25-34	363	13.34	10.10	18.60	11/07	ACS 3-yr estimates, 2006-08
	% of Population 55-64 Years of Age	Percent	%55-64	363	10.87	6.00	14.40	11/07	ACS 3-yr estimates, 2006-08
Taxes	Taxes--Other Business Taxes	\$ per employee	Tax-OB	362**	91.35	14.80	607.42	State	Census State Gov Tax Collections
	Taxes--Corp Income Tax	\$ per employee	Tax-Corp	362**	411.26	0.00	3,326.62	State	Census State Gov Tax Collections
	Taxes--Sum	\$ per employee	Tax-Sum	362**	502.61	84.40	3,484.91	State	Census State Gov Tax Collections
Proprietorship rates	% of Employment from Proprietorships	Percent	PropRate	365	19.21	11.51	31.62	12/09	BEA REIS
	% of Income from Proprietorships	Percent	PropIncRate	365	8.14	0.84	22.22	12/09	BEA REIS
Public Capital Per worker	State and Local Government spending Per Worker	\$ per worker in the MSA	PubCap	365	0.71	0.29	2.00	12/09	BEA REIS

\*\*Less than the full 363 MSAs

3\*\*\*\* represents an industry specific variable

<sup>1</sup>The variables with blank cells are left that way because the count, average, minimum and maximum change depend on the industry being study.

<sup>2</sup> None of the 58 MSAs used in the tests changed definitions between 2007 and 2009, so the different MSA definitions are not an issue

Table 4. Regression Results

Variable	Coefficient	T-stat	P-value
<b>Industry</b>			
<b>Medical equipment and supplies manufacturing</b>			
<b>1</b>			
R-sqrd	0.79		
%25-34	-6.74	-0.54	0.60
%BA+	4.35	1.77	0.09
Est33911	0.24	0.36	0.72
KPHr	19.82	7.16	0.00
PATSpC	-0.37	-1.25	0.23
Pop07	0.00	-0.55	0.59
PropIncrRate	13.89	2.42	0.03
PubCap	-100.00	-0.98	0.34
TaxSum	-0.04	-1.06	0.30
<b>2</b>			
R-sqrd	0.75		
%55-64	3.10	0.20	0.85
%BA+	2.28	0.79	0.44
AvgMfgEmpy	1.08	0.58	0.57
KPHr	17.53	6.22	0.00
PATSpC	-0.21	-0.69	0.50
PropRate	6.94	1.03	0.31
TaxSum	-0.06	-1.24	0.23
<b>3</b>			
R-sqrd	0.80		
%25-34	-8.14	-0.70	0.49
%BA+	4.55	1.94	0.07
KPHr	19.59	7.44	0.00
PATSpC	-0.33	-1.23	0.23
Pop07	0.00	-1.28	0.22
PropIncrRate	13.82	2.47	0.02
PubCap	-106.23	-1.08	0.29
TaxSum	-0.04	-1.07	0.30
<b>4</b>			
R-sqrd	0.81		
%55-64	19.65	1.34	0.20
%BA+	3.28	1.36	0.19
Emp33911	0.00	-1.38	0.18
KPHr	19.62	8.02	0.00
PATSpC	-0.21	-0.81	0.43
PropIncrRate	15.51	2.57	0.02
TaxSum	-0.04	-0.91	0.37
<b>5</b>			
R-sqrd	0.81		
%55-64	11.15	0.66	0.52
%BA+	4.60	1.77	0.09
AvgEmp3391	-0.01	-1.82	0.09
KPHr	20.31	7.90	0.00
PATSpC	-0.35	-1.32	0.21
PropIncrRate	18.45	2.70	0.02
PubCap	-165.74	-1.49	0.15
TaxSum	-0.03	-0.83	0.42
<b>6</b>			
R-sqrd	0.80		
%55-64	12.92	0.80	0.43
%BA+	3.82	1.47	0.16
KPHr	19.43	7.95	0.00
PATSpC	-0.27	-1.01	0.32
Pop07	0.00	-1.17	0.26
PropIncrRate	15.52	2.56	0.02
PubCap	-94.46	-0.93	0.37
TaxSum	-0.04	-1.02	0.32
<b>7</b>			
R-sqrd	0.80		
#MfgEst	0.00	-1.06	0.30
%55-64	13.60	0.84	0.41
%BA+	3.65	1.41	0.17
KPHr	19.24	7.89	0.00
PATSpC	-0.25	-0.92	0.37
PropIncrRate	15.59	2.55	0.02
PubCap	-93.49	-0.91	0.37
TaxSum	-0.04	-1.02	0.32

Var	Coefficient	T-stat	P-value
<b>Plate work and fabricated structural product manufacturing</b>			
<b>1</b>			
R-sqrd	0.30		
%25-34	5.77	1.37	0.18
%BA+	1.62	1.58	0.13
Emp33231	0.00	-0.02	0.98
KPHr	10.63	4.33	0.00
PATSpC	-0.12	-1.21	0.24
Pop07	0.00	0.27	0.79
PropIncrRate	-2.99	-1.36	0.19
PubCap	-26.82	-0.83	0.42
TaxSum	0.01	0.67	0.51
<b>2</b>			
R-sqrd	0.36		
%55-64	-10.27	-2.02	0.05
%BA+	2.35	2.48	0.02
Est33231	-0.01	-0.08	0.94
KPHr	10.49	4.56	0.00
PATSpC	-0.17	-1.73	0.09
PropIncrRate	-3.93	-1.71	0.10
PubCap	-39.01	-1.29	0.21
TaxSum	0.01	0.58	0.57
<b>3</b>			
R-sqrd	0.35		
%25-34	4.25	1.02	0.32
%BA+	1.62	1.88	0.07
AvgEmp332	0.00	0.05	0.96
KPHr	11.15	4.17	0.00
PATSpC	-0.13	-1.35	0.19
PropIncrRate	-3.31	-1.56	0.13
PubCap	0.12	0.00	1.00
TaxSum	0.01	0.93	0.36
<b>4</b>			
R-sqrd	0.33		
#MfgEst	0.00	0.11	0.92
%25-34	5.85	1.57	0.13
%BA+	1.74	1.89	0.07
KPHr	10.50	4.46	0.00
PATSpC	-0.13	-1.36	0.18
PropIncrRate	-2.77	-1.31	0.20
PubCap	-28.59	-0.97	0.34
TaxSum	0.01	0.80	0.43
<b>5</b>			
R-sqrd	0.37		
%25-34	4.03	1.26	0.22
%BA+	1.45	1.98	0.06
KPHr	10.53	4.67	0.00
PATSpC	-0.08	-1.12	0.27
PropIncrRate	-1.85	-1.00	0.33

Var	Coefficient	T-stat	P-value
<b>Other plastics product manufacturing</b>			
<b>1</b>			
R-sqrd	0.09		
%25-34	-5.46	-2.17	0.04
%BA+	-0.15	-0.24	0.81
Est332619	0.02	0.32	0.75
KPHr	3.34	2.26	0.03
PATSpC	0.18	0.98	0.34
PropIncrRa	1.35	1.01	0.32
PubCap	10.14	0.37	0.71
TaxSum	0.01	0.63	0.53
<b>2</b>			
R-sqrd	0.05		
%55-64	7.95	1.87	0.07
%BA+	-0.30	-0.46	0.65
Emp332619	0.00	0.16	0.88
KPHr	3.18	2.06	0.05
PATSpC	0.17	0.93	0.36
PropIncrRa	2.24	1.45	0.16
PubCap	33.97	0.97	0.34
TaxSum	0.02	1.22	0.23
<b>3</b>			
R-sqrd	0.05		
%55-64	7.81	1.86	0.07
%BA+	-0.41	-0.60	0.55
KPHr	3.41	2.26	0.03
PATSpC	0.17	0.94	0.36
Pop07	0.00	0.52	0.61
PropIncrRa	1.88	1.23	0.23
PubCap	33.06	0.95	0.35
TaxSum	0.01	1.06	0.30
<b>4</b>			
R-sqrd	0.00		
%55-64	8.22	1.96	0.06
%BA+	0.32	0.47	0.64
AvgEmp32	0.00	0.27	0.79
KPHr	1.46	0.76	0.45
PATSpC	0.00	0.02	0.98
PropIncrRa	2.21	1.51	0.15
PubCap	57.54	1.49	0.15
TaxSum	0.02	1.43	0.17
<b>5</b>			
R-sqrd	0.04		
#MfgEst	0.00	0.28	0.78
%55-64	7.50	1.80	0.08
%BA+	-0.33	-0.51	0.62
KPHr	3.37	2.23	0.03
PATSpC	0.16	0.88	0.39
PropIncrRa	1.98	1.28	0.21
PubCap	30.24	0.88	0.38
TaxSum	0.01	1.06	0.30

Var	Coefficient	T-stat	P-value
<b>Ornamental and architectural metal products manufacturing</b>			
<b>1</b>			
R-sqrd	0.20		
%25-34	-2.59	-0.94	0.36
%BA+	-0.22	-0.30	0.77
Est33232	-0.03	-0.65	0.52
KPHr	6.66	2.34	0.03
PATSpC	0.09	1.32	0.20
PropIncrRate	3.24	2.30	0.03
PubCap	-10.03	-0.51	0.61
TaxSum	0.01	0.55	0.59
<b>2</b>			
R-sqrd	0.22		
%55-64	-3.88	-0.98	0.34
%BA+	0.02	0.02	0.98
Emp33232	0.00	-1.43	0.17
KPHr	6.32	2.18	0.04
PATSpC	0.06	0.91	0.37
PropIncrRate	2.21	1.46	0.16
PubCap	-37.53	-1.43	0.16
TaxSum	0.01	0.63	0.53
<b>3</b>			
R-sqrd	0.03		
%25-34	-0.28	-0.10	0.92
%BA+	-0.48	-0.58	0.57
KPHr	5.40	1.75	0.09
PATSpC	0.08	1.07	0.30
Pop07	0.00	-0.27	0.79
PropRate	0.87	0.49	0.63
PubCap	-20.92	-0.98	0.34
TaxSum	0.00	0.26	0.79
<b>4</b>			
R-sqrd	0.19		
%25-34	-2.29	-0.80	0.43
%BA+	-0.19	-0.26	0.80
AvgEmp33232	0.00	-1.08	0.29
KPHr	5.83	1.96	0.06
PATSpC	0.09	1.35	0.19
PropIncrRate	3.50	2.45	0.02
PubCap	-13.60	-0.67	0.51
TaxSum	0.01	0.57	0.57
<b>5</b>			
R-sqrd	0.19		
#MfgEst	0.00	-0.48	0.63
%25-34	-2.76	-0.99	0.33
%BA+	-0.26	-0.35	0.73
KPHr	6.69	2.33	0.03
PATSpC	0.09	1.34	0.19
PropIncrRate	3.17	2.24	0.03
PubCap	-9.29	-0.47	0.64
TaxSum	0.01	0.51	0.61

Var	Coefficient	T-stat	P-value
<b>Machine Shops</b>			
<b>1</b>			
R-sqrd	0.09		
%25-34	0.40139275	0.316981	0.75
%BA+	0.05063655	0.204294	0.84
Emp33271	-0.0001245	-0.16873	0.87
KPHr	1.23781453	1.535877	0.13
PATSpC	0.05424871	1.678912	0.10
PropIncrRa	0.89670526	1.28382	0.21
PubCap	-1.9129177	-0.18282	0.86
TaxSum	0.00096328	0.184253	0.85
<b>2</b>			
R-sqrd	0.09		
%25-34	0.40699152	0.321665	0.75
%BA+	0.04848588	0.195319	0.85
Est332710	-0.0012436	-0.13426	0.89
KPHr	1.23309794	1.532236	0.13
PATSpC	0.05423888	1.677418	0.10
PropIncrRa	0.89175677	1.269957	0.21
PubCap	-1.8214674	-0.17467	0.86
TaxSum	0.00090477	0.173102	0.86
<b>3</b>			
R-sqrd	0.09		
%25-34	0.41357392	0.326885	0.75
%BA+	0.03665808	0.143837	0.89
KPHr	1.22802385	1.527222	0.13
PATSpC	0.05465975	1.659597	0.10
Pop07	2.2267E-08	0.029089	0.98
PropIncrRa	0.85675736	1.195326	0.24
PubCap	-1.576531	-0.15111	0.88
TaxSum	0.00063949	0.124174	0.90
<b>4</b>			
R-sqrd	0.09		
%25-34	0.39613544	0.313022	0.76
%BA+	0.05560469	0.224911	0.82
AvgEmp33	-0.0002457	-0.25009	0.80
KPHr	1.24256089	1.542466	0.13
PATSpC	0.05417976	1.677668	0.10
PropIncrRa	0.91232304	1.306852	0.20
PubCap	-2.0612787	-0.19698	0.84
TaxSum	0.00109395	0.209603	0.83
<b>5</b>			
R-sqrd	0.09		
#MfgEst	-6.73E-06	-0.01266	0.99
%25-34	0.41463516	0.327851	0.74
%BA+	0.04027692	0.160053	0.87
KPHr	1.22764884	1.526783	0.13
PATSpC	0.05440308	1.66145	0.10
PropIncrRa	0.86693941	1.223132	0.23
PubCap	-1.6372616	-0.15711	0.88
TaxSum	0.00070034	0.134775	0.89

## A. Individual Industries

**33271: Machine shops:** The models tested using the data from the machine shop industry consistently yielded an adjusted  $R^2$  of just .09, meaning less than one-tenth of the variation in machine shop productivity across MSAs can be explained by the independent variables in the model.

Only the innovation variable (PATSpC) was significant at the 10% level. Physical capital (KPHr) exhibited a p-value of .13 in all models. None of the economies of scale variables returned significant results for this industry. The industry definition mentioned that machine shops tend to be low-volume, so it is not surprising that internal economies of scale are absent. This does not explain why external economies of scale are unrelated to productivity.

Public capital (PubCap) and Education (%BA+) both returned negative regression coefficients, but neither was statistically significant. Possible explanations are that increased government spending brings increased inefficiencies to the market and that, while education is unlikely to hinder productivity, an MSA with an educated population is likely to specialize in other industries.

**33231: Plate work and fabricated structural product manufacturing:** The models for this industry returned some of the higher adjusted  $R^2$ 's of any industry—around 35%. Physical capital (KPHr) was consistently significant for this industry with p-values close to zero.

Human capital was also statistically significant for this industry in several models, both through the education variable (%BA+) and the age range variables (%25-34 and %55-64). The education variable was significant in four models at the ten percent level. While the percent of the population ages 25 to 34 was not significant at the ten percent level, it did have a 13% p-value, but more importantly the percent of the population ages 55 to 64 was significant and negative in the model in which it was tested. These results suggest that a well-educated MSA will be more productive in the plate work industry, and that having a large portion of the population in a younger age range could also be beneficial.

The portion of income attributed to proprietorship (PropIncRate) was never significant, but this was the only industry where this variable carried a negative sign. Also, the public capital variable (PubCap) had a large, negative coefficient, but was never statistically significant.

**32619: Other plastics manufacturing:** The industry “other plastics manufacturing” also returned relatively low adjusted  $R^2$ 's—ranging from less than .01 to .09. Capital was once again a significant and positive variable, being significant at the ten percent level in four of the five models. The only other significant variable was the human capital variable which accounted for the age range. The percent 25 to 34 variable was actually negative and significant, while the percent 55-64 variable was positive and significant (at 10%) in every model in which it was tested. These results suggest having a population which is near the top of the working age ranges is beneficial to the manufacturing of miscellaneous plastic products.

**33232: Ornamental and architectural metal products manufacturing:** This industry's models generally returned adjusted  $R^2$ 's around 20%. Again capital per production worker hour (KPHr) was positive and significant at the ten percent level—this time in every model. An interesting result from this industry is that the percentage of income from proprietorships was positive and significant at the 5% level in three separate models. This suggests that having successful proprietorships in the MSA is beneficial to productivity. The link suggested here is that an MSA with high levels of entrepreneurship will succeed in this industry. This is also another industry where public capital (PubCap) has a large and negative coefficient, but it was never significant. The education variable was also negative in four models, but was not significant.

**33911: Medical equipment and supplies manufacturing:** By far the most compelling results came from the medical products manufacturing industry, with adjusted R<sup>2</sup>'s showing that the models account for around 80% of the variance between MSA's in medical product manufacturing productivity. Physical capital (KPHr) was significant at the one percent level for every model tested. Education (%BA+) also accounted for a lot of the explanatory power—being significant at the ten percent level in three of the seven models. It makes sense that the medical products industry would benefit more from education as these products are likely changing often and are more complicated.

Medical equipment manufacturing was also the only industry where an economies of scale variable returned a significant result, but it was unexpectedly negative. The average employment of firms in the industry (AvgEmp) was significant and negative at the ten percent level. This suggests it is better for medical equipment to be manufactured on a small scale.

In this industry, the proportion of income from proprietorships was significant at the five percent level in six of seven models. These results suggest that, like the ornamental and architectural manufacturing industry, medical product manufacturing is more productive in MSAs with high levels of entrepreneurship and successful entrepreneurship.

## **B. Broad Conclusions**

Some interesting trends surface which shed additional light on the results. The most emphatic trend is the significant positive effect of capital on productivity in every industry (with the exception of machine shops where it was close). As has been mentioned earlier, the capital stock variable is actually a proxy, investment, which doesn't capture the amount of capital stock as well as we'd like. Despite this, evidence is found to support its positive relationship with productivity in nearly every industry.

While capital is consistently confirmed as a determinant, no other variable has the same consistency. Higher education, for instance, is only positive and significant in one industry. In another industry--ornamental and architectural metal products--education even has a negative impact on productivity, although it is not statistically significant. This negative relationship is not entirely surprising. While education is expected to benefit productivity, MSAs with a highly educated workforce are likely to specialize in industries other than lower-tech manufacturing industries.

Innovation is similar to education in that, while it is expected to be a clear positive determinant, in several industries it is not significant. The data reveal how certain industries rely on determinants such as innovation and education, much more than others.

Even the wide range of adjusted R-squareds reveals that some industries are determined mostly by the variables in the model, while others have very little relation to the determinants tested here. 80% of the spatial differences in productivity within the medical products manufacturing industry can be explained by differences in the independent variables. This indicates that the determinants tested have a very large impact on productivity differences. However, only around 5% of spatial productivity differences in the manufacturing of "other plastic products" are tied to differences in the independent variables—meaning the lion's share of productivity differences is determined outside of the model.

Some of this variation may have to do with the NAICS categorization. In the two industries just mentioned, one can see that "medical products manufacturing" is a rather specific industry, while "other plastics" contains a wide range of products. It is possible that the differences in R<sup>2</sup> between industries are tied to the scope of the industry definitions, so specific industries can be examined more accurately than broader ones.

While the theory suggests benefits to productivity from economies of scale, none of the models produce a positive, significant relationship between the two. However, this issue may be attributed to data availability. The Census Bureau does not report data that will disclose information about a specific company. In industries where economies of scale are present, the firms are already operating at large scale—perhaps so large that reporting the data for a given area would provide an idea of that company's

information. For example, the data is very limited for auto manufacturing, even though this is a large sector. But if the data were reported for a specific county that houses an auto plant, it would give too much information about that plant.

As a result, data is only available for industries which operate at a smaller scale. If data were available for, say, the auto industry, it is likely that a model would support the benefits of economies of scale. So while internal economies of scale cannot be ruled out as a determinant of productivity in general—the models do not show that they are present in any of the five industries,

Still, this only addresses internal economies of scale, but does not explain why external scale benefits, such as those from localization, are not present. Considering the amount of literature on this issue and its popularity, this is surprising. Regardless, the models presented here do not support the theory that external economies of scale have a positive impact on manufacturing productivity—at least in the industries studied.

One more trend revealed by the results was that the share of an MSA's income produced by proprietorships was a reasonably effective variable at predicting productivity, even though the link is not immediately obvious. This variable was intended to capture the influence of entrepreneurship in a given MSA. The variable for the percent of employment from proprietorships was not a strong variable, though, suggesting that proprietorships only benefit an MSA if they produce a larger percentage of the income in that MSA. This is most likely a suggestion that the proprietorships need to be successful to be beneficial to productivity. The positive results of the income variable (with the exception of one negative case) support the theories that flexible specialization, creative destruction, and increased competition brought about by entrepreneurship increase productivity—as opposed to the converse idea that larger firms would achieve economies of scale. Of course, it has already been pointed out that the industries for which data are available are naturally different than those which exhibit economies of scale, which may be why these positive results are so consistent. It is also worth noting that in the plate work industry, the entrepreneurship variable (PropIncRate) had a negative sign.

Testing the determinants of productivity in specific manufacturing industries has revealed a number of important results. It has shown, with little room for doubt, that capital is crucial to productivity regardless of industry, while other determinants are influential in certain industries but insignificant in others. Economies of scale could not be supported as a determinant; however there is a clear link between these results and the data restrictions. Entrepreneurship—measured as the share of income attributed to proprietorships—was one of the well-supported variables, demonstrating the importance this type of firm has in American MSAs.

Future research should seek to expand on these results. Much of this could be done if better data were available. Specifically, better proxy variables for physical and public capital would present a better picture of the determinants of productivity. Obtaining data for different industries—especially those which tend to operate at a higher volume—could confirm or overturn the results presented here about economies of scale.



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