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Productivity and economic growth in the Pittsburgh region from 1850 to 1900

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PRODUCTIVITY AND ECONOMIC GROWTH IN THE PITTSBURGH REGION FROM 1850 TO 1900

Ben Morton

Thesis submitted to the College of Arts and Sciences at West Virginia University in
partial fulfillment of the requirements for the degree of

Master of Arts

in

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ABSTRACT

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Ben Morton

This research presents an empirical test of the effect of economic growth on productivity in manufacturing within the Pittsburgh region from 1850 to 1900. Theoretical research in economic geography refers to this as Verdoorn's 'law'. The underlying reason for this relationship is the positive impact of economic growth on technological development, which translates into changes in productivity. This study provides an empirical test of this relationship at a very different scale and time frame than previous studies, namely the counties within the Pittsburgh nodal economic region. The period from 1850 to 1900 was one in which the Pittsburgh region developed from a relatively minor economic center to a major steel producing region of the American manufacturing belt. The period also closely corresponds to the second Kondratieff wave of competitive industrial capitalism which began in the 1840s, peaked in the 1870s and ended in the depression of the 1890s. Using data for 37 counties from the Census of Manufacturers, the Verdoorn relationship was estimated by OLS regression. The results indicate that the relationship was positive throughout the time period, and significant only in the earlier and later decades of the second half of the nineteenth century. The study concluded with an analysis of residuals for each decade, which provided evidence of other general and county-specific factors which were responsible for productivity change in the region.

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TABLE OF CONTENTS

PRODUCTIVITY AND ECONOMIC GROWTH IN THE PITTSBURGH REGION FROM 1850 TO 1900.....	i
ABSTRACT	ii
ACKNOWLEDGEMENTS	iii
TABLE OF FIGURES	v
Chapter 1 - INTRODUCTION	1
Chapter 2 - ECONOMIC GROWTH AND PRODUCTIVITY	3
Chapter 3 - HISTORICAL BACKGROUND	6
Chapter 4 - RESEARCH DESIGN.....	10
Chapter 5 - RESULTS	14
Chapter 6 - CONCLUSIONS	21
REFERENCES	23

TABLE OF FIGURES

Figure 1 Study Area.....	12
Figure 2 Major Cities.....	13
Figure 3 Residual Map for the 1850 - 1860 period.....	16
Figure 4 Residual Map for the 1860 - 1870 period.....	16
Figure 5 Residual Map for the 1870 - 1880 period.....	18
Figure 6 Residual Map for the 1880 - 1890 period.....	18
Figure 7. Residual Map for the 1890 - 1900 period.....	20

Chapter 1 - INTRODUCTION

The goal of this research is to provide an empirical test of the effect of economic growth on productivity in manufacturing within the Pittsburgh region from 1850 to 1900. Previous theoretical research in economic geography has claimed that economic growth is a major determinant of changes in productivity, particularly in manufacturing. This relationship is termed Verdoorn's 'law'. The underlying reason for this relationship is the positive impact of economic growth on technological development, which translates into changes in productivity.

There have been only a few empirical tests of this law in geographical research, and these have analyzed the relationship at the state or equivalent scale in the second half of the twentieth century. This study will provide an empirical test of this relationship at a very different scale than previous studies, namely the counties within the Pittsburgh nodal economic region.

The study will examine this relationship from 1850 to 1900, a period during which the Pittsburgh region developed from a relatively minor economic center to a major component of the American manufacturing belt. During this period, the Pittsburgh economy was dominated by the development of the steel industry, which was accompanied by significant technological change. The period from 1850 to 1900 corresponds to the second Kondratieff wave of industrial capitalism. This competitive cycle of capitalist development began in the 1840s, peaked in the 1870s and ended in the depression of the 1890s. This study will examine whether the effect of economic growth on productivity in the Pittsburgh region changed during this cycle.

The remainder of this thesis is organized as follows: Verdoorn's law and the derivation of the model used to test the law in the Pittsburgh region is described in section two; a narrative historical geography of the Pittsburgh region in the second half of the nineteenth century, as it

relates to the research objective, is presented in section three; methods of analysis and sources of data are presented in section four; results are discussed in section five; and conclusions of the study are provided in section six.

Chapter 2 - ECONOMIC GROWTH AND PRODUCTIVITY

Verdoorn's law was proposed by the economist Verdoorn in the 1940s, who identified a persistent empirical regularity between productivity and economic growth. He found that productivity rises faster in economies that are expanding, and tends to rise more slowly, or even fall, in economies which are not growing. This relationship can be modeled as follows:

$$P = a + bO$$

where P represents productivity change over time, O represents output change over time, and a and b are model coefficients.

Since its initial formulation, the law has been tested numerous times using national data. The model has rarely been tested at scales other than the nation. Casetti is the only geographer who has tested the model at other spatial scales. One study tested the model for manufacturing in US states between 1954 and 1977 (Casetti, 1982, 1983). He found that the Verdoorn relationship was positive and significant during this time, although the overall explained variance of the model was low (ranging from 6% to 26% depending on the subperiod). The regression coefficient 'b' was estimated to be 0.21 in the 1950s, 0.11 in the 1960s and 0.10 in the 1970s, indicating a decline in the effect of growth on productivity among states over the entire period. Another study by Casetti and Tanaka (1992) tested the model for manufacturing in Japanese prefectures (roughly comparable in importance to the national economy as states) between 1965 and 1975. They also found a positive and significant relationship between growth and productivity, although the estimate of 'b' (0.43) and the overall explained variance (34%) were both greater than in the US study.

The traditional explanation for Verdoorn's law (Casetti, 1982) is that economic growth is accompanied by capital deepening (i.e. less labor input relative to fixed capital), increasing internal economies of scale (i.e. reduced costs brought about by increasing size of a firm's production system) and technological progress (i.e. more efficient production).

An alternative explanation of Verdoorn's law has been presented by Storper and Walker (1989). They argue that the key processes underlying this law are technological change and external economies of scale. Technological change has four main forms: new social knowledge, new or improved products, new or improved techniques of production, and improved worker skills. All of these forms are capable of raising the productivity of human labor in manufacturing (or any other sector of the economy). According to Storper and Walker, technological progress is largely generated by external economies of scale. For example, industrialization increases the social and spatial division of labor, which results in the expansion of the tasks and skills of workers and an increase in the specialization of production and products by firms.

Storper and Walker (1989) argue that the relationship between productivity, technological change and external economies can be used to explain the development and growth of industrial regions. New centers of production are created by 'windows of locational opportunity'. This occurs when technological change in a new industry provides the industry with the freedom to locate almost at will because, for example, it has the ability to attract the resources, infrastructure and labor necessary for production. For example, although the development of the new steel industry in the Pittsburgh area in the 1860s and 1870s was to some extent limited in its choice of location by the location of coal and iron ore, it was able to move away from the traditional center of iron production to new sites because it could attract the

resources (especially coke), infrastructure (particularly railroads) and labor (especially non-craft workers) required to produce the very profitable new product of steel.

Storper and Walker (1989) further argue that the key to understanding why a new industrial center develops into a major regional industrial complex is through the growth that is created by expanding external economies of scale, which is itself produced by the geographical agglomeration of a complex of interlinked workplaces and firms in one area. External economies, in turn, encourages technological change and improvements in productivity within the regional production complex, which stimulates new rounds of growth. For example, the development of the steel-dominated regional industrial production complex in the Pittsburgh area from the 1870s through the end of the nineteenth century can be attributed to the enormous improvements in productivity which were generated by the rapid technological change that was due to the growing agglomeration of increasingly specialized production in the area.

Chapter 3 - HISTORICAL BACKGROUND

The second half of the nineteenth century was a period of great significance for Pittsburgh's development. During this time, towns in the American manufacturing belt evolved from being primarily centers serving local and regional markets to ones producing for the national market (Meyer, 1983). Nationally, these centers developed strong inter-industry links with each other during this period (for example, Pittsburgh with Detroit). Locally, these centers expanded their economic influence into the smaller towns and rural areas that surrounded them. This process created distinctive functional regions throughout the manufacturing belt such as steel dominated region centered on Pittsburgh.

Underlying these geographic changes was a major change in the behavior and character of industrial capitalism. The period 1850 to 1900 corresponds to the second Kondratieff cycle (or wave) of global capitalist development (Storper and Walker, 1989). This cycle began in the late 1840s in both Europe and North America and ended with the great depression of the 1890s in both continents. The cycle peaked in the 1870s. Although the second Kondratieff cycle was characterized by a very competitive form of industrial capitalism, the first half of the cycle was distinguished by rising prices, industrial output, world trade and profits. The first half was a period of rapid growth and technological change, stimulated in particular by developments in the coal-powered steam engine, steel, railroads, machine tools and shipping (Knox and Agnew, 1994). This was also a period in which manufacturing labor processes were transformed from craft-dominated production to 'machinofacture', which employed less skilled wage labor in greater numbers. The second half of the cycle, however, was quite different from the first half. It was characterized by falling prices and profits, by slower growth rates in industrial output and

trade and by increasing labor unrest (Gordon, 1977). The nineteenth century ended in depression. In the 1890s in the United States, seven of the ten years were characterized by national recession and only three by growth. The development of industrial capitalism in the second Kondratieff cycle had a major impact on the development of Pittsburgh and its economy.

By 1850, Pittsburgh and the surrounding region had begun to develop from a relatively small consumer based economy into a major industrial center. The locational advantage of proximity to the Ohio, Monongahela and Allegheny Rivers led this region to be termed the Gateway to the West. This region also had the inestimable advantage of containing resources that would have great value in the development of industry. Abundant stocks of timber offered a great reserve of wood for fuel and building. The fertile soil assured its residents adequate supplies of food. Inexhaustible beds of coal gave it the necessary fuel for the expanding manufactories. And the abundant veins of iron ore enabled the region to become the center of the iron and steel industry (Lorant, 1975). Changes in technology and transportation as well as the Civil War were also major influences on development in the second half of the 19th century. These factors and economic reaction to them led to the development of this region as a major component of the American manufacturing belt (Meyer, 1983).

In the first half of the century, industry in the Pittsburgh region consisted of many small independent firms. Poor manufacturing techniques and lack of efficient modes of transportation hindered the development of larger markets and kept industry focused at the local level. Thus, iron furnaces and glass houses dotted the countryside. Each firm employed small numbers of skilled craftsmen. These workers enjoyed a relatively high level of control in the mill due to their skill level and nature of the production processes.

In the 1850's transportation improvements began to open up markets and create a much higher demand for the industrial products of the region. The introduction of rail transportation to the region was the first step in the emergence of the Pittsburgh as an industrial center. With the opening of the Baltimore and Ohio line, the region was now connected to both the established markets in the east and those emerging in the west. Raw materials were made available and the owners of industrial firms began to see the potential for growth. During the course of the next five decades the railroads transformed the region by both promoting and facilitating industrialization and urbanization (Muller, 1998).

If improvements in transportation were the impetus for change in the region, the Civil War marked a dividing point. The war created a huge demand for iron and steel rail, cannons, and other war related materials. This increased demand had a huge impact on the technology used to produce these materials. New metallurgical techniques led to quicker and easier smelting processes that were less labor intensive and produced much stronger alloys. By the end of the decade, the Bessemer process for steel production had been introduced. This process allowed industrialists such as Andrew Carnegie to better utilize the huge reserves of low-sulfur coking coal prevalent in the region (primarily southeast of the city) to produce superior product while allowing for the division of labor previously unseen in the metals industry. The emergence of these new methods and the changes they produced were the basis for great reorganization of the built environment of the region. From Wheeling, Weirton and Youngstown in the west to Cumberland in the east, small mill towns were transformed into huge industrial complexes.

Out of this reorganization, four major industries emerged dominant in the region. Iron and steel, glass, and railroad equipment firms were able to develop production systems to capitalize on the changes in the regions industrial makeup (Muller, 1998). These changes had

profound effects on the regions' inhabitants as well. The need for unskilled labor grew rapidly during this period. Waves of immigrants arrived to fill the needs of industry. They were quickly adopted into the work force. The skilled craftsmen of the previous period gave way to a new group of laborers completely dependent to their employers for food, housing, security, and the essentials of life. In a span of no more than twenty years, Industry had been able to establish large markets, increase production, improve technology and subjugate labor.

While Pittsburgh formed a dense urban core for the region by 1900, industrial towns and residential suburbs had spread linearly away from this core along the major river valleys and the main railroad lines. A series of satellite cities in the surrounding counties and the industrial settings at the natural resources completed the regional industrial pattern (Muller, 1998).

Industrialists, no longer bound by the need for accessibility to river transportation and confident in the ability to attract and control labor, located their firms broadly throughout the region to more fully utilize supply networks, lesson production costs, and centralize operations in their large industrial complexes. By the end of the century the events of the previous 50 years had completely altered the landscape.

Chapter 4 - RESEARCH DESIGN

The study area consists of thirty-seven counties in southwest Pennsylvania, eastern Ohio, northern (West) Virginia and western Maryland (Figure 1). The counties were not chosen using any specific criteria normally employed to define a functional region. They were chosen instead to produce a region with Allegheny county as its center and consisting of sufficient observations to estimate the model by means of regression. The first task of the project was to identify whether there were any changes in county boundaries from 1850 to 1900. The only change involved the two westernmost counties in Maryland, which had to be aggregated over the entire time period. The choice of counties as spatial units of analysis does potentially impact the estimated results. It is quite possible, for example, that significant change within a county is limited to one or two communities, while the remaining places in the county are undergoing little economic growth. County data will hide this variation. Data for towns would be a more appropriate vehicle for uncovering this variation. Unfortunately, consistent data for places smaller than counties are not available for the entire period from 1850 to 1900.

The Verdoorn model presented in section 2 was estimated by ordinary least squares regression using the thirty-seven counties as observations. The model was estimated separately for each decade between 1850 and 1990 (1850-60, 1860-70, 1870-80, 1880-90 and 1890-1900) to see if there were any changes in the Verdoorn relationship over time. This could be expected given the major changes which occurred in manufacturing production over the course of the second Kondratieff cycle. For example, one might expect to find that the relationship between productivity and output to break down in the second half of the cycle as producers who are confronted by falling or stagnant output adopt productivity enhancing technologies to remain

competitive. The choice of decennial data does have a limitation, given that business cycles and short-term changes in the relation between economic growth and productivity are not likely to be captured in this analysis. Unfortunately, data for this study are only available at ten year intervals.

Data were obtained from the US Census of Manufacturers for 1850, 1860, 1870, 1880, 1890 and 1900. Output data were converted to constant dollars using a GNP deflator to control for inflation. Variables representing changes in manufacturing productivity and output were defined in an identical way as by Casetti in his studies of the Verdoorn relationship. Change in output was defined as follows (using 1850 and 1860 as an example):

$$O = \text{natural log (output in 1860 / output in 1850)}$$

Change in productivity (using the same period as an example) was defined as:

$$P = O - (\text{natural log (employment in 1860 / employment in 1850)}).$$

Caution should be exercised in interpreting the results of this analysis for earlier decades, particularly those involving data for 1850 and 1860, because of minor data incompatibilities.

According to census records, there were small changes in the way in which manufacturing industry was defined between these two years and there were also some inconsistencies in the way in which the census was administered in both years.

Figure 1. Study Region.

Figure 2. Major Cities.

Chapter 5 - RESULTS

The results of the regression analyses are as follows (* represents a significant estimate at the 0.10 level) :

$$P(1850/1860) = 0.019^* + 0.221^* O(1850/1860) \quad R^2 = 16\%^*$$

$$P(1860/1870) = -0.027^* + 0.152 O(1860/1870) \quad R^2 = 4\%$$

$$P(1870/1880) = 0.020^* + 0.214 O(1870/1880) \quad R^2 = 6\%$$

$$P(1880/1890) = -0.006 + 0.352^* O(1880/1890) \quad R^2 = 42\%^*$$

$$P(1890/1900) = 0.021^* + 0.264^* O(1890/1900) \quad R^2 = 9\%^*$$

As expected the regression coefficients are positive for each decade, indicating that changes in output were partly responsible for changes in productivity. However, the estimates for the periods 1860/1870 and 1870/1880 were not significantly different from zero. It appears that the Verdoorn relationship was strongest at the beginning and end of the second Kondratieff cycle and weakest in the middle periods. In other words, changes in productivity were initially driven by changes in economic growth in the 1850s, but became uncoupled from output in the 1860s and 1870s. Economic growth reasserts itself as a determinant of productivity in the 1880s and 1890s. The value of the coefficient estimates are very similar to those found by Casetti (1982;

Casetti and Jones, 1983) in his study of American states, despite the very different scales of the spatial units being examined.

The explained variances of the Pittsburgh models are also very similar to those of Casetti's state models. Casetti made no attempt to analyze the unexplained variance resulting from his models, which would shed light on other factors responsible for changes in manufacturing productivity. Such an analysis was performed in this research. Standardized residuals for each county were calculated from the models for each time period and mapped in Figures 3 through 7. The maps are suggestive of a number of factors which explain why some counties had productivity growth rates that were either greater than or less than expected after accounting for changes in local output.

The residual map for the 1850-1860 period (Figure 3) shows that eleven counties had extreme residual values. Of these, six have residual values one standard deviation above the mean, and five are one standard deviation below the mean. Those above include Allegheny, Butler, and Clarion counties. These counties, which are primarily in the core of the region, showed productivity gains greater than that which could be expected from changes in output levels. This suggests that the early technological advances taking place in the growing industrial firms of these counties had a substantial impact on productivity levels. The counties where productivity was less than expected from the model were located in the periphery of the region, and included Columbiana, Alleghany, Marshall, and Hancock. These counties had not yet fully industrialized and were hit particularly hard by the recession of 1858.

The residual map of the 1860-1870 period (Figure 4) shows that twelve counties had extreme residual values. Those with positive residuals were located in both the core and periphery of the region.

Figure 3

Residual Values
1850 - 1860

Figure 4

Residual Values
1860 - 1870

Figures 3, 4. Residual Maps for the 1850 - 1860 and 1860 - 1870 periods.

One possible interpretation of this spatial pattern is the effect of the Civil War on manufacturing production in the region, which resulted in the expansion of industry across the city boundary of Pittsburgh. The emergence of satellite cities such as New Kensington, Greensburg and Youngstown in counties bordering Pittsburgh may also play a role in this pattern. Counties which performed below expectations were again located in the periphery and predominantly in the southern part of the region. This area was the most rural and the slowest to see improvement in transportation and the expansion of industry.

The residual map for the 1870-1880 period (Figure 5) shows that ten counties had extreme residual values. Counties with positive values included Carroll, Harrison (Ohio), Monroe, Harrison (WV), and Taylor. These counties lay in the periphery of the region. This suggests that during this period advancements in transportation and technology were beginning to diffuse from the core. The railroads were opening up markets, helping to increase population and the demand for industry. Cities such as Youngstown, Wheeling and Weirton were able to capitalize on the expansion of the railroads to connect with new markets and sources of raw materials. Counties with negative residuals were again located in the southern part of the region and included Brooke, Ohio, Marshall, and Preston. While this was a time of relative economic prosperity, many smaller industrial cities were slower to reap the benefits of this economic growth. Another factor that might account for the poor performance of these counties is a shift of industry in this time period from iron to steel production. Counties which had a thriving iron industry suffered tremendously due to the fall in iron prices. Some companies in this area failed to capitalize on the changing technology and were left without a market for their product.

Figure 5

Residual Values
1870 - 1880

Figure 6

Residual Values
1880 - 1890

Figures 5, 6. Residual Maps for the 1870 - 1880 and 1880 - 1890 periods.

During the 1880-1890 time period (Figure 6) a smaller number of counties had extreme residual values because output growth was more responsible for changes in productivity than in other time periods. Three peripheral counties, Venango, Marshall, and Preston, had greater than predicted productivity growth. In the case of Venango county, substantial growth in its major city, Oil City was due to the emergence of new industrial sites which accompanied the discovery of crude oil in the area. The county emerged as a strong economic force during this period. Counties which performed significantly below the predicted productivity level included Washington, Butler, Brooke, Taylor, and Carroll counties.

The residual map for the 1890-1900 period (Figure 7) shows evidence of the end of the second Kondratieff cycle of industrial capitalism. This period was marked by a deep depression which lasted the better part of the decade. The core was hit hardest by this recession, as is evidenced in the residual map for this period. The effects of the depression were not immediately felt in the periphery. While cities such as Grafton, Wheeling and Butler suffered economically, they managed to escape the productivity setbacks witnessed in Pittsburgh and other core cities. The map suggests that many outlying counties were still performing above that expected by the model. Many core counties, however, showed negative residuals for the first time during the second half of the nineteenth century.

Figure 7. Residual Map for the 1890 - 1900 period.

Chapter 6 - CONCLUSIONS

This research has examined the effect of economic growth on productivity in manufacturing within the Pittsburgh region from 1850 to 1900, a period during which this area was transformed into one of the major industrial centers of the country. This is the first occasion in which the Verdoorn 'law' has been tested at this scale. Statistically, the results were comparable to those of Casetti's study of the United States (Casetti, 1982; Casetti and Jones, 1983). This study, however, covered an entire Kondratieff cycle. It was found that the impact of output on productivity growth was strongest at the beginning and end of the cycle. Spatially, the pattern of productivity growth was very uneven within the region throughout the cycle. However, the pattern changed from 1850 to 1900. At the beginning of the cycle, productivity growth in core counties (those closer to the city of Pittsburgh) exceeded predicted levels. At the end of the cycle, these counties had lagging productivity growth. After the 1850s, rapid improvements in productivity spread to various peripheral counties (those further from Pittsburgh) in the every decade until the end of the century. However, the specific counties which benefited from this growth changed from decade to decade.

Improvements in productivity are the key to industrial development. This study has shown that manufacturing productivity in the formative years of the Pittsburgh region was significantly determined by a rapidly growing economy, and that this growth spread into the hinterland of Pittsburgh throughout the second half of the nineteenth century. Although productivity in the core of the region was curtailed in the final decade of the century, a study of the third Kondratieff cycle from 1900 to the 1940s would no doubt show a rejuvenated core once again benefiting from improvements in productivity.

Although the results confirm the positive relationship between output and productivity in the Pittsburgh region during its formative years, there are clearly many other factors at work. Some factors, such as access to river and rail transportation, were of general importance throughout the second half of the century, but there were also numerous isolated factors which were responsible for changes in productivity in particular towns at particular times. Further study would need to identify these many influences in order to construct a more comprehensive explanation of the development of this industrial region. Finally, any further analysis would need to examine to the different contributions of the various industries that comprised the region during this period. It has been assumed that developments in the steel industry were a key to understanding technological change and productivity, given the prominence of this industry in the region. The role of other industries, both growing and declining, to technological change in the region was important and would need to be included in further studies of this area.

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