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ECONOMIC CONVERGENCE AMONG U.S. STATES

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ABSTRACT

The consensus on whether economic convergence is occurring abroad or among the U.S. states remains unclear. This paper seeks to understand whether convergence has been occurring across U.S. states, as reflected in their economic growth rates. By understanding whether convergence is occurring among states, specifically among poorer states, we can make potential inferences about current economic policy. For example, given that we can understand what role convergence plays among states, this knowledge will help policy makers make informed decisions on where to invest taxpayer money.

The Solow Growth Model, which is the foundation of what has come to be known as the neoclassical growth model, is the theoretical basis of this research. To test one of the implications of the Solow Growth Model, multiple regression was used to analyze U.S. state-level economic data from various sources. Variables were included within the multiple regression model to control for differences in attributes among states. Of particular relevance in the context of the Solow Growth Model is a variable that measures differences across states in the *initial-period capital-per-labor ratio*. An important implication of the Solow Growth Model is that (poorer) states with lower levels of this ratio will experience higher growth rates compared to (richer) states with higher starting levels of capital per labor. This theoretical result may have potential implications across the U.S. states with respect to policies intended to stimulate economic growth. This research contributes to the growing body of literature on economic convergence inside the United States by analyzing data for a more recent time period (2002-2022) and by using a different starting-point variable (capital per worker) compared to previous studies on this topic.

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Chapter 1

RESEARCH BACKGROUND

Does investing more money in poorer U.S. states lead to greater economic success for those states? Are poorer states doomed no matter how much we spend on them? What policies should the United States implement to have a positive impact on poorer states? This findings from this research study may help to answer some of these questions.

The concept of economic convergence was first analyzed internationally, when economists observed that poorer countries had a higher growth rate in their GDP (Gross Domestic Product) over time than richer countries did. Many economists have analyzed the international economic convergence phenomenon and have tried to apply the analysis to the individual states and regions of the United States. For convergence to be occurring in the United States, economists must see poorer states or regions growing at faster rates than richer states. This paper examines convergence across the lower forty-eight U.S. states, identifying poor and rich states by their capital-per-worker ratios at the starting period of 2003. Measuring the level of wealth in a state by the capital-per-worker ratio allows for an important connection to be made between state convergence and the Solow Growth Model.

This study will serve to add to the growing body of research on economic convergence inside the United States by analyzing data for a more recent time period (2003-2022). This research will also try to see if the prediction of the Solow Growth Model holds true given the data available and data analysis methods employed. Most research on economic convergence within the United States looks at GDP per capita levels from a starting point to an ending point, seeing if states that had lower GDP per capita to start with grew at a faster rate over time than richer states did. This paper uses a different starting-point variable already mentioned, capital per worker, which will allow the research to be compared directly to the predicted outcomes of the Solow Growth Model.

Initial Interest

The topic of economic convergence in the United States became of interest because of an International Economics class I had my senior year of college. During this class we learned about convergence, and I was curious if convergence happened within the United States. Having lived in Erie, Pennsylvania for the past three years, seeing the economy develop the way it has in my time here, I wondered what effect surrounding cities like Pittsburgh, Buffalo, and Cleveland had on Erie. This curiosity quickly grew to the state level and led to the question of whether the U.S. states were growing apart from each other or converging.

Research Objectives and Thesis Overview

The objectives of this research include first determining whether economic convergence is occurring among U.S. states from 2003 to 2023. Secondly, this paper seeks to draw a connection between our research methods and the Solow Growth Model. Given that the Solow Growth Model predicts convergence, we hope to structure our research to test this implication of that model. The final objective of the research is to identify areas of further research. Since no paper is perfect, including this one, we hope to explore avenues where no one has yet traveled down, and come back from them with innovative ideas that other researchers can use.

Chapter 1 of this paper gives an overview of the research topic and its motivation. Chapter 2 will provide a literature review of other research papers on the topic of convergence, their research methodology and their discoveries. Chapter 3 gives a detailed description of the methodology used for this research paper, explaining how our methodology connects to the Solow Growth Model and discussing the other control variables we included and why. Chapter 4 discusses the findings of our research in detail. Chapter 4 will also include potential areas of improvement that others who decide to research this topic can implement into their research.

Chapter 2

LITERATURE REVIEW

Overview

Chapter 2 will serve as a literature review. In this literature review, the reader will gain the background knowledge necessary to understand the findings of my research project. As with almost any research topic, inspiration was taken from others who have researched the topic before. At the end of chapter 2 the reader will gain a clear understanding of what convergence is, how economists test for convergence, and the Solow Growth Model. Finally, with all this knowledge, the methodology of my research should be clear to the reader.

Previous Research on Economic Convergence

In a series of early academic studies, Robert Barro and Sala-I-Martin set out to investigate whether the 48 contiguous U.S. states have exhibited economic convergence. (See Barro and Sala-I-Martin, 1990 1991, and 1992.) The main assumption made in these studies is that the 48 U.S. states which were used as datapoints are all closed economies. The authors use per capita personal income since 1840, and per capita gross state product since 1963 to test for convergence within the neo-classical growth model, which is based on Solow's (1956) pioneering work on the theory of economic growth.

Before getting too much farther into the review, it is important to review the meaning of economic convergence. Economic convergence occurs when closed or separate economies grow closer to each other over time in terms of an economic metric. This assumes that there is a considerable gap between the closed or separate economies at the beginning period of measurement. As time goes on, given that the economies are converging, the gap between the economies will get smaller. The gap between the 48 states in the journal article by Robert Barro and Sala-I-Martin is measured by differences in per capita income. A general overview of how the authors tested for convergence can be summarized in the following explanation: The authors analyzed the per capita incomes of each state in 1840, identifying which states were poor and which states were rich. The authors then compared each state's ending per capita income to see if the initial gap between states closed over time.

The authors originally ran a regression to determine if convergence occurred in U.S. states without holding any other variables constant and found that there are periods between 1840 and 1988 where convergence is observed. The authors then ran a second regression holding individual state characteristics constant, such as the U.S. region where each state is located and the relative share of various economic sectors for each state. The results they got were similar to their first regression. The results from the second regression only confirmed that U.S. states below the steady-state level of production grew at a faster rate than states that were closer to the steady state.

The authors then decide to compare the results they got from the 48 U.S states to a similar regression run on 98 countries. The authors found similar conditional convergence growth rate values for the 98 countries as they did in their regression with the 48 U.S. states. This further confirmed the theoretical implication of the neoclassical growth model, which predicts convergence with exogenous technological progress and within closed economies (like the U.S. states). The authors point out in their conclusion that the empirical results from the 48 U.S. states imply a higher level of convergence than anticipated by the closed-economy neoclassical growth model. This is because in a closed economy, diminishing returns to capital set in sooner than in an open economy. The research by Barro and Sala-I-Martin is seminal in its exploration of whether the 48 contiguous U.S. states, treated as closed economies, are converging. Their focus on per capita income and gross state product positions these studies as foundational. Their methodology, especially the regression techniques holding various variables constant, and their unexpected findings of higher levels of convergence, provide a benchmark against which our research on convergence among U.S. states and the alignment with the Solow Growth Model can be compared.

A different way of measuring convergence that follows the Solow Growth Model was introduced by Ball, Hallahan, and Nehring (2004). These researchers analyzed convergence in agricultural productivity among U.S. states from 1960-1999. This is a different approach compared to the Barro and Sala-I-Martin studies and aligns closely with my research model. Their work is based on research from another study by Abramovitz (1986), which found trends of convergence occurring in the past century (1870-1979) and concluded that there is an "almost perfect inverse relationship between labor productivity levels in 1870 and the rate of labor productivity growth between 1870-1979." In other words, states that had lower labor productivity levels in 1870 experienced faster growth rates in labor productivity from 1870-1979 compared to states that had higher labor productivity levels in 1870.

The study by Ball, Hallahan, and Nehring (2004) looks specifically at the agriculture industry in each state from 1960-1999. Diverging from Barro and Sala-I-Martin's approach, their study measures convergence in agricultural productivity. Their focus on the "catch-up hypothesis" and the role of technological diffusion is pivotal, particularly when considering our objective of understanding whether poorer states grow at faster rates. Their findings, which underscore the impact of technological advancements on convergence, also contribute to the discussions around the Solow Growth Model. Ball, Hallahan, and Nehring want to find out if total factor productivity levels in agriculture have converged over time, and if there is convergence, whether it is explained by growth of factor intensities or by productivity catch up. To explain total factor productivity, it is the ratio of output relative to the amount of capital, labor and material inputs that went into making the output. Therefore, a higher TFP (Total Factor Productivity) ratio is what every agricultural producer wants. The authors found that states which were behind in productivity in 1960 often caught up or grew at faster rates over time than states which had higher levels of productivity in 1960. Based on their hypothesis test from a linear regression Ball, Hallahan, and Nehring found that the catch-up hypothesis seemed to be validated: the empirical results were statistically significant and showed an inverse relationship between the initial productivity level and the rate of productivity growth in a state.

The catch-up hypothesis states that new technology is passed down by technology leaders to followers, allowing followers the ability to grow at faster rates assuming they adopt the new technology. In other words, states that had a lower productivity level to begin with most likely had a lower technological level to begin with as well. As time went on, technology was passed down from leaders in the agricultural industry and as a result, lower productivity states grew at much faster rates due to the adoption of "new" technologies from technology leaders in agriculture. Ball, Hallahan, and Nehring's findings in the agriculture field from 1960-1999 show that technological advancement can promote convergence among states, closing the gap between high productivity states and low productivity states.

Holt and Jamison (2009) investigate the economic benefit that broadband technology can generate in the areas where it is deployed. This research stresses the significance of technological advancements, especially broadband penetration, for economic development and convergence. By highlighting technology as a factor that can elevate an economy's growth potential, it builds upon the Solow Growth Model's implications and solidifies the need for our research to account for technological variables. This paper is especially pertinent in the context of our objective to control for differences across U.S. states. The authors of the study set out to explore the economic benefits of broadband development in the U.S. because they cite a lack of research done on this topic. The authors utilize FCC data from 2003-2005 for the lower 48 states in the U.S. to calculate the amount of growth in output and employment because of an increased broadband deployment across the country.

Holt and Jamison also discuss the history of research on Information Communications Technology (ICT) development and the so-called Information Productivity Paradox. Their brief overview of the shortfalls of previous research conducted on ICT's impact emphasizes the importance of this current study. Due to the difficulty of researching ICT, the authors instead decide to research broadband penetration across the U.S. and its effect on state-level employment and output. The authors use an OLS regression to estimate the impact of broadband penetration in the states, hypothesizing that an increase in broadband (BB) lines deployed will lead to an increase in economic output and employment.

Holt and Jamison's focus is on the effect of BB lines per capita on a state's economic growth. The regression results show a positive and statistically significant coefficient on the variable measuring BB lines per capita, which supports the authors' hypothesis.

In addition to running two OLS regressions on broadband's effect on GDP and employment at the state level, Holt and Jamison also run a regression displaying broadband's effect on specific economic sectors. The author's found that broadband penetration has a strong relationship with employment in the service, finance, education, and healthcare sectors.

Holt and Jamison conclude their research study with policy implications regarding broadband development in the US. Their study serves to highlight the important role technology plays in economic development. In the context of Solow's Growth Model, technology is the factor that pushes an economy's steady-state level of growth higher over time. Since my research is based on one of the key implications of the Solow Growth Model, including a variable to account for technological development is critical.

Bernard and Jones (1996) also explore how technology promotes economic convergence among closed economies. The difference between their study and the one by Holt and Jamison (2009) is that the closed economies examined are countries rather than states. These researchers argue that convergence is looked at incorrectly by other scholars. Although they analyze country data, I think this study is useful for my research. The authors claim that other scholars focus on capital accumulation rather than technology to explain convergence. The authors' main motivation for conducting this study is to advocate for technology to be included in convergence research, providing inspiration similar to that of Holt and Jamison (2009). The authors go on to propose a growth model that both accounts for technological change as well as a country’s ability to adopt new technologies. The ability of other countries to have the bandwidth to adopt new technologies is a key consideration. The authors also argue that the dispersion of technology corresponds closely to the change in labor productivity, and that this signals the importance of the adoption of technology for economic growth. Their research findings also highlight the fact that convergence can occur at different rates across different sectors depending on how much technological development is occurring in a particular sector.

Bernard and Jones conclude their study by restating the importance of researching technology’s role in convergence. They pose many interesting questions such as: “How do we measure technology? Why do countries have different levels of technology? How do technologies change over time?” The answers to these questions could possibly result in a more precise economic growth model. This study emphasizes an important aspect of economic growth regarding technology, namely the adoption rate of new technologies. How can poorer states/countries gain from new technologies if they cannot even adopt them? How do researchers measure a state or country’s ability for technological adoption? These are some of the questions that inspired my research.

Chapter 3

METHODOLOGY

The Solow Growth Model

The Solow Growth Model will serve as the backbone of my research. To understand the methodology of this research paper, the reader must understand the basic structure of the Solow Growth Model as well as the law of diminishing marginal returns.

At the heart of the Solow Growth Model is the production function, which formulates how output (Y) is generated through inputs of capital (K) and labor (L), mathematically represented as $Y = F(K, L)$. Here, $\boldsymbol{k}$, or capital per worker, emerges as an important variable and is mathematically expressed as $k = (K/L)$. Furthermore, output per worker, denoted as $\boldsymbol{y}$, is expressed as $y = Y/L = f(k)$, where $f(k)$ is the function that shows the relationship between output and capital per worker.

As an economy begins to accumulate capital, the change in capital per worker over time (Δk) is represented by the equation $\Delta k = s \cdot f(k) - (n + \delta) \cdot k$. The variable $\boldsymbol{s}$ signifies the savings rate, while $\boldsymbol{n}$ and $\boldsymbol{\delta}$ represent the population (labor) growth rate and the depreciation rate of capital, respectively. The concept of the steady state in the model illustrates a scenario where capital per worker (k) is constant, so that $\Delta k = 0$. By solving $s \cdot f(k^*) = (n + \delta) \cdot k^*$, the steady-state level of capital per worker (k^*) can be found. Consequently, the steady-state level of output per worker (y^*) is denoted as $y^* = f(k^*)$, and consumption per worker in the steady state (c^*) is determined by $c^* = y^* - (n + \delta) \cdot k^*$.

Examining the dynamic behavior of the Solow model, if capital per worker is below its steady-state level ($k < k^*$), investment per worker surpasses what is necessary to both equip new workers with capital and offset depreciation, leading to a growth in $\boldsymbol{k}$ over time. Conversely, if $k > k^*$, $\boldsymbol{k}$ diminishes over time as depreciation and equipping new workers surpass investment per worker. Therefore, the economy gradually converges to the steady state, where it persists unless disturbed by parameter shifts.

One of the key predictions of the Solow Growth Model, through the lens of capital per laborer, is that economies with lower initial levels of $\boldsymbol{k}$ will experience more rapid growth, allowing them to grow towards convergence with the steady state. However, it's crucial to highlight the notion of "conditional convergence." In essence, while poorer economies tend to grow faster and catch up with richer ones, this convergence is *conditional* on these economies having similar savings rates, population growth rates, and other model parameters. The convergence this paper seeks to identify is this very form of conditional convergence.

Another implication of the model is that, in the absence of technological progression, long-run growth of the per worker variables, such as output and capital, is unattainable. Moreover, policies influencing the savings rate, population growth, or depreciation will sway the steady-state levels of output and capital per worker but will not alter their perpetual growth rates.

However, it's paramount to acknowledge the limitations, such as the assumption of a closed economy without technological change, which dampens the real-world applicability of the model to some extent. The model, while elegantly tying together concepts of savings, labor growth, and capital depreciation, perhaps overly simplifies the myriad factors influencing economic growth in real-world scenarios. Nevertheless, the Solow Growth Model, especially when analyzed with a focus on capital per worker, furnishes invaluable insights into economic growth in a closed economy.

The law of diminishing marginal returns plays a significant role in explaining the reason for the prediction of the Solow Growth Model that economies with lower initial levels of capital per worker ($\boldsymbol{k}$) will experience more rapid growth. As capital accumulates in an economy, each additional unit of capital results in a progressively smaller increase in output, mirroring the concept of diminishing returns. This behavior underpins the model's prediction that economies with a lower starting level of capital per worker will experience more rapid growth rates initially, but as they accumulate more capital, growth rates decline.

Assuming each U.S. state analyzed in this thesis is a closed economy, the Solow Growth Model predicts that a lower starting level of capital per worker in a state will lead to a higher growth rate in that particular state's economy. The law of diminishing marginal returns helps explain how poorer states grow at faster rates than richer states do. Poorer states have more room to grow (a wider gap between them and richer states), and the Solow Growth Model suggests they will grow at faster rates to reach the steady state. As those poorer states catch up, or converge, with the richer states, their growth rates begin to decline.

Regression Model

This section describes the regression model upon which this research study is based. The model is expressed in the following equation:

$$ANNUALGRWTH = \alpha + \beta_1\ CAPEXP + \beta_2\ STRTPC + \beta_3\ STPOP + \beta_4\ REPDEM + \beta_5\ INFO + \beta_6\ MANU + \beta_7\ FIRE + \beta_8\ POPHS + \beta_9\ POPBACH + \beta_{10}\ INDIV + \beta_{11}\ CORP + \varepsilon$$

Each variable in this equation is defined in the next section and ε is a random error term. Ordinary Least Squares (OLS) regression is used to estimate the coefficients in this model ($\alpha, \beta_1 \ldots \beta_{11}$) using data for the 48 contiguous U.S. states during the period 2003-2022.

Explanation of Variables and Hypotheses

Below I will describe the variables that are included within my multiple regression model. I will provide a description of the variables, the use case for each variable, and my hypotheses regarding the impact of the explanatory variables in the regression model.

Dependent Variable: Average Annual Rate of Growth (*ANNUALGRWTH*)

The average annual rate of growth (***ANNUALGRWTH***) is the outcome (dependent) variable in the regression model. The variable is exactly what it sounds like, namely the average annual growth in per capita income for each of the 48 states within the study over the period 2003-2022. This variable is positive within the regression. The variable is also adjusted for inflation.

Two Main Explanatory Variables: Capital Expenditures Per Employee in Manufacturing (*CAPEXP*) and Real Per Capita Income Starting Amount (*STRTPC*)

These are the two main explanatory variables in the present study which are used to test one of the key predictions of the Solow Growth Model. The first variable (***CAPEXP***) measures the level of capital expenditures per employee in manufacturing in 2003 for each of the 48 U.S. states in the regression. The variable was constructed using two different data series. One data series which measures the capital expenditures in manufacturing for each state in 2003 was obtained from the U.S. Census Bureau. The second data series provided the number of employees in manufacturing in 2003 and was obtained from the U.S. Bureau of Labor Statistics. The two data series were used to compute the ***CAPEXP*** variable measuring the per capita spending on manufacturing capital in each state. The estimated coefficient for this variable in the regression model is expected to be negative and statistically significant. If the estimated coefficient is both negative and statistically significant, this would provide support for the hypothesis that states with lower initial levels of capital grow at faster rates than states with higher initial levels of capital, as the Solow model predicts.

The second main explanatory variable (***STRTPC***) is included to control for the per capita income level in each of the 48 contiguous states in the initial year 2003, adjusted for inflation. It is included within the regression to see whether states with lower initial per capita income levels experience faster growth rates than states with higher initial per capita income levels starting in 2003. Based on the predictions of the Solow Growth Model, we expect the estimated coefficient for this variable to be negative and significant, which would indicate that there is a causal relationship between a state's initial level of per capita income and its average annual growth rate. This is the same explanatory variable that Robert Barro and Sala-I-Martin used in their research.

In addition to these two main explanatory variables, a series of control variables is also included in the regression model. These control variables are included since this study is based on the notion of *conditional* convergence as predicted by the Solow Growth Model. That is, we expect to observe economic convergence when specific state attributes as measured by these control variables (such as educational attainment, industrial structure, etc.) are *comparable* across individual states. These control variables are defined below.

Percent of Population with High School Diploma (*POPHS*)

This control variable (***POPHS***) is included in the regression model to hold constant high school graduation rates. The variable measures the proportion of the population with high school diplomas in the 48 contiguous U.S. states in 2003. The reason for including this variable in the regression model is that states have different educational systems, and therefore may have different proportions of the population with high school degrees. The estimated coefficient for this variable is expected to be positive because the more educated people there are within a state, the higher the growth rate of the state is likely to be due to the greater stock of human capital.

Percent of Population with a Bachelor's Degree or Higher (*POPBACH*)

This control variable (***POPBACH***) is similar to the previous one, but measures the percentage of the population in a particular state that has completed *higher education* from a bachelor's degree to a doctorate degree. The rationale for including this as well as the previous variable (***POPHS***) is that this will hold constant the different levels of education throughout the U.S., allowing us to test for *conditional* convergence. That is, we expect to observe economic convergence when attributes such as educational attainment are comparable across individual states. The estimated coefficient for this variable is also expected to be positive because higher education adds to the stock of human capital within a state and is therefore likely to increase the growth rate of the state.

Share of Manufacturing Employment (*MANU*)

This control variable (***MANU***) is a combination of two data series from the U.S. Bureau of Labor Statistics. The variable is included to hold constant the relative size of the manufacturing sector in each of the 48 states. The first data series measures the level of employment in manufacturing for each state in 2003. The second data series measures the level of total employment for each state in 2003. To capture the relative size of each state's manufacturing sector, we took the number of employees in manufacturing divided by the total number of employees in a state to compute the manufacturing share of employment in each state. This allows us to hold constant the different shares of manufacturing employment throughout the country. The estimated coefficient for this variable is expected to be positive since overall U.S. manufacturing output has remained relatively strong during the period covered by this study, suggesting that a greater presence of manufacturing is likely to increase the growth of a state's economy.

Share of Finance, Insurance, and Real Estate (*FIRE*) and Share of Information (*INFO*)

Two other control variables are included to hold constant the *industrial structure* across states: the employment share for the finance, insurance, and real estate industries (***FIRE***), and the employment share for the information industry (***INFO***). These variables are constructed in the same way as the manufacturing employment share across the states.

Percent of Revenue from Individual Taxes (*INDIV*)

This variable (***INDIV***) measures individual taxes (as a percent of total government revenue) that different states levy on their residents. The variable is included to hold constant the different tax rates and tax laws between states in 2003. We hypothesize that the estimated coefficient for this variable will be negative because the disincentive effects of higher individual taxes are likely to lower a state's growth rate.

Percent of Revenue from Corporate Taxes (*CORP*)

This control variable (***CORP***) is similar to the previous variable (***INDIV***), but measures *corporate* taxes (as a percent of total government revenue) that different states levy. The variable is included to control for different corporate tax rates and tax laws across the country in 2003. The estimated coefficient for this variable is expected to be negative as well because of the disincentive effects of higher corporate taxes that are likely to have a negative impact on growth.

Republican or Democrat (*REPDEM*)

This variable (***REPDEM***) is included to control for the different political leanings of each of the 48 states in the country in 2003. Using data from the 2004 presidential election, a dummy variable was created that had a value of *zero* if a state voted for the Democratic candidate, and a value of *one* if a state voted for the Republican candidate. We did not have any hypotheses regarding the estimated coefficient for this variable. The variable was included to hold constant the different political leanings of each state.

State Population (*STPOP*)

This variable (***STPOP***) measures the size of the population in each of the 48 states in 2003. This is yet another control variable to hold constant the different population sizes between states. The estimated coefficient for this variable is expected to be positive, since a larger population implies a potentially bigger labor force, which can increase the growth rate of a state.

Chapter 4

DATA

Data collected for this research paper are all compiled from secondary sources and will be used in the regression analysis of U.S. states to test multiple hypotheses. The advantage of using secondary sources like the U.S. Census Bureau or the U.S. Bureau of Labor Statistics is that those entities have publicly available data that no individual researchers would have the resources to collect themselves. Especially when testing for economic convergence across the 48 U.S. states, the data almost always must be from secondary sources.

Data Sources

Data were collected from multiple government websites with online databases. The U.S. Census Bureau's website is the source for most of the data collected, such as population by state, educational attainment in each state, capital expenditures in the manufacturing sector for each state, percent of revenue from personal taxes, and percent of revenue from corporate taxes in each state. Data on the number of employees in manufacturing come from the U.S. Bureau of Labor Statistics, while data on state per capita income, per capita income growth over time, and share of employment in different industries come from the U.S. Bureau of Economic Analysis. Data on whether a state voted Republican or Democrat in the 2004 presidential election come from the U.S. National Archives.

The Census Bureau is a part of the U.S. Department of Commerce. Its main job is to count how many people live in the U.S. every ten years and learn about who they are. The Bureau of Economic Analysis (BEA), also in the Department of Commerce, looks at how the U.S. economy is doing. They keep track of statistics such as the country's total output of goods and services (or "real gross domestic product"). The Bureau of Labor Statistics (BLS), under the U.S. Department of Labor, compiles data about jobs, providing information about who's working, who's not, and how much they get paid. The U.S.

National Archives is a big storage place for keeping important historical records, including old papers, pictures, and other items. It helps people learn about U.S. history by keeping and showing these items.

Data Selection Criteria

Statistics were compiled from U.S. government organizations that focus on large-scale data collection because the resources required to collect data on all 48 U.S. states would be prohibitively expensive for a single researcher. Data had to be available for the 48 contiguous U.S. states going as far back in time as possible to get the most out of the data and ensure a strong regression. For that reason, these government entities with public data were the best option to use in conducting the research for this study. The reason for focusing on the 48 contiguous U.S. states is that this is consistent with the methodology used by the early studies (summarized above) on economic convergence in the U.S. In those early studies, the data sometimes extended back to before Alaska and Hawaii attained statehood in 1959, so that these two states were typically excluded from the analysis.

Description of the Data and Data Analysis

The data used in this paper are almost all quantitative in nature. The data span the period from 2003 to 2022 and cover the 48 contiguous U.S. states, excluding Alaska and Hawaii. Data were collected on all the variables specified in the regression model described above. As stated before, the statistics come from government sources that exist for the main purpose of providing data to researchers, policymakers, and the public. Given their long history of data collection, the degree of reliability of the data released by U.S. government agencies such as the Census Bureau, the Bureau of Labor Statistics, and the Bureau of Economic Analysis is typically very high.

Data analysis was conducted in Posit Cloud, formerly called R Studio Cloud. Before the data were imported into R Studio Cloud, they were uploaded and formatted within Microsoft Excel to prepare the data for R Studio Cloud. Data formatting and clean-up in Excel mainly consisted of removing data for Alaska and Hawaii, ensuring all the data were correctly assigned to the correct state, and also searching for null values and understanding the root cause of the null value. After the data had been cleaned and were ready to go into R Studio Cloud, a multiple regression was performed on the data.

Summary of Data Section

As already noted, the data for this research were sourced entirely from secondary sources, primarily because collecting data for the 48 U.S. states is a vast endeavor beyond the capacity of individual researchers. Key datasets were extracted from U.S. government websites, with the majority originating from the Census Bureau, detailing aspects like population, education, and tax revenue by state. Additional datasets encompassed information from the Bureau of Labor Statistics, the Bureau of Economic Analysis, and the National Archives. These government entities, renowned for their comprehensive and reliable data repositories, were invaluable for this research, especially given the broad time frame (2003-2022) and the specificity of excluding Alaska and Hawaii. After collection, the data were preliminarily processed in Microsoft Excel for accuracy and completeness. Subsequent analysis, including multiple regression, was performed using Posit Cloud, formerly known as R Studio Cloud.

Chapter 5

RESULTS

Introduction

As a refresher, the goal of this research paper is to compare what is found in the real world with the Solow Growth Model predictions. Therefore, our hypothesis is that the estimated coefficient on the capital expenditures per employee in manufacturing variable (***CAPEXP***) should be negative and statistically significant. This would follow in line with the Solow Growth Model's prediction that economies with lower starting levels of capital grow at faster rates than economies with higher starting levels of capital.

Table 1 provides descriptive statistics for each of the variables in the model and Table 2 summarizes the regression results.

Table 1: Descriptive Statistics for Each Variable in the Multiple Regression

Variable	Min	1st Quartile	Median	Mean	3rd Quartile	Max
AVGGRWTH (%)	**0.2369%**	**1.0857%**	**1.3445%**	**1.3797**	**1.5808%**	**2.5726%**
CAPEXP ($)	**33.85**	**73.46**	**110.22**	**128.19**	**134.31**	**681.35**
STRTPC ($)	**22616**	**26399**	**28769**	**29619**	**32326**	**42204**
STPOP (Number)	**501242**	**1858549**	**4321743**	**6007083**	**6671649**	**35484453**
REPDEM (1=REP; 0=DEM)	**N/A**	**N/A**	**N/A**	**0.6042**	**N/A**	**N/A**
INFO (Share)	**0.016**	**0.021**	**0.024**	**0.025**	**0.028**	**0.044**
MANU (Share)	**0.043**	**0.089**	**0.117**	**0.116**	**0.141**	**0.201**
FIRE (Share)	**0.039**	**0.049**	**0.058**	**0.059**	**0.068**	**0.113**
POPHS (%)	**77.20%**	**82.53%**	**86.75%**	**85.86%**	**88.70%**	**92.10%**
POPBACH (%)	**15.30%**	**23.45%**	**25%**	**26.35%**	**29%**	**37.60%**
INDIV (%)	**0.00%**	**9.7%**	**13.8%**	**12.2%**	**16.3%**	**24.6%**
CORP (%)	**0.00%**	**0.41%**	**1.15%**	**3.85%**	**4.94%**	**26.6%**

Table 2 Regression Results, Posit Cloud

Regression 2003-2022 Adjusted for Inflation

	Dependent variable:
	AVGGRWTH
CAPEXP	-0.00001
	(0.00003)
STRTPC	-0.0001***
	(0.00003)
STPOP	0.000
	(0.000)
REPDEM	-0.011
	(0.145)
INFO	24.640*
	(14.441)
MANU	-2.471
	(1.792)
FIRE	0.819
	(4.819)
POPHS	0.044**
	(0.020)
POPBACH	0.016
	(0.027)
INDIV	-2.064*
	(1.089)
CORP	1.015
	(1.266)
Constant	-0.392
	(1.801)
Observations	48
R2	0.513
Adjusted R2	0.364
Residual Std. Error	0.379 (df = 36)
F Statistic	3.446*** (df = 11; 36)
Note:	*p<0.1; **p<0.05; ***p<0.01

Interpretation

The empirical results from the regression analysis display reasonable measures of goodness of fit for the overall regression model as indicated by the F-statistic and the adjusted R-squared.

Below I will provide an interpretation of the estimated regression coefficients on the two explanatory variables that are most closely related to a key prediction of the Solow Growth Model. Since the other variables in the regression model are included mainly as controls so that we can test for *conditional* convergence, interpretations of the estimated coefficients for these other control variables will not be included.

Interpretation of *CAPEXP*

Interpretation of the estimated coefficient on the ***CAPEXP*** (or *K/L*) variable is important to understand. Even though the variable is found to be insignificant after running the regression, it is important to review the interpretation because it was our main explanatory variable that was used to test one key prediction of the Solow Growth Model. The variable is measured in thousands of dollars per employee in manufacturing. So, the estimated coefficient suggests that a one unit ($1,000/employee) increase in ***CAPEXP*** leads to a 0.00001% *decrease* in a state's average annual growth rate in per capita income. The negative sign on the estimated coefficient for this variable indicates that the more capital per laborer a state has, the *lower* will be its average annual growth rate in per capita income. Therefore, the empirical results do not seem to support the prediction of the Solow Growth Model. In addition, it's important to note that the estimated coefficient on the ***CAPEXP*** variable is statistically insignificant.

Interpretation of *STRTPC*

The ***STRTPC*** variable measures the real per capita income for each state in 2003. The estimated coefficient on this variable is highly significant at a p-value of 0.01 and has the correct (negative) sign. These empirical results are consistent with a *variation* of a key implication from the Solow Growth Model, namely that *poorer* economies (states) would tend to grow at a faster rate over time. The negative sign on the estimated coefficient indicates that states which had higher per capita incomes at the initial period experience lower growth rates over time, and the opposite is true for states with lower initial per capita income levels. The size of the estimated coefficient on the ***STRTPC*** variable suggests that a one thousand dollar increase in a state's initial level of real per capita income results in a 0.1% decrease in a state's average annual growth rate in real per capita income over time.

Other Results to Note

The coefficient on the ***INFO*** variable ended up being statistically significant with a positive sign at the 10% level, indicating that an increase in the employment share of the information industry in any of the 48 states leads to an increase in that state's growth rate. The coefficient on the ***POPHS*** variable was also statistically significant and positive, indicating that states with more high school graduates as a proportion of the population tend to experience higher growth rates. Another interesting result is the statistical significance and negative value of the estimated coefficient on the ***INDIV*** variable measuring the percentage of state government revenue from taxing individuals. The results indicate that states which collect higher individual taxes as a percent of their total state revenue tend to experience lower growth rates.

Chapter 6

CONCLUSION

Main Conclusions

This research sought to find the real-world applicability of the Solow Growth Model by mimicking certain aspects of the theory. The aspect of the Solow Growth Model that was replicated is the capital per labor ratio. It is explained in the Solow Growth Model that an economy with a lower initial capital per labor ratio will have a higher rate of growth over time. According to the empirical analysis conducted in this study, the regression result for the variable measuring the impact of the amount of capital per labor (***CAPEXP***) in manufacturing in the U.S. economy over the period 2003-2022 was not statistically significant and therefore does not support the prediction of the Solow Growth Model.

However, the empirical analysis seems to confirm a *variation* of the Solow growth prediction. Specifically, the regression results for the variable that measured initial-level real per capita income (***STRTPC***) suggest that *poore*r economies (states) that start out at lower levels of real per capital income would tend to grow at a faster rate over time. This empirical finding mirrors what was found in previous research by Robert Barro and Sala-I-Martin (1990, 1991, 1992) for different time periods.

Suggestions for Potential Improvements

Suggestions for improving this research or adding to it include the following. The first potential improvement is to increase the number of years included within the dataset. This research study only included the years 2003-2022 because of data constraints, but if more data were to become available in the future, this research could be replicated. Other improvements may include incorporating more variables within the regression model to hold constant more differences in attributes among U.S. states. The Solow Growth Model predicts *conditional* convergence based on initial differences in capital per labor among closed economies, holding all else constant. Therefore, if a future researcher can think of more variables to hold constant among all the U.S. states, that would only improve the validity of the regression results.

Appendix A

Raw Manufacturing Data

Data on the capital expenditures of manufacturing firms in each state from the U.S. Census Bureau were acquired using this API:

https://api.census.gov/data/timeseries/asm/state?get=NAICS_TTL,GEO_TTL,CEXTOT&for=state:*&YEAR=2003&NAICS=31-33&key=dc1e2dbe3f3e19a695bd1960015895e776a4f221

Scatter Plots

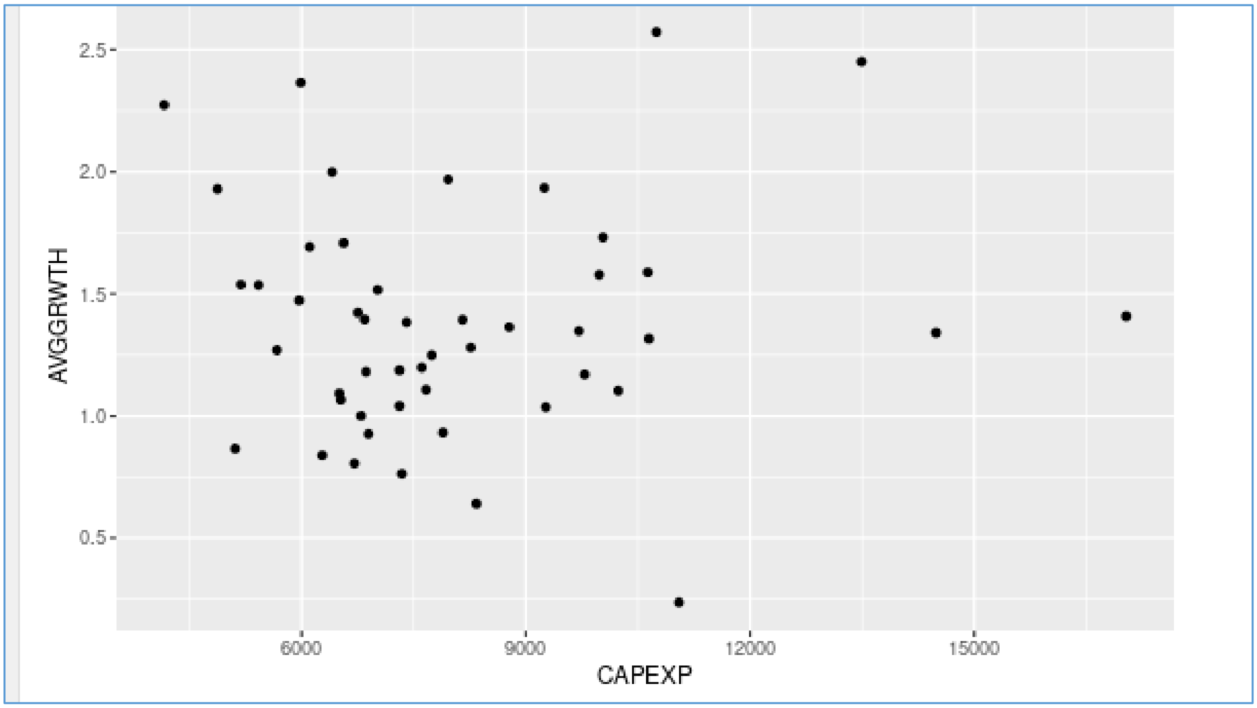

Figure 1: CAPEXP and AVGGRWTH Scatter Plot

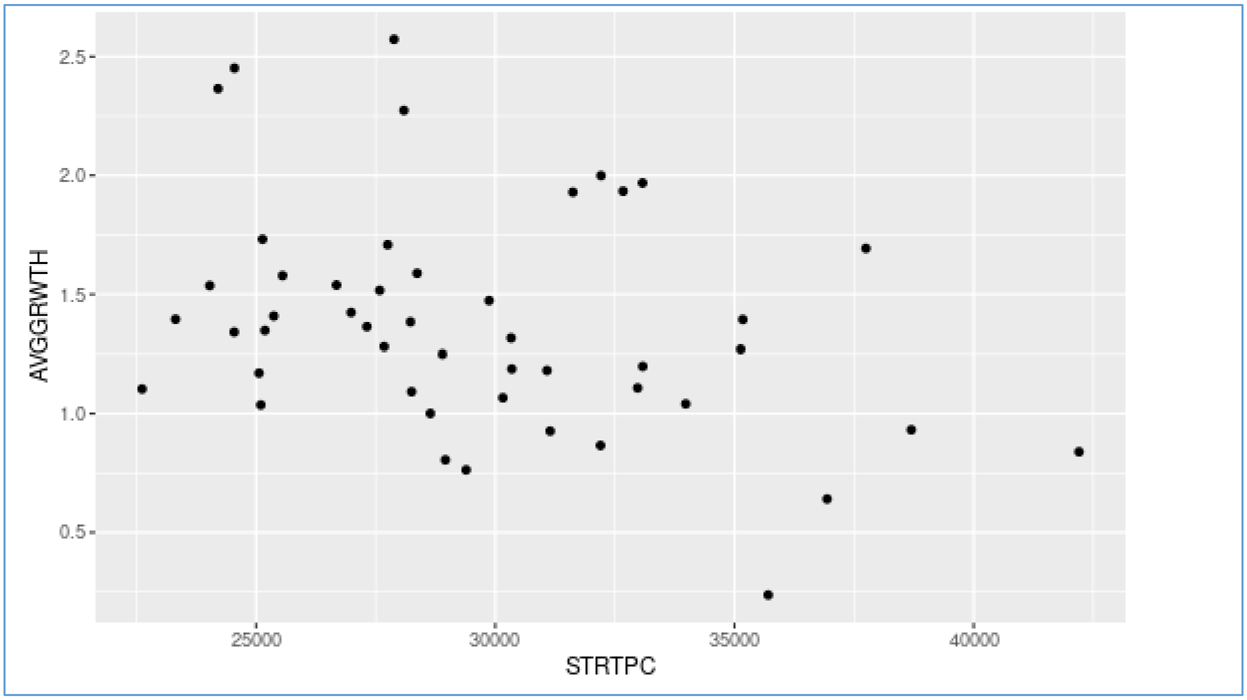

Figure 2: STRTPC and AVGGRWTH Scatter Plot

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ACADEMIC VITA

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Education

The Pennsylvania State University

Graduation: December 2023

Internship Experience

Deloitte GPS Risk and Financial Advisory Paraprofessional | Harrisburg, PA | March 2023-August 2023

- Worked with Pennsylvania school districts and the Department of Education to monitor COVID grants given to school districts during COVID.
- Worked on the project management team, creating expense reports and reconciliating billed time to ensure accurate invoicing.
- Monitored several school districts, ensuring they were using the correct procurement techniques when making purchases with federal money.
- Worked alongside seasoned professionals at Deloitte to come up with solutions to client specific problems.

Deloitte GPS Risk and Financial Advisory Intern | Deloitte | Arlington, VA | June 2022-July 2022

1. Supported the United States Air Force in preparing for their annual IT audit
2. Used SQL automate an excel report consisting of over 30,000 values and a matrix of SoD conflicts, reducing the amount of time spent preparing the report drastically
3. Worked alongside other Deloitte professional and Interns to brainstorm potential solutions for the Air Force

4. Reviewed NIST guidelines to find potential errors in Air Force IT systems

Tax Intern | McGill Power Bell and Associates | Erie, PA | January 2022-April 2022

5. Complete 1040s for high wealth individuals
6. Contact the client to ask for more information regarding tax forms
7. Utilize tax software to better serve my clients as well as track my progress
8. Learn the tax laws locally and statewide to benefit my clients

Cost Accounting Intern | 4Front Solutions | Erie, PA | May 2021-August 2021

1. Created purchase price variance reports to help analyze current purchases
2. Helped develop and manage a company specific cycle count program
3. Investigate why there are variances in inventory after preforming a cycle count
4. Come up with more efficient and controlled processes in receiving, picking, and WIP to limit inventory variance

Work Experience

5. **Accounting Tutor | Penn State Behrend Learning Resource Center | August 2021-December 2021**
6. **Fulfillment | JC Penny | Erie, PA | May 2021-October 2021**
7. **Mailroom Clerk | Penn State Behrend | February 2021-May 2021**
8. **U.S. Census Bureau Enumerator | U.S. Census | San Diego, California | Summer 2020**

Volunteering

Technology Assistant | Brevillier Village Senior Living Facility | Erie, PA | February 2021-May 2022

1. Help residents with basic call and text functions on their iPhone or Android smartphones
2. Ensure residents know how to perform whatever I taught them how to do without help
3. Help residents transfer photos of family and friends to new devices

Skills

Technology: Microsoft Excel, Microsoft Access, Microsoft PowerPoint, SQL, R Studio Cloud