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Comparison of Economic Growth Rates between China and America dependent on Solow Residual Analysis

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ABSTRACT

China has touted one of the fastest-growing economies in the world over the past 50 years- and for good reason. The country's GDP has grown from $5.972B produced in 1960 to $14.28T produced in 2019. Over the same yearly boundaries, the United States' GDP has grown from $543B in 1960 to $21.43T in 2019 (World Bank). The issue that persists in this situation is that despite China's initial GDP equaling approximately 1% of America's initial GDP, China's GDP has grown to about 66% of America's current GDP. This paper analyses different reasons for the explosive nature observed in China's economic growth through mathematical analysis of Solow model variables and the Solow residual. Measurements of subcategories under labor, capital, and technology growth are used in determining which variable has the largest effect on the growth in Total Factor Productivity.

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Chapter 1

Introduction

The metrics and foundations by which the United States and China have incurred economic growth over the past 50 years vary greatly. This thesis stands to analyze the differences in the causes that yielded said divergences. Specifically, it depicts a comparison of the two economies' growths under the specific variables seen in the Solow model: capital (K), labor (L), and technology (A). These variables are utilized as a comparison point to attribute the countries' respective growth rates a specific metric. The growth rate of each specific economy is measured by the annual growth in GDP (Y). Labor (L) is a function of the labor force participation rate, the unemployment rate, and human capital per worker. Capital (K) is a function of capital stock. Technology (A) is a function of evolution in domestic primary education enrollment, patent applications, and research and development expenditure. Throughout the rest of this paper, I will be referring to the independent variables as L, K, and Y, and I will be referring to the dependent variable as A.

From these calculations, numerical analysis and the discussion of results attained become available. This thesis provides a definitive answer to which variables of the explanatory variables yield the largest growth in total factor productivity for both China and the United States. It also includes deliberation on categorically determined aspects of each country which determine the divergence observed in growth rates. The Solow residuals for each country allows for the analysis of each country's percentage of growth attributed to the specific independent variables used. Tables and figures as well as the STATA code utilized to produce the mathematical results are included below.

The regression analysis that was run for China showed that the independent variable that caused the largest percentage change in technology growth was research and development expenditure. This was the only significant value at an alpha level of .05, and the parameter value on the variable was 1.302977. This provides the information that for every 1% increase in research and development expenditure, it caused a 1.3% increase in the total factor productivity. The p-value for this variable was < .000, showing that it is statistically significant.

The regression analysis that was run for the United States showed that the independent variable that caused the largest percentage change in technology growth was patent applications. However, this was concluded under 95% confidence with an alpha value of .05. At 90% confidence and an alpha value of .1, the independent variable that showed the largest percent change in A was again research and development expenditure. The coefficient on the variable was 1.154416, meaning a 1% change in research and development expenditure caused a 1.154% increase in A. The p-value on the variable here was .08, meaning that at an alpha level of .1, it is statistically significant.

Chapter 2

Literature Review

2.1 Cultural Differences (Literary Analysis)

This paper utilizes both categorical data as well as empirical data in the mathematical analyses that follow. To complete said analyses, data and information needed to be collected from reputable sources. Firstly, each of the specific variables utilized in mathematical calculations is gathered and reproduced in the tables below. Information on both China's and America's GDP from 1960-2019 was collected from the World Bank open-source data. GDP stands for Gross Domestic Product, and it is a monetary measure of all goods and services produced in a single time-period

To properly utilize the results and develop an understanding of the outputs from the empirical data stated above, knowledge regarding the categorical reasoning behind the growth in total factor productivity is necessary. Felicia F. Tian and Mu Zheng produced a paper analyzing women in the Chinese workforce from the 1960s-2010s titled, *Female Labor Force in Reform-era China*. They explained that under Mao Zedong's rule, a concept referred to as "Maoism" was perpetuated into society. The philosophy ridded China of the concept of patriarchy, and because of this, women's employment rate during the Mao era was close to 90%- one of the highest in the world (Tian, Zheng). During the pre-Mao era, women were consistently overlooked when it came to social mobility. They were expected to stay at home and complete their daily tasks of cooking, cleaning, and taking care of the family's children while the husband of the household went out and worked. Unfortunately, once the "one-child generation", which was the generation that grew up during Mao's reign, began to die off, women were slowly beginning to be relegated back to old ways (Tian, Mu). In fact, the employment rate of women in the 1960s and 1970s was higher than it has been in recent years. The information in this source allows for clear consideration of a commonality seen between the United States and China in that when women entered the workforce, they allowed for huge expansionary periods in both respective economies.

In Francesca Bray's *Technology and Culture in Chinese History: An Introduction*, there is information that allows for the comparison between America and China and how their respective cultures deal with technology advancements. The paper mentions that when Western countries such as the United States acquire a technological advancement, they use the heightened stature to promote themselves as a strong force on a global scale. From this comparison-based system of validation, the incentive to develop better technologies is heightened and technological advancement occurs. However, in many Eastern-Asian countries, tech advancement in the mid 1950s failed to live up to the desire that was seen in America. Even still, as China became more westernized in the late 20th century, this ideal was adopted, and China saw a technology boom that was almost incomparable to anything the country had experienced before (Bray). From this, China's GDP was able to expand at a rapid rate which could explain a fraction of the explosion in their economy.

In Hongfei Du's (et al) paper about Chinese social mobility, he found that, in general, the Chinese believe in social mobility. In fact, the paper went on to discuss how past social mobility failed to negatively affect future social mobility. During the mid-20th century, most Chinese people experienced very low rates of social mobility. In such, there was little incentive to assume that by working hard, an individual would be able to climb the social ladder and reinstate themselves as an upper-class citizen. However, as time progressed, more and more people were able to expel themselves from poverty-stricken life due to higher rates of education availability, higher economic growth, and cultural changes. Therefore, even though social mobility was once a sought-after concept that could never be attained, people were now able to achieve it (Du). This new concept promoted workers to increase labor productivity, which could have yielded a positive effect on China's GDP.

In Ayesha Ilyas's paper, *Chinese's Cultural Diplomacy,* it becomes objectively apparent that Chinese culture has taken a U-turn over the past 60 years with respect to how it handles itself on a global scale. She explains that in the early 20th century, China was war-stricken and often failed to have the means of establishing itself as a powerhouse country in terms of the global economic scale. Also, since China remained culturally homogenous and essentially cut off from the rest of the world for most of the 1900s, there was little opportunity to progress and evolve. However, the open-door policy in the 1980s allowed for Chinese businessmen to take advantage of a newly found opportunity to expand their businesses. This expansion led to many new trade opportunities to come China's way. Due to the global shock that the expansion of the Chinese economy had on the world, China was quickly thrown into the global market and established itself as an economic force (Ilyas, Chinese's Cultural Diplomacy).

2.2 Economics Literature

Robert Lucas's paper, *Making a Miracle,* discusses the basis and background of the Solow model both in general terms and specifics. The utilization of this paper was to expand knowledge of how each of the Solow model variables: labor, capital, and investment interact with each other. The paper delves into a discussion of each of the specific variables and how they affect GDP singularly as well. Human capital growth and disembodied technical change have the same effect on output when the production function is Cobb-Douglas. However, reinterpreting

Solow's technology variable as a China/United States specific stock of human capital was considered because of Lucas and "Making a Miracle".

Douglas C. North's paper, *Economic Performance Through Time,* deals with the generalities of how the world has progressed economically with respect to institutions and how they affect economic progress. North discusses the possibility of environmental differences and how they lead to economic growth and economic downfall. Take Europe in the mid to late millennia: countries like Britain and France thrived economically, whereas Spain and Portugal fell. He considers the possibility that there exists some sort of environmental aspect of each respective culture/nation, and said environmental aspect has a profound impact on the establishment of long-term economic growth (North, Economic Performance Through Time). When it comes to the consideration of China's economic growth, it could be that there had existed a paralleled environmental detriment that held them back from progressing; environmental reasons such as bizarre proposed solutions to economic downturns, absent rulers, or even warmongering countries (North). However, when considering the United States in the 1600s compared to the late 1800s, economic growth was heightened in the later century. Of course, trade, population, the industrial revolution, and countless other factors paved the way for economic growth over two hundred years, but North argues that the establishment of a domestic government and the lack of absent rule played a part in America's economic prosperity.

Similar to Robert Lucas's paper, Paul Romer's *Endogenous Technological Change* delves into aspects of the Solow model and discusses the variables at length. The paper goes into how each Solow variable affects GDP mathematically, and it presents derivations and models to represent the changes in GDP. Romer's paper provided a backbone to manipulating Solow variables and how they can be utilized in different ways to measure change in technology, productivity, and changes in labor. This thesis uses his explanation of productivity growth and how it is determined by changes in labor and capital to gain a metric of significant independent variables.

Lastly, the main portion and motivation of this thesis surrounds the Solow residual and using the residual to complete a mathematical analysis of China's and the United States' total factor productivity. Therefore, it is necessary to gather literature regarding the Solow residual to have a better understanding of how to manipulate variables mathematically to calculate different growth rates. In such, Pablo Kurlat's, *A Course in Modern Macroeconomics*, was a perfect textbook to study in pursuit of learning more about Growth Accounting. In section 5.4, Growth Accounting, Kurlat derives a formula to calculate the change in GDP, from here, it is possible to move the function of labor and the function of capital to the side of GDP and calculate the Solow residual (see **Chapter 4 – Solow Residual**). The Solow residual is total factor productivity; it captures everything in an economy that contributes to GDP growth that is not included in increases in labor or accumulation of capital. It is often listed as the following:

Solow Residual = GDP growth – (Capital share*Capital Growth) – (Labor Share*Labor Growth)

Chapter 3

Summary of Solow Model

The Solow Model is a function typically comprised of 4 main variables- 1 dependent variable and 3 independent variables. The dependent variable is GDP, denoted as Y, and the 3 independent variables are Labor (L), Capital (K), and Investment (A). GDP is a function of all these variables, and the specific variables of capital and labor have percentage share values attached to them in regression analysis that can be denoted as alpha (α) for capital, and 1-alpha (1-α) for the share on labor. The current shares for capital in the United States and China respectively is 0.31 and 0.4, and the current labor share in the United States and China respectively is 0.69 and 0.59.

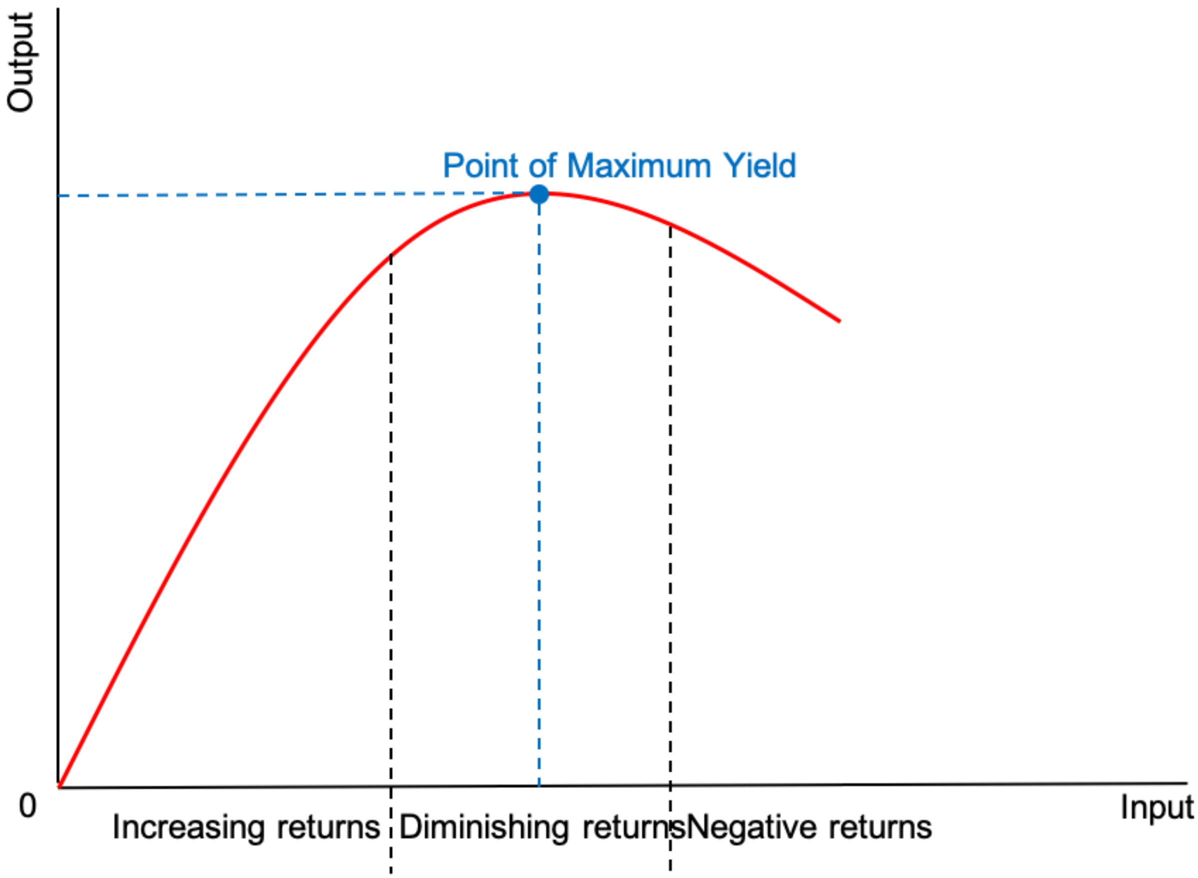
The model operates to measure long-run economic growth. It analyses the growth changes in labor, capital, and investment, and provides economists with a clear view of how GDP will grow given the constraints. The model is listed as follows:

$$Y(t) = A(t)K(t)^{a}L(t)^{1-a}$$

where Y, K, A, L, and α are all listed above. Another interesting and useful provision that this model provides is that poorer countries will grow much faster than rich countries, inevitably catching up to them. This is especially useful in this paper because it will clearly demonstrate the difference in growth rates that the United States and China experienced independently.

Assumptions under this model are vast, and because of that, many econometricians choose to use other, more sophisticated models in hopes to predict more accurate results. One key assumption of this model is that capital (K), in a closed economy, is subject to diminishing marginal returns. Diminishing marginal returns is the concept that when a company acquires new capital such as new machinery or land, the additional benefit brought in from the newly acquired capital will be less than or equal to that of the previous capital acquisition. The marginal returns curve is a negative, concave function as listed below.

Figure 1: ***Diminishing Marginal Returns***



There is a reason the Solow Model has withstood the test of time and is still taught at an undergraduate and graduate level. Robert Solow was the first of his time to show that long run economic growth measured by change in GDP was caused by technological growth. The Solow model is one of the most revolutionary models in all of macroeconomics.

Chapter 4

Solow Residual

The individual variable contributions to the Solow Residual are produced by running a regression of said various independent variables onto TFP in a growth accounting model.

First, start off with a Cobb-Douglas aggregate production function:

$$Y_t = A_t K_t^a L_t^{1-a}$$

Next, take the log of both sides:

$$\log(Y_t) = \log(A_t) + \log(K_t^a) + \log\,(L_t^{1-a})$$

Expand:

$$\log(Y_t) = \log(A_t) + a\log(K_t) + (1-a)\log\,(L_t)$$

Next, do the same steps for t+1:

$$Y_{t+1} = A_{t+1} K_{t+1}^a L_{t+1}^{1-a}$$

$$\log\,(Y_{t+1}) = \log\,(A_{t+1}) + alog(K_{t+1}) + (1-a)\log\,(L_{t+1})$$

Take the difference between:

$$\log\,(Y_{t+1})\ and\ \log(Y_t):$$

$$\log(Y_{t+1}) - \log(Y_t) =$$

$$[\log(A_{t+1}) + alog(K_{t+1}) + (1-a)\log(L_{t+1})] - [\log(A_t) + a\log(K_t) + (1-a)\log(L_t)]$$

$$= \Delta\log(Y_t) = \Delta\log(A_t) + a\Delta\log(K_t) + (1-a)\Delta\log(L_t)$$

We conclude:

$$\Delta\log(x) \approx \%\Delta x:$$

$$\Delta\log(Y_t) = \Delta\log(A_t) + a\Delta\log(K_t) + (1-a)\Delta\log(L_t)$$

$$\rightarrow \%\Delta Y_t = \%\Delta A_t + a\%K_t + (1-a)\%L_t$$

Next, write out the equation in terms of $\%\Delta A_t$:

$$\%\Delta A_t = \%\Delta Y_t - [a\%K_t + (1-a)\%L_t]$$

$\%\Delta A_t$ is our Solow Residual, otherwise coined TFP.

From here, we construct L_t *and* K_t. L_t is constructed by utilizing:

- ⇒ Working Age Population = L
- ⇒ Labor Force Participation Rate = $(1-u)$
- ⇒ Employment Rate = l
- ⇒ Human Capital/Worker = h

$$\rightarrow L_t = H$$

$$H = L * l * (1-u) * h$$

$$lnH = lnL + lnl + ln(1-u) + lnh$$

K_t is constructed by considering the capital stock and taking the log:

$$\rightarrow K_t = C$$

$$lnK = lnC$$

Lastly, we plug in all our newly derived equations:

$$\Delta A = \Delta Y - [a\Delta K + (1-a)\Delta H]$$

$$ln\Delta A = ln\Delta Y - \mathrm{a}\Delta \ln K + (1-a)\Delta \ln H$$

The resulting final function is:

$$lnA = lnY - a\ln C + (1-a)(lnL + lnl + ln(1-u) + lnh)$$

Chapter 5

Variables

5.1 Discussion of Individual Variables

The Solow Growth Model fosters 3 main variables: technology, capital, and labor. Measuring said variables is difficult given the generalized nature of each of them. In such, a more specific view of labor and technology is required for a transparent analysis of economic growth. **Labor** will be measured through as the **working age population** multiplied by the **labor force participation rate**, the **employment rate**, and **human capital per worker**; to ensure consistent metrics, working age population will be measured as a constant: ages 15-64. **Capital** is a function of **capital stock.** Lastly, **change in the Solow residual** will be correlated with the evolution in **domestic primary education enrollment**, **patent applications**, and **research and development expenditure**.

Labor force participation rate and unemployment rate are good measures for labor in the Solow growth model because they account for the percentage of the working population that is currently employed; this will provide the analysis with a foundation of how working percentages contribute to economic growth. Human capital per worker allows for a direct analysis of labor productivity. Human capital per worker is calculated through indexing a certain element within human capital- in this case it is education. The statistic is then measured per worker in an economy. Capital investment will supply a numerical value of how much each specific country is contributing to the expansion of the physical production process. Gross fixed capital formation is the acquisition of productive assets, in laymen’s terms, investment. Domestic education is one of the largest divergences seen between the United States and China, and it is also one of the largest growing realms in China currently. As education improves, innovation and in turn technological change will cause a large shift in economic prosperity. Therefore, the change in primary education enrollment will serve as a good metric to measure educational improvement. Patent applications provide specific statistics for how much a country is innovating and inventing new things. The trend in patent applications shows if a country is improving their innovation sector, and it gives economists a measure of technological advancement. Lastly, research and development expenditure provides a clear view of the priorities of a specific country. If a country begins to spend and invest more into research and development, it is a safe assumption that their technological development will improve.

In the United States, the labor force participation rate is calculated by the Bureau of Labor Statistics monthly. It is the number of employed people plus the number of unemployed people divided by the total civilian noninstitutional population. In China, it is estimated by the ILO instead of a bureau like in the United States. Despite providing a monthly labor survey, China's methodology and the data produced are sometimes questioned by Western entities in terms of validity. Unemployment rate is calculated by dividing the number of unemployed people looking for work by the total number of people in the labor force. Economists use capital stock in analysis by comparing the contribution to GDP that capital stock provides on a year-to-year basis. If it represents a higher percentage one year than the last, it is assumed that stock was higher and therefore capital increased in the Solow Growth Model. Lastly, when observing technological growth, it is usually the hardest to materialize an actual numerical value for it. This lack of empirical validity has caused argument on which specific aspect of technological change causes the changes observed in economic growth through the Solow Growth Model. Even still, it will be related to domestic improvements in education not captured by the human capital index. Variables like number of schools built, the increase or decrease in brain drain-sponsored education, and quality of management indisputably influence technological growth; however, obtaining data on such variables is next to impossible. That is why generalized variables like patent applications, research and development expenditure, and primary school enrollment are used to measure technological growth. Productivity change, however, grants the best examination of the change in technology that a country faces. If labor force productivity increases, it could be a consequence of a multitude of variables. However, productivity is most associated with an increase in technology due to heightened innovation or a positive technological change to the process of production- i.e., replacing certain aspects of production like a machine with a more efficient machine.

5.2 Culture Divergence (variable analysis)

The United States and China have always been very different countries in terms of religion, politics, ethics, and philosophy. However, economically over the past 50-or-so years, commonalities have arisen consistently with the shifting of China as a whole. China has always been at odds with America in how the country should be run economically, and because of that reality alongside very questionable government decisions, China’s economic growth has been slower than the United States for much of the last 300 years. In the changing landscape that

China has endured, things such as women's rights, China's social and structural hierarchy, and the speed of business transactions have all drastically changed. Each of these changing aspects of Chinese culture greatly differs with that of the United States.

In America, women were not granted the right to vote until 1920. In China, women were gained suffrage on a national level in 1949 (Tian, Zheng, Female Labor Force in Reform-era China). Even though Chinese women were granted the right to vote just 30 years following the United States, they still faced harsh restrictions on property ownership and mobility in the workforce (Tian, Zheng). Consider the divergence in suffrage to the workforce: in America, women were stay-at-home bound until around 1960. In China, the economy experienced the same shock to the labor force as America did (Steven, Women Workers in China). Before the 1960s, the employment rate for women in China was negligible. However, once the Cultural Revolution began in 1966 and subsequently Mao Zedong's reign started, China experienced the first wave of women entering the workforce. Therefore, the 1960s brought on a supply shock to the labor force for both countries under the labor force and the labor force participation rate (Tian, Zheng, Female Labor Force in Reform-era China). The introduction of half the population contributed to a huge economic surge in terms of GDP, productivity, and production in general which is depicted in the data collected from the World Bank database on GDP. In the United States, the 1960s and 1970s saw much of the same trend once women joined the workforce. This shows that the changing of ideals in China led to a large production shock paralleled with the United States.

Another aspect of Chinese culture that differs from American culture and caused a change in economic growth rate is the difference in social/structural hierarchy. In the United States, it is not unheard of to have first-hand contact with a C.E.O. or a boss. However, in China, it is extremely rare to have relationships with far-up superiors on a first name basis, or really any basis at all; that is because of the honor code they live by and the stringency in cultural norms that exist in China. Even still, it is not just contact with superiors; in the United States, companies are touted around the world as offering unprecedented access to job mobility and opportunities to climb the ladder and reach the top. A general thought is that an entry level worker could one day become a board member if they work hard enough- that concept is what drives immigrants and workers from all over the world to the United States. Whether or not there actually exists the commonly perpetuated upward mobility in the United States is questionable. Even still, the thought of the “American Dream” is key to many companies attracting workers. However, in China, job mobility was essentially non-existent before the mid-twentieth century. It was extremely hard for an individual to work up from a basic position into a supervising role and higher (Du, Chinese Perceive Upward Mobility). This unfortunate aspect of Chinese business demotivated workers and lowered productivity. Economists assume rationality for producers and consumers. In a labor market, the concept that workers respond to incentives is a key assumption of rationality. If an underling or entry-level worker had little-to-no mobility within the company, they simply did not work as hard as they would have if they were granted an incentive like promotion for their work. However, again, progressivism is rapidly moving throughout most of the world and China’s experience is no different. Chinese values are changing such that in recent years, job mobility has changed. People are now able to achieve job titles they would not have dreamed of 50 years ago (Steven, Women Workers in China). Due to this positive shock in job mobility- productivity has increased, and in turn overall GDP was improved through the increase. Alongside job mobility is social mobility. Chinese social mobility has increased within the past 30 years as well (Du H, Chinese Perceive Upward Mobility). Under the same conceptual increase that was seen in job mobility, social mobility creates a positive change in GDP as well.

Lastly, business transactions produce yet another divergence when comparing the United States and China. Even though on the surface, speed in which business leaders complete their agreements and other things may not seem like a cultural hiccup, it is. In the United States, the hustle and bustle of everyday life is a given, and it is no different in China. However, where the two countries differ is in each country's respective speed for which they desire closing business deals. American culture has always been to provide every aspect of one's life with the most efficient way of doing things no matter the cost- business life is no different. C.E.O.s are constantly making deals and decisions under the assumption that the current amount of information they have is enough to make a fair and optimal choice at the specific time. They want to optimize timesaving and risk in an efficient way. However, Chinese culture with respect to business deals is essentially the opposite. Chinese business makers prioritize gathering all the available information possible and making an extremely calculated decision that will benefit their company (Differences in American and Chinese Business Customs). They strive to become acquainted with everyone they make deals with whether that acquaintance is having dinner or sharing a drink. While this aspect of business may make things slower, they become more personable with their new business partners. Even still, with most of the country conducting deals at a slower rate than the United States, it will cause inefficiencies on a large scale at the end of the day.

Overall, cultural differences between the United States and China have always been a talking point in the economic world. The reasoning behind the exponential explosion of China's economy in the past 30 or so years is realized in the cultural comparisons between these two countries without question. Some aspects of Chinese culture that at are odds with the United States and inadvertently negatively impact Chinese economic growth are the restrictions that were in place regarding women and their place in daily life/the workforce, the stagnation in social and structural hierarchy, and the speed of business deals. In each of these cases, there is a core difference between America and China. However, over the past 50 years, Chinese culture has been changing; with that being said, the particular facets listed above are changing right alongside it.

After the Tiananmen Square incident in the late 1980s, China faced a complete overhaul of their long-standing institutions (Barron). Rapidly, China began undergoing a foundational change that contributed to their exponential economic growth and education evolution. Prior to this jurisdictional change, China's overall economic platform was inefficient in a multitude of ways. Since then, their culture has been shifting alongside the rest of the world and their country is reaping the benefits. As Chinese culture and the culture seen in the economic spectrum in the United States become more and more similar, the Chinese economy is bound to grow.

Chapter 6

Data Collection

The collection of data for this thesis proved to be an uphill task given the lack of accessible data and information on many aspects of China's economy. The labor force participation rate was a figure that I was confident would be readily available for both the United States and China. However, the most recent data for the Chinese labor force participation rate I could find enclosed in any credible database was listed on the World Bank open-source database, and the years ranged from 1990-2019. However, as assumed, the United States labor force participation rate was fully available from 1960-2019 on the World Bank database.

GDP for each country was readily available for both the United States and China from 1960-2019 on the Federal Reserve Economic Database and the World Bank open-source database respectively. I feel confident in concluding that both data sets are credible and reflect accuracy in their elements.

The unemployment rate was another variable that seems like it is an extremely important figure to keep, yet the only time set that was offered for China was 1990-2019. Neither FRED nor World Bank had data on China's unemployment rate prior to 1990. However, once again, the United States' unemployment rate was gathered from the World Bank open-source database from 1960-2019.

Human capital per worker was collected from the Federal Reserve Economic Database for both the United States and China from 1960-2019.

Capital stock was also gathered from 1960-2019 for both the United States and China, and the data was collected from the World Bank open-source database.

Gross fixed capital formation was gathered for the United States from the Federal Reserve Economic Database and for China from the World Bank open-source database. Both data sets were gathered from 1960-2019.

Capital investment was only found from 1970-2019 for China, and the data was collected from the World bank open-source database. For the United States, capital investment ran from 1960-2019, providing a full data set from the Federal Reserve Economic Database.

Patent applications was the first variable in which the data for the United States faltered. For both China and the United States, the years available ranged from 1980-2019. The data for both countries was collected from the World Bank open-source database.

Research and development expenditure was another variable in which both countries suffered heavy blows to the years that were available. The only data on research and development expenditure that was accessible was found on the World Bank open-source database, and the years ranged from 1996-2019.

Lastly, primary school enrollment was collected from the World Bank open-source database for both the United States and China. The years available were scattered for both countries, with years ranging from 1970-2019.

Overall, data on each of these representative variables have been collected from both the Federal Reserve Economic Database (FRED) and the World Bank open-source database. Therefore, I feel very confident in concluding that the data I gathered is valid and verifiable. My calculations are accurate based on the data that was collected. Even though some of the variables had missing ranges of time, that is a limitation of working with older Chinese economic data.

Chapter 7

Results

7.1 Numerical Analysis

Essentially all mathematical calculations were completed through STATA; the code and outputs are listed within the appendices. This thesis stands to compare differences in total factor productivity between China and the United States by solving a Cobb-Douglas production function for productivity growth, and further regressing different contributing explanatory variables of A onto TFP. By regressing the different explanatory variables of A onto itself, the regression results provide insight into which variable causes the largest change in TFP.

The Solow residual is calculated by subtracting the labor variable times the share of labor and the capital variable times the share of capital from GDP. Next, this thesis utilizes three different independent variables to explain the Solow residual: patent applications, research and development expenditure, and primary school enrollment. After solving for TFP through the method described above and in Chapter 4 – The Solow Residual, regressions can be conducted.

First, a clear vision of the OLS regression model being utilized is listed:

$$\ln\left(A_{c_t}\right) = \beta_0 + \beta_1 \ln(pa_{ct}) + \beta_2 \ln(pse_{ct}) + \beta_3 \ln(rde_{ct}) + \varepsilon_{ct}$$

Where β_0 is the coefficient of the intercept point, β_1 is the parameter, or the coefficient, on patent applications, β_2 is the parameter on primary school enrollment, β_3 is the parameter on research and development expenditure, and ε_t is the error term. Also, t indicates the year and c indicates the country.

7.1.1 United States

The regression results for the United States are listed below:

Figure 2: ***Regression Results for United States***

```
. reg Aus lnpaus lnpseus lnrdeus
```

Source	SS	df	MS			
				Number of obs	=	10
				F(3, 6)	=	156.24
Model	.508301829	3	.169433943	Prob > F	=	0.0000
Residual	.006506862	6	.001084477	R-squared	=	0.9874
				Adj R-squared	=	0.9810
Total	.514808691	9	.057200966	Root MSE	=	.03293

Aus	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnpaus	.5037156	.0950791	5.30	0.002	.2710654	.7363658
lnpseus	1.6438	1.545867	1.06	0.329	-2.1388	5.4264
lnrdeus	1.154416	.5474938	2.11	0.080	-.1852529	2.494085
_cons	-10.36617	7.755984	-1.34	0.230	-29.34438	8.612045

As the code suggests, the natural log of patent applications (lnpaus), the natural log of primary school enrollment (lnpseus), and the natural log of research and development (lnrdeus) expenditure were all regressed on Aus.

7.1.1a Correlation

The regression table presents a strong R-squared value at .9874; from this statistic, the

R-squared = 0.9874

conclusion that the three independent variables and total factor productivity have an extremely strong correlation is reached. The correlation coefficient, R, turns out to be $\pm$ 0.9937. Next, observe the coefficients on each of the regressors- if the coefficient is positive, it insinuates the correlation between that specific regressor and the dependent variable is negative; the same can be said about a negative coefficient value. In such, after considering all the regressors' parameter signs, all correlations are positive.

7.1.1b Mean Squared Error

The root MSE is listed at 0.03293. This figure provides the analysis that the standard

Root MSE	=	.03293

deviation of the residuals is very small. Since the standard deviation of the residuals is a small number, it is concluded that the residuals of each of the variables fall close to the line of best fit- meaning the data points do not vary from their respective averages.

7.1.1c Parameter Analysis

Next, consider the parameters listed for each of the independent variables. The coefficient on patent applications is 0.50372 with a standard error of 0.09508. A coefficient of .50372

lnpaus	.5037156	.0950791

suggest the interpretation that patent applications have a positive impact on changes in productivity; if there was a 1% increase in patent applications, it could possibly lead to an increase of about 0.5% in total factor productivity. This relationship may not be causal, so certainty on impact is not fully granted. The standard error of patent applications is 0.0951. This means that the standard deviation of $\boldsymbol{\beta_1}$ is 0.095- the coefficient moves approximately 0.1 away from the listed parameter value of 0.503720 for every 1 standard deviation accumulated. Most importantly, an analysis of each variable's p-value required. The p-value of patent applications is

0.002 with a t-score of 5.30. This means that the change in patent applications is a statistically

5.30	0.002

significant metric at an alpha level of .01. Lastly, I am 95% confident that the true parameter value of patent applications falls between [0.271, 0.736]. Overall, given a p-value of 0.002, we to reject H_0 at any alpha level and conclude a change in patent applications is significant with respect to a change in TFP in the United States.

The next parameter to be considered is β_2, the coefficient on primary school enrollment. First, the parameter value on the variable is 1.6438. This shows that for a 1% increase in primary

lnpseus	1.6438	1.545867

school enrollment, total factor productivity will increase by 1.64385. However, the standard error for this variable is 1.546. That is a significantly high value considering it is almost at a 1-to-1 ratio with the coefficient. The standard error being so high provides the insight that the results regarding primary school enrollment likely are not statistically significant. Consider the t-score and p-value of lnpseus: the t-score is only 1.06 which yields a p-value of 0.329. A p-value that

1.06	0.329

high fails to be significant at any value of alpha. Even still, I am 95% confident that the true parameter value of primary school enrollment falls withing the interval: [-2.1388, 5.2464]. Overall, given a p-value of 0.329, we fail to reject H_0 at any alpha level and conclude a change in primary school enrollment is not significant with respect to a change in TFP in the United States. Even still, since primary school enrollment rate is close to 100% during the sample period, there is insufficient variation in this variable to support accurate inferences.

Consider the parameter value on the variable research and development expenditure, β_3. The parameter value is 1.15442 and the standard error is 0.5475. Immediately, it is apparent that

lnrdeus	1.154416	.5474938

this result is much more significant than the result produced for primary school enrollment due to the smaller ratio between the coefficient and the standard error. The coefficient is positive, meaning there is a positive relationship between research and development expenditure and total factor productivity. A 1% increase in research and development expenditure leads to a 1.15442% increase in TFP. Given that the standard error is 0.54794, the standard deviation of the coefficient is approximately 0.55, and it is expected that the coefficient moves about 0.55 away from 1.15442 for every additional standard deviation. Next, consider the t-score and p-value to determine if the result produced is significant. With a t-score of 2.11, the p-value is 0.08. This

2.11	0.080

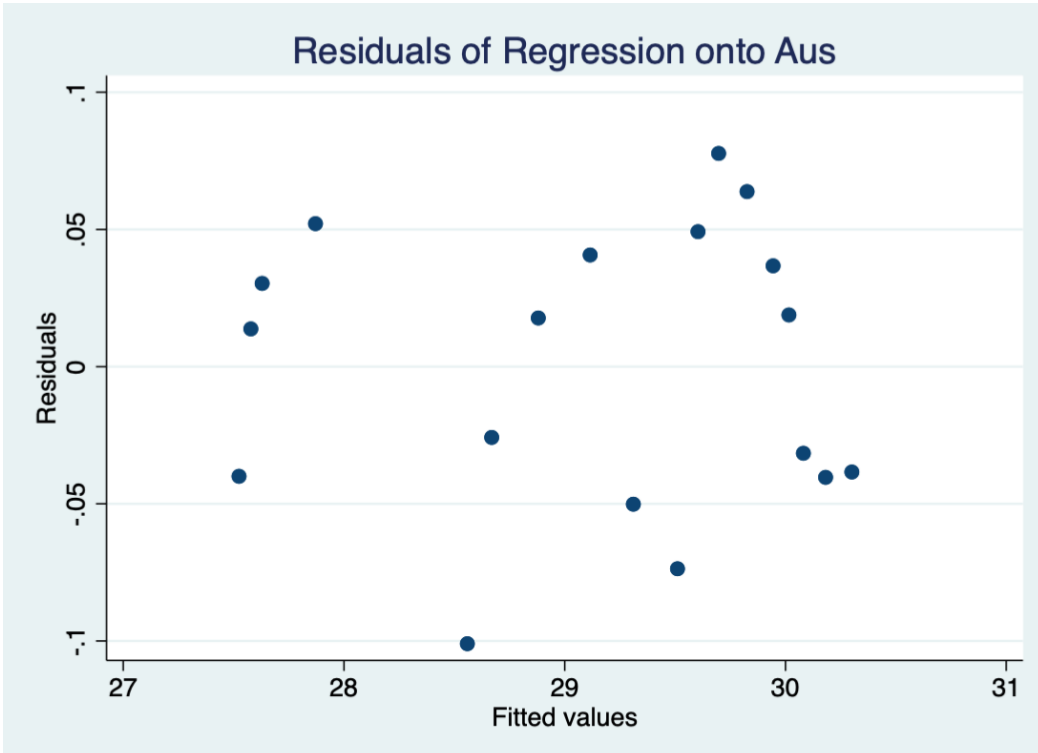
data shows that the result is significant only at an alpha level of 0.1. Therefore, while there exists significance at an alpha level of 0.1, compared to patent applications, the data is less significant. I am 95% confident that the true value of the coefficient is contained within [-0.18525, 2.4941]. Overall, given a p-value of 0.08 and an alpha level of .1, we reject H_0 and conclude a change in research and development expenditure is significant with respect to a change in TFP in the United States

The two independent variables shown to be statistically significant with respect to total factor production in the United States are patent applications and research and development expenditure. Patent applications is significant at any alpha level, and research and development expenditure is only significant at alpha = .1

7.1.1d Residual Analysis

The residual plot for the United States' TFP with the given regressors is depicted below:

Figure 3: ***Residual of the Regression onto TFP for United States***



Lastly, let us consider the residual graph that plots the residuals of the coefficients based on the OLS model of TFP for the United States listed above. A residual plot depicts the difference in the observed values and the fitted response values. If there is no funnel shape or obvious pattern in the graph, heteroskedasticity cannot be concluded. Since the absence of a heteroskedastic pattern is shown, and there exists no other obvious patterns, the linear model provides a good fit to the data.

The linear regression model that was produced by this regression for TFP in the US is

$$\ln(A_{c_t}) = -10.3662 + .5037 \ln(pa_{ct}) + 1.644 \ln(pse_{ct}) + 1.1544 \ln(rde_{ct}) + \varepsilon_{ct}$$

7.1.2 China

Next, the regression results for China regressing the same three independent variables of patent applications, primary school enrollment, and research and development expenditure onto the dependent variable of total factor productivity are listed below:

Figure 4: ***Regression Results for China***

```
. reg Ac lnpac lnrdec lnpsec

      Source |       SS           df       MS      Number of obs   =        18
-------------+----------------------------------   F(3, 14)        =     63.74
       Model |  5.77116722         3  1.92372241   Prob > F        =    0.0000
    Residual |  .422537598        14  .030181257   R-squared       =    0.9318
-------------+----------------------------------   Adj R-squared   =    0.9172
       Total |  6.19370482        17  .364335577   Root MSE        =    .17373

------------------------------------------------------------------------------
          Ac |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lnpac |  -.1743539   .2565872    -0.68   0.508    -.7246787    .3759709
      lnrdec |   1.302977   .2208176     5.90   0.000     .8293704    1.776584
      lnpsec |  -1.603316   1.758121    -0.91   0.377     -5.37411    2.167478
       _cons |    11.9694   8.398253     1.43   0.176    -6.043059    29.98187
------------------------------------------------------------------------------
```

The natural log of patent applications (lnpac), the natural log of primary school enrollment (lnpsec), and the natural log of research and development (lnrdec) expenditure were all regressed on Ac.

7.1.2a Correlation

When considering regression outputs, let us first delve into the values for R-squared and root mean-squared error for the model. The R-squared value is 0.9318; another strong correlation

```
R-squared       =    0.9318
```

between the independent variables and TFP. From the R-squared value, the correlation coefficient can be calculated; it turns out to be ± 0.9653. However, to analyze if $R > 0$ or $R < 0$, a simple observation of the parameter values will grant the result. The signs on the parameters for patent applications and primary school enrollment are negative, whereas the sign on the parameter for research and development expenditure is positive. This means that the correlation between the two dependent variables: patent applications and primary school enrollment, and the dependent variable TFP is negative. However, the correlation between research and development expenditure and TFP is positive. Overall, it is observed that there is a strong negative correlation between patent applications and TFP, a strong negative correlation between primary school enrollment and TFP, and a strong positive correlation between research and development expenditure and TFP.

7.1.2b Mean Squared Error

Observing the Root MSE, the value is 0.17373- a much larger value than that of

```
Root MSE        =    .17373
```

America’s. Since the mean-squared error is so high, it provides the interpretation that the values of the residuals are high, and the variance/bias in these estimators is large. In turn, the points in these data vary greatly from their averages.

7.1.2c Parameter Analysis

The first variable to be considered is patent applications in China. The parameter value for patent applications is -0.17435 with a standard error of 0.25659. It should be readily apparent

```
lnpac |   -.1743539   .2565872
```

that these results are very questionable based on the standard error presented. The standard error is about 1.5 times that of the absolute value of the coefficient, meaning the data's variance and bias is very high. Even still, a coefficient of -0.17435 provides context that a 1% change in patent applications leads to a -.01744% change in total factor productivity. Next, consider the p-value of β_1 in China: 0.508 with a t-score of -0.68. This figure shows that this data is not statistically

-0.68	0.508

significant at any alpha level. Therefore, we cannot conclude that a change in patent applications has any effect on a change in total factor productivity in China. Even though the data for this independent variable is proved to not be statistically significant, I am 95% confident that the true parameter value falls within the interval [-0.7247, .37597]. Overall, given a p-value of 0.508, we fail to reject H_0 and conclude a change in patent applications in China is not a statistically significant variable and does not cause changes in total factor productivity at any alpha level.

The second independent variable listed in the regression is primary school enrollment. The coefficient is once again a negative value at -1.60332. This coefficient depicts a negative

lnpsec	-1.603316	1.758121

relationship between a change in primary school enrollment and a change in TFP; a 1% increase in primary school enrollment will lead to a -1.60332% change in TFP. However, the standard error is greater than a 1-to-1 ratio with the coefficient, meaning it is likely the data isn't viable since the standard deviation is so high. For every-one standard deviation traveled away from the mean, the value changes by 1.758. The p-value of primary school enrollment is 0.377 with a t-score of -0.91. Once again, the data is not statistically significant at any alpha level. Nonetheless,

-0.91	0.377

I am 95% confident that the true parameter value of primary school enrollment in China is captured within the interval [-5.37411, 2.16748]. Overall, since the hypothesis test produced a p-value of 0.377, which is greater than the value of alpha at any level, we fail to reject H_0 and conclude that a change in primary school enrollment does not influence total factor productivity in China.

The final independent variable that was regressed onto the Solow residual for China is the change in research and development expenditure. The parameter, β_3, is calculated and has a value of 1.303. Since the coefficient is a positive value, a positive relationship between the

lnrdec	1.302977	.2208176

change in research and development expenditure and a change in TFP. A 1% increase in the independent variable leads to a 1.303% increase in TFP. The standard error of the regressor is very small compared to the coefficient- listed at 0.221; from this, the result that the data for research and development expenditure does not have a high standard deviation, and it surrounds the mean very well. The t-score and p-values depict statistical significance at values of 5.90 and

5.90	0.000

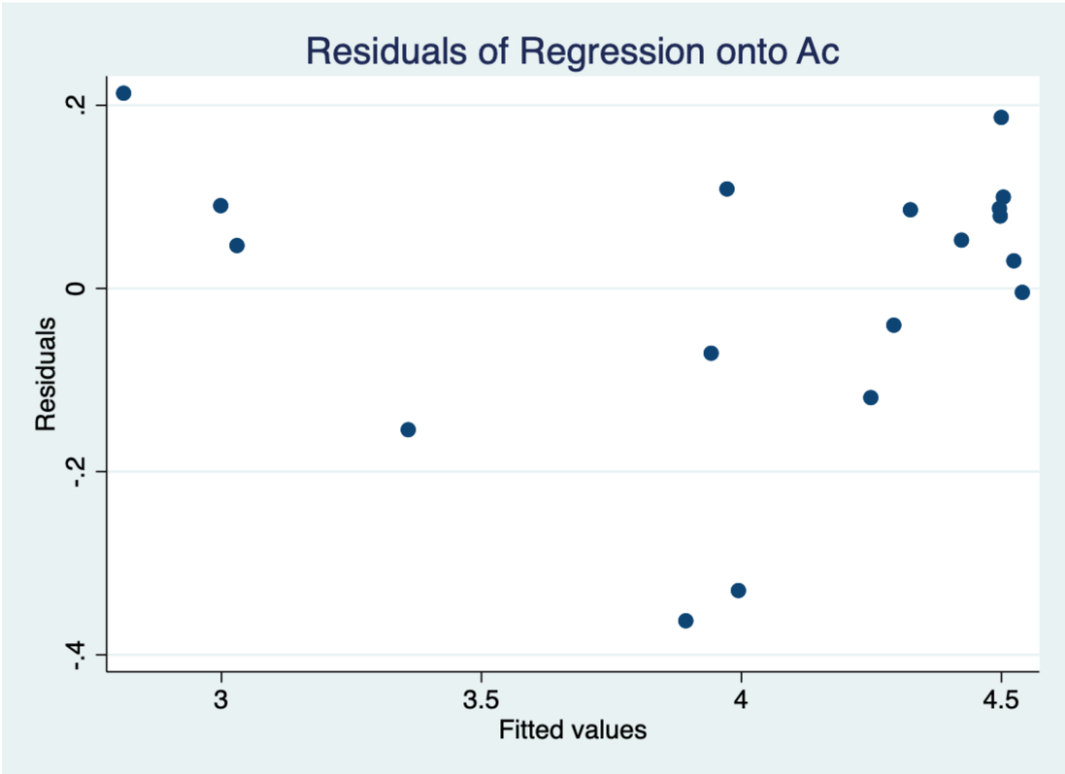
0.000 respectively. I am 95% confident that the true parameter value of research and development expenditure falls within the interval [.8294, 1.7766]. Overall, since the hypothesis test produced a p-value of 0.000, which is less than the value of alpha at any level, we reject H_0 and conclude that a change in research and development expenditure influences a change total factor productivity in China or vice versa.

The only independent variable that is shown to be statistically significant with respect to total factor production in China is research and development expenditure. This variable is significant at any alpha level.

7.1.2d Residual Analysis

The residual plot for China's TFP with the given regressors is depicted below:

Figure 5: ***Residuals of Regression onto TFP for China***



Lastly, let us consider the residual graph that depicts the residuals of the coefficients based on the OLS model of TFP for China listed above. The plot does show any prominent patterns or a cone-shape surrounding the line of best fit, the linear model provides a good fit to the data. There is a cluster on the right-hand side at approximately fitted values = 4.5; this shows that not all the fitted values listed in the graph are equally frequent.

The linear regression model that was produced by this regression for TFP in China is

$$\ln\left(A_{c_t}\right) = 11.9694 - 1.1744\ln(pa_{ct}) - 1.6033\ln(pse_{ct}) + 1.303\ln(rde_{ct}) + \varepsilon_{ct}$$

7.2 Time Trend

The inclusion of a time trend in each regression allows for comparing the total factor productivity over time between China and the United States. After the regressions on TFP were run with the given independent variables listed above as regressors, time was included as a time trend variable. The outputted results of the coefficient on the time variable- year, are listed below.

year	.0248779

year	.0774902

The left graphic shows the parameter value on year for the United States, whereas the right graphic shows the parameter value on year for China. The coefficient on the time variable in OLS regression represents the rate in which the dependent variable changes with respect to time. Therefore, from here, an obvious difference is presented. For every increasing year (t+1), the United States experiences a .025% increase in total factor productivity whereas China experiences a .077% increase in total factor productivity. This result shows that China's Solow residual has been increasing at a rate 3x that of the United States from 1960 to 2019. Since both coefficients are positive, total factor productivity increases with time for both the United States and China.

7.3 Qualitative Analysis

The conclusions that were generated from the respective regressions ran on total factor productivity by patent applications, primary school enrollment, and research and development expenditure provide access to develop qualitative reasoning for the differences exposed between the United States and China.

The two significant variables observed in the United States regression were the change in patent applications and the change in research and development expenditure. Divergently, patent applications failed to gain a significant p-value when it came to the data collected for China even though the regression produced significance with respect to research and development expenditure. With the knowledge of how the Chinese economy has evolved over the past 60 years, it is readily apparent that patent applications simply were not a priority in the development of technology for the early half of the twentieth century (Bray). Since Eastern-Asian cultural customs failed to generate the drive of capitalizing off inventions and new innovative tendencies compared to Western cultures, subsets of innovations such as patent applications were negligible

Figure 6: Scatter*plot of Patent Applications by Year in China*

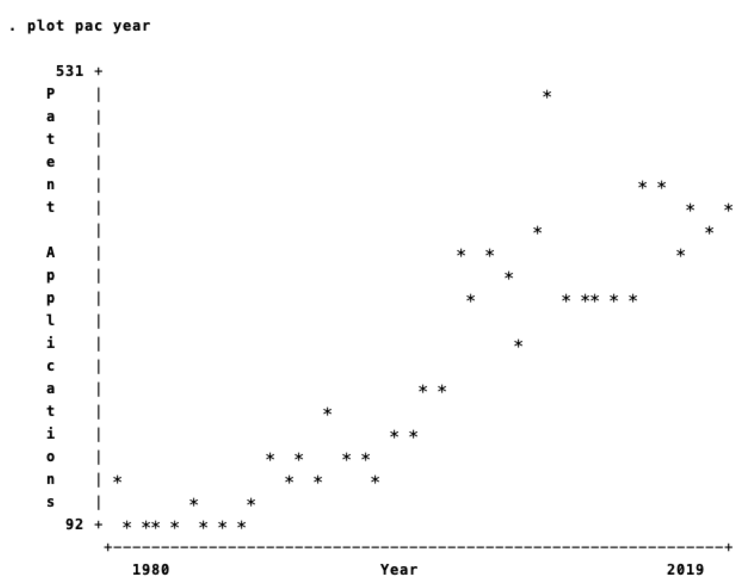
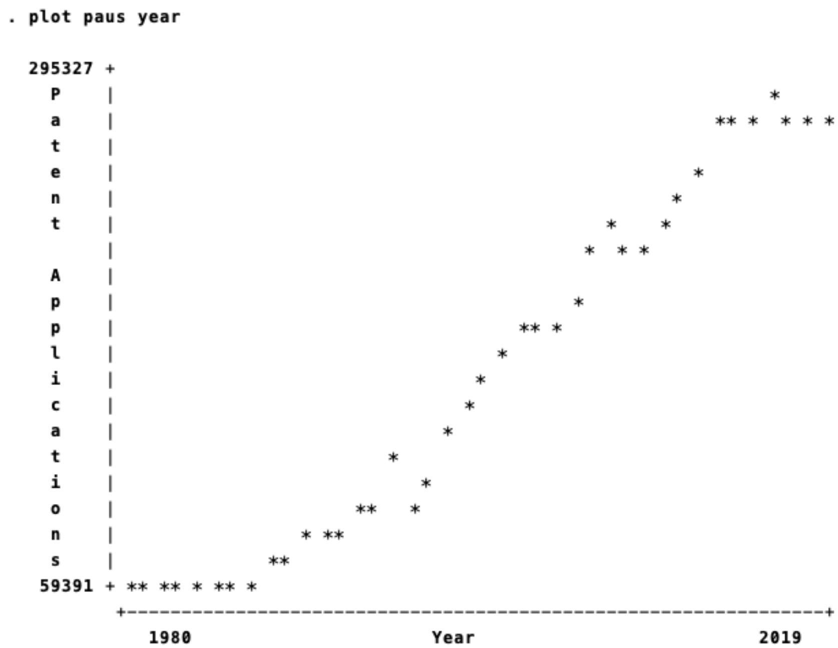


Figure 7: Scatter*plot of Patent Applications by Year in the US*



(Bray). However, in the United States, the mid to late-twentieth century gave way to arguably the largest explosion in patent applications in the history of the country. As observed in the above graphs, the United States has experienced a much steeper and consistent rise in patent applications since 1980. Therefore, it is safe to assume that the difference observed between the culture in the United States and China regarding innovation is a key reason total factor productivity is affected differently.

The difference observed in the effect regressing research and development on TFP had between the countries was fairly substantial. The t-score for (rde) in China was 5.9 compared to a t-score of 2.11 seen in the United States. This difference in significance provides the context that an increase in research and development expenditure in China would lead to a larger change in TFP than an increase in research and development expenditure in the United States. A potential qualitative reasoning for the difference observed here is that the United States is already investing much more into their research on average than China is. Therefore, the United States would be experiencing a higher amount of diminishing marginal returns on investment compared to China. If China were to increase their governmental spending of research and development, the return on investment would be higher than that of the United States' based on the higher value of the coefficient on R&D in China compared to America. Evidence for the current difference in expenditure is granted by Figure 8. The mean of the expenditure seen in the United

Figure 8: ***Difference in mean expenditure by Country***

```
. mean rdeus rdec

Mean estimation                    Number of obs   =         23
```

	Mean	Std. Err.	[95% Conf.	Interval]
rdeus	2.648436	.0248849	2.596828	2.700045
rdec	1.427239	.1112838	1.196451	1.658028

States is 2.65, whereas the mean of expenditure in China is 1.43- granting a ratio of approximately 1.85. Both figures are expressed as percentages of each respective country's GDP. If we compare this to the ratio of GDP for each respective country, 0.3814. we see that the United States is already spending much more of their GDP on research and development based on ratio comparison. Therefore, the assumption that the United States faces higher diminishing marginal returns by investing more into their research expenditure than China does is fair.

Since primary school enrollment for both countries produced insignificant results, it is unnecessary to compare the differences in statistics observed in the regression output. However, a substantial qualitative reason supporting the general increase in GDP observed in the 1960s for both countries is the introduction of women in the workforce. In both the US and China, the 1960s and 1970s gave way to an explosion into the labor force of millions of women. From this, GDP grew exponentially for both China and the US (Tian, Zheng).

Chapter 8

Conclusion

This thesis considered differences in the growth rates of total factor productivity observed between China and the United States from 1960-2019. Total factor productivity was calculated by subtracting the labor share multiplied by a labor function and the capital share multiplied by capital stock from each country's respective GDPs. From here, the sub-variables that are assumed to contribute to changes in the Solow residual such as patent applications, research and development expenditure, and primary school enrollment were regressed on the calculated TFP to determine which variable caused the largest change in productivity.

The results that were produced through each country's specific regression analysis insinuated research and development expenditure was the only variable of the three to be significant for both countries. A difference observed between outputs was seen in the proposed parameter and p-value figures for patent applications. Patent applications were significant at an alpha level of .1 for the United States but were insignificant for any alpha level in China. Primary school enrollment was an overall insignificant variable for both countries and failed to contribute any real change to the total factor productivity.

The difference seen in patent application significance can be attributed to the divergence in priorities between China and the United States regarding their respective innovation sectors. The United States and other Western countries prioritize fame and fortune granted through invention, while Eastern countries generally fail to focus on potential gains from invention (Bray). Therefore, it is understandable that patent applications in China will be increasing at a lower and much less consistent rate than in the United States.

Research and development expenditure differences can be justified by the contrast in the rates of diminishing marginal returns in expenditure investment each country individually experiences. Since the United States has a higher rate of diminishing marginal returns than China, they will be less incentivized to invest more into research and development than China will. In such, China's return on investment is higher and they have more incentive to spend more building up this specific sector of their economy.

Overall, the Solow residual provides economists and governments insight into what aspects of production yield the highest changes in total factor productivity. If there is a clear view to the instrumental variables that increase or decrease the Solow residual, governments and financial institutions can allocate more effort towards them. This thesis utilizes the Solow residual as a method of comparison between the United States' and China's respective changes in productivity. In such, based on the quantitative reinforcement provided by Chapter 7, the United States should invest more in research and development while also promoting patent applications. Both independent variables cause significant increases in total factor productivity. China should invest heavily into their research and development as well, while ignoring increasing patent applications. Doing this will increase their country's total factor productivity- in turn increasing GDP and improving their economy in general by making workers more productive.

I began this project with the hopes that I could gain a better understanding of the reasoning behind the polarity seen between China and the United States in terms of productivity. I also was hoping to provide a qualitative reason for said differences based on my knowledge of Chinese history and culture granted by my minor. Interestingly enough, the difference in each country's Solow residual wasn't as abrupt as I initially expected it to be. Both countries' economies have grown mass amounts, but the growth rate that China experienced was much larger due to having a smaller initial economy. Regardless, even though the economies have fundamental differences in policy, the data within this paper showed they are not as different as the regular perception exhibited in daily media.

Chapter 9

Limitations

This thesis dealt with a fair amount of data and instrumental variables that were utilized in capital, labor, and technology functions. However, economies are vast- especially when considering the sheer magnitude of the two largest economies in the world. It is apparent that some explanatory power of omitted variables was lost in the error terms of the regressions. Variables such as birth rate, urbanization, graduation rate, etc. could have been included in my calculations. However, due to the inability to account for every variable that could have some effect on GDP, and the reality that endogeneity could be present with the inclusion of too many variables, I decided to include only the variables listed above in the growth accounting model.

Another concern that was apparent while crafting this thesis was that I simply failed to have first-hand experience with Chinese culture. I have a minor in Chinese, and through that I was required to take multiple cultural classes which presented a lot of information. I also utilized many scholarly articles relating to Chinese culture and how it has changed since the mid 20th century. However, I recognize that there is potential for bias to come through in some instance, especially when analyzing categorical reasoning and explanations behind some of the results. What may seem completely surprising to me may seem like a very normal realization to someone who lives in China.

In my opinion, the largest potential problem that could have developed while completing this thesis is that there was unbalanced panel data due to inconsistent time-series entries for certain variables. Since the crux of this thesis was to analyze the total factor productivity, or the Solow residual, the data surrounding investment/technology (A) is important. However, (A) is where the data was lacking the most. There are multiple missing entries when it comes to patent applications, primary school enrollment, and research and development expenditure. Therefore, the produced metrics of the Solow residuals for both China and the United States could be skewed or incorrect.

Lastly, I feel as though endogeneity could potentially be a problem for my regressions ran at the end of the program. I regressed patent applications, primary school enrollment, and research and development expenditure onto the total factor productivity. Research and development expenditure has the potential to respond to productivity shocks, as businesses and the government does not have unlimited budget to spend. If endogeneity is present in the regression analysis, the parameter values on the independent variable, research and development expenditure, will be underestimated since some of the weight is caught up in the error term. One way to deal with endogeneity if it was apparent in these results is to utilize instrumental variables. Two stage least squares analysis could have offset endogeneity and revalidated the outputs granted by the OLS regression.

Appendix A

Code

```
> *COMPARISON OF ECONOMIC GROWTH RATES BETWEEN CHINA AND AMERICA >
DEPENDENT ON SOLOW GROWTH MODEL VARIABLES
> *Honors Thesis
> *James Perry
>
> clear
> use "/Users/jamesperry/Downloads/Honors Thesis/Current work/thesis_data.dta"
>
> log using thesisdataanalysis_log
>
> *--------------------------------------US--------------------------------------*
>
> gen lnwapc = ln(wapc)
> gen lnwapus = ln(wapus)
> /* H represents the labor function within the prodcution function */
> /* Calculating the labor function below for the United States */
> rename yus Yus
> rename yc Yc
>
> *employment rate US
> gen erus = 100-urus
>
> *ln(age dependency ratio) US
> gen lnadrus = ln(adrus)
>
> *ln(enployment rate) US
> gen lnerus = ln(erus)
> gen Hus = lnwapus+lnlfprus+lnerus+lnhcpwus
> list Hus

> /* K Represents the capital function within the production function */
> /* Calculating the capital function below for the United States */
> gen Kus = lncsus
> list Kus
>
> /* Since we now have change in GDP, change in Labor, and change in Capital for the US, we
> can calculate the Total Factor Productivity, or the Solow Residual */
> /* Set the change in A equal to the following equation */
> /* Use the alpha measures given by the labor share from FRED */
>
> gen alphaus = .69
```

```
> gen Aus = Yus - alphaus*Hus - (1-alphaus)*Kus
> list year Aus
>
> *-------------------------------------CHINA-------------------------------------*
> /* Hc represents the labor function within the production function */
> /* Calculating the labor function below for China */
> *employment rate china
> gen erc = 100-urc
>
> *ln(age dependency ratio) china
> gen lnadrc = ln(adrc)
>
> *ln(employment rate) china
> gen lnerc = ln(erc)
> gen Hc = lnwapc+lnlfprc+lnerc+lnhcpwc
> list Hc
>
> /* K Represents the capital function within the production function */
> /* Calculating the capital function below for China */
> gen Kc = lncsc
> list Kc
>
> /* Since we now have change in GDP, change in Labor, and change in Capital for China, we
> can calculate the Total Factor Productivity, or the Solow Residual */
> /* Set the change in A equal to the following equation */
> /* Use the alpha measures given by the labor share from FRED */
> gen alphac = .59
> gen Ac = Yc - alphac*Hc - (1-alphac)*Kc
> list year Ac
>
> * REGRESSING DIFFERENT INDEPENDENT VARIABLES ON Aus AND Ac *
> gen DA = Aus/Ac
> list DA
> reg Aus lnpaus lnpseus lnrdeus
> reg Ac lnpac lnrdec lnpsec
> * REGRESSING THE INITIAL INDEPENDENT VARIABLES ON Yus AND Yc *
> reg Yus Hus Kus lnpaus lnpseus lnrdeus
> reg Yc Hc Kc lnpac lnrdec lnpsec
>
> plot paus year
> plot pac year
> plot rdeus year
> plot rdec year
> mean rdeus rdec
> log close
> translate thesisdataanalysis_log.smcl thesisdataanalysis_log.pdf
```

Appendix B

Data/Regression Output

Figure 9: ***Hus: Labor Function for US; Kus: Capital Function for US***

```
21 . list Hus
```

	Hus
1.	28.21457
2.	28.23751
3.	28.23991
4.	28.28123
5.	28.31072
6.	28.3465
7.	28.38155
8.	28.42085
9.	28.44847
10.	28.48697
11.	28.52378
12.	28.53786
13.	28.56968
14.	28.61109
15.	28.65827
16.	28.68014
17.	28.68198
18.	28.72647
19.	28.77329
20.	28.81704
21.	28.84588
22.	28.8501
23.	28.86238
24.	28.85367
25.	28.87553
26.	28.91823
27.	28.94415
28.	28.9658
29.	28.99239
30.	29.01986
31.	29.04103
32.	29.04597
33.	29.05177
34.	29.0582
35.	29.08372
36.	29.10706
37.	29.12782
38.	29.15065
39.	29.16861
40.	29.1887
41.	29.21755
42.	29.22844
43.	29.23077
44.	29.23375
45.	29.2402
46.	29.26058
47.	29.28218
48.	29.30245
49.	29.31453
50.	29.30515
51.	29.26946
52.	29.26809
53.	29.28574
54.	29.29938
55.	29.31181
56.	29.33396
57.	29.35786
58.	29.37035
59.	29.38803
60.	29.40324
61.	.

```
27 . list Kus
```

	Kus
1.	16.50417
2.	16.53715
3.	16.57296
4.	16.61044
5.	16.65012
6.	16.69204
7.	16.73495
8.	16.77373
9.	16.812
10.	16.84855
11.	16.87912
12.	16.90922
13.	16.9425
14.	16.9781
15.	17.00745
16.	17.0292
17.	17.05438
18.	17.08431
19.	17.11884
20.	17.15392
21.	17.18223
22.	17.20902
23.	17.22998
24.	17.25354
25.	17.2844
26.	17.31687
27.	17.34824
28.	17.37786
29.	17.40633
30.	17.43406
31.	17.45897
32.	17.47874
33.	17.49921
34.	17.52083
35.	17.54411
36.	17.56813
37.	17.59419
38.	17.62167
39.	17.65163
40.	17.68312
41.	17.71482
42.	17.74212
43.	17.76533
44.	17.78927
45.	17.81505
46.	17.84237
47.	17.8686
48.	17.89161
49.	17.90955
50.	17.91833
51.	17.92728
52.	17.93735
53.	17.94965
54.	17.96234
55.	17.97633
56.	17.99079
57.	18.00477
58.	18.01935
59.	18.03513
60.	18.05047
61.	.

Figure 10: ***Aus: Solow Residual for US listed by year***

```
35 . list year Aus
```

	year	Aus
1.	1960	2.436029
2.	1961	2.446147
3.	1962	2.505341
4.	1963	2.519883
5.	1964	2.558211
6.	1965	2.601688
7.	1966	2.655347
8.	1967	2.672281
9.	1968	2.731167
10.	1969	2.771761
11.	1970	2.784746
12.	1971	2.846457
13.	1972	2.912624
14.	1973	2.983832
15.	1974	3.022759
16.	1975	3.08147
17.	1976	3.179536
18.	1977	3.24599
19.	1978	3.325024
20.	1979	3.396537
21.	1980	3.451694
22.	1981	3.555927
23.	1982	3.580658
24.	1983	3.662625
25.	1984	3.744986
26.	1985	3.777087
27.	1986	3.803302
28.	1987	3.838524
29.	1988	3.886634
30.	1989	3.932643
31.	1990	3.965503
32.	1991	3.988968
33.	1992	4.035421
34.	1993	4.075111
35.	1994	4.111086
36.	1995	4.134427
37.	1996	4.166777
38.	1997	4.203788
39.	1998	4.236546
40.	1999	4.273933
41.	2000	4.311459
42.	2001	4.324191
43.	2002	4.343303
44.	2003	4.387406
45.	2004	4.434055
46.	2005	4.475033
47.	2006	4.51172
48.	2007	4.540082
49.	2008	4.53988
50.	2009	4.523011
51.	2010	4.585689
52.	2011	4.616302
53.	2012	4.644479
54.	2013	4.667502
55.	2014	4.695411
56.	2015	4.714866
57.	2016	4.721144
58.	2017	4.749896
59.	2018	4.787686
60.	2019	4.81053

Figure 11: ***Hc: Labor Function for China; Kc: Capital Function for China***

50 . list Hc

31.	30.1167
32.	30.14702
33.	30.17735
34.	30.20997
35.	30.24204
36.	30.27074
37.	30.30242
38.	30.32868
39.	30.35053
40.	30.37422
41.	30.39564
42.	30.40393
43.	30.41503
44.	30.4327
45.	30.44811
46.	30.46264
47.	30.4732
48.	30.47821
49.	30.48392
50.	30.49154
51.	30.49576
52.	30.51241
53.	30.53104
54.	30.54883
55.	30.56245
56.	30.57365
57.	30.58326
58.	30.59213
59.	30.59458
60.	30.59477

56 . list Kc

	Kc
1.	13.59192
2.	13.60444
3.	13.59338
4.	13.60558
5.	13.63918
6.	13.69545
7.	13.76816
8.	13.80376
9.	13.83655
10.	13.878
11.	13.96001
12.	14.04281
13.	14.11744
14.	14.19071
15.	14.26914
16.	14.35674
17.	14.43014
18.	14.49939
19.	14.579
20.	14.65246
21.	14.73179
22.	14.79989
23.	14.87185
24.	14.9461
25.	15.02601
26.	15.11597
27.	15.20378
28.	15.28891
29.	15.37858
30.	15.43734
31.	15.48626
32.	15.54467
33.	15.6264
34.	15.73411
35.	15.84226
36.	15.9474
37.	16.05103
38.	16.14931
39.	16.25307
40.	16.34906
41.	16.44074
42.	16.53573
43.	16.63419
44.	16.74287
45.	16.85281
46.	16.96259
47.	17.07271
48.	17.18229
49.	17.29126
50.	17.417
51.	17.54075
52.	17.6576
53.	17.7695
54.	17.87783
55.	17.98001
56.	18.07878
57.	18.17407
58.	18.26483
59.	18.35334
60.	18.43757

Figure 12: ***Ac: Solow Residual for China listed by year***

```
64 . list year Ac
```

31.	1990	2.49365
32.	1991	2.512287
33.	1992	2.568356
34.	1993	2.545797
35.	1994	2.720722
36.	1995	2.924284
37.	1996	3.025143
38.	1997	3.076725
39.	1998	3.089034
40.	1999	3.09696
41.	2000	3.148334
42.	2001	3.204978
43.	2002	3.252078
44.	2003	3.317968
45.	2004	3.427375
46.	2005	3.530202
47.	2006	3.664349
48.	2007	3.871084
49.	2008	4.080844
50.	2009	4.129681
51.	2010	4.25297
52.	2011	4.410894
53.	2012	4.476038
54.	2013	4.535935
55.	2014	4.576838
56.	2015	4.583601
57.	2016	4.554117
58.	2017	4.603495
59.	2018	4.68652
60.	2019	4.679566

Figure 13: ***Regression of initial Cobb-Douglas variables onto GDP for the US***

```
. reg Yus Hus Kus lnpaus lnpseus lnrdeus

      Source |       SS           df       MS      Number of obs   =        10
-------------+----------------------------------   F(5, 4)         =  10855.60
       Model |  1.12714715         5  .22542943   Prob > F        =    0.0000
    Residual |  .000083065         4  .000020766   R-squared       =    0.9999
-------------+----------------------------------   Adj R-squared   =    0.9998
       Total |  1.12723022         9  .125247802   Root MSE        =    .00456

------------------------------------------------------------------------------
         Yus |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         Hus |   .4946479   .2014096     2.46   0.070    -.0645549    1.053851
         Kus |   2.139432   .1264101    16.92   0.000     1.788462    2.490403
      lnpaus |  -.2172844   .0453026    -4.80   0.009    -.3430647   -.0915042
     lnpseus |  -.9377686   .4185932    -2.24   0.089     -2.09997    .2244326
     lnrdeus |   .4008424   .1099101     3.65   0.022     .0956829    .7060018
       _cons |   -15.8214   3.059357    -5.17   0.007    -24.31554   -7.327265
------------------------------------------------------------------------------
```

Figure 14: ***Regression of initial Cobb-Douglas variables onto GDP for China***

```
. reg Yc Hc Kc lnpac lnrdec lnpsec

      Source |       SS           df       MS      Number of obs   =        18
-------------+----------------------------------   F(5, 12)        =    833.24
       Model |  15.4605209         5  3.09210417   Prob > F        =    0.0000
    Residual |  .044531339        12  .003710945   R-squared       =    0.9971
-------------+----------------------------------   Adj R-squared   =    0.9959
       Total |  15.5050522        17  .912061894   Root MSE        =    .06092

------------------------------------------------------------------------------
          Yc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          Hc |  -8.322958     1.7402    -4.78   0.000    -12.11453   -4.531389
          Kc |   1.826945   .1570262    11.63   0.000     1.484815    2.169076
       lnpac |   .1561052   .1010237     1.55   0.148    -.0640065    .3762169
      lnrdec |   .5943957   .2083983     2.85   0.015     .1403347    1.048457
      lnpsec |  -1.322154   .6569475    -2.01   0.067     -2.75352    .1092115
       _cons |   256.1314   49.60199     5.16   0.000     148.0579    364.2048
------------------------------------------------------------------------------
```

Appendix C

Data Tables

Table 1: GDP

Y = GDP	A = Technology
L = Labor	K = Capital

	GDP	
Year	China	United States
1960	5.972E+10	5.43E+11
1961	5.006E+10	5.63E+11
1962	4.721E+10	6.05E+11
1963	5.071E+10	6.39E+11
1964	5.971E+10	6.86E+11
1965	7.044E+10	7.44E+11
1966	7.672E+10	8.15E+11
1967	7.288E+10	8.62E+11
1968	7.085E+10	9.43E+11
1969	7.971E+10	1.02E+12
1970	9.260E+10	1.07E+12
1971	9.980E+10	1.16E+12
1972	1.137E+11	1.28E+12
1973	1.385E+11	1.43E+12
1974	1.442E+11	1.55E+12
1975	1.634E+11	1.68E+12
1976	1.539E+11	1.87E+12
1977	1.749E+11	2.08E+12
1978	1.495E+11	2.35E+12
1979	1.783E+11	2.63E+12
1980	1.911E+11	2.86E+12
1981	1.959E+11	3.21E+12
1982	2.051E+11	3.34E+12
1983	2.307E+11	3.63E+12
1984	2.599E+11	4.04E+12
1985	3.095E+11	4.34E+12
1986	3.008E+11	4.58E+12
1987	2.730E+11	4.86E+12
1988	3.124E+11	5.24E+12
1989	3.478E+11	5.64E+12
1990	3.609E+11	5.96E+12
1991	3.834E+11	6.16E+12
1992	4.269E+11	6.52E+12
1993	4.447E+11	6.86E+12
1994	5.643E+11	7.29E+12
1995	7.345E+11	7.64E+12
1996	8.637E+11	8.07E+12
1997	9.616E+11	8.58E+12
1998	1.029E+12	9.06E+12
1999	1.094E+12	9.63E+12
2000	1.211E+12	1.03E+13
2001	1.339E+12	1.06E+13
2002	1.471E+12	1.09E+13
2003	1.660E+12	1.15E+13
2004	1.955E+12	1.22E+13
2005	2.286E+12	1.30E+13
2006	2.752E+12	1.38E+13
2007	3.550E+12	1.45E+13
2008	4.594E+12	1.47E+13
2009	5.102E+12	1.44E+13
2010	6.087E+12	1.50E+13
2011	7.552E+12	1.55E+13
2012	8.532E+12	1.62E+13
2013	9.570E+12	1.68E+13
2014	1.048E+13	1.75E+13
2015	1.106E+13	1.82E+13
2016	1.123E+13	1.87E+13
2017	1.231E+13	1.95E+13
2018	1.389E+13	2.06E+13
2019	1.428E+13	2.14E+13

Table 2: Labor Force Participation Rate

	Labor Force Participation Rate	
Year	China	United States
1960		59.41666667
1961		59.325
1962		58.76666667
1963		58.65833333
1964		58.71666667
1965		58.83333333
1966		59.15
1967		59.56666667
1968		59.625
1969		60.075
1970		60.38333333
1971		60.15833333
1972		60.38333333
1973		60.775
1974		61.275
1975		61.23333333
1976		61.58333333
1977		62.23333333
1978		63.15
1979		63.65
1980		63.775
1981		63.875
1982		63.99166667
1983		64.00833333
1984		64.36666667
1985		64.80833333
1986		65.24166667
1987		65.575
1988		65.90833333
1989		66.44166667
1990	84.24	66.53333333
1991	84.18	66.16666667
1992	84.14	66.44166667
1993	84.11	66.3
1994	84.06	66.575
1995	83.96	66.625
1996	83.82	66.76666667
1997	83.62	67.10833333
1998	83.36	67.08333333
1999	83.01	67.08333333
2000	82.58	67.06666667
2001	81.9	66.83333333
2002	81.1	66.58333333
2003	80.25	66.24166667
2004	79.45	65.98333333
2005	78.78	66.03333333
2006	78.24	66.16666667
2007	77.84	66.03333333
2008	77.52	66.025
2009	77.19	65.4
2010	76.79	64.70833333
2011	76.69	64.10833333
2012	76.58	63.7
2013	76.46	63.25833333
2014	76.35	62.88333333
2015	76.26	62.65833333
2016	76.19	62.8
2017	76.12	62.85
2018	76.02	62.86666667
2019	75.88	63.09166667

Table 3: Unemployment Rate

	Unemployment Rate	
Year	urc	urus
1960		5.45
1961		5.541666667
1962		6.691666667
1963		5.566666667
1964		5.641666667
1965		5.158333333
1966		4.508333333
1967		3.791666667
1968		3.841666667
1969		3.558333333
1970		3.491666667
1971		4.983333333
1972		5.95
1973		5.6
1974		4.858333333
1975		5.641666667
1976		8.475
1977		7.7
1978		7.05
1979		6.066666667
1980		5.85
1981		7.175
1982		7.616666667
1983		9.708333333
1984		9.6
1985		7.508333333
1986		7.191666667
1987		7
1988		6.175
1989		5.491666667
1990	2.4	5.258333333
1991	2.4	5.616666667
1992	2.7	6.85
1993	2.9	7.491666667
1994	3	6.908333333
1995	3.1	6.1
1996	3.2	5.591666667
1997	3.2	5.408333333
1998	3.3	4.941666667
1999	3.3	4.5
2000	3.8	4.216666667
2001	4.2	3.966666667
2002	4.6	4.741666667
2003	4.5	5.783333333
2004	4.5	5.991666667
2005	4.4	5.541666667
2006	4.3	5.083333333
2007	4.6	4.608333333
2008	4.7	4.616666667
2009	4.5	5.8
2010	4.5	9.283333333
2011	4.6	9.608333333
2012	4.6	8.933333333
2013	4.6	8.075
2014	4.6	7.358333333
2015	4.5	6.158333333
2016	4.4	5.275
2017	4.3	4.875
2018	4.6	4.358333333
2019	5	3.891666667

Table 4: Human Capital per Worker

	Human Capital per Worker	
Year	China	United States
1960	1.230372787	2.721250534
1961	1.252714992	2.755555153
1962	1.275462866	2.790292025
1963	1.298623919	2.825466871
1964	1.322205424	2.861085176
1965	1.346215248	2.897152424
1966	1.366382241	2.928370714
1967	1.386851192	2.959925413
1968	1.407626987	2.991819859
1969	1.428713799	3.024058342
1970	1.450116634	3.056643963
1971	1.477851629	3.089885235
1972	1.506117105	3.123487711
1973	1.534923077	3.157455921
1974	1.564280152	3.191793442
1975	1.594198585	3.226504326
1976	1.623608828	3.249995708
1977	1.653561592	3.273658037
1978	1.684067011	3.297492504
1979	1.713660836	3.321500778
1980	1.737435699	3.345683813
1981	1.759069204	3.354768991
1982	1.780972004	3.363878965
1983	1.803147554	3.373013735
1984	1.825599194	3.3821733
1985	1.848330379	3.39135766
1986	1.869394302	3.400060654
1987	1.890698195	3.408786058
1988	1.912244678	3.417533636
1989	1.93403697	3.426303864
1990	1.956077456	3.435096502
1991	1.991196871	3.452302456
1992	2.026946783	3.469594955
1993	2.063338518	3.486973524
1994	2.100383759	3.504439592
1995	2.138093948	3.52199316
1996	2.17208457	3.533238888
1997	2.206615448	3.544520617
1998	2.241695404	3.555838585
1999	2.277333021	3.567192554
2000	2.313537359	3.578582525
2001	2.329683542	3.578582525
2002	2.345942497	3.588337183
2003	2.362315178	3.598118544
2004	2.378801823	3.60792613
2005	2.395403624	3.617760897
2006	2.404458523	3.627622366
2007	2.413547754	3.642328978
2008	2.422671318	3.657094717
2009	2.431829453	3.671920776
2010	2.441021919	3.686806679
2011	2.475469828	3.701753378
2012	2.510403633	3.707010984
2013	2.545830488	3.712275982
2014	2.574622154	3.717548609
2015	2.599027872	3.722828627
2016	2.623665094	3.728116274
2017	2.648535967	3.733411312
2018	2.673642397	3.73871398
2019	2.698987007	3.7440238

Table 5: Capital Stock

	Capital Stock	
Year	csus	csc
1960	1.50E+07	799646
1961	1.50E+07	809718
1962	1.60E+07	800808
1963	1.60E+07	810642
1964	1.70E+07	838339
1965	1.80E+07	886865
1966	1.90E+07	953755
1967	1.90E+07	988321
1968	2.00E+07	1.00E+06
1969	2.10E+07	1.10E+06
1970	2.10E+07	1.20E+06
1971	2.20E+07	1.30E+06
1972	2.30E+07	1.40E+06
1973	2.40E+07	1.50E+06
1974	2.40E+07	1.60E+06
1975	2.50E+07	1.70E+06
1976	2.60E+07	1.80E+06
1977	2.60E+07	2.00E+06
1978	2.70E+07	2.10E+06
1979	2.80E+07	2.30E+06
1980	2.90E+07	2.50E+06
1981	3.00E+07	2.70E+06
1982	3.00E+07	2.90E+06
1983	3.10E+07	3.10E+06
1984	3.20E+07	3.40E+06
1985	3.30E+07	3.70E+06
1986	3.40E+07	4.00E+06
1987	3.50E+07	4.40E+06
1988	3.60E+07	4.80E+06
1989	3.70E+07	5.10E+06
1990	3.80E+07	5.30E+06
1991	3.90E+07	5.60E+06
1992	4.00E+07	6.10E+06
1993	4.10E+07	6.80E+06
1994	4.20E+07	7.60E+06
1995	4.30E+07	8.40E+06
1996	4.40E+07	9.40E+06
1997	4.50E+07	1.00E+07
1998	4.60E+07	1.10E+07
1999	4.80E+07	1.30E+07
2000	4.90E+07	1.40E+07
2001	5.10E+07	1.50E+07
2002	5.20E+07	1.70E+07
2003	5.30E+07	1.90E+07
2004	5.50E+07	2.10E+07
2005	5.60E+07	2.30E+07
2006	5.80E+07	2.60E+07
2007	5.90E+07	2.90E+07
2008	6.00E+07	3.20E+07
2009	6.10E+07	3.70E+07
2010	6.10E+07	4.10E+07
2011	6.20E+07	4.70E+07
2012	6.20E+07	5.20E+07
2013	6.30E+07	5.80E+07
2014	6.40E+07	6.40E+07
2015	6.50E+07	7.10E+07
2016	6.60E+07	7.80E+07
2017	6.70E+07	8.60E+07
2018	6.80E+07	9.30E+07
2019	6.90E+07	1.00E+08

Table 6: Gross Fixed Capital Formation

	Gross Fixed Capital Formation	
Year	China	United States
1960	32646342.3	29812125000
1961	18991256.9	30876750000
1962	15479189.5	33368250000
1963	17756415.6	35525562500
1964	20265533.2	38430312500
1965	20642377.5	42065500000
1966	21824175.3	46029750000
1967	18177610.0	47625437500
1968	17367008.2	51778250000
1969	20982639.6	55983875000
1970	24140258.0	56962812500
1971	24846261.5	61769250000
1972	24627096.0	69931437500
1973	24284664.3	79171937500
1974	26557681.5	84175375000
1975	29047891.6	86978125000
1976	29037200.2	98938250000
1977	28125113.8	116862687500
1978	29340030.5	139538187500
1979	28351440.8	160440562500
1980	28560613.3	168094687500
1981	27257714.0	187189937500
1982	28239419.3	188222750000
1983	28177268.9	203607875000
1984	29321047.0	236966750000
1985	30431240.8	256926000000
1986	30959561.9	270165875000
1987	30558437.0	279916250000
1988	31052822.0	294220375000
1989	25606067.7	310610250000
1990	23988753.6	317318062500
1991	25703798.9	309707812500
1992	30347319.6	323198937500
1993	37092233.0	344473687500
1994	34440616.4	371718312500
1995	32340968.8	398500812500
1996	31642004.7	430303625000
1997	31003096.2	462819750000
1998	32882594.6	504238187500
1999	32537125.9	548680312500
2000	32577417.6	593178375000
2001	33453526.4	596252187500
2002	35058366.1	588529687500
2003	38257685.3	619295750000
2004	39529663.7	675847375000
2005	39425815.6	747623250000
2006	38725488.1	795714500000
2007	37892468.3	807771000000
2008	39061178.1	784112375000
2009	43811571.0	680836125000
2010	43929304.8	689014875000
2011	43861361.5	730729625000
2012	44249832.0	792893250000
2013	44518765.6	830471375000
2014	43856093.7	890694875000
2015	42094328.3	930744687500
2016	41552364.9	952180750000
2017	41861185.3	1005066312500
2018	42843030.6	1070419875000
2019	42822584.5	1123156375000

Table 7: Capital Investment

	Capital Investment	
Year	China	United States
1960		112.226
1961		118.306
1962		124.71
1963		131.975
1964		139.145
1965		145.675
1966		151.532
1967		157.997
1968		166.161
1969		173.905
1970	7826569761	179.7
1971	7760111257	183.697
1972	10362865504	185.113
1973	11988448169	185.371
1974	13401676869	186.527
1975	15906077500	188.209
1976	17412576659	190.453
1977	19098934387	193.122
1978	14287622006	196.174
1979	16713843750	199.603
1980	20397779195	203.721
1981	20982709853	208.821
1982	22287236994	214.583
1983	24776022031	221.047
1984	26554930603	228.972
1985	28848825806	239.088
1986	30075800000	251.68
1987	27069822500	265.884
1988	28090896644	280.247
1989	32719001183	293.254
1990	35309761290	304.557
1991	38160630415	315.192
1992	40133301873	323.976
1993	46658194509	330.427
1994	62106296100	334.886
1995	79298524520	337.573
1996	95887606425	339.761
1997	1.11928E+11	342.62
1998	1.26118E+11	346.227
1999	1.30993E+11	351.05
2000	1.42414E+11	357.73
2001	1.52863E+11	364.828
2002	1.64756E+11	371.682
2003	1.8937E+11	379.948
2004	2.21256E+11	389.418
2005	2.61763E+11	400.479
2006	3.30329E+11	412.409
2007	4.39875E+11	425.288
2008	5.99422E+11	439.057
2009	7.05645E+11	453.339
2010	8.83724E+11	466.728
2011	1.23645E+12	477.883
2012	1.44925E+12	486.953
2013	1.67911E+12	493.618
2014	1.8747E+12	498.24
2015	1.99342E+12	501.094
2016	1.93627E+12	503.373
2017	2.01254E+12	506.755
2018	2.31258E+12	512.013
2019	2.41147E+12	519.218

Table 8: Patent Applications

	Patent Applications	
Year	China	United States
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969		
1970		
1971		
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980	140	62098
1981	92	62404
1982	96	63316
1983	96	59391
1984	105	61841
1985	122	63673
1986	96	65195
1987	108	68315
1988	111	75192
1989	135	82370
1990	169	90643
1991	151	87955
1992	178	92425
1993	155	99955
1994	219	107233
1995	171	123962
1996	176	106892
1997	161	119214
1998	207	134733
1999	204	149251
2000	241	164795
2001	246	177513
2002	391	184245
2003	329	188941
2004	382	189536
2005	361	207867
2006	291	221784
2007	403	241347
2008	531	231588
2009	343	224912
2010	328	241977
2011	339	247750
2012	336	268782
2013	340	287831
2014	452	285096
2015	443	288335
2016	386	295327
2017	425	293904
2018	406	285095
2019	438	285113

Table 9: Research and Development Expenditure

	Research and Development Expenditure	
Year	China	United States
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969		
1970		
1971		
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991		
1992		
1993		
1994		
1995		
1996	0.56324	2.45001
1997	0.63873	2.47983
1998	0.64689	2.50401
1999	0.74963	2.54965
2000	0.89316	2.62879
2001	0.94033	2.6483
2002	1.05786	2.55926
2003	1.12037	2.56455
2004	1.21498	2.50243
2005	1.30792	2.51697
2006	1.36854	2.55764
2007	1.37369	2.63161
2008	1.44592	2.76791
2009	1.6648	2.8127
2010	1.71372	2.7354
2011	1.78034	2.76525
2012	1.91214	2.68166
2013	1.99786	2.70972
2014	2.02243	2.71924
2015	2.05701	2.71742
2016	2.10033	2.76145
2017	2.11603	2.81741
2018	2.14058	2.83283
2019		

Table 10: Primary School Enrollment

Year	Primary School Enrollment China	United States
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969		
1970	107.0421677	
1971	106.3358307	88.860878
1972	108.0415115	88.4217987
1973	115.4007492	90.7070465
1974	119.1142426	89.8160782
1975	121.4987564	89.6162109
1976	121.5533981	90.4418488
1977	116.5009689	90.6578827
1978	110.6123276	91.0734863
1979	109.2433014	90.6162491
1980	109.719368	98.9110489
1981	111.1699905	98.6317978
1982	110.754158	100.481621
1983	110.7784119	99.0345078
1984	111.5861969	97.8936615
1985	116.6951828	98.232933
1986	121.48349	99.9011307
1987	126.1507111	101.173691
1988	128.0993958	
1989	128.4742126	
1990	127.5487823	106.033234
1991	124.3763809	105.328598
1992	121.7244873	
1993	118.3772278	103.899277
1994	114.9444885	103.115479
1995	111.7638168	104.106407
1996	108.0741577	103.55983
1997	105.5070877	
1998	105.769371	102.562042
1999		101.930832
2000		
2001	112.3415909	
2002		
2003		
2004		
2005	100.9932785	101.874023
2006	100.7070465	
2007	100.7424393	
2008	100.0061035	
2009	98.96421814	
2010	99.04701996	
2011	99.79109955	
2012	99.56459808	
2013	95.7964325	99.4554367
2014	96.31860352	99.673378
2015	97.96192169	100.299911
2016	99.40480804	101.362862
2017	100.2227478	101.821442
2018	101.9257202	101.256561
2019	103.1739578	100.9813

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ACADEMIC VITA

EDUCATION

The Pennsylvania State University — **University Park, PA**

College of the Liberal Arts — May, 2023

Master of Arts in Economics — May, 2022

Bachelor of Science in Economics — Schreyer Honors College

Eberly College of Science — Paterno Fellow

Bachelor of Science in Mathematics — Phi Beta Kappa Honor Society

Minor in Chinese

EXPERIENCE

Wilsbach Distributors — **Harrisburg, PA**

Operations Management Intern — May 2021 – August 2021

- Optimized purchasing decisions in determining cost/benefit analyses
- Assisted in the implementation of a new tracking system for the distribution trucks
- Developed efficiency reviews for workers to determine if their work was on-par with expectations

Department of Economics, College of the Liberal Arts, Penn State — **University Park, PA**

Economics Undergraduate Teacher's Assistant

Econ 451, Econ 402, Econ 315 — January 2020 – Present

- Graded midterms, final exams, quizzes, and homework throughout the semester in each class
- Held office hours to assist students on concepts they were struggling with

Economics Tutor — November 2019 – January 2020

- Provided assistance to student athletes struggling with introductory economics courses
- Offered extra hours beyond the originally allocated time to verify my students understood given material

LEADERSHIP

Penn State Dance MaraTHON — **University Park, PA**

2022 THON DANCER — October 2018 – Present

- Stood for 46 hours straight in a no sitting, no sleeping dance marathon to promote the fight against childhood cancer.

Family Relations Chair (SE) — October 2019 – Present

- Connected my Special Events committee with a family to develop personal connections
- Solidified communication between my committee and our THON family; sent Christmas cards and holiday grams

Fundraising Specialist (R&R) — October 2018 – May 2019

- Implemented new fundraising tactics in pursuit of generating money for my THON committee
- Proposed a university-wide raffle for Apple Airpods; the fundraiser ended up being lucrative
- Raised $644; instead of an individual purchasing the Airpods in bulk or donating them to our committee, I proposed all committee members give $5 for the purchase to mitigate the cost. Raffle tickets were sold for $2

AWARDS/INTERESTS/SKILLS

Academic Scholarships: Chaiken Trustee Academic Scholarship of Excellence, "Woodsman of the World" Award, American Legion Scholarship Post 265, Rotary Club Academic Scholarship, East Hannover Lions Club Academic Scholarship

Interests: Football, Baseball, Powerlifting, Penn State CARE Program, PSU Economics Association,

Skills: Chinese; Elementary Proficiency, Microsoft Excel, Programming Languages: STATA, MatLab, Python,