Investment and the Rise of the Service Economy

by

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Abstract

This paper investigates the importance of investment as countries shift towards the service sector. After linking the service sector with large developments in human capital, I examine the theoretical implications of several models which incorporate human capital into the production function. I use variants of these models to provide empirical evidence for the importance of human capital within modern economies. After the effects of human capital are established, I extend one of the previous models by including an interaction term for investment and human capital. My results suggest that the importance of investment actually grows as countries shift towards the service economy because of the high degree of complementarity between physical and human capital.

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Section 1 - Introduction

In February 2007, the annual Economic Report of the President suggested that the US was losing some of its appeal to foreign investors (Lazear, et al. 2007). This news, along with concerns about the long-run sustainability of Medicare, Social Security, and the current path of government expenditures has led to an increased appreciation of the United States' potentially precarious economic position. In particular, these trends might predict a future drop in private investment in the US and a consequent decline of future growth rates. While some economists have applied traditional methods to evaluate the severity of the situation (see Gale and Orszag 2004; Laubach 2003), these studies have not taken the growth of the service sector into account. This paper documents the rise of the service sector and attempts to determine how the fundamental shift in economies around the globe towards human capital might affect the importance of investment in a modern economy.

The service sector notably differs from traditional manufacturing industries by employing, and helping to create a highly educated workforce (Fuchs 1968; Haukness 1996). Since most countries lack the necessary statistics to study the development of services directly, I model the growth of the service sector through growth in human capital. This substitution allows the use of theoretical frameworks such as the Solow Growth Model and the Uzawa-Lucas Model, both of which are particularly useful when considering the impact of human capital on economic output. These neoclassical growth models indicate that if human and physical capital are substitutes, sudden changes in investment, should have a reduced effect upon output as the economy shifts towards human capital.[1] However, several recent studies have claimed that skilled labor and physical capital are complementary factors in a country's output (Autor, et al. 1998; Acemoglu 1998). If human capital and physical capital are sufficiently complementary, then one would expect the importance of investment to rise as human capital increases. The primary empirical goal of this paper is to determine if this complementary nature exists and if it is strong enough to overwhelm the effects predicted by the theoretical models.

My empirical section is divided into two stages. The first empirical section, using both a US time series and an international panel data set, attempts to ascertain human capital's contribution to economic output. I present two simple models of economic output which take gross domestic investment, labor, and human capital as inputs. When possible, I also break the time series into sub periods in order to observe the changing importance of variables over time as economies develop and shift towards the service sector.

The second empirical section attempts to determine how the increasing levels of human capital affect investment's relative importance in economic output. Using the international data set, I construct a model similar to those used in the first empirical section; this new model includes an interaction term for human capital and investment. This interaction term is meant to capture the effect that an increase in human capital will have upon investment's contribution to output.

This paper reaches several important conclusions. As demonstrated in the first empirical section, human capital has always been a significant contributor to the United

[1] Investment represents the annual change in physical capital. Thus, a change in investment will alter physical capital growth and future economic output.

States' economic growth, particularly during the past twenty years. The preliminary international results reveal that while current secondary-school enrollment rates are negatively correlated with output, lagged enrollment rates are both significantly and positively correlated with current output. Moreover, the strength and size of the enrollment rates' effect upon output grows as the variables are lagged by an increasing number of years. These results indicate that current human capital available in the workforce helps determine economic output in countries around the world.

In order to analyze how the growth of the service sector impacts investment's role in economic output, I include an interaction term for investment and human capital. This interaction term has a positive coefficient in the final results, suggesting that investment and human capital are complementary factors. Given this result, the movement towards an educated workforce implies an increase in the importance of investment in economic output, since investment's effect will be increased through its interaction with human capital. This result makes it even more crucial that steps be taken to narrow the expected gap between government expenditures and revenues in order to relieve the United States from extensive future crowding out and economic stagnation.

Section 2 provides a summary of relevant past work regarding human capital and the service sector. Section 3 discusses the theoretical implications of several models as well as the importance of the relationship between human capital and investment within the production function. Section 4 describes the empirical methods used to determine the importance of human capital. Section 5 presents a summary of the data used in both the US study and the international regressions. Section 6 then displays the initial results from the US as well as international data. The final empirical analysis used to examine the changing importance of investment is described in Section 7. Finally, Section 8 lists the results of this final test and presents the findings.

Section 2 - Background Literature and Motivation

2.1 Service Sector Definition

When studying the service sector, a logical first step is to determine exactly what the term encapsulates. The simple answer is that the service sector includes all industries which are not categorized under agriculture or manufacturing. However, this definition is rather unsatisfactory, as it reveals little about the nature of the service sector, and leaves the precise definition open to interpretation. Unfortunately, while economists have struggled to arrive at a uniform definition for some time, no general consensus has yet been reached.

Victor Fuchs at least provides some intuition to his readers by proposing two typical characteristics of service industries; he claims that, "The two criteria most frequently mentioned are closeness to the consumer and the presence or absence of a tangible product" (1968, 15). Service industries, unlike those within the primary or secondary sector, typically have close contact with consumers and offer no tangible product. Financial services are a good example of such an industry, as they provide consumers with human expertise on a personal level. One potential breakdown of the areas within the service sector can be seen in Figure 1. This chart presents the varying levels of income found in each service industry in the US in 1987, the last year for which the data was available.[2]

[2] Data found at the Bureau of Economic Analysis, online at http://www.bea.gov.

2.2 Service Sector Employment Growth

Economies at the start of the twentieth century were vastly different from what people in developed countries experience today. John Galbraith (1967) was among the first to notice a change in modern economies: as summarized in the STEP report, Galbraith argued that corporations were shifting to "large scale knowledge intensive manufacturing industries and... new productive structures with access to strategic knowledge and technology" (Hauknes 1996, 3).[3] A year after Galbraith (1967) published his work, Victor Fuchs (1968) argued that the United States, which had previously been dominated by agriculture and manufacturing, began to shift towards a service economy in the 1920's. This movement initially consisted of a massive transition in employment. Fuchs (1968) notes that seventeen million new jobs were added to the US economy between 1947 and 1967; virtually all of these jobs were within the service sector. In stark contrast, the manufacturing sector has maintained a fairly steady workforce since the 1940's. This growing gap between service sector and manufacturing employment in the US can be seen in Figure 2, which shows the development of employment in both sectors over the past fifty years.

The development of the service sector has not been restricted to the United States; rather, it has been a global phenomenon, particularly amongst developed nations. A recent report on innovation within the service economy estimates that services account for roughly two thirds of all employment in most OECD countries (Hauknes 1996). This study also notes that specific industries such as real estate, business services, consulting,

[3] The NIFU STEP group is an economic research institution located in Norway. The STEP report mentioned here is the 1996 publication of a report on innovation within the service sector. The NIFU STEP group website can be found online at http://english.nifustep.no/.

engineering, software development, and research and development more than tripled their employment from 1970 to 1993.

Fuchs (1968) provides three possible explanations for the phenomenal growth in service sector employment. His first argument is that as output per capita rises and consumers have more disposable income, individuals devote an increasing fraction of their available funds to service products. Service industries react by increasing the size of their workforce to provide for the growing demand. This argument essentially takes the stance that the service sector is a form of luxury good which people consume more of as their income rises. Fuchs' second explanation also supposes a growth in the demand for services. This argument suggests that as industry becomes increasingly specialized, manufacturing companies begin to require more services.

Fuchs' third argument is that productivity gains in services have consistently underperformed productivity gains in goods manufacturing and agriculture. This is essentially identical to the "cost disease argument" as presented by Hilda and William Baumol in their paper *On the Cost Disease and its True Policy Implications for the Arts* (1985). Fuchs presents a considerable amount of evidence for this last argument, and argues that it is the main cause of employment growth in services. Service industries are known for having close contact with consumers; retail store attendants would be a prime example of the personalized attention often found in the service sector. This human component cannot yet be replaced by machines and automated effectively. As a result, services require significantly more manpower in the modern era than manufacturing or agricultural industries.

A more recent analysis conducted by Jack E. Triplett and Barry P. Bosworth (2000) complicate this argument. These authors emphasize that it is difficult to measure output for many industries within the service sector using traditional methodologies.[4] As an example, Triplett and Bosworth point out that ATM usage was not included in banking output until 1999. Furthermore, Triplett and Bosworth's research indicates that while services have had lower productivity growth overall, some industries such as financial institutions have recently increased their productivity growth. Thus, while the cost disease argument may contribute significantly to the growth of service employment, it does not explain all of this development by itself.

2.3 The Service Sector and Output

Most evidence of service sector growth in previous research has focused on employment. While employment is the area most obviously affected, it is important to understand the service sector's growing contributions to economic output as well. Fuchs (1968) argued that service's share in US output was relatively constant from 1929 to 1965. However, given the innovations of the last few decades, it is necessary to analyze whether Fuchs' conclusion has continued to hold.

To study the service sector's contribution to the United States gross domestic product, I used data from the Bureau of Economic Analysis.[5] Using the BEA's definition of the service sector, I found that services surpassed manufacturing to become

[4] This point is also made by Zvi Griliches (2002).

[5] The BEA measurements use the following definitions.

The Goods Producing sector includes the following industries: agriculture, forestry, fishing, hunting, mining, construction and manufacturing.

The Service Sector includes the following industries: Utilities, wholesale trade, retail trade, transportation, warehousing, information, finance, insurance, real estate, rental, leasing, professional and business services, educational services, health care, and social assistance.

the largest component of the United States' gross domestic product in 1968. A graph comparing the output of services versus manufacturing in billions of US dollars is shown in Figure 3. Moreover, as suggested by Figure 4, the value added by the service sector has continued to outpace the goods producing sector during the past two decades.

As seen in Figure 2, services and manufacturing made roughly equal contributions to total output until mid 1980's. Some recent economists have argued that the service sector has benefited significantly from the recent computer revolution, starting in the mid 1980's (Acemoglu 1998; Autor et al. 1998). Given that this did not occur until almost two decades after Fuchs published his book in 1968, it is understandable how he could have failed to observe or predict the service sector growth. Fuchs' conclusions might also be the result of his definition of services, which differ from the Bureau of Economic Analysis' in that his does not include utilities or telecommunications. In any event, the service sector is now the largest contributor to economic output in the United States. While data is not as readily available for other areas, one would expect similar results in countries with large service sectors.

2.4 The Service Sector and Human Capital

Over time economists have noted an increased need for skilled labor in growing economies, due in great part to the development of the service sector. Fuchs (1968) notes two particular ways in which the demand for skilled labor grows. First, companies in the 1960's increased the number of internal managerial and white collar positions. This trend has continued through today; Johan Hauknes (1996, 6) discovered that "While manufacturing employment has diminished [in OECD countries], employment of high skilled white collar employees [within manufacturing] has increased." This trend corresponds to Galbraith's (1967) insights into the changing nature of corporations. Secondly, the growth of intellectually demanding industries within the service sector has also increased the need for skilled labor. For example, the employment growth in financial services from 1950 to 1960 was greater than the total workforce of the mining industry in 1960 (Fuchs 1968). As industries requiring an educated workforce double and triple in size, the supply of human capital must become more significant to an economy's output and growth.

To add to the increasing demand for educated workers, the innovation in services report argues that "service sectors are major users, originators and agents of transfer of technological and non-technological innovations, playing a major role in creating, gathering and diffusing organizational, institutional and social knowledge" (Hauknes 1996, 31). Thus, service sectors facilitate the creation and improvement of human capital within an economy as well as increase the demand for skilled labor. If this assertion is correct, one might expect more innovation and technological discoveries within countries with large service sectors.

Figure 7 presents some evidence for the connection between service sector growth and human capital development.[6] This graph shows the growth of human capital in the United States alongside the ratio of service output to total gross domestic product. Note that this graph does not establish a causal relationship by itself; it merely shows that the two variables have followed very similar paths over the last sixty years.

Thus, both past economists and current data present a consistent argument: the service sector requires, and even encourages the development of human capital within a

[6] Data found at the Bureau of Economic Analysis, on the web at http://www.bea.gov.

country. Perhaps partly due to the difficulties in accurately measuring service sector industries (Triplett and Bosworth 2000; Griliches 2002), most countries lack historical data which separates the service sector output from the gross domestic product. As a result, I chose to model the growth of the service sector through the growth of human capital. I consider this a fair substitution due to the preponderance of evidence which suggests that the two are highly correlated.

2.5 Human Capital and Economic Growth

Several different approaches have previously been used to evaluate the role that human capital plays in determining economic growth. Robert Barro and Sala-i-Martin (2001), for example, analyze the importance of different factors of production through simple growth regressions, a method pioneered by Kormendi and Meguire (1985). Gong, Greiner and Semmler explain that these studies "do not suppose a certain economic model by which growth rates are explained but simply undertake regressions with the growth rate of real per capita gross domestic production (GDP) as the dependent variable which is explained by various exogenous variables" (2004, 402). Using a data set compiled by Barro and Lee in 1994, Barro and Sala-i-Martin employ a growth regression model in their 2001 book, *Economic Growth*. The authors conclude that the average number of years of male secondary school attainment is positively correlated with growth. Oddly, their results indicate that growth decreases as average female secondary schooling rates rise. The authors conclude that this counterintuitive effect is due to the reality that low levels of female education typically arise in undeveloped countries which have high growth potential.

Barro encounters similar results with regard to average level of male secondary schooling in his 1999 paper, *Human Capital and Growth in Cross Country Regressions*. However, in this study Barro finds the female schooling variable to be insignificant. Given the importance of secondary schooling, Barro (1999) argues that highly educated societies are able to absorb new technologies more efficiently, thus increasing the rate of productivity growth. Referring back to Hauknes' (1996) argument that service sectors help create knowledge, a logical extension to Barro's argument would be that highly educated societies also create new technologies at a higher rate.

Unfortunately, these results are somewhat confused by the results of Sala-i-Martin's (1997) later study. Sala-i-Martin ran a number of regressions with different sets of explanatory variables in an attempt to isolate factors which consistently prove significant. His work indicates that secondary school enrollment is insignificant, as is average years of schooling, although there is some evidence that primary schooling is positively linked to growth. It is important to note that Sala-i-Martin includes several variables pertaining to religious affiliation and geographic location. Given the generally poor schooling systems in some religious groups and geographic areas, it is possible that some of human capital's significance is hidden by these robust variables.

David Renelt and Ross Levine (1992) take a different approach to evaluate human capital's importance, choosing to study growth using Edward E Leamer's extreme bound analysis. This method is designed such that only particularly robust and consistent correlations are deemed relevant (Sala-i-Martin 1997). During their initial regressions, Renelt and Levine find secondary schooling enrollment rate in 1960 to be a positive and robust variable when analyzing growth.

The evidence to date therefore suggests that education in some form is important to economic growth, although there is some dispute as to which measure of human capital is most significant. One point which should be taken into account is that while Barro and Sala-i-Martin (2001) include a range of human capital measures over time, Sala-i-Martin (1997) and Renelt and Levine (1992) only use the initial level of secondary schooling in 1960. Thus, any increases in growth due to an increase in human capital would fail to be properly attributed in these studies. This lends additional credibility to the claim that secondary schooling is an important variable in determining economic growth.

2.6 Human Capital and Investment

One possible objection to using education as well as investment in a study on economic output is that the two factors are possibly correlated. One could make the argument that countries with more developed educational systems have a greater appeal to international investors. There is some empirical support for this concern as well; Paul Romer concludes that literacy growth rates help explain investment growth, although he qualifies his results by stating they should not be taken as definitive causal relationships (1989). Moreover, basic regressions within my own data sets seem indicate a degree of correlation as well. However, it should be noted that the presence of correlation does not necessarily indicate causality. Both human capital and investment have shown consistent long-term growth during the last sixty years, and thus it is unsurprising that some correlation can be observed.

There is also some evidence to support to the idea that education and investment are unrelated. Barro (1999) found no correlation between investment and male secondary schooling enrollment.[7] This finding can be partially explained through the idea that human capital changes slowly over time in response to a number of social and political variables rather than economic ones. The relationship between human capital and investment therefore remains unclear, and both possibilities should be considered throughout the empirical sections.

2.7 Skilled Labor and Physical Capital

A number of recent studies have argued that a complementary relationship exists between skilled labor and physical capital within the US. Autor, Katz and Krueger (1998) attribute the recently increased demand for college-graduates in the United States to the computer revolution. These authors "consistently find for both the manufacturing and nonmanufacturing sectors that increases in the utilization of more-skilled workers are greater in the most computer-intensive industries, although it is not clear whether a causal interpretation of these relationships is appropriate" (Autor, et al. 1998, 1172). Given the large numbers of computers used in the service sector, especially in industries such as financial services or insurance, this relationship suggests that technological progress substantially contributes to the importance of an educated workforce. While the computer revolution has been most apparent in the US, virtually all countries in the world have experienced changes due to this new set of technologies. Therefore, it is possible that this argument is applicable across the globe.

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[7] Barro's Investment data is taken from the Penn World Tables Mark 5, which was compiled by Summers and Heston in 1991. I have taken his use of investment to indicate a change in capital stock as opposed to the current size of the capital stock.

Acemoglu (1998) takes a slightly different stance on the relationship between human capital and technology. He notes that after a surge in college enrollment in the 1970's, the financial benefits of a tertiary education briefly fell as the market was flooded with college graduates. However, after a few years, a set of technologies were developed which complemented this new group of skilled workers. This then led to a rise in the "college premium" which has remained high ever since. In this view of the world, technology develops in order to complement the existing workforces' skills.

Both of these studies suggest a complementary relationship between human capital and physical capital within the United States. These arguments thus contradict Barro's findings on the lack of correlation between investment and human capital. It remains to be seen if these results hold within an expanded international data set, and if this complementary effect proves to be the deciding factor in investment's overall significance as a country shifts towards the service sector.

Section 3 - Theoretical Expectations

3.1 Complements or Substitutes

The foremost theoretical consideration for this paper is the degree to which physical capital and human capital complement each other. The Constant Elasticity of Substitution Production Function presents us with a flexible model which takes the range of possibilities into account. The form of this function, as presented in Barro and Sala-i-Martin (2001), is shown below:

$$F(K,L) = A\{a(bK)^{\Psi} + (1-a)[(1-b)L]^{\Psi}\}^{\frac{1}{\Psi}}.$$

Here, by controlling the value of ψ, one controls the amount of substitution between physical capital and labor (K and L). If $\psi=1$, K and L are perfect substitutes and the production function is linear. Meanwhile, as ψ approaches 0, the function becomes a standard Cobb-Douglas production function. Finally, ψ is negative if physical capital and labor are complementary. Note that human capital can be combined with the labor term, as is done in the Solow Growth Model with Human Capital, in order to incorporate it into the model. To begin, I will assume that $\psi=0$ and assess the theoretical predictions for a Cobb-Douglas production function. Finally, I will also discuss the theoretical implications if one assumes that $\psi<0$.

3.2 Cobb-Douglas Model

During the past few decades a number of growth models which incorporate human capital into a Cobb-Douglas production function have been developed. The primary differences in these models arise from their differing assumptions regarding the development of human capital; these assumptions play a critical role in the models' theoretical predictions. Given Barro's (1999) conclusion that investment is uncorrelated with human capital, I focus primarily on models which do not incorporate physical capital in the development of human capital. If one makes this assumption, both exogenous and endogenous growth models confirm the theory that investment becomes less significant as a country demands more human capital. In addition to these two older theories, I discuss a recently proposed addition to the Uzawa-Lucas model which attempts to adjust the model to more accurately fit data from the United States and Germany.

3.3 Solow Model with Human Capital

The Solow Growth Model with Human Capital, as described by Jones (2002), is quite similar to the standard Solow Growth Model. The production function is altered from the traditional Solow Model to include total human capital. Thus,

$$Y = K^{\alpha}(AH)^{1-\alpha}.$$

$$H = e^{\Psi u}L.$$

In the first equation, 'K' represents the amount of physical capital in a country. 'A' represents a measure of technological advancement. H is a measure of human capital and labor, while α is a relative measure of the importance of physical capital in the economy. Note that as α falls, the importance of human capital rises. This equation calculates a country's output, 'Y'. In the second equation, u is a measure of time devoted to education rather than output, and Ψ is a positive constant. Thus, human capital in the Solow Growth Model is purely a function of labor and the amount of time or resources a country dedicates to education.

From the production function, one can derive a steady state equation for output per capita. Note that any effect upon the per capita output will translate into total output as well, provided we do not change L. The steady state function is as follows (Jones 2002):

$$y^{*}(t) = \left(\frac{s_k}{n+g+d}\right)^{\alpha/(1-\alpha)} hA(t).$$

Here, s_k represents the portion of income which citizens invest in physical capital. The variables 'n', 'g', and 'd', represent the rate of population growth, technological development, and depreciation respectively. A(t) is a measure of technology as a function of time, while ‘h’ is merely the average level of human capital within the labor force, or H/L. Thus, this steady state equation is identical to the normal Cobb-Douglas steady state function for output per workers, except that here the typical output is multiplied by the average level of human capital in the population.

To simulate the hypothesized shift towards human capital, one can reduce α in the original production function, and thus reduce physical capital’s importance in affecting economic output. In the original equation for output, as α falls, the importance of labor and human capital rises. In the steady state equation, the effect of s_k, meaning investment, on output is dampened as α falls. Therefore, the Solow Model with Human Capital predicts that investment’s contribution towards economic output should fall as an economy relies more on human capital.

It should be noted that changes in investment should be interpreted here as causing changes in potential output rather than demand. It is also important to understand that this analysis assumes that a country was in or close to its steady state initially. If one does not make this assumption, it is impossible to make such a generalized argument. If a country was previously adjusting to new economic conditions, the speed of its convergence could be either sped up or slowed down depending upon the direction the economy was moving and the new relative position of the steady state.

3.4 Uzawa-Lucas Model with Endogenous Growth

The Uzawa-Lucas model, as described by Jones (2002), argues that future levels of human capital are a function of the current human capital in the society and the fraction of people’s time dedicated to education. Unlike the Solow Growth Model with

Human Capital, in this model human capital development is separated from the labor pool. We can again use a Cobb-Douglas function, along with our new definition of human capital development, to describe the economy.

$$Y = K^{\alpha}(hL)^{1-\alpha}.$$

$$\dot{h} = (1-u)h.$$

Here, h enters the equation just the same way that exogenous technological growth does in the Solow Growth Model presented above. This allows us to derive a very similar steady state function for this economy. As a result, we reach the same conclusion that reducing α will reduce the effects of investment shocks upon the economy.

3.5 Extension of Uzawa-Lucas

A recent paper by Gong, Greiner and Semmler (2004) has pointed out that economic data from the US and Germany does not match the predictions of the typical Uzawa-Lucas model. These authors argue that as the amount of time dedicated to education rises, the growth rate of human capital falls due to decreasing marginal benefits. In order to explain this, Gong, Greiner and Semmler develop two different growth functions for human capital in which growth slows as more human capital exists. The first of these functions is as follows:

$$\frac{\dot{h}(t)}{h(t)} = h(t)^{p_1 - 1}\kappa(1-u(t))^{p_2} - \delta_h.$$

In this scenario, both p_1 and p_2 are between 0 and 1. Their second function is similar; the only difference is that this version allows κ to be a function of time, as follows:

$$\frac{\dot{h}(t)}{h(t)} = h(t)^{p_1 - 1}\kappa(t)(1-u(t))^{p_2} - \delta_h.$$

As shown by the authors, these diminishing return functions better explain the growth in both the US and Germany due to human capital expansion. Again, while these changes would alter the value of h in the model, they do not alter our basic steady state function. Thus, the original analysis is still valid in concluding that the importance of investment should fall as economic output becomes more dependent upon human capital.

3.6 Other Definitions of Human Capital

More generic versions of the Uzawa-Lucas model, as described by Barro and Sala-i-Martin (2001), suppose that human capital development is also tied to the current capital stock. The conclusions in this case are ambiguous, as decreasing investment would have a negative effect on human capital growth as well as dampening the effect of physical capital. In fact, if human capital development relies sufficiently on physical capital, a reduction in alpha might increase the effect of a shock in investment.

Given Barro's result that investment does not have a significant impact upon levels of education, the Uzawa-Lucas model seems to present a fairly accurate representation of reality. Current theory, therefore, seems to generally support the conclusion that as α decreases, the effect of s_k will diminish. However, the function defining the accumulation of human capital can influence the predicted effects. As a result, any definitive ruling on this subject will have to wait until the economic community reaches a consensus regarding the correct way to model human capital growth.

3.7 Complementary Factors

The models described above assume that physical and human capital are substitutes; however, there is also a possibility that the two factors complement each other. There are a number of different possible arguments supporting this theory. For example, an educated or skilled workforce may make better use of new physical capital, thus increasing its contribution to a firm's output. This type of argument is particularly relevant to the IT industry and the increasing need for technically skilled workers. On the other hand, Acemoglu (1998) argues that technology and physical capital can adjust to better suit new waves of skilled workers. While these arguments have only been applied to US studies so far, they could just as easily be applied to any nation.

If human capital and physical capital are complements, the significance of investment will rise as human capital increases within an economy. While several authors have argued that a complementary nature exists between the physical and human capital in the United States, it will be necessary to empirically test this hypothesis to determine which theoretical arguments more accurately reflect reality.

Section 4 – Initial Methods

4.1 The Basic Models

This paper's first empirical goal is to establish the importance of human capital in determining the United States' economic output. I begin in this way for two reasons. First, I consider it useful to examine human capital in a single country for its own sake. Secondly, if this analysis corresponds with the international results, it will provide some evidence that the final empirical results are applicable to the US.

In order to determine the contribution of human capital to output in the US economy, I ran a series of regressions using two different economic frameworks. The first model is based on the Uzawa-Lucas Model, combining labor and human capital into the same term. When using log levels, this model took the following form:

$$\ln(Y_t) = \alpha \times \ln(K_t) + (\beta) \times \ln(HL_t).$$

I calculated HL by multiplying national employment by the percentage of the population with college degrees. This calculation assumes that there is no correlation between having a college degree and being employed. In fact, research indicates that college graduates have higher employment rates than the overall population, indicating that this estimate would be biased below the correct representation (Sandy Baum, et al. 2006). It is also possible that more highly educated people work more hours on average, and ages of retirement may differ as well.

In addition to this two variable model, I also ran a series of regressions which separated education from the labor supply. The separation of human capital from labor is to some degree a product of the growth regressions used by Barro and Sala-i-Martin (Barro 1999; Barro and Sala-i-Martin 2001; Sala-i-Martin 1997). I took the natural logs of each variable once again in order to use the regression to calculate the linear values of α, β, and γ. This three variable model took the following form:

$$\ln(Y_t) = \alpha \times \ln(K_t) + \beta \times \ln(H_t) + \gamma \times \ln(L_t).$$

This model was then applied to an international data set to ensure that human capital growth was a significant contributor to economic output throughout the world.

Given the distinctions between the service sector and traditional manufacturing, a model which separates these two economic areas would have some inherent advantages.

A two-sector model would allow for the different rates of employment and output growth to be taken into account within the model itself, thus allowing for a more detailed examination of the growth of the service sector. While this approach might provide useful information, I wanted to pursue a modeling strategy which could be applied to both the US and to the international data sets. Most countries have only recently begun recording manufacturing and service sector statistics independently, making a two-sector model quite difficult to study empirically. For this reason, I chose to use a series of single sector models in both of my empirical studies. A future study using a two-sector model could significantly contribute to our understanding of the service sector and its impact upon modern economies.

4.2 Empirical Considerations

It should be recognized that there are potential endogeneity issues with the regressions. One concern in this paper, as in any macroeconomic empirical study, are errors caused by correlation between variables. Specifically, one could imagine that output has a direct impact on investment, the size of the employed labor force, or even human capital. In addition, while Barro (1999) failed to find a significant relationship between investment and human capital levels in his international data, it is possible that this result does not hold true for the US specifically.

Economists have developed several methods, such as the use of vector autoregressions or instrumental variables, which attempt to address these endogeneity problems. However, each approach has its own difficulties. Vector autoregressions are subject to highly variable results based upon what data are entered, and are thus thought to be unreliable by some economists (Runkle 1987). Instrumental variables attempt to avoid the problem by substituting in variables which are uncorrelated with other factors; however, it is generally either difficult or impossible to find variables which completely avoid the traditional endogeneity issues inherent in macroeconomic research. Thus, the purpose of these studies is to isolate as best one can the various factors at work, and hopefully develop a sense of their relative importance. The numbers presented in this paper should therefore not be taken as definitive values, but merely as indicators of the general contributions of various factors to economic output.

However, some sources of error can be somewhat accounted for with econometric methods. In order to discover the extent of serial correlation in the US time series regressions I used the Durbin-Watson statistic (Durbin and Watson, 1950). Given that every case exhibited at least some evidence of autocorrelation, I then performed the Prias-Winsten procedure to correct for errors in the final regressions. While this test made a few small changes to the values of the coefficients, each significant variable maintained its original sign. Moreover, all of the major conclusions can be drawn from either set of output.

When using the international panel data set it became necessary to determine which kinds of unobserved effects should be taken into account when performing the regression. Fixed effects are useful when controlling for variables which tend to be specific for given countries and relatively stable over time. However, random effects would be more appropriate if these factors change over time. I used a Hausman test (Hausman 1978) to determine which set of specifications would be most appropriate for my models.

I also made some assumptions in the formulation of this model. For example, these regressions suppose a constant return to increases in the log of human capital. Some economists, such as Paul Romer (1986), have suggested that human capital may have increasing marginal effects, a possibility that these models do not take into account. Moreover, while it is my intention that business cycle activity be taken into account through changes in investment, it is possible that omitted variables will cause small errors in the final output. I consider these small errors to be unavoidable; fortunately, none of these issues appear large enough to threaten the basic goals of the models.

Section 5 - Data

5.1 United States Data:

In order to study the evolution of the service economy and human capital in the United States, it was necessary to gather data for the four key variables in the production function: Gross Domestic Product, Investment, Employment, and Human Capital. For GDP, I used real gross domestic product as calculated by the Bureau of Economic Analysis from 1946 to 2005.[8] Investment data, indicating the change in capital stock, came from the same source. Employment information for this time period was available from the Bureau of Labor Statistics. I chose to include public employment in my measure of employment because while the government does not, in general, produce goods for the public, it does provide a number of services. Figures 5 and 6 provide a visual presentation of the investment, gross domestic product, and employment variables used in the US regressions.

[8] Although data was available from 1940-1945, I choose not to include this time period in the regressions as the economy during World War II was not operating normally under market forces.

It was necessary to deviate from the traditional measure of human capital since the United States does not have a record of secondary schooling statistics which I consider adequate to provide meaningful results. The percentage of the US population with a college degree is a reasonable alternative measure of human capital because of the United States' position as a technological leader. While Barro (1999) argued that more secondary schooling allows faster adaptation to new technology from abroad, the US is more concerned with discovering new technology for its economic expansion. Therefore, I used the Census Bureau's 10-year observations on the percentage of US citizens with a college degree as a substitute measure of human capital. As the trend for college education appears fairly linear over time, I used linear estimations to fill in the gaps between measurement points. The values used for human capital can be seen in Figure 7.

This measure of human capital differs from Barro's (1999) not only in the type of schooling, but also in that it includes both males and females. While female education levels may be insignificant for many countries with severe sex discrimination, the United States' economic development during the past sixty years has hinged upon the large entrance of women into the workforce. The number of employed women, as well as the number of women with a college degree, has risen consistently from 1946 through 2005. Therefore, failing to include females in the measures of human capital and employment would seriously misrepresent the variation in each throughout this time period.

5.2 International Data

In order to analyze a wider range of countries, I turned to the World Bank's Global Development Network Growth Database, compiled by William R. Easterly and published in 2001.[9] This report presents a large number of variables for over two hundred countries. Unfortunately, it was necessary to eliminate a majority of the countries from the database due to missing values. In the end, I was left with information on real gross domestic product, real gross domestic investment, population, and secondary school enrollment from 1960 to 1995 for forty two different countries. There might be a slight bias towards rich or very small countries in which statistics gathering is relatively simple; however, the group as a whole contains a surprising amount of economic and geographic diversity.[10]

A few observations should be made regarding this data. Population was used as a substitute for employment since employment data was not generally available. While annual secondary enrollment rates were contained in the data set, these data were only available in five year increments prior to 1975. Given the linear development of human capital observed in the United States, I again used linear estimations to extend the time series back to 1960. In addition, in order to maximize the data set, I chose to use output as measured in current US dollars rather than in PPP international dollars, which were only available from 1975 onwards. While PPP international dollars purportedly give a better estimate of the impact of investment within a country, empirical results using the

[9] Can be found at http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20701055~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html

[10] Countries include: Algeria, Australia, Austria, Botswana, Canada, Chile, Cote d'lvoire, Denmark, Egypt, Finland, France, Greece, Guyana, India, Ireland, Israel, Italy, Japan, Kenya, South Korea, Lesotho, Malaysia, Malta, Mauturius, Mexico, Morocco, Netherlands, New Zealand, Norway, Papa New Guinea, Paraguay, Peru, The Philippines, Saudi Arabia, Spain, Sweden, Thailand, Togo, The United Kingdom, Uruguay, Venezuela, and Zimbabwe.

two measurements proved very similar. Therefore, it seemed worthwhile to use the current US dollars measurements in order to keep an additional fifteen years in the time series.

I chose to use secondary school enrollment to represent human capital for a number of reasons. Secondary schooling statistics reappears consistently throughout previous studies which consider the importance of human capital (Barro 1999; Levine and Renelt 1992; Barro and Sala-i-Martin 2001); the historical precedents make this variable an obvious choice. In addition, international enrollment statistics are readily available for an extended time period. While many other indicators of human capital, such as the percentage of adults with a college education, might be useful, these statistics are kept very infrequently. Secondary school enrollment is arguably not a perfect substitute for human capital. Many developing countries receive aid and help from foreign institutions, thus artificially inflating the enrollments above the natural norm for the country. Therefore, while enrollment rates are clearly correlated with future human capital, but it is unclear how well correlated they tend to be with current levels. It will be useful to explore this connection further during the empirical results.

5.3 International Data Set Summary

It is worth examining the range of values that exist within the international data set; some summary statistics can be found in Table 5. The variety in the values can be accounted for by the large range of countries in the study and the growth that occurred in each country over the 35 year period. For example, while Uruguay produced a mere \$1,285,700 in GDP in 1960, Japan produced an incredible \$5,137,400,000,000 worth of goods and services in 1995. Investment has a similar range depending upon a country's reputation and the current state of the global economy. Population varies considerably as well.

Current secondary school enrollment, used here to measure human capital, ranges far beyond logical bounds, going as high as 142.5%. These unusually large values present the reader with something of a mystery. I concluded that these strange results are a result of the methods used in calculating the variable and social trends. There are several ways in which the number of students could exceed government expectations of one hundred percent enrollment. First, it is normal for large numbers of wealthy students in undeveloped countries to attend universities outside of their home countries in order to receive a better education. This pattern extends, to a lesser degree, to secondary schooling as well. Moreover, certain schooling systems might either enable children to skip grades or force students who do badly to repeat a grade. Through mechanisms like these, the total number of enrolled students can exceed the original projections. Since these kinds of situations occur primarily in societies with rigorous education systems and a highly skilled population, it seemed logical that values over 100% continue to provide useful data.[11] For this reason, these odd values were left unaltered.

Section 6 - Preliminary Results

6.1 Preliminary US Results

This section's goal is to determine the importance of human capital within US economic output. Many economists have attempted similar studies before. Barro (1999)

[11] These strangely large values came almost exclusively from developed countries. The following countries had enrollments over 100% in at least one year: Austrailia, Austria, Canada, Denmark, Finland, France, Ireland, Japan, Korea, Netherlands, New Zealand, Norway, Spain, Sweden, and The United Kingdom.

and Sali-i-Martin (1997) used growth regressions to study different variables' impact upon growth; each reached different conclusions regarding human capital's importance. Meanwhile, Levine and Renelt (1992), used an extreme bounds analysis and found that human capital had a robust impact on economic growth. This section uses simple models inspired by the Uzawa-Lucas model and growth regressions to analyze exactly what effect human capital has upon output in the US. Regressions showing signs of autocorrelation were adjusted using the Prais-Winsten procedure (1954).

Recall that the first model used is a two-variable model resembling the Uzawa-Lucas framework. The model used in these initial regressions is as follows:

$$\ln(Y_t) = \alpha \times \ln(K_t) + (1-\alpha) \times \ln(HL_t).$$

The results from the Uzawa-Lucas model for the entire time period, shown in Tables 1 and 2, indicate that both investment and the supply of educated labor have a significant impact upon US economic output. Table 1 shows the initial results, while Table 2 displays the results of the Prais-Winsten procedure (Prais and Winsten 1954). Surprisingly, human capital and investment initially appear to have the same coefficient of .380, although human capital proves to be the more robust variable. In the Prias-Winsten regression, while both variables remain significant, human capital has a far larger coefficient of .539 as opposed to investment's .166.

I then ran regressions using a three variable model, specified as follows:

$$\ln(Y_t) = \alpha \times \ln(K_t) + \beta \times \ln(H_t) + \gamma \times \ln(L_t).$$

This model has the advantage of highlighting the differing impacts of labor versus human capital. The idea of separating human capital from labor came from the growth regression models which typically allow each independent variable its own coefficient.

This expanded model gave similar results to the two-variable model as shown in Tables 3 and 4. Remarkably, the initial regression showed that all three variables had roughly the same effect upon economic output, each having a coefficient of approximately .380. Moreover, both investment and human capital were significant, while total employment narrowly missed the 5% significance cutoff. The corrected Prais-Winsten regression proved to be quite different. In this version, college graduate levels were the largest contributor to economic output with a coefficient of .627. Total employment came in second with a coefficient of .403, while investment was assigned a relatively small .182. Moreover, each of these variables was significant at the 5% level.

In order to develop a more exact understanding of the development of these variables over time, I decided to divide the sixty years into three twenty-year sub periods. The results of these regressions can be seen in Tables 3 and 4. The first of these sub periods, from 1946 through 1965, proved quite similar to the regressions over the entire time period. College graduate levels proved to have the largest coefficient in both regressions, with values of .795 and .850; this variable was consistently significant as well. Total employment proved less robust of a variable, as it was only significant in the initial regression. However, it had fairly large coefficients of .642 and .452. Surprisingly, investment had relatively small coefficients of .117 and .149, and was found to be significant only after autocorrelation was taken into account.

The second period, covering the time period from 1966 to 1985, was quite similar to the first period overall. All three variables were found to be significant in both regressions. There are two major distinctions between the first and second period which should be noted. First, total employment's coefficient of .384 in the initial regression is much smaller than in the first period, although the values when using the Prais-Winsten method are fairly consistent. More importantly, while college graduate levels remains the most important variable, its coefficients are much smaller than in the previous period, dropping to .399 and .415 respectively.

The third period from 1986-2005 shows that college graduate percentage rebounds to be by far the most important variable in economic output; this measure of human capital has coefficients of 1.120 and 1.015 in the two regressions, and is significant in both cases. Investment shows some increase in importance over the previous periods in both cases with coefficients of .237 and .201, and is significant in both cases. However, employment shows a severe drop in its contribution to output, as its coefficients are insignificant in both regressions. In fact, the coefficient for employment is negative in the initial regression, with a value of -.046. This suggests that the impact of employment has recently been overwhelmed by demand for skilled labor and investment.

These results correspond to previous claim that the development of computers has significantly increased the demand for college graduates since the mid 1980's (Autor et al. 1998). The temporary fall in the importance of college graduate levels can be attributed to the sharp increase in college graduates which occurred in the 1960's and 1970's as the baby boom generation finished its schooling (Acemoglu 1998). In any case, it is clear that an educated labor force is a vital factor in US economic output. Given the vastly different effects of employment versus levels of college education at different times, these results justify considering skill and basic labor as two distinct factors in the production function. In addition, given the increases in human capital during the past fifty years, the growing importance of investment presents some preliminary evidence that physical and human capital are complementary factors.

6.2 Preliminary International Results

While it would have been useful to split the international panel data into sub periods as was done in the US study, I did not believe the time series was long enough to accommodate such a division. This unfortunately prevented an investigation into the change of effects over time. I began this study by investigating what kinds of effects should be accounted for in the regression. Through the use of a Hausman test, I confirmed that a random effects model was suitable for this regression (Hausman 1978). The results of the three-variable model when applied to the international data set are shown in Table 6. Note that all three variables are significant at the 5% level. Investment and population remain positively correlated with growth.

The surprising result is that human capital, which had proved so important in the US study, has negative impact on output. This result directly contradicts not only the theoretical expectations, but also the results from the United States study. This unexpected discovery requires some further exploration. There are three important ways in which the international test differs from the US case. While fairly evident, it should be noted that this second test deals with multiple countries, and in fact does not include the United States. Therefore, a simplistic conclusion would be that human capital somehow negatively affects output in countries worldwide. This argument seems to contradict not only one’s intuition but also a great deal of previously published work and study.

Therefore, I shall discount it for now, although it will prove a useful idea later on in the analysis.

In addition, the international study uses a different set of variables than the US regressions to model the basic factors of production. First, the international regression uses population instead of employment. However, this is a fairly traditional substitution and is unlikely to have caused any large changes in the results. Moreover, the overall effect of population is what one would expect from this test. Therefore, it seems fair to discount this substitution as the primary cause of the discrepancy. The international test also reverted to using secondary school enrollment rates as a measure of human capital. One could certainly argue that there is a clear distinction between a college and a high school education. However, it seems fairly evident that both should be positively correlated with human capital. Yet these two measurements differ in another, more substantial way. While the US variable measures the level of people who have previously been educated, the secondary school variable represents to the number of people who are currently in school.

There are a number of reasons why increasing current enrollments might decrease economic output in the short term. For one, if more young adults decide to continue their education, total employment drops. Moreover, the country's government and population face increased pressure to finance their children's education, and thus invest a larger portion of their available resources into schooling. In our models which incorporate human capital, this is equivalent to increasing the variable u, which measures the fraction of a country's energy dedicated to education. Thus, over only one or two years, a country's output might in fact be reduced by increasing the levels of education.

These arguments might seem to clash with the evidence of past research, which indicates that schooling positively affects growth and/or output (Barro 1999; Levine and Renelt 1992). However, recall that two of the past studies included only one stock variable of secondary schooling in the year 1960, while Barro's regression only included three years. In addition, Barro used the average number of secondary schooling rather than an enrollment rate. Thus, these papers focused not on the current enrollment rates, but in fact upon previous enrollment rates. The previously described US regression uses a similar metric, focusing upon the current education levels within the workforce. These results indicate that it is in fact the human capital of the working population, not the future levels of available human capital, which positively affect growth.

To test this hypothesis, I then performed a number of regressions which lagged the secondary schooling rate by one to six years; these results are shown in Table 7. The results show that the more education is lagged, the greater is its positive coefficient. Moreover, the results are statistically significant when secondary schooling is lagged by three or more years. I consider the use of at least a three or four year lag appropriate, given that this is the length of time required for all of the students in a secondary school in a given year to cycle through the system. I then performed a regression including both education lagged by four years and the current enrollment rates; these results are shown in Table 8. As expected, past enrollment rates had a significant, positive impact upon output, having a coefficient of .160. Current enrollment rates had a negative coefficient of -.097 which was significant at the 10% level but not at the 5% level.

It should also be noted that current enrollment rates have a positive coefficient if the time series is restricted to the period between 1975 and 1995. However, the coefficient on lagged enrollment rates remains both more statistically significant and larger in absolute terms than that of current enrollment. The reversal of the coefficient's sign might here be read similarly to the US results. As the world incorporates new technology, human capital becomes more significantly tied to total output. As a result, since current enrollment rates are correlated to some extent with past enrollment rates, this positive effect overwhelms the previously observed negative effects of educating more people.

Thus, we can conclude that human capital, measured by previous enrollment rates, is in fact a significant factor in determining economic output; this is the end result of both the US and the international regressions. However, enrollment rates appear to have two distinct effects. Current human capital accumulation causes a steady drain upon a country's resources, thus lowering current output levels. However, the impact of past education has a more significant, and larger positive impact upon total output.

Section 7 - Secondary Methods

Having established the importance of human capital within countries around the globe, I now investigate how investment's significance changes as economies shift towards the service sector and human capital. Following Barro's (1999) intuition that a valid understanding of economic growth and output can only be obtained from studying a wide range of countries, I chose to focus on the international data set for my final empirical analysis. The model used in this section originates from the three variable model used to test the importance of human capital. Once again, we start with a Cobb-

Douglas-like production function. Note that we will make later additions to account for the possibility of K and H having complementary qualities.

$$Y = K^{\alpha} H^{\beta} L^{\gamma}.$$

In order to find a linear model, we take the natural log of both sides of this equation, which produces the following:

$$\ln(Y_{it}) = \alpha_0 + \alpha_{\mathrm{I}} \times \ln(I_{it}) + \alpha_{\mathrm{H}} \times \ln(H_{it}) + \alpha_L \times \ln(L_{it}) + \varepsilon_i \,.$$

The important question is how increasing the size of the service sector, and therefore increasing the amount of human capital, affects the significance of I. This effect can be captured through the use of an interaction term for investment and lagged human capital. Adding such a term produces the following model:

$$\ln(Y_{it}) = \alpha_0 + \alpha_{\mathrm{I}} \times \ln(I_{it}) + \alpha_{\mathrm{IH}} \times \ln(I_{it}) * \ln(H_{Lagged\_it}) + \alpha_{\mathrm{H}} \times \ln(H_{Current\_it}) +$$
$$\alpha_{\mathrm{H\_}Lagged} \times \ln(H_{Lagged\_it}) + \alpha_L \times \ln(L_{it}) + \varepsilon_i .$$

Note that this equation includes measures of both current and past human capital in order to account for the dual nature of enrollment rates seen in the preliminary international results. The interaction term between lagged human capital and investment is meant to capture how these two terms interact. Given the insignificance of current enrollment rates, none of the other variables provide an intuitive reason for why an interaction term should be included in the regression for them. Note that I will use the Hausman test once again to determine which set of effects should be used when performing the regression (Hausman 1978).

This model should be able to determine what effect, if any, the growth of the service sector has upon investment’s impact on total output. If, as proposed by Acemoglu (1998) and Autor, Katz and Krueger (1998), investment and human capital are complementary, this term will likely have a positive coefficient. If, on the other hand, human capital acts as a substitute for investment as services take over an economy, the ln(I)*ln(HC) term should have a negative coefficient.

Section 8 - Secondary Results

It was first necessary to determine what kinds of unobserved effects should be accounted for within this panel-series regression. I performed another Hausman test in order to determine whether fixed effects or random effects would be more appropriate (Hausman 1978). The results showed that while random effects had proven usable for the preliminary tests without an interaction term, it would be necessary to switch to fixed effects for the final set of regressions. In retrospect, this outcome is not particularly surprising. While countries have the ability to develop and change very rapidly at times, long term development tends to be much slower and more gradual. Thus, one would expect that there is a set of constant, unobserved variables which affect each country fairly consistently from 1960 to 1995. Fortunately, these are exactly the types of factors taken into account by a fixed effect regression. Ultimately this is an academic debate, as the differences between the fixed effects and random effects regressions are small in this study and do not affect the sign of any of the coefficients.

Recall that the model used included terms for the log values of investment, population, human capital, and an interaction term for investment and human capital. This model can be defined as follows:

$$\ln(Y_{it}) = \alpha_0 + \alpha_{\mathrm{I}} \times \ln(I_{it}) + \alpha_{\mathrm{IH}} \times \ln(I_{it}) * \ln(H_{Lagged\_it}) + \alpha_{\mathrm{H}} \times \ln(H_{Current\_it}) + \\ \alpha_{\mathrm{H}\_Lagged} \times \ln(H_{Lagged\_it}) + \alpha_L \times \ln(L_{it}) + \varepsilon_i .$$

The results of the final regression with a four year human capital lag can be seen in Table 9; results using random effects can be seen in Table 10. Increasing the number of years which secondary enrollment is lagged has little effect upon the coefficients of the variables. Investment and population remain significant and have large positive coefficients, with values of .476 and .426 respectively. Current secondary enrollment, as before, remains insignificant with a small negative coefficient.

On the other hand, the final two variables require more analysis. Lagged school enrollments have a negative coefficient in the final regression. This is a rather unexpected result, as it implies that short of any interaction with physical capital, an educated workforce has a negative impact upon economic output. There are some potential explanations for this observation. For example, as discussed above, companies at times prefer to stay at sub-optimal levels of employment during economic downturns rather than accept a high turnover amongst its more skilled workers, leading to less variation in service sector employment rates. However, this increased stability comes at a price of inefficiency during recessions. However, most economists would at present be hesitant to accept such a critical interpretation of the effects of human capital upon an economy.

The term expressing the interaction of lagged school enrollment rates and current investment has a positive and significant coefficient. This implies that skilled workers and physical capital are highly complementary, and thus agrees with the arguments made by Acemoglu (1998) and Autor, Katz and Krueger (1998). Clearly, this complementary effect overwhelms any effects caused by the adjustment of alpha as discussed within the theoretical section. Taken in conjunction with the negative coefficient on lagged enrollment rates, the extreme conclusion would be that education enhances economic output solely through its interaction with physical capital.

Section 9 - Conclusion

This paper set out to investigate how the rise of a service sector within an economy would affect the relative importance of investment in determining economic output. The analysis was based upon the well observed link between service economies and increased demand for educated laborers. Using the recently developed economic models which include human capital in the production function, I proposed two contrasting theoretical possibilities; the degree of complementarity between investment and human capital would determine which theory was correct. Preliminary results showed that human capital was in fact a significant contributor to economic output; in the US's case, this was particularly true during the past twenty years.

With the importance of human capital established, the final results indicate that human capital and physical capital are in fact complementary. Thus, the empirical results show that as a country moves towards a service economy and the number of skilled workers rises, the importance of investment will also rise. As the importance of investment rises, economic hardships brought on by crowding out will become more severe. This result therefore exacerbates the future fiscal dilemma faced by the United States, and increases the need for steps to be taken to address the current and predicted growth of the national debt.

This paper has demonstrated that physical capital and human capital are complementary factors in the production function throughout the global economy. There are several ways in which this type of research could be expanded upon and refined. Other than performing the tests above with larger data sets, one possible extension to this work would be to further explore the unexpected negative effect of human capital on output in the final regression. Further study into this area might prove useful in developing our understanding not only of service economies, but also of education and human capital in general. Understanding how the shift towards a service economy affects human capital could allow economists to develop more realistic models of modern economies. In particular, a two-sector model might enable researchers to more thoroughly understand the consequences of the rise of the service sector.

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Tables and Figures

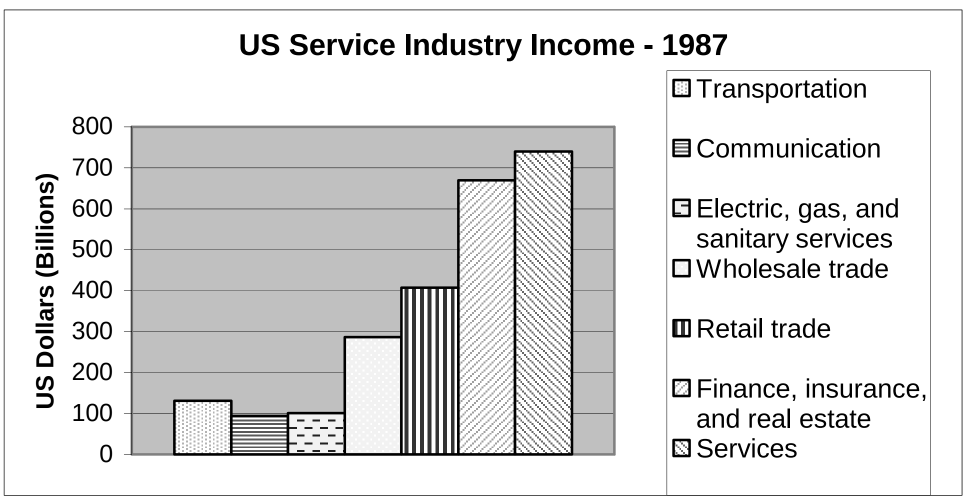

Figure 1: US Service Industry Income in 1987
Data from the Bureau of Economic Analysis

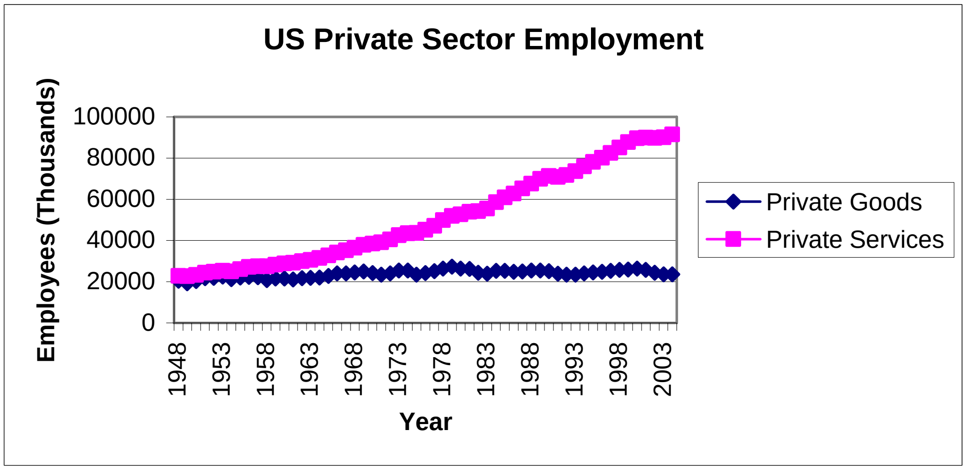

Figure 2: Employment in US Manufacturing versus Services
Data from the Bureau of Economic Analysis

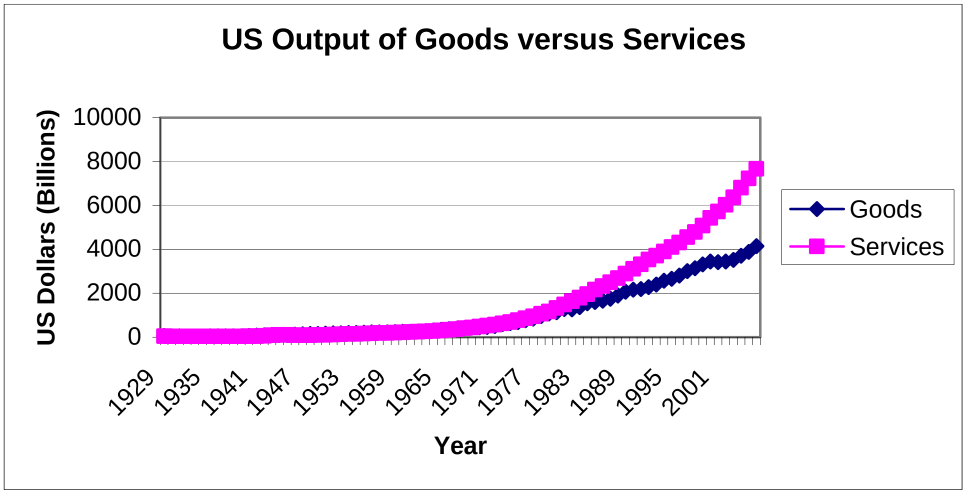

Figure 3: Output of US Goods versus Services
Data from the Bureau of Economic Analysis

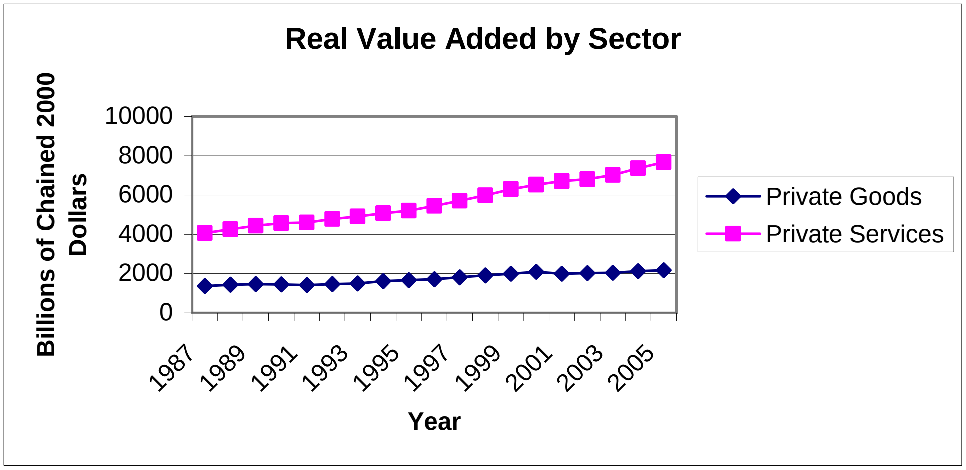

Figure 4: Comparison of Real Value Added by Goods versus Services
Data from the Bureau of Economic Analysis

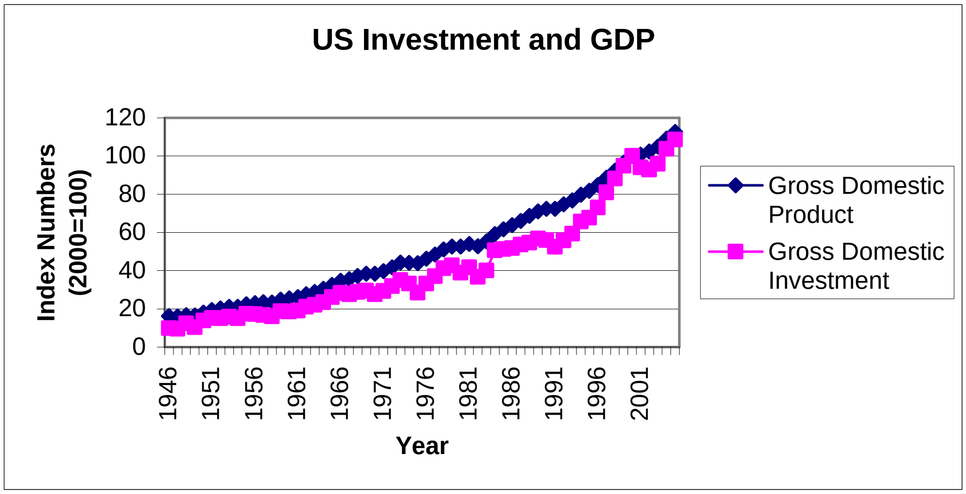

Figure 5: US Real Output and Investment 1946-2005
Data from the Bureau of Economic Analysis

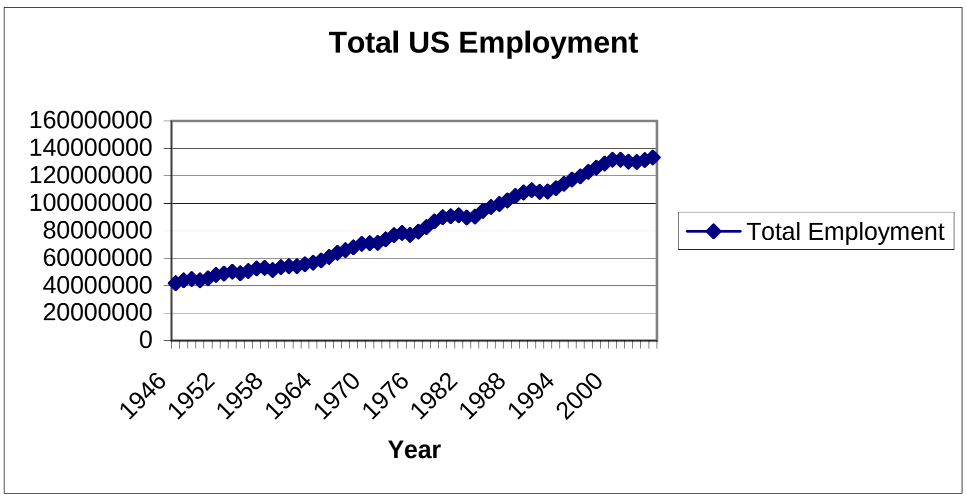

Figure 6: US Total Employment, 1946-2005
Data from the Bureau of Labor Statistics

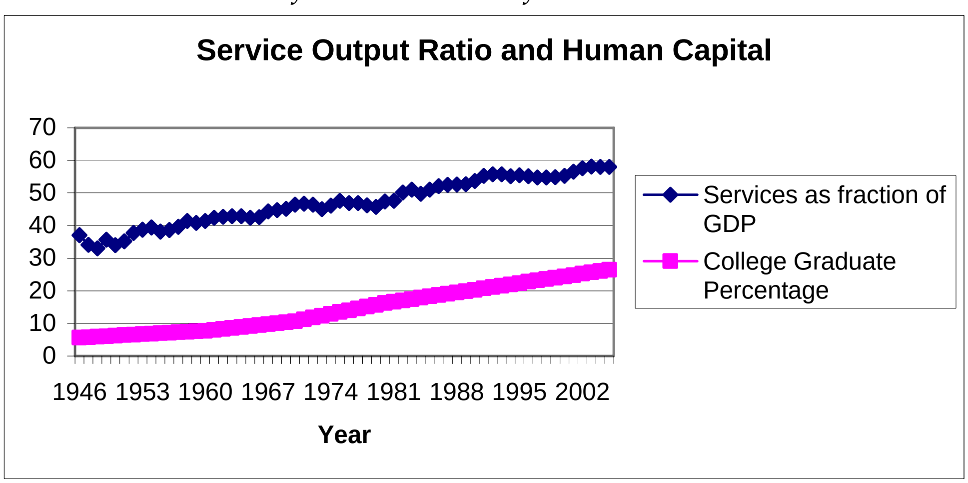

Figure 7: Comparison of Service Output Growth and Human Capital Development in the US - Data from the Bureau of Economic Analysis and the Census Bureau

	Coefficient	Standard Error	T Statistic
ln_gdi	.380	.032	11.74
ln_human_capital	.380	.025	15.34
Constant	-3.69		

Table 1: US Two Variable Model - 1946-2005 – Standard Regression

	Coefficient	Standard Error	T Statistic
ln_gdi	.166	.021	7.92
ln_human_capital	.539	.030	18.24
Constant	-5.48		

Table 2: US Two Variable Model, 1940-2005 –
Regression using Prais-Winsten Procedure

	1946-1965	1966-1985	1986-2005	1946-2005
ln_gdi	.117 (.066)	.201* (.036)	.237* (.044)	.380* (.043)
ln_college_grad	.795* (.137)	.399* (.079)	1.120* (.111)	.381* (.104)
ln_total_employment	.642* (.252)	.384* (.162)	-.046 (.170)	.380 (.192)
Constant	-10.169*	-4.921	.800	-5.421

Table 3: US Three Variable Model – Standard Regression
** indicates significance at the 5% level*

	1946-1965	1966-1985	1986-2005	1946-2005
ln_gdi	.149* (.057)	.184* (.036)	.201* (.032)	.182* (.024)
ln_college_grad	.850* (.139)	.415* (.086)	1.015* (.093)	.627* (.073)
ln_total_employment	.452 (.236)	.403* (.171)	.211 (.121)	.403* (.107)

Constant	-6.984	-5.233	-3.450	-5.762*

Table 4: US Three Variable Model – Regression using Prais-Winsten Procedure
** indicates significance at 5% level*

	Gross Domestic Product (millions)	Investment (millions)	Population	Secondary Enrollment
Average Value	$107,800.47	$26,440.53	34,564,811	54.58%
Minimum	$1.28	$.275	318,820	1.00%
Maximum	$5,137,400.00	$1,468,834.03	929,360,000	142.50%

Table 5: Summary of International Data from 1960-1995

	Coefficient	Standard Error	Z Statistic
ln_investment	.9149688	.0091847	99.62
ln_population	.1119555	.0182618	6.13
ln_sec	-.0636823	.020328	-3.13

Table 6: International Output Regression Results – 3 Variable Model

	Secondary Schooling Coefficient	Standard Error	Z Statistic
One Year Lag	-.0362859	.0200875	-1.81
Two Year Lag	.000777	.0198929	-.04
Three Year Lag	.0404298	.0198504	2.04
Four Year Lag	.0881959	.0199055	4.43
Five Year Lag	.1118377	.0197245	5.67
Six Year Lag	.1345592	.0195429	5.79

Table 7: International Output Regression Results – Delayed Education

	Coefficient	Standard Error	Z Statistic
ln_investment	.8612387	.106395	80.95

ln_population	.1651801	.0202449	8.16
ln_sec	-.0973394	.0503839	-1.93
ln_sec_lagged	.1598441	.0421065	3.80

Table 8: International Output Regression: 4 Year Lag – Random Effects

	Coefficient	Standard Error	Z Statistic
ln_investment	.4733604	.0198352	23.86
ln_population	.425922	.058588	7.27
ln_human_capital	-.0244135	.0442393	-.055
ln_lagged_hc	-1.485738	.0824442	-18.02
ln_interaction	.0833004	.0038923	21.40
constant	4.92526	.9307326	5.29

Table 9: Interaction Term Results with a 4-year lag using Fixed Effects

	Coefficient	Standard Error	Z Statistic
ln_investment	.4968316	.0193412	25.69
ln_population	.227213	.0197474	11.51
ln_human_capital	-.0229829	.0436628	-.053
ln_lagged_hc	-1.396396	.0815653	-17.12
ln_interaction	.0807851	.0037907	21.31
constant	7.486172	.3836013	19.52

Table 10: Interaction Term Results with a 4-year lag using Random Effects