DETERMINANTS OF LIFE EXPECTANCY FOR SUB-SAHARAN AFRICA: EXAMINING INTERNATIONAL TRADE

by

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Contents

1 Introduction

There has been an increased interest over the last decade over the effects economic growth has on health and life expectancy. Has economic growth really improved health conditions or is it a simple case of "survival of the fittest", where humans are still continually adapting to our ever changing surroundings? Past studies have found the relationship between economic growth and life expectancy to be positively, albeit, weakly correlated.

Since globalization plays a major role in economic growth in contemporary society, one would assume that by integrating markets and having access to newer technology and medical advancements (that each country has to offer) that life expectancy would undoubtedly improve. Countries that are open to international trade may experience an improvement in health conditions through imported goods that do not exist or are unavailable domestically, or through exported goods that generate a source of revenue stream for countries to increase their national spending as well as GDP. Thus international trade could theoretically improve health conditions through these channels, as it can lead to increase in economic prosperity and increases in consumer wealth. However, the question remains whether these effects are long or short term, or if they are even at all significant.

Furthermore, while most of the world as experienced economic growth and prosperity during the last half century, Sub-Sahara Africa remains an under-developed region that is torn by poverty, violence, and an overall weak economy. While health conditions have improved over the last half century in Sub-Sahara Africa, when compared to other regions, it still remains one of the poorest regions in the world today.

However, there is evidence in Sub-Sahara Africa that certain countries have improved dramatically economically. Acemoglu, Johnson, and Robinson (2001) look at the African success story of Botswana, a country that has had extraordinary growth rate in the last 35 years due to its sound policies and great institutions. Before it's independence in 1966, the life expectancy in Botswana increased by only 4.2% between 1960-1966, while international trade increased by 147%. However, from 1966-1992, before the AIDS pandemic hit Botswana, life expectancy increased by 17.8% from 53.17 years to 62.66 years. International trade during this period increased by 8047%. In contrast, during the same period between 1966-1992, Botswana's neighboring country of Zimbabwe only saw a 532% increase in international trade, and it's life expectancy only increased by 12% from 54.04 years to 60.50 years. While these countries are not representative of all Sub-Saharan African countries, the data does seem to suggest that improvement in economic freedom and openness to trade improve health conditions.

This paper will focus on Sub-Sahara Africa, and study the determinants that affect its health conditions. If Sub-Saharan African countries could improve their health and life expectancy, they could possibly experience an increase in productivity and stronger economic growth. This paper will examine the effect economic trade has on health, and whether a long run equilibrium relationship can be obtained between life expectancy and trade. The goal of the paper is to provide further insight on the determinants that affect health and life expectancy for Sub-Sahara Africa, and compare these results with developed Western nations.

The results indicate that there is a strong positive correlation between life expectancy and international trade for all countries. A 1% increase in trade will increase life expectancy by 2.45 years for Sub-Saharan African countries, but this effect is smaller when compared to Western countries, where

a 1% increase in trade will increase life expectancy by 2.66 years. Democracy, on the other hand, only seems to affect Sub-Saharan African countries and not Western countries. Conversely, good institutions measured by a constraint on the executive, indicate that only Western countries are affected by leadership accountability. Furthermore, a long run equilibrium relationship between life expectancy and international trade is established for Sub-Saharan African countries where a 1% in trade will increase life expectancy by 4.15 years in the long run.

The paper is organized by the following sections. Section 1, the current section, is the introduction to the topic. Section 2 includes literature review on recent papers dealing with factors that impact health and life expectancy. Section 3 describes the models and data used during estimation. Section 4 presents the empirical results as well as analysis of the estimated models. Section 5 takes a time series approach in analyzing long run equilibrium effects trade may have on life expectancy. Section 6 concludes the paper, while the Section 7 appendix includes tables highlighting the results of the estimation and Section 8 includes references of papers used.

2 Literature Review

In developmental economics, there have recently been an increased interest in literature studying the effect of economic growth on health and life expectancy. Preston (1975) studies the effect income has on life expectancy, and finds a non-linear relationship where life expectancy is increased the most for an increase among the lowest income group. The relationship is described by the Preston Curve, which demonstrates the non-linear relationship between life expectancy and income.

Besley and Kudamatsu (2006), however, argue that the increases in life expectancy can be at-

tributed to three factors - reduction in malnutrition and improvement in infrastructure, medical advancement, and improvement in health knowledge and lifestyle. In their paper, they instead look at the impact of democracy on health for all countries. They use panel data for a cross-section of countries to study whether democracy is positively correlated with health improvements. Holding income levels, legal origins, schooling, and regional effects fixed, they find that short term democracy is positively correlated with an increase in life expectancy and a decrease in infant mortality. When they include the dummy variable for whether a country has been democratic since 1955, they find that this long term democratic effect becomes highly significant, while short term transitional democratic effects become insignificant.

Kudamatsu (2008) also studies the effect of democratization in Sub-Saharan Africa. He compares the survival rate of infants born to the same mother over time, and find that infant mortality has decreased significantly after the introduction of multiparty elections and a move to democracy. He notes that the survival rates are much higher after democratization, and that these results were not present under dictators that stayed in power after winning the elections or when leaders assumed power through non-democratic means. He argues that the improvement in health conditions in Sub-Saharan Africa is a result of better health policies after democratization, rather than improvement in economic conditions.

While these studies show that democracy is perhaps an important factor in explaining improvement in health, it does not explain the dramatic increase in life expectancy over the past 40 years in Sub-Sahara Africa, as many countries are non-democratic and others have only recently changed their government structure. It's perhaps not only the particular form of government, but also the type of

policies adopted that has an impact on life expectancy.

Govindaraj and Rannan-Eliya (1994) study the effect of democracy and communism on health. They create dummy variables for democracy, defined as a country that has multiple political parties, and a dummy variable for communism, defined as a country that has only one major political party that stay in power. They regress health measures (life expectancy and infant mortality) on democracy and communism while holding income fixed, and find that both democracy and communism are significant and positively correlated with improvement in health.

While the results presented by Govindaraj and Rannan-Eliya (1994) do not contradict previous studies, it does indicate that perhaps it is not democracy that affects health, but rather a suitable form of government that can properly implement health policies. Perhaps incorporating other economic factors such as international trade could help to explain the dramatic increase in life expectancy over the past half century.

Acemoglu and Robinson (2008) look at the differences in government to explain their effect on health. They examine three different channels through which a form of government can affect health. Firstly, they model autocracies as a dictatorship for the rich, while democracies are seen as a dictatorship of the poor. Health is more likely to increase in a democracy, as the poor have more incentive to focus on social welfare, whereas a rich dictatorship will have less incentive on public health and more on prosperity. Secondly, there is a constraint on the executive in terms of authority and accountability. Governments who are held more accountable will likely create policies that benefit everyone, and failure to implement the policies could result in a removal from office. Thirdly, democracies are more

likely to elect honest leaders that are willing to implement policies more efficiently. In this sense, health policies under democracies will have a greater effect as they are implemented more swiftly.

Acemoglu and Johnson (2007) study the effect that health conditions have on economic growth, and attempt to find a robust relationship between life expectancy and economic growth. After controlling for diseases and medical advancements, they find that while improvements in life expectancy significantly increased total population, the effect of life expectancy on GDP was minimal. The effect of life expectancy on GDP growth was small during the first 40 years of the study, and grew during the next 20 years, but the increase in GDP did not compensate for the immense growth in population, and as a result income per capita actually decreases over the same period. While they found no evidence to support the theory that life expectancy leads to faster growth of income per capita, their study still provides some evidence of the importance that health conditions have on GDP growth.

Brunner (2003) investigates the impact that trade has on income and income growth. While this study is not directly related to improvements in health and life expectancy, it can be argued that income and GPD are positively correlated with improvements in life expectancy, as studied by Preston (1975). Using panel data, he finds that international trade has a large positive effect on income, but not income growth. However, there is clear endogeneity between income and trade, as richer countries will likely have higher volumes of trade while higher volumes of trade will increase income. To control for this effect, Brunner uses an instrumental variable regression where geographic variables such as a country's size and proximity to another country is used. He argues that geographic variables are strong predictors of trade, but are unlikely to affect income. Using this IV estimation, he finds that there still exists a strong positive relationship between income and trade. While this study is not

directly related to health, it does indicate that trade has a positive effect on income, which will also improve health conditions.

While there are many studies relating democracy and income on health, and trade on income, there is a lack of literature that looks at globalization and international trade, and how they affect health condition and life expectancy. Furthermore, there has not been a study that have demonstrated if such a link existed, and if it is at all significant. It is with these concerns that I will focus my paper on, in an attempt to find both a robust and long-run relationship between international trade and life expectancy.

3 Model, Data, and Summary Statistics

Sub-Sahara Africa is one of the poorest regions in the world today, containing some of the least developed countries. The area suffers from a poor economy, poor and corrupt government, as well as constant ethnic conflicts. While the region has the highest fertility rate in the world, it's infant mortality rate is alarmingly high, with 1 in 6 children dying before the age of 5[1]. Sub-Saharan African countries also have one of the lowest life expectancy in the world.

This section of the paper will attempt to describe a robust model that examines the determinants which affect life expectancy, a measure of health. The idea is that improving health conditions and life expectancy will help to develop the region of Sub-Sahara Africa. After a model is created and estimated, the paper will compare and contract the determinants that affect life expectancy between developed Western nations and Sub-Saharan African countries.

[1] http://www.worldbank.org

3.1 Model

The basic model incorporating life expectancy on its determinants is

$$LE_{i,t} = \delta Tr_{i,t} + \beta_1 Inc_{i,t} + \beta_2 Inc2_{i,t} + \lambda Sch_{i,t} + \gamma Dem_{i,t} + \theta ExCons + \epsilon_{i,t} \quad (1)$$

where $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

- **LE**$_{i,t}$ is the dependent variable - life expectancy.

- **Tr**$_{i,t}$ is the natural log of the volume of trade (measures as the sum of imports and exports). International trade can have several indirect effects on life expectancy. Firstly, countries that import goods are likely importing products that are either comparatively cheaper to purchase internationally rather than allocating precious resources to produce these goods themselves. In this sense, they can allocate their resources more efficiently in producing other goods and services that can benefit economic growth, increase productivity, and as a result, improve an individual's wealth. Thus international trade may have an indirect affect on income, which directly and indirectly affect life expectancy (discussed below).

  Secondly, countries will also import goods that do not exist and are unavailable domestically. Such goods can include medical and technological products such as new equipment used in health facilities or safer equipments used in daily labor. An example could be a new machine in a factory that is safer to handle and emits less toxic chemicals into the workplace. Other goods may include new drugs and medicines from more developed countries that directly improve health conditions and life expectancy. Health goods can also be introduced through imports. Another type of good, albeit a more expensive "luxury" good, are health goods that being de-

veloped each year that improve and strengthen the body through increased blood circulation, better maintenance of vital organs, and provide increased energy. By importing these goods into a country, life expectancy should be directly affected.

Exports also indirectly affect life expectancy, as it can promote economic growth. Exports is a source of revenue stream for countries, and increasing exports will lead to an increase in national wealth, GDP, and even employment. This indirectly affects life expectancy, as increased economic prosperity can lead to an increase in consumer wealth, which again can increase individual income, and subsequently life expectancy.

- **Inc**$_{i,t}$ is per capita income. Income can affect life expectancy directly and indirectly. Preston (1975) argues that an increase in household income leads to better living standards as better housing, food, and products and services are more affordable, all of which could improve health conditions, reduce mortality rates and subsequently, increase life expectancy. One would expect that as personal wealth increases, individuals are also more likely to substitute away from inferior goods. Furthermore, income indirectly affects life expectancy through policies that are formed that focus on income as the dominant measurement of economic growth. Income also affects life expectancy indirectly through a better accessibility of health and medical services, as well as higher levels of education.

- **Inc2**$_{i,t}$ is per capita income squared. The effect of income on life expectancy may be a non-linear, concave relationship that exhibits diminishing returns[2]. While increased levels of income can improve health conditions, there could also be a negative effect of excess income on health. It is possible that once an individual reaches a certain level of wealth, he or she may start buying

[2] As shown by the Preston Curves in the Appendix

goods that are actually harmful to one's health, such as a greater consumption of alcohol and cigarettes. Thus by incorporating a squared term of income, this variable can capture not only the diminishing returns of income on life expectancy, but also the negative associates that come with higher levels of income.

- **Sch**$_{i,t}$ is the average number of years an individual over 15 has attended school for. One would expect that the pursuit of higher education should increase life expectancy, and individuals will generally be more knowledgable and can improve their health. In Besley and Kudamatsu (2006)'s paper, they find that schooling has a significant positive effect on life expectancy.

- **Dem**$_{i,t}$ is a dummy variable that equals 1 if country i is democratic during year t, and 0 otherwise. Past studies have shown that life expectancy is higher in democratic countries compared to non-democratic countries, due to improved health policies, accountability of the leaders, and less corruption among other factors. Both Besley and Kudamatsu (2006)'s and Govindaraj and Rannan-Eliya (1994)'s papers have found that democracy is significant and positively correlated with life expectancy.

- **ExCons**$_{i,t}$ is a measure of institutionalized constraint on the executive. It measures the level of authority that executives have within the country. This variable is included in the model as a proxy for corruption, with the idea that the less corrupt a country and its government is, the more efficient policies will be implemented. Thus officials that have unlimited authority are easily corrupted, which will affect policy implementation, and accountability. One would expect that countries that demand more accountability should experience higher life expectancy. The argument is that if officials are held accountable, they will be less likely to abuse their leadership powers and more likely to implement policies that are beneficial to the citizens (as suggested by Acemoglu and Robinson (2008)).

3.2 Data

This paper uses panel data ranging from 1960-2002.

- **LE**$_{i,t}$ is taken from the World Bank dataset[3]. Countries that had missing observations for several years had these values replaced by an average of the years immediately preceding and following it.

- **Inc**$_{i,t}$ is taken from Besley and Kudamatsu (2006)'s dataset. It is measured as real GDP per capita averaged over the years a country has been democratic.

- **Tr**$_{i,t}$ is taken from the World Bank dataset[4]. Imports and Exports for countries are taken, and then summed up. We then take the natural logarithm of the total.

- **Sch**$_{i,t}$ is taken from Besley and Kudamatsu (2006)'s dataset.

- **Dem**$_{i,t}$ is taken from Besley and Kudamatsu (2006)'s dataset.

- **ExCons**$_{i,t}$ is taken from the POLITY IV dataset[5]. It is given a value between 1 to 7, with 1 indicating that the executive has unlimited authority and will not be held accountable for their actions, while a 7 indicates that the executives are held accountable for their decisions and can be effectively removed from office. As mentioned earlier, this variable is a suitable proxy for corruption[6].

One would suspect that the variables for democracy and constraint on executive are highly correlated, as one would expect democratic countries to demand more accountability from its leaders. We

[3] http://www.worldbank.org/

[4] http://www.worldbank.org/

[5] http://www.systemicpeace.org/polity/polity4.htm

[6] Note however that since Western countries are all democracies, the average value for ExCons is 6.94 with a standard deviation of 0.24, whereas Sub-Saharan African countries do not have established democracies, and the average value for ExCons is 3.66 with a 1.76 standard deviation

test for multicollinearity and find the R^2 value between democracy and constraint on executive to be 0.8553. A possible measure of democracy that is uncorrelated with constraint on the executive could be POLITY2. It is taken from the POLITY IV dataset and given a measure between -10 to 10, with -10 being highly autocratic and 10 being highly democratic. We find that the R^2 value between democracy and polity2 is 0.5310. We then test to see if there is still a high level of collinearity between polity2 and constraint on executive, and find that the R^2 is only 0.2840. Thus while polity2 is not the perfect proxy variable for democracy, it is sufficient to use this measure of democracy instead.

One would also expect income and education levels to be highly correlated, as higher income results in affordability of further education, while further education can increase earnings. A test for multicollinearity between income and education indicate that the R^2 between these two variables is 0.8512. This is one problem in our paper, as we were unable to find a suitable proxy variable for education that was not highly correlated with income.

Thus the original model is modified to the following,

$$LE_{i,t} = \beta_1 Inc_{i,t} + \beta_2 Inc2_{i,t} + \delta Tr_{i,t} + \lambda Sch_{i,t} + \gamma Polity2_{i,t} + \theta ExCons + \epsilon_{i,t} \quad (2)$$

where $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

3.3 Summary Statistics

Taking a quick examination of the panel dataset, there are several interesting results that were expected a priori. From Figures 1-5 in the appendix, we see that the Preston Curves defining the non-linear relationship between life expectancy and income (first shown by Preston (1975)) holds for Western countries as well as Sub-Saharan African countries. The findings also agree with Preston (1975)'s

finding there has been an increase in income for Western nations, while life expectancy remained relatively the same from 1960 to 2000. The interesting observation is that while life expectancy has increased for Sub-Saharan African countries from 1960 to 2000, income has increased by a much smaller account. This result also follows from Preston (1975)'s findings, where an increase in the lowest income group results in a greater increase in life expectancy. These findings can be explained by the non-linear, concave relationship between life expectancy and income, as there is a diminishing return effect of income on life expectancy.

Taking a look at the summary statistics from Table I in the appendix, it is obvious that there are some major differences between Sub-Saharan African countries and Western nations. While the averages of each variable during 1960-2002 between the two regions suggest major differences, it is perhaps more important to look at the averages for 1960 and the averages for 2000 to show any real improvements in these variables.

The average life expectancy for Western countries in 1960 was 70.12 while it increased by 11.5% to 78.20 in 2000. The standard deviation also decreased from 2.41 to 10.6 during the same period, indicating that there is a convergence between life expectancy between Western nations. In contrast, the life expectancy for Sub-Saharan African countries increased by 22.2% from 42.07 to 51.40. However, the standard deviation for the same period increased from 5.74 to 7.59, suggesting that while health conditions have improved in this region, there is still a great disparity between countries as not all countries improved by the same amount.

Income per capita increased by 191% from 7.5 to 21.79 for Western countries, while it only increased by 46.5% for Sub-Saharan African countries. Thus while Western nations experienced great economic

growth during the period between 1960-2000, the growth of Sub-Saharan African countries remained minimal by comparison.

The natural logarithm of international trade for Western countries increased by 17.7% from 21.81 to 25.68 (or a 4694% increase in net trade) while it only increased by 14.6% from 18.32 to 20.99 (or a 1344% increase in net trade) for Sub-Saharan African countries. While the increase in trade is significant for both regions, trade appears to have impacted Western countries a lot more than for Sub-Saharan African countries.

The other interesting observation is that while democracy (measured by polity2) appeared to increase slightly for Western nations from 7.12 to 9.94, democracy appears to have advanced a lot more in Sub-Saharan African countries, as the measure increased from -4.17 (autocratic) to 0.66. This improvement in democracy reflects the political reform for the region of Sub-Saharan African countries during the 1990s, and it's effects are yet to be observed as the change in regime was very recent.

4 OLS estimations and results

Two separate regressions are run for Sub-Saharan African countries and Western countries.
For Sub-Saharan African countries, a dummy variable for the year 1990 is included. During the early 1990s, a lot of countries in this region changed their political structure to democracies, and the dummy

variable is included to capture the structural break during this period.

$$LE_{i,t} = \beta_1 Inc_{i,t} + \beta_2 Inc2_{i,t} + \delta Tr_{i,t} + \lambda Sch_{i,t} + \gamma Polity2_{i,t} + \theta ExCons + \tau Year1990 + \epsilon_{i,t} \quad (3)$$

where $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

For Western nations, the model follows from the previous model (2) derived in section 3.

$$LE_{i,t} = \beta_1 Inc_{i,t} + \beta_2 Inc2_{i,t} + \delta Tr_{i,t} + \lambda Sch_{i,t} + \gamma Polity2_{i,t} + \theta ExCons + \epsilon_{i,t} \quad (4)$$

where $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

4.1 Empirical Results

The regression results for both regions are displayed in Tables II and III of the Appendix. For Western countries, 7 separate regressions were run. Regression (1) is a simple regression of life expectancy on income. Regression (2) takes into account the fact that income may not be a simple linear relationship with life expectancy. While both income and income squared are highly statistically significant at the 99% level, once we include international trade in regression (3), we notice that only log of trade is statistically significant at the 99% level and that income becomes insignificant. The amount of education an individual receives is statistically insignificant once it is included in regression (4). This could be due to the previously mentioned fact that education and income were highly collinear, so that income captured most of the effect schooling has on life expectancy. When the democracy measure (polity2) and constraint on the executive are included in regressions (5) and (6), they are both statistically insignificant. However, once both are included in regression (7), they are both statistically significant at the 99% level.

The estimated model for Western nations in regression (7) results is

$$LE_{i,t} = 0.04Inc_{i,t} + -0.01Inc2_{i,t} + 2.66Tr_{i,t} + -0.05Sch_{i,t}$$
$$+ -0.98Polity2_{i,t} + 3.11ExCons \qquad (5)$$
$$\text{where } i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T.$$

For Sub-Saharan African countries, 8 separate regressions were run. Regressions (1) through (7) remain the same as those for Western countries. The main results here indicate that log of trade is statistically significant in all regression models. However, in regression (5), the democracy measure is statistically significant at the 90% level while constraint on the executive is statistically insignificant for all regressions. When both variables are included in regression (7), only the measure for democracy remains statistically significant at the 90% level. In regression (8), a dummy variable for the year 1990 is included that is statistically significant at the 99% level.

The estimated model for Sub-Saharan African countries in regression (8) is

$$LE_{i,t} = 1.33Inc_{i,t} + -0.05Inc2_{i,t} + 2.45Tr_{i,t} + 0.68Sch_{i,t}$$
$$+ 0.43Polity2_{i,t} + -0.86ExCons + 2.47Year1990 \qquad (6)$$
$$\text{where } i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T.$$

The results estimated above give us some insight to the determinants that affect life expectancy in both regions. Firstly, note that in both models, income exhibits a non-linear, concave relationship with life expectancy, a finding that is consistent with Preston (1975). From the estimated equation (6) and from Table II in the Appendix, we notice that trade, democracy, and the dummy variable for 1990

affect life expectancy the most in Sub-Saharan African countries. A percentage increase in the natural logarithm of trade will increase life expectancy by 2.45 years, while a unit increase in the democratic measure polity2 will increase life expectancy by 0.43 years. The structural break in 1990 also affects life expectancy, as it appears that the effect of countries becoming democratic during 1990 increased life expectancy by 2.47 years.

F-tests were performed on income and income squared, as well as including schooling into the test. The p-value for the tests were 0.3609 and 0.5172 respectively, indicating that there is no joint significance between these variables. However, a joint test on all variables resulted in a p-value of 0.0000, indicating that none of the variables could be dropped.

From the estimated equation (5) and from Table III in the Appendix, we notice that trade, democracy, and constraint on the executive affect life expectancy the most in Western countries. A percentage increase in the natural logarithm of trade will increase life expectancy by 2.66 years, while a unit increase in the democratic measure polity2 will decrease life expectancy by 0.98 years. Improvement in institutions will increase life expectancy by 3.11 years.

F-tests were again performed on income and income squared, as well as schooling. The p-values for the tests were 0.0310 and 0.0668, indicating that the variables are jointly significant and cannot be dropped from the model. Also, a joint test on all the variables again resulted in a p-value of 0.0000, indicating that none of the variables could be dropped.

4.2 Analysis

The regression results present some interesting findings with respect to Sub-Saharan African and Western countries in terms of factors that affect health. While in both cases, trade has a significant affect on life expectancy, the magnitude is slightly higher for Western countries compared to Sub-Saharan African countries. While a percentage increase in the natural logarithm of trade increases life expectancy for Western countries by 2.66 years, it only increases life expectancy for Sub-Saharan African countries by 2.45 years. An explanation for this could be the fact that Western nations are a lot more established in terms of policies and wealth than Sub-Saharan African countries. As a result, trade has a greater impact on life expectancy, whereas other factors may affect life expectancy in Sub-Sahara Africa more.

Another interesting result is the degree to which constraint on the executive affects both regions. While this variable is insignificant for Sub-Sahara Africa, it is highly significant for Western countries, as a unit increase in this measure increases life expectancy by 3.11. The intuition behind this is that Western nations already have a good political system in place, and thus the degree to which leaders have power and the accountability of leaders when implementing policies is a lot more important in Western nations. In contrast, a lot of countries in Sub-Sahara Africa are either non-democratic, or have recently just transitioned into a democratic society. As a result, constraint on the executive is not as important for these countries. Instead, these countries should focus more on moving towards a more a stable government. This theory is further supported by the results of democracy on life expectancy.

For Sub-Sahara African countries, a unit increase in the democratic measures will increase life expectancy by 0.43 years (a result that agrees with the findings of Besley and Kudamatsu (2006)),

while there is a negative effect of democracy on life expectancy for Western nations, as a unit increase will decrease life expectancy by 0.98 years. However, we must note from the summary statistics that in 2000, the average measure of democracy was 9.94, with the maximum value attainable being 10. Thus it may not be that democracy decreases life expectancy, but rather that there are diminishing returns to how democracy affects health and life expectancy.

These results demonstrate that for Sub-Saharan African countries, a move towards a more open form of government is more beneficial to life expectancy than simply trying to eliminate corruption. This is not surprising, as democracy and corruption should be closely related. One would assume that as countries become more democratic, the degree to which leaders are corrupt should reduce significantly. Thus, Sub-Saharan African countries should first focus on changing into a more open form of government before focusing on corruption and leadership authority. However, the findings of trade on life expectancy should also be noted, as trade is positively correlated and highly significant with life expectancy for both regions. Even for the developed Western nations, trade appears to have a great affect on life expectancy. The implication of this on policy formation in Sub-Saharan Africa becomes clear, as countries should maintain an open economy and encourage international trade with more developed nations for better and more advanced goods.

5 Life Expectancy and Trade

There have been significant focus on how democracy and wealth affect life expectancy in past literature, but very few papers have looked at the channel through which trade affects life expectancy. This paper attempts to find a long run equilibrium relationship between trade and life expectancy for Sub-Saharan African countries.

Following the empirical results from the previous OLS estimates, only trade and democracy were statistically significant for Sub-Saharan African countries, and of these two, only import was found to be statistically significant at the 1% level for all regressions.

However, the problem with simple OLS cross-section estimates is that if variables are non-stationary, they will tend to give misestimated test statistics which will often lead to incorrect inferences about the model. Economic theory suggests that life expectancy and trade are non-stochastic processes that depend on previous values. One should expect these processes to be serially correlated and non-stationary, as trade in the current period undoubtedly depends on trade from previous periods via already established trade partners or agreements. If the variables are non-stationary, then estimating them will yield spurious results. While this problem will not bias the OLS coefficient estimates, the standard errors will tend to be underestimated, leading to an overestimation in the t-statistic.

As a result of this, testing under the existence of serial correlation will lead to more (inaccurate) rejections of the null hypothesis (H_0: coefficient = 0) when it should fail to reject. Furthermore, the R^2 value may be overestimated so that variables that have no explanatory power could be perceived as having high levels of correlation with the dependant variable, when in fact it does not. This problem can be dealt with in a cointegration framework, and the resulting estimates can be used to establish long run equilibrium relationships. While OLS estimates only provide inference on correlation between variables, cointegration estimates can establish a meaningful economic equilibrium between variables by testing whether the processes move together over time. Using panel cointegration to deal with the problem of non-stationarity, the next section of the paper will attempt to find a long run equilibrium

relationship between life expectancy and trade for Sub-Saharan African countries.

5.1 Unit Root Processes and Cointegration

Before we attempt to find a long run equilibrium relationship between life expectancy and trade, let us first define a process's integration order.

DEFINITION 1[7]: Suppose we have a linear process

$$Y_t - E(Y_t) = \sum_{i=1}^{\infty} \Psi_i \epsilon_{t-i} \neq 0 \qquad (7)$$

$$\text{where } \epsilon_t \sim iid(0, \Sigma)$$

If Ψ (1) = $\sum_{i=1}^{\infty} \Psi_i \neq 0$, then $Y_(t) \in$ I(0). Y_t is said to be integrated of order 0.

DEFINITION 2[8]: A process x_t is said to be integrated of order d, or I(d), for d integer if Δ^d (x_t - E(x_t)) is I(0).

DEFINITION 3[9]: A series x_t with no deterministic component which has a stationary, invertible, ARMA representation after differencing d times, is said to be integrated of order d, denoted $x_t \in I(d)$.

Suppose life expectancy and import are related by the following equations[10].

[7] taken from Prof. Morten Nielsen's lecture notes, Queen's University
[8] taken from Prof. Morten Nielsen's lecture notes, Queen's University
[9] Engle and Granger's (1987) definition
[10] Let LE denote life expectancy and Tr denote trade

$$LE_{i,t} = \gamma Tr_{i,t} + \epsilon_{1,i,t} \in I(1) \tag{8}$$

$$Tr_{i,t} = Tr_{i,t-1} + \epsilon_{2,i,t} \in I(1) \tag{9}$$

where $\epsilon_{1,i,t}, \epsilon_{2,i,t} \sim MWN(0, \Omega)$.

Both equations are non-stationary and integrated of order 1[11]. The resulting estimation of such a model will yield spurious results (see Phillips (1986)). In order to avoid spurious results, first difference the two equations so that the resulting equations are stationary (i.e. contain no unit root processes) and are integrated of order 0.

$$\Delta LE_{i,t} = \gamma \Delta Tr_{i,t} + \Delta\epsilon_{1,i,t} \in I(0) \tag{10}$$

$$\Delta Tr_{i,t} = \epsilon_{2,i,t} \in I(0) \tag{11}$$

where $\Delta LE_{i,t} = LE_{i,t} - LE_{i,t-1}$

and $\Delta Tr_{i,t} = Tr_{i,t} - Tr_{i,t-1}$.

Substituting (10) into (11) yields

$$\Delta LE_{i,t} = \gamma\epsilon_{2,i,t} + \Delta\epsilon_{1,i,t} \in I(0) \tag{12}$$

While both $LE_{i,t}$ and $Tr_{i,t}$ are I(1) processes, the linear combination $\Delta LE_{i,t} = \gamma\epsilon_{2,i,t} + \Delta\epsilon_{1,i,t}$ is I(0) and stationary. Furthermore, $[LE_{i,t}, Tr_{i,t}]^T$ is said to be cointegrated and $\beta = [1, -\gamma]^T$ is the cointe-

[11] Fisher test for panel unit roots using augmented ADF test follows

grating vector that relates them.

The cointegrating relationship is then defined as

$$\begin{aligned}
&\beta^T[LE_{i,t}, Tr_{i,t}]^T \\
&= [1, -\gamma][LE_{i,t}, Tr_{i,t}]^T \\
&= LE_{i,t} - \gamma Tr_{i,t} \\
&= \epsilon_{1,i,t} \in I(0) \qquad (13)
\end{aligned}$$

which is stationary, and can be rewritten as

$$LE_{i,t} = \gamma Tr_{i,t} + \epsilon_{1,i,t} \qquad (14).$$

The cointegrating vector can be interpreted as a long run equilibrium relationship between life expectancy and trade. Economically, this relationship is much stronger than a simple OLS regression, as we can now interpret the effect that an increase in trade will have on life expectancy in the long run.

5.2 Unit Root Tests for Panel Data

Testing for unit roots within a panel data framework is slightly different than testing for unit roots within a simple time series framework. Instead of testing for unit roots in one variable for one country, we are instead testing to see whether the variable is a unit root process for the entire sample between all cross-sections.

There are three typical unit root tests for panel data, all of which are examined by Maddala and Wu (1999).

- The Levin-Lin (LL) test for unit roots
- The Im-Pesaran-Shin IPS test for unit roots
- The Fisher Test for unit roots

Levin and Lin (1992, 2002) created their unit root test for panel data from the following model.

$$\Delta y_{i,t} = \rho y_{i,t-1} + \alpha_0 + \delta t + \alpha_i + \theta_t + \epsilon_{i,t} \tag{15}$$

where $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

δt captures a time trend,

α_i captures individual effects,

θ_t captures time-specific effects.

The test applies the Augmented Dickey-Fuller (ADF) test for unit roots to each individual series, where

$$\Delta y_{i,t} = \rho_i y_{i,t-1} + \sum_{i=1}^{p_i} \theta_{ij} \Delta y_{i,t-j} + \alpha_i + \epsilon_{i,t} \tag{16}$$

where ρ_i denotes the value of ρ for the i-th cross-section.

The LL test specifies the null H_0 and alternative H_1 hypotheses as

$$H_0 : \rho_1 = \rho_2 = ... \rho_N = \rho = 0 \tag{17}$$

$$H_1 : \rho_1 = \rho_2 = ... \rho_N = \rho < 0 \tag{18}$$

Thus, the test under H_0 specifies that there is no unit root, or that the process is stationary. However, Maddala and Wu (1999) argue that the LL test is rather limited, as it is testing whether ρ is the same for all observations. They use the example of convergence in growth between countries to argue that it does not make economic sense to assume that all countries will converge at the same rate, which is what the current H_1 assumes.

Im et. al (1997) relax the H_1 assumption that $\rho_1 = \rho_2 = ... \ \rho_N = \rho$ in their test. Instead of pooling all observations and testing whether ρ is the same, they instead perform separate unit root tests for each of the N cross-sections. They then combine the results from the N unit root tests performed. However, a limitation with this test is that T must be the same for all cross-sections and contain the same number of observations. Thus the IPS test only works with balanced panel data. This can be impractical, as it is often difficult to have a balanced panel where every single observation for every cross-section is available.

Maddala and Wu (1999) find that a third test, the Fisher test for unit roots, is the simplest and most straight forward of the three tests. The Fisher test is similar to the IPS test, in that both tests perform separate unit root tests for the cross-sections and then combine the significance of each test. However, the Fisher test is not limited to work with only a balanced panel. It also works with other unit root tests, not just the ADF test. Also, the null and alternative hypotheses are switched, so that in the Fisher

test H_0: unit root exists, or that the process is non-stationary.

5.3 Empirical Results

This paper employs Fisher's test for unit roots. The results of the test are shown below in Table 1. The null hypothesis H_0 in both cases are that the processes contain a unit root and are non-stationary. The test indicate that $LE_{i,t}$ and $Tr_{i,t}$ are both non-stationary, with p-values of 0.1824 and 0.6651 respectively. Thus we fail to reject the null hypothesis in both cases. Once each series is differenced, the p-values become 0.0014 and 0.0000, indicating that the null hypothesis is rejected and that each series does not contain a unit root.

Table 1: Fisher test for unit roots

Variables	LE (1 lag)	Δ LE (1 lag)	Tr (1 lag)	Δ Tr (1 lag)
		H_0: unit root		
χ^2	97.72	130.46	79.88	724.75
p-value	0.1824	0.0014	0.6651	0.0000

Estimating equation (14), a cointegrating vector of $\beta = [1, 4.15]^T$ is found. The coefficient for life expectancy is normalized to 1. These results establish a long run equilibrium relationship between life expectancy and trade, namely

$$LE_{i,t} = 4.15 \quad Tr_{i,t} \qquad (19).$$
$$[0.0955]$$

The estimated long run equilibrium relationship (19) indicates that a percentage increase in trade will increase life expectancy for 4.15 years. This result also agrees with previous OLS estimations, as trade is positively correlated with life expectancy. The result approximately holds with the historical data

figures for life expectancy and trade. The average life expectancy for Sub-Saharan African countries rose from 42.07 in 1960 to 51.42 in 2000, increasing by 9.35 years. The average volume of trade increased by roughly 2.67% during the same period. According to the established long run equilibrium relationship, this increase in trade should increase life expectancy by 11.08. Looking at the figures from 1980-2000, the average life expectancy rose from 49.89 to 51.42, an increase of 1.53 years. The average volume of trade during the same period increased by 0.43%. The model predicts that life expectancy should increase by 1.78 years as a result of this, which is not far off from the actual increase of 1.53 years.

6 Conclusion

This paper used panel data for Sub-Saharan African countries and Western nations between 1960-2002 to study the determinants that affect life expectancy. The first section dealing with OLS estimates found that trade and democracy are positively correlated with life expectancy for Sub-Saharan African countries while trade, democracy, and institutions are significantly correlated with Western nations. The first result agrees with Besley and Kudamatsu (2006) in that democracy is positively correlated with life expectancy. However, for Western nations, democracy is negatively correlated with life expectancy, while institutions are positively correlated with life expectancy. This suggests that for more developed nations that have already experienced a long period of democratic government, the goodness of institutions in these countries have a much higher effect on life expectancy. This result makes intuitive sense, as democratic countries are affected more by how effective it's government is in implementing policies and being held accountable for them, and less with whether the country is democracy. Furthermore, there are diminishing returns to how beneficial democracy is on life expectancy for highly developed countries.

The inclusion of the volume of trade for a country is highly positively correlated with life expectancy for both Sub-Saharan African countries and Western nations, which suggests that trade is just as important to developing nations as it is to developed nations. This result is consistent with economic theory, as exports promote economic growth as it is an important revenue stream for countries, while imports can bring in new technological advancement as well as new products that benefit health. However, the impact of trade on life expectancy is lower for Sub-Saharan African countries than for Western nations. One explanation for this is that because Western nations are already more developed than Sub-Saharan African countries, they likely have greater access to more advanced products when trading. Furthermore, while trade is important for Sub-Saharan African countries, there are other factors such as democracy which still has a large effect on life expectancy, whereas Western nations are less likely to be affected by these variables.

The second section looked specifically at Sub-Saharan African countries and establishes a long run equilibrium relationship between life expectancy and trade. The resulting cointegrating relationship predicts that a percentage increase in trade will increase life expectancy by 4.15 years in the long run. The result holds true with historical values of life expectancy and trade for Sub-Saharan African countries. These results suggest that while democracy will affect life expectancy, the volume of trade a country experiences is equally important in continually improving health conditions in Sub-Saharan African countries. As the region continues to move towards democracy, it is key to ensure that sound policies are created with regards to international trade so that these countries will develop and improve their conditions in the long run.

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Appendix

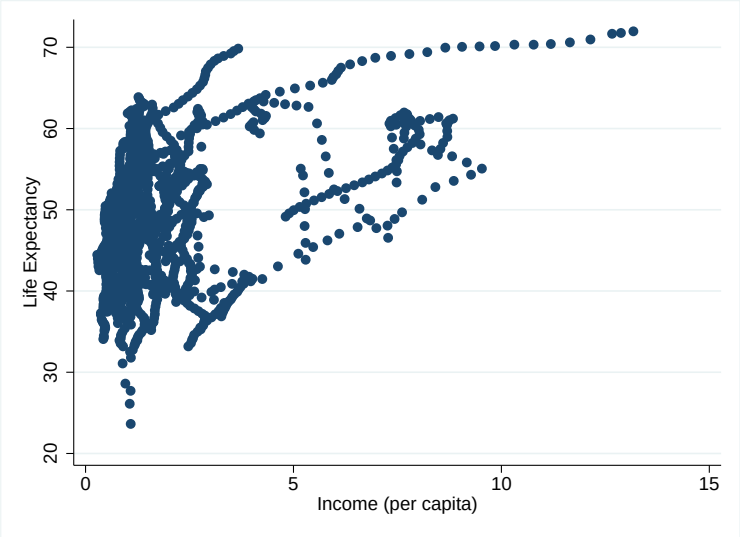

Figure 1: Preston Curve for Sub-Saharan African Countries, 1960-2002

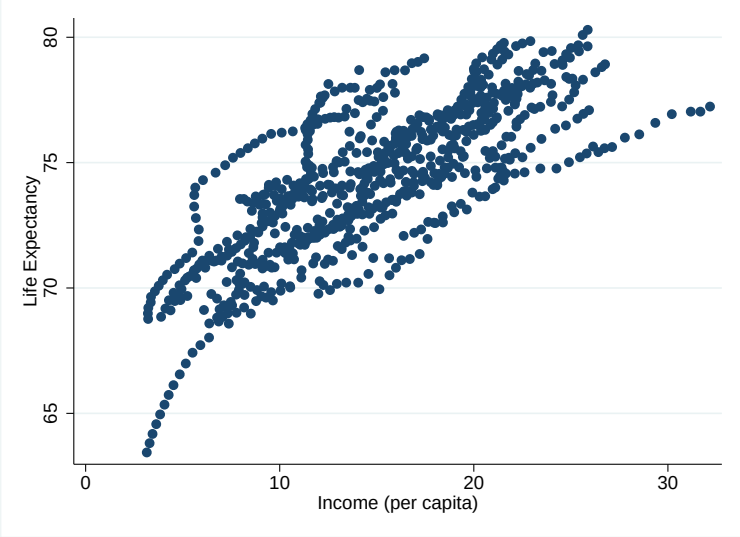

Figure 2: Preston Curve for Western Countries, 1960-2002

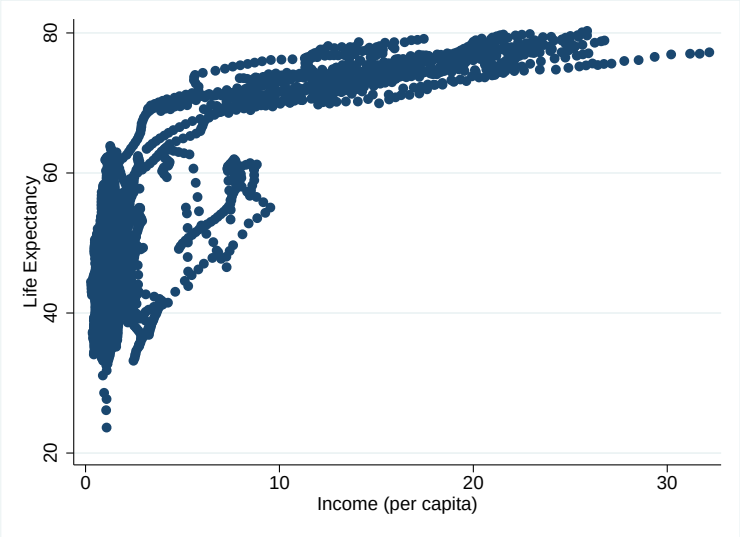

Figure 3: Preston Curve for All Countries, 1960-2002

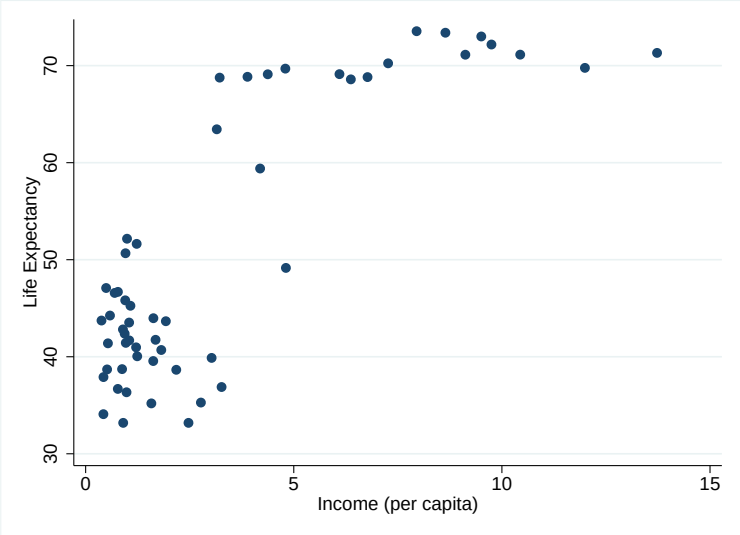

Figure 4: Preston Curve for All Countries, 1960

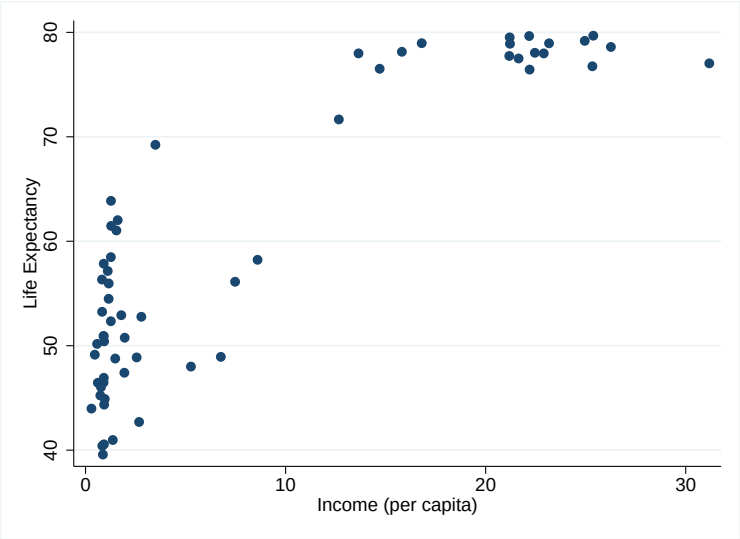

Figure 5: Preston Curve for All Countries, 2000

Table I: Summary Statistics

		1960-2002		1960		1980		2000	
Variables		**Western**	**SSA**	**Western**	**SSA**	**Western**	**SSA**	**Western**	**SSA**
Life Expectancy	Average	74.35	48.84	70.12	42.07	74.19	49.89	78.20	51.42
	Min	63.44	23.64	63.44	32.28	71.39	37.77	76.44	39.58
	Max	80.30	71.97	73.55	59.40	75.74	65.98	79.68	71.66
	S.D.	2.94	7.52	2.41	5.74	1.22	6.52	1.06	7.59
Infant Mortality	Average	15.56	123.48	30.84	163.92	12.11	118.38	4.81	96.91
	Min	3	17	16.6	67	6.9	33	3	17
	Max	81	285	81	285	25	192	6.9	167
	S.D.	13.13	44.35	16.49	42.03	4.86	37.26	1.07	32.21
Income	Average	14.76	1.81	7.50	1.42	14.60	1.88	21.79	2.08
	Min	3.15	0.28	3.15	0.38	6.70	0.53	13.64	0.30
	Max	32.17	13.17	13.72	4.81	20.98	9.53	31.18	12.66
	S.D.	5.78	1.80	2.99	1.03	3.92	1.84	4.37	2.51
Log of Trade	Average	24.07	19.99	21.81	18.32	24.52	20.56	25.68	20.99
	Min	18.87	15.39	18.88	15.15	21.27	17.37	22.23	17.31
	Max	28.34	24.88	24.33	21.21	26.90	24.53	28.34	24.81
	S.D.	1.97	1.69	1.52	1.41	1.53	1.57	1.58	1.50
Polity 2	Average	8.71	-3.44	7.12	-4.17	9.65	-4.51	9.94	0.66
	Min	-9	-10	-9	-9	8	-10	9	-9
	Max	10	10	10	8	10	9	10	10
	S.D.	4.05	5.64	5.99	4.99	0.70	5.58	0.24	4.97
Constraint on Ex.	Average	6.50	2.73	6.06	2.67	6.70	2.54	6.94	3.66
	Min	1	1	1	1	5	1	6	1
	Max	7	7	7	7	7	7	7	7
	S.D.	1.44	1.85	2.14	1.76	0.69	1.82	0.24	1.76
Schooling	Average	6.20	1.56	6.20	1.56	6.20	1.56	6.20	1.56
	Min	1.86	0.22	1.86	0.22	1.86	0.22	1.86	0.22
	Max	9.11	4.29	9.11	4.29	9.11	4.29	9.11	4.29
	S.D.	1.89	1.15	1.94	1.17	1.94	1.17	1.94	1.17
Countries		18	43	18	43	18	43	18	43

Table II: Determinants of Life Expectancy for Sub-Saharan African countries

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Dependent Variable	Life Expectancy at Birth							
Income	14.50***	32.68***	1.91	1.55	1.08	1.22	1.34	1.33
	[2.58]	[3.27]	[1.24]	[1.18]	[1.00]	[1.00]	[0.95]	[0.94]
$Income^2$		-2.96***	-0.09	-0.05	-0.03	-0.02	-0.05	-0.05
		[0.59]	[0.12]	[0.07]	[0.07]	[0.07]	[0.06]	[0.06]
Log of Trade			2.29***	2.23***	2.33***	2.24***	2.45***	2.45***
			[0.07]	[0.12]	[0.12]	[0.12]	[0.18]	[0.18]
Schooling				0.92	0.44	0.41	0.68	0.68
				[0.99]	[0.97]	[0.99]	[0.98]	[0.98]
Constraint on Executive						0.31	-0.87	-0.86
						[0.39]	[0.79]	[0.79]
Polity2					0.21*		0.42*	0.43*
					[0.11]		[0.24]	[0.24]
Dummy for 1990								2.47***
								[0.46]
Adjusted R^2	0.557	0.812	0.979	0.986	0.988	0.987	0.988	0.988
Countries	42	42	42	22	22	22	22	22
Observations	1709	1709	1707	868	812	813	812	812

Robust standard errors are reported in square brackets.

Statistical significance at 90% (*), 95% (**), and 99% (***) confidence levels.

Table III: Determinants of Life Expectancy for Western countries

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Dependent Variable	Life Expectancy at Birth						
Income	4.39***	9.50***	0.21	0.17	-0.53	-0.65	0.04
	[0.21]	[0.55]	[0.62]	[0.66]	[0.47]	[0.39]	[0.31]
$Income^2$		-0.27***	-0.02	-0.01	0.00	0.01	-0.01
		[0.03]	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]
Log of Trade			3.10***	3.08***	3.27***	3.15***	2.66***
			[0.23]	[0.21]	[0.16]	[0.13]	[0.16]
Schooling				0.13	0.20	0.03	-0.05
				[0.33]	[0.31]	[0.34]	[0.31]
Constraint on Executive						0.85	3.11***
						[0.57]	[0.84]
Polity2					0.09		-0.98***
					[0.13]		[0.23]
Adjusted R^2	0.887	0.975	0.997	0.997	0.998	0.998	0.998
Countries	18	18	18	18	17	17	17
Observations	757	757	757	757	729	729	729

Robust standard errors are reported in square brackets.

Statistical significance at 90% (*), 95% (**), and 99% (***) confidence levels.