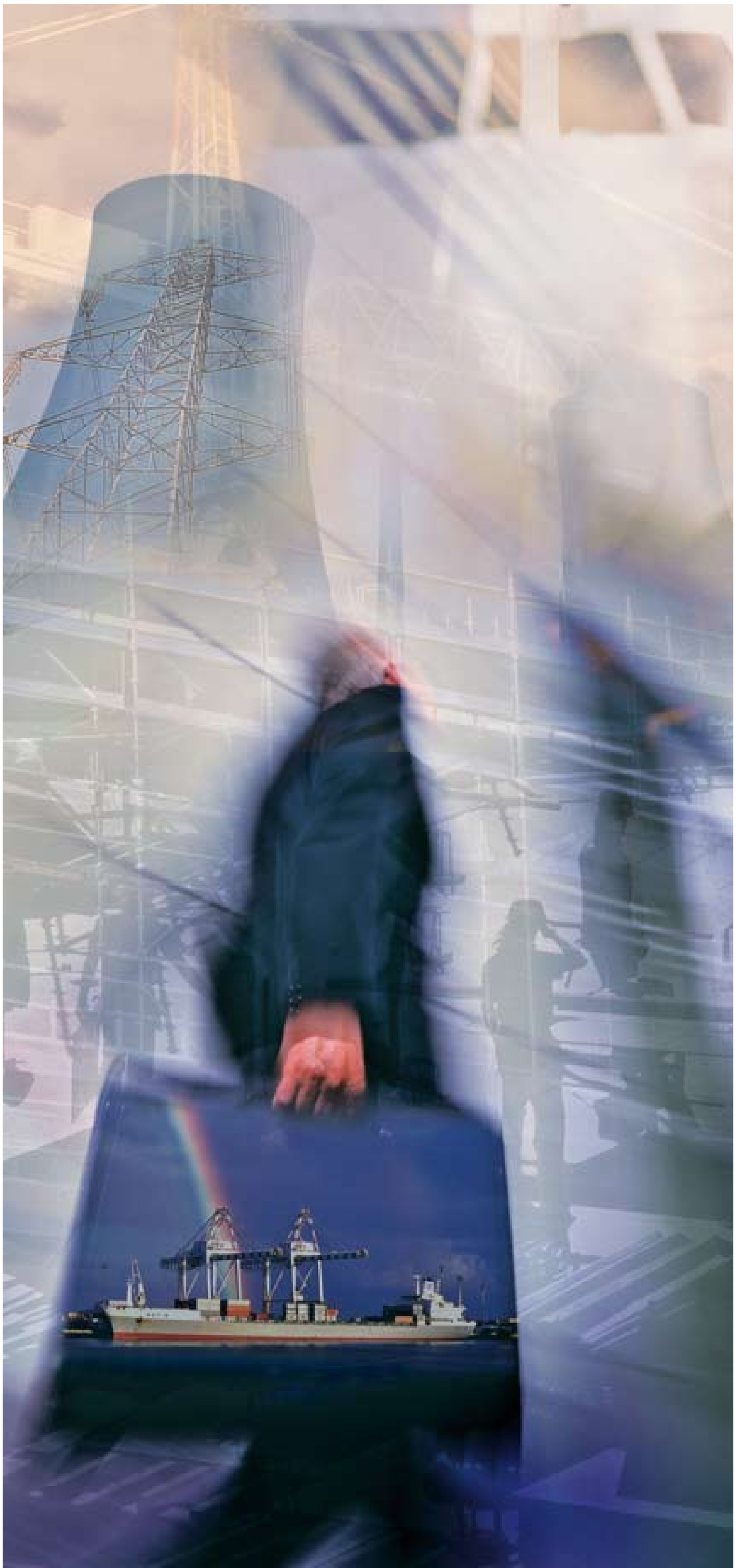

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Welcome

The Economic Society of Australia warmly welcomes you to the Gold Coast, Queensland, Australia for the 37th Australian Conference of Economists.

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How Much Do Improvements in Health Contribute to Economic Growth:

Long-run Evidence from the OECD Countries

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How Much Do Improvements in Health Contribute to Economic Growth: Long-run Evidence from the OECD Countries

ABSTRACT

This paper uses Johansen multivariate cointegration analysis to examine the relationship between health and GDP for thirteen OECD countries over the last two centuries, for periods ranging from 1820-2001 to 1921-2001. A similar, long run, cointegrating relationship between life expectancy and both total GDP and GDP per capita was found for all of the countries estimated. The relationships have a significant influence on both total GDP and GPD per capita in most of the countries estimated, with 1% increase in life expectancy resulting in an average 6% increase in total GDP in the long run, and 5% increase in GDP per capita. Total GDP and GDP per capita also have a significant influence on life expectancy for most countries. There is no evidence of changes in the relationships for any country over the periods estimated, indicating that shifts in the major causes of illness and death over time do not appear to have influenced the link between health and economic growth.

1. INTRODUCTION

There has been increasing interest in the relationship between health and economic growth over the last few years. The World Health Organisation (CMH, 2001) and the European Commission (European Commission, 2005) have produced extensive reports that have argued for greater spending on health as a means of promoting growth in GDP, for both developed and developing countries.

In the past, it has generally been well accepted that populations in countries with higher levels of GDP will have better health and longer life expectancy, as higher living standards lead to enhanced prevention and treatment of disease (see, for example, the review by Smith (1999)). However, the reverse effects, through the influence of better health in raising the level of GDP, may potentially be of equal or even greater importance. Barro (1996), for example, found that health had a substantial positive effect on growth similar to that of education, in a panel estimation of nearly 100 countries from 1960 to 1990. But many questions remain about the nature and size of these effects.

Improvements in health may influence GDP both directly and indirectly. Total GDP will increase if longer life expectancy results in an increase in population, so that more people are available to participate in the labour force. But GDP per capita in this situation may be unaffected, or may even decline if capital-to-labour ratios fall as population increases (Acemoglu and Johnson, 2006).

Growth in GDP per capita can occur through changes in productivity, in savings and investment, or in labour supply (Bloom et al., 2001). Healthier workers would normally be expected to make better use of the time and resources available to them, directly increasing productivity. However, increases in productivity are more likely to occur indirectly through education and human capital effects. Healthier students should achieve more from their learning experiences, but more importantly, longer life expectancy increases the potential benefits and thus the incentive for higher educational attainment.

The positive effects on productivity will be amplified if lower childhood mortality leads to a decline in fertility, increasing both the motivation and the ability of parents to better educate their children (Guest and Swift, 2008). Similarly, longer life expectancy increases the motivation and the ability to save and invest in physical and intellectual capital, so that the growth in human capital that results from improvements in health may be accompanied by growth in capital more generally.

Changes in labour supply as health improves are likely to have more ambiguous effects. Longer life expectancy and higher wages earned by healthy workers can provide greater incentives to work, in addition to the increase in labour supply that occurs as healthy workers find working easier and lose less time to illness. Conversely, the higher lifetime earnings and lower medical costs of healthy workers may reduce the motivation to work. The effects on labour supply can also extend to family members and carers whose working lives are interrupted by the ill-health of others (see CMH (2001) for a survey of this literature).

There is extensive empirical evidence to support the influence of health on productivity and income through these channels. However, most of the previous research has been microeconomic in nature, studying effects on individuals or small groups, and primarily focussing on low income and developing countries (see, for example, the review by Strauss and Thomas (1998)).

Studies of broader macroeconomic effects have shown more mixed results. Among recent papers, Bhargava et al. (2001) found that the effect of health on the growth rates of GDP per capita was positive only for low income countries, in a panel estimation of 92 countries from 1965-1990. Jamison et al. (2005) reported similar results in their estimation of a panel of 53 countries from 1965-1990. They found that the positive effects of health on GDP per capita declined as life expectancy increased, that is, the effects were larger for low income countries with lower life expectancy.

Acemoglu and Johnson (2006) exploited the wave of medical innovations that began in the 1940s in their estimations of the effects of improvements in health in a panel of 59 countries from 1940-1980. The introduction of new drugs and public health measures during this period, such as penicillin and mass immunisation, was followed by a significant reduction in illness and death from infectious diseases, especially amongst children. These innovations resulted in an “epidemiological transition”, or a shift in the major causes of death from infectious diseases to degenerative or non-communicable diseases (NCDs), particularly in developed countries. Acemoglu and Johnson (2006) found that the increase in life expectancy that followed these health improvements led to a large increase in population and a smaller increase in total GDP, but the increase in total GDP was not sufficient to compensate for the growth in population. The authors concluded that there was no evidence of any significant positive effects on GDP per capita within the 40 year horizon.

The study by Suhrcke and Urban (2006) also relates to the recent epidemiological transition, but took a different approach by focussing on the effects of a specific disease on economic growth. Cardio-vascular disease (CVD) is the most prevalent of the NCDs, and is now the predominant cause of deaths in developed countries, as well as being a major contributor to death and ill-health in developing countries. Using a panel of 73 countries from 1960-2000, the authors found that deaths from CVD did significantly reduce growth in GDP per capita in high-income countries, but not in low and middle income countries.

The varied results from this literature raise some interesting questions for research, particularly for high income countries. As noted by Suhrcke and Urban (2006), life expectancy varies very little between high income countries. It is therefore not surprising if panel data estimations which use life expectancy as a proxy for health find that it has little explanatory power for GDP growth in high income countries. Moreover, many of the most important mechanisms by which better health leads to growth in GDP per capita will show their full effects only after very long periods of time. This is particularly true for the growth in both human and physical capital that is generated by the incentive effects of longer life expectancy. Here maximum gains will be achieved only as children born and educated after the increase in life expectancy reach the end of their working lives, perhaps 60 or 65 years later (Bleakley, 2006). The effects will be even more prolonged if a decline in fertility, induced by increasing life expectancy, contributes significantly to growth in human capital.

The extended data series required to show very long term effects like these are available only for high income countries, suggesting that these countries may provide better opportunities for examining the macroeconomic benefits of improvements in health. This paper uses Johansen multivariate cointegration analysis to examine the individual relationship between health and GDP for thirteen OECD countries over the last two centuries. This method avoids the discrimination problems found with panel data, and allows for the non-stationarity and potential endogeneity of both health and GDP, including testing for exogeneity of each variable.

The data series used in the analysis cover very long time periods, ranging from 1820-2001 to 1921-2001. The data for all countries thus includes the most recent epidemiological transition starting in the 1940s, and for many, it also includes the earlier epidemiological transition in the second half of the nineteenth century, following the industrial revolution in Europe (Acemoglu and Johnson, 2006). In the early 1800s, Europe was only starting on the path of industrial development, so the relationship between health and GDP in European countries since that time should provide some guide for the similar if accelerated path followed by developing countries more recently.

The results show that there is a similar long run cointegrating relationship between life expectancy and both total GDP and GDP per capita for all of the countries estimated. This relationship has a significant influence on both total GDP and GPD per capita in nearly all of the countries estimated, with 1% increase in life expectancy resulting in an average 6% increase in total GDP and 5% increase in GDP per capita in the long run. Total GDP and GDP per capita also have a significant influence on life expectancy for most countries. There is no evidence of any change in the relationships for any country over the periods estimated, indicating that shifts in the major causes of illness and death over time do not appear to have influenced the link between health and economic growth.

The rest of the paper is organised as follows. Section 2 describes the data and methodology to be used in the estimations. Section 3 discusses the results of the estimations for each country in more detail, while Section 4 provides some concluding comments.

2. DATA AND METHODOLOGY

The aim of this study is to determine if there is a long term endogenous relationship between health and total GDP, or between health and GDP per capita, for each country, and whether these relationships have remained constant over time. Data on other variables often included in growth regressions, such as investment and education, are not included because they are not available for the extended time periods used here. This should not cause problems for the estimates as a cointegrating relationship is invariant to extensions of the information set, that is, if a long run or cointegrating relationship does exist between health and GDP, the estimates will not be significantly affected by the presence or absence of additional variables (Juselius, 2006, p.11).

2.1 DATA

The data on total GDP and GDP per capita for each country were taken from (Maddison, 2003), and are all expressed in terms of 1990 international dollars. Data on life expectancy at birth for each country were taken from the Human Mortality Database, which provides comparable data for each country calculated by a uniform method.[1] Life expectancy is the only measure of health status that is available for the extended time periods used here. It suffers from the disadvantage of being an incomplete measure of population health because it does not include improvements, such as better nutrition, that

[1] *Human Mortality Database,* University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany), available at www.mortality.org .

may increase worker productivity but have little effect on the length of life (Bhargava et al., 2001). However, this under-measurement should be of less significance in a very long run analysis if most long term gains in human and physical capital are the result of the incentive effects of having a longer life span to recoup the investment, as suggested by the theoretical literature discussed in Section 1.

Figure 1 shows the changes in life expectancy and GDP for England and Wales over the period, which are representative of the patterns observed in the other OECD countries. In 1841, England and Wales were in the early stages of the road to industrial development, with life expectancy of only 41 years, and GDP per capita of $1900. Life expectancy was relatively constant at around 40 - 45 years until the late 1870s, when it began to rise steadily. The falling mortality rates underlying this upward trend were the result of the economic and social changes that followed the Industrial Revolution in Europe, as better nutrition and advances in public hygiene improved health and reduced deaths, particularly from infectious diseases. This period marks the first epidemiological transition.

There was a sharp increase in deaths around the time of the First World War and the influenza pandemic in 1918-1919, and a similar but smaller effect during the Second World War (Figure 1). Apart form these episodes, the increase in longevity continued at a similar rate until about 1950. Since the second epidemiological transition, which started in the late 1940s, the rate of increase in life expectancy has slowed somewhat as NCDs have replaced infectious diseases as the major causes of death in developed countries.

2.2 METHODOLOGY

Stationarity testing of the variables was performed using Augmented Dickey-Fuller (ADF) tests. All three variables in log form, life expectancy (LE), total GDP, and GDP per capita (GPC), for all the included countries were non-stationary but their first differences were found to be stationary. That is, all variables (in log form) were I(1).[2] It is therefore appropriate to use cointegration analysis to estimate the relationships between the variables, provided that the method used allows for the possible joint causality of the variables as suggested by the previous literature discussed in Section 1.

The Johansen multivariate cointegration method was chosen for this reason, because it provides estimates of both the long run and short run relationships within a system of equations in which all variables are potentially endogenous. The system of equations estimated in the Johansen method is a vector error correction model (VECM) derived from a standard unrestricted vector autoregressive model (VAR) of lag length *k*. The VAR system of equations is algebraically re-arranged into a VECM, written as:

$$\ddot{A}z_t = \tilde{A}_1\ddot{A}z_{t-1} + \ldots + \tilde{A}_{k-1}\ddot{A}z_{t-k+1} + Dz_{t-1} + \grave{\imath} + \O D_t + \mathring{a}_t \qquad (1)$$

where z_t is the vector of variables,   is a vector of constants, and D_t a vector of other deterministic variables such as a time trend. In order to distinguish between the effects of health on total GDP and on GDP per capita, two estimations were performed for each country, the first with life expectancy (LE) and total GDP (GDP) as the vector of variables in z_t, and the second with LE and GDP per capita (GPC).

The first group of terms on the right hand side of equation (1), up to and including z_{t-k+1}, represents the short run lagged effects of differences in the variables in z, or z, on

[2] Results of the ADF tests are available on request.

each variable in the system. The next term, Πz_{t-1}, is the error correction term (ECT) that represents the long run cointegrating relationship between the levels of the variables in z. The number of cointegrating relationships between the variables is given by the rank (r) of the matrix of long run coefficients Π.

If a cointegrating relationship exists between the variables, Π can be factorised into $\Pi = \alpha\beta'$, where β' is the coefficients on the individual variables in the long run or cointegrating vector and α is the coefficient on the ECT itself, which represents the speed of adjustment to disequilibrium. If α is not significantly different from zero in one of the equations of the system, then the long run cointegrating relationship represented by the ECT does not have a significant influence on the dependent variable in that equation. This variable can then be said to be weakly exogenous for the long run relationship (Johansen, 1988, 1991; Johansen and Juselius, 1990).

Johansen uses a canonical correlation technique, solved by calculating eigenvalues (λ_i), to provide a set of eigenvectors that form the maximum likelihood estimate of the long run coefficients (β). A likelihood ratio (LR) statistic, the Trace statistic, is used to test the significance of the eigenvalues and thus to determine the maximum number of statistically significant vectors (r) within β.

Lag lengths for the Johansen estimation were determined by LR tests of paired comparisons of different lag lengths in the original VAR system. The choice was confirmed by Lagrange-Multiplier (LM) tests of the residuals which showed that the included lags were sufficient to avoid serial correlation in all systems. Doornik-Hansen tests for normality indicate that the residuals in all systems are free from skewness, although there is evidence of non-normality in some equations due to kurtosis. This should not cause problems for the estimates because, as noted by Johansen (1995, p. 29), the "asymptotic properties of the methods only depend on the i.i.d. assumption of the errors".[3]

Deterministic components were included in the cointegrating relationships where indicated by tests of the joint hypothesis of both the rank order and the deterministic components, as described by Johansen (1992). Dummy variables were also included in the short run components for all countries for the period of 1914-1919 to allow for the effects of the First World War and the subsequent influenza pandemic, and for 1939-1945 for the Second World War. For Spain, the period of the second dummy variable was extended to 1936-1945 to allow for the effects of the Spanish Civil War.

3. ESTIMATION RESULTS

Tables 1 and 2 show the results of the trace test for the rank (r) of the matrix of long run coefficients ($\boldsymbol{\beta}$), which indicates the number of cointegrating vectors between the variables. In all cases, the null hypothesis of $r = 0$ is rejected, but $r = 1$ cannot be rejected. This means that there is a long run or cointegrating relationship between LE and GDP, and between LE and GPC, in all of the thirteen countries tested.

3.1 LONG RUN RELATIONSHIPS

Table 3 gives the $\boldsymbol{\beta}$ coefficients of the long run relationship between LE and GDP for each country, together with the $\boldsymbol{\alpha}$ coefficients on the long run relationship in the error-correction equation for each variable.[4] The $\boldsymbol{\beta}$ coefficients indicate that 1% increase in LE in the long run is associated with an increase in total GDP ranging from just under

[3] Results of residual tests are available on request.
[4] The results were obtained using CATS in RATS, version 2 (Dennis et al, 2005).

3% in the case of England and Wales to around 9% for Australia, Canada and Norway, with an average increase across all thirteen countries of 6.124%. The α coefficients on the long run relationship in the equations for dGDP are significant for eleven countries, with the only exceptions being Finland and Spain. This implies that, for most of the OECD countries estimated, the long run relationship between LE and GDP has resulted in significant increases in total GDP as LE has increased over the period.

The α coefficients on the long run relationship in the equations for dLE are also significant for nine countries. These results confirm the dual endogenous nature of the relationships suggested by the previous literature, as rising GDP has also led to an increase in LE for most countries over the period. However, the α coefficients on the long run relationships in the equations for LE are generally smaller than those in the equations for GDP, suggesting that LE adjusts more slowly to any disequilibrium in the long run relationship than does GDP.

The result of the estimations between LE and GPC in Table 4 show very similar patterns for both the α and β coefficients as those for GDP, except that the β coefficients are generally smaller. Here, 1% increase in LE in the long run is associated with an increase in GPC ranging from around 2% to 7%, with an average increase across all countries of 4.995%. The α coefficients show that, as before, the long run relationship between LE and GPC has resulted in significant increases in GPC as LE has increased for eleven countries, with a similar endogenous increase in LE as GPC has increased in eight countries. The results for GPC appear to confirm that, for most of the OECD countries, longer LE has lead to the gains in productivity suggested by the previous literature discussed in Section 1.

The larger size of the effects on total GDP are to be expected if part of the increase in total GDP is a consequence of population growth, in addition to the productivity effects that increase GPC. In this case, the size of the difference in the $\boldsymbol{\beta}$ coefficients between GDP and GPC will be affected by individual factors that may have influenced population growth in each country over the period, such as the age structure of the population or migration. For example, the decrease in the $\boldsymbol{\beta}$ coefficients between the estimations with GDP and GPC is greatest in the settler economies of Australia and Canada, whilst at the other extreme, England and Wales is the only estimation in which the coefficient on GDP is actually smaller than that on GPC. These three estimations are for the countries in the group that have been most affected by migration during the period, inward and outward respectively, suggesting that the mass movement of primarily younger able-bodied workers may have had some influence on the effects of LE on total GDP.

Other variations in results that are common to the estimations with both GDP and GPC may also be due to differences in individual countries or groups of countries, such as the weak exogeneity of LE that is shared by the Scandinavian countries of Denmark, Norway and Sweden. The Scandinavian countries have generally achieved longer LE earlier in the period than the other countries in the group, suggesting that health in these countries may have benefited from some more specific influences. For Spain especially, the weak exogeneity of GDP and GPC for the long run relationship may have been affected by the long aftermath of the extended period of conflict in the middle of the period, as both GDP and GPC remained depressed for much longer in Spain than in the other European countries after the end of the Second World War.

3.2 SHORT RUN RELATIONSHIPS

Tables 5 and 6 give the coefficients on the short run variables in each equation of the VECM, for the models with GDP and GPC respectively. The most noticeable feature is that changes in LE have had no significant short run effects on either GDP or GPC in the majority of countries, even though the long run results demonstrate that rising LE has led to significant increases in both GDP and GPC in these countries in the longer term.

The difference in the results over time found here for these countries lends support to the argument that improvements in health may take many years to lead to greater economic growth, and consequently may not be found to be significant in models that cover only shorter time periods, or use methodology that does not allow for the identification of long term relationships. Conversely, both GDP and GPC do show significant effects on LE in the short run in most countries in Table 5 and 6, even in countries where the effects do not continue into the long run, such as Norway and Sweden. These results also imply that the benefits of economic growth in generating improvements in health may be more likely to be over emphasised in models that are limited to shorter term effects.

3.3 STABILITY OF THE RELATIONSHIPS

The stability of the long run coefficients for each country was investigated by recursive estimation, in order to determine if the relationships have changed over time. The recursive estimation procedure tests the difference between $\beta^{(n)}$ and $\beta^{(T)}$, where $\beta^{(T)}$ is the full sample estimate of the cointegrating vector. $\beta^{(n)}$ is obtained by successively estimating the model using increasing subsamples from ($t = n$) to ($t = T$), where ($t = 1, . . . n$) provides the base sample for the recursive estimation. The test statistic, $Q_T^{(n)}$, is derived from Hansen and Johansen (1999). To test parameter constancy over the whole period, all of the models were estimated using both forward and backward recursion, that is, the first half of the sample was used as the base to recursively test the stability of the parameters in the second half of the period, and vice versa.

Figures 2 and 3 show the results of the stability tests for the β coefficients in the relationship between LE and GPC for Sweden, which is used here as an example because it has data for the longest time period of the countries tested (1820-2001). The test statistic labelled "*X(t)*" represents the estimated cointegrating relations as a function of the short run dynamics and deterministic components, whereas the test statistic labelled "*R1(t)*" is corrected for the short run effects. *R1(t)* represents the "clean" cointegrating relation which is actually tested for stationarity to determine the cointegrating rank, and provides the estimated β coefficients shown in Table 4. All the test statistics in Figures 2 and 3 are indexed so that the 5% critical value is equal to 1.00, for ease of comparison. In both Figure 2 and 3, the test statistics are well below the 5% critical value for the whole period, indicating that there has been no significant change in the coefficients of the long run cointegrating relationship between LE and GPC for Sweden over the period of estimation.

Similar results were obtained for the other recursive estimations, both for the relationships between LE and GPC, and between LE and GDP, for all thirteen countries tested.[5] The results of the stability tests confirm that the long run relationships found here

[5] Results of recursive estimations for all the countries tested are available on request.

between longer life expectancy and economic growth have been stable over very long time frames of up to 180 years. There does not appear to be any evidence that changes in the major causes of illness and death following the epidemiological transitions of either the 19th or 20th centuries have caused any breaks in the relationships. Similarly, the relationships do not appear to have changed even though LE has increased well beyond the usual end of the working life at round 60-65 years, which has occurred in all of the countries in the test group over the last fifty to seventy years.

The stability of the relationships between health and GDP over time found here suggest that the benefits to economic growth in these countries have come from the productivity and incentive effects of having a longer life in general, rather than from reductions in any specific illness or group of illnesses, or changes in the age group most affected. If this is the case, then the shift from infectious diseases to NCDs as the major cause of death in developed countries should only affect economic growth to the extent that these degenerative or "lifestyle" diseases are more resistant to prevention and treatment, so that it becomes more difficult to maintain the previous rate of increase in the length of life.

4. CONCLUSION

Better health can lead to economic growth not only through an increase in total GDP as population increases, but also more importantly, through long term gains in human and physical capital that raise productivity and per capita GDP. The thirteen OECD countries tested here all show long run cointegrating relationships between life expectancy and both total GDP and GDP per capita, and the coefficients of these relationships have remained stable over very long time periods, ranging from 80 to 180 years. In most of the countries tested, the long run relationships have led to significant increases in both total GDP and GDP per capita as life expectancy has increased, and to similar endogenous increases in life expectancy as GDP has risen.

For developed countries, the results suggest that improvements in health can continue to make valuable contributions to economic growth, even though degenerative and non-communicable diseases are now the main concern in these countries, rather than the infectious diseases that have led to the major gains in the past. There are also implications for developing countries seeking to emulate the growth path of the OECD countries over the last two centuries. If each 1% increase in life expectancy has contributed an average 5% to growth in GDP per capita in Europe over this period, then policies that promote better health in developing countries deserve high priority for their potential economic benefits, not just for humanitarian or quality of life motives.

Many questions remain for further research. This study has used a simple model in order to examine the basic relationships for the longest possible periods. More complex models for individual countries or groups of countries over shorter periods, possibly incorporating measures of health that include both morbidity and mortality, could help to explain the source of the gains in GDP in more detail, and to account for some of the difference in the results between countries.

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Figure 1: Life Expectancy, total GDP and GDP per capita for England and Wales (1841 - 2001)
(ln form, indexed, 1841 = 100)

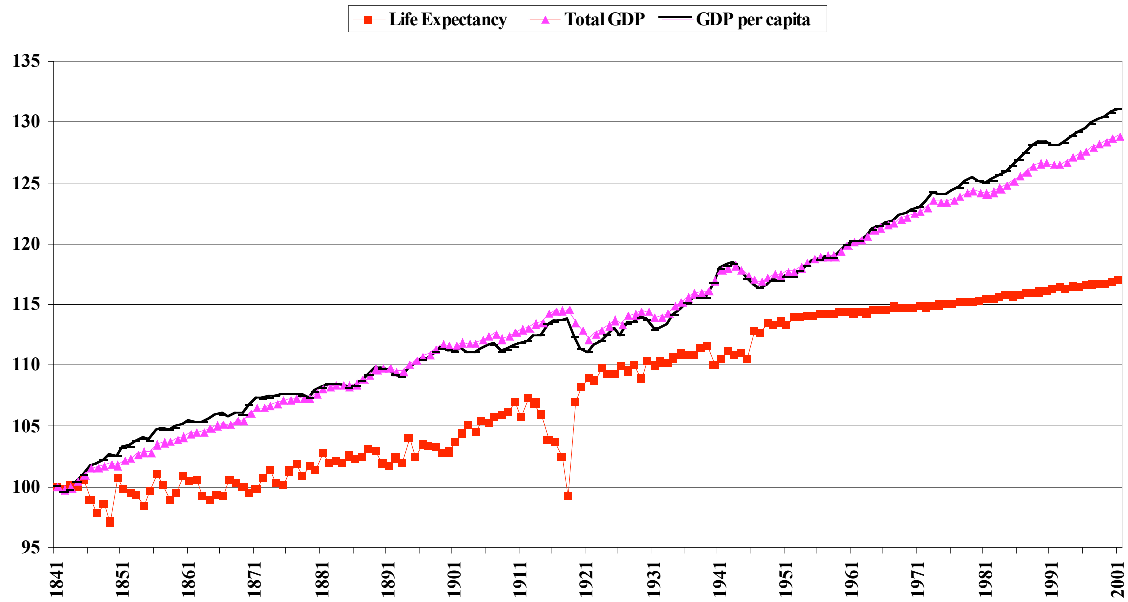

Figure 2: Test of Beta Constancy for Sweden (LE and GPC)
Base period: 1986-2001
5% Critical value = 1 (2.18 = Index)

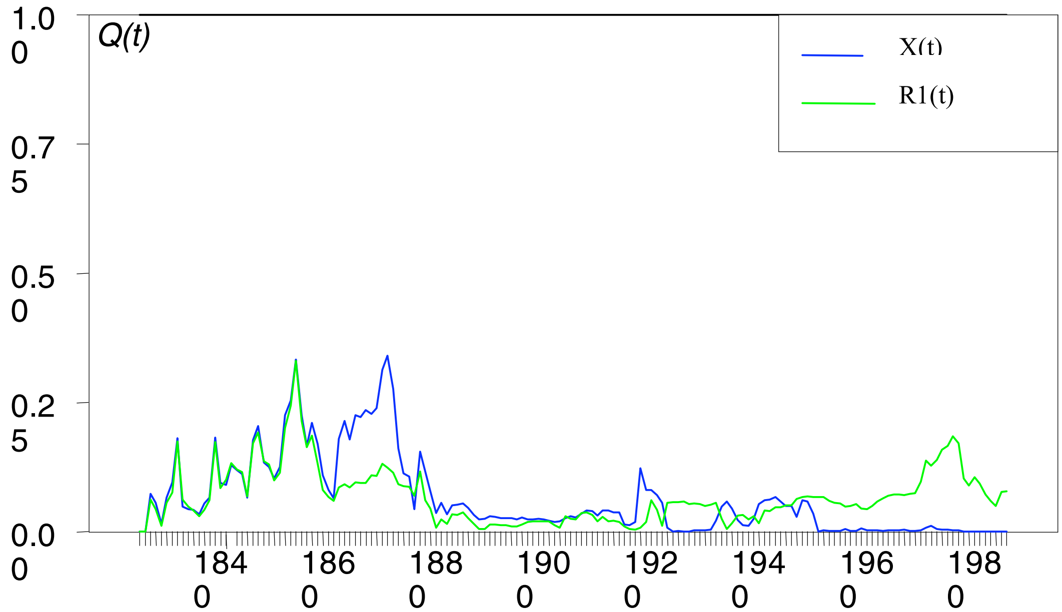

Figure 3: Test of Beta Constancy for Sweden (LE and GPC)
Base Period: 1825-1840
5% critical Value = 1 (2.18 = Index)

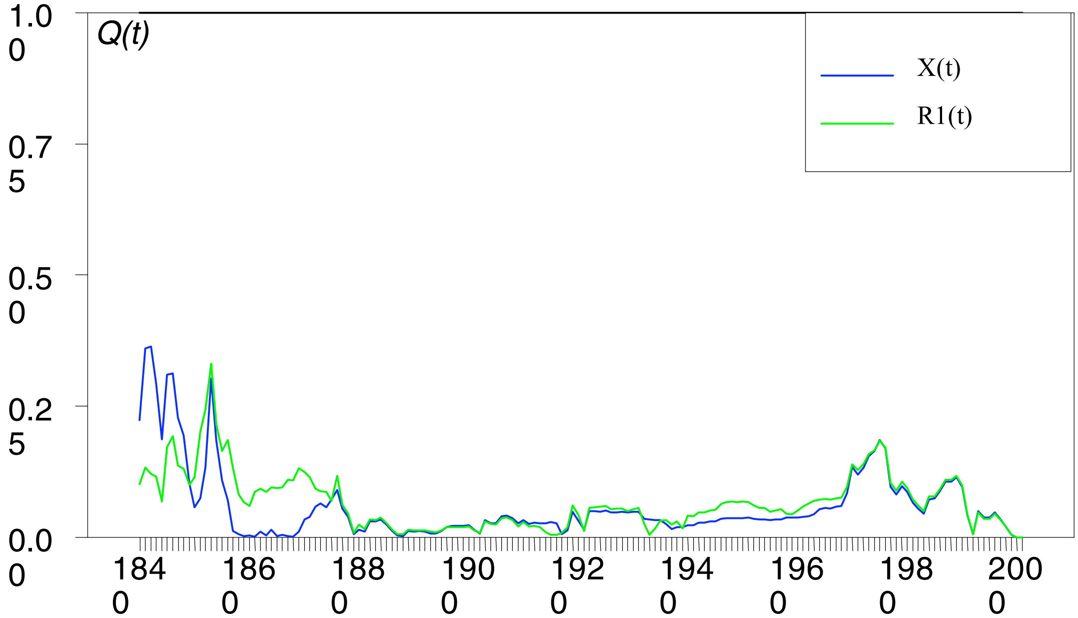

Table 1: Life Expectancy (LE) and total GDP

Rank Test for the determination of the number of cointegrating vectors

	Null	Eigenvalues	Trace Statistic	*p*-value
Australia	r = 0	0.424	49.988*	0.000
1921-2001	r = 1	0.085	6.899	0.160
Belgium	r = 0	0.282	51.561*	0.000
1846-2001	r = 1	0.012	1.804	0.817
Canada	r = 0	0.477	57.392*	0.000
1921-2001	r = 1	0.101	8.080	0.105
Denmark	r = 0	0.328	70.738*	0.000
1835-2001	r = 1	0.035	5.850	0.228
England/Wales	r = 0	0.363	78.583*	0.000
1841-2001	r = 1	0.052	8.260	0.097
Finland	r = 0	0.170	22.505*	0.001
1878-2001	r = 1	0.003	0.396	0.529
France	r = 0	0.286	36.267*	0.000
1899-2001	r = 1	0.036	3.525	0.060
Italy	r = 0	0.196	29.704*	0.000
1872-2001	r = 1	0.016	2.025	0.155
Netherlands	r = 0	0.238	42.796*	0.000
1850-2001	r = 1	0.019	2.894	0.614
Norway	r = 0	0.292	49.949*	0.000
1865-2001	r = 1	0.032	4.301	0.397
Spain	r = 0	0.137	14.402*	0.020
1908-2001	r = 1	0.009	0.836	0.361
Sweden	r = 0	0.194	43.527*	0.000
1820-2001	r = 1	0.030	5.453	0.265
Switzerland	r = 0	0.213	34.896*	0.001
1876-2001	r = 1	0.046	5.748	0.256

* denotes significance at 5%.

Table 2: Life Expectancy (LE) and GDP per capita (GPC)

Rank Test for the determination of the number of cointegrating vectors

	Null	Eigenvalues	Trace Statistic	*p*-value
Australia	r = 0	0.410	50.512*	0.000
1921-2001	r = 1	0.114	9.420	0.060
Belgium	r = 0	0.243	43.659*	0.000
1846-2001	r = 1	0.013	1.917	0.795
Canada	r = 0	0.157	14.454*	0.012
1921-2001	r = 1	0.019	1.491	0.222
Denmark	r = 0	0.306	63.915*	0.000
1835-2001	r = 1	0.027	4.384	0.388
England/Wales	r = 0	0.290	60.878*	0.000
1841-2001	r = 1	0.044	7.126	0.152
Finland	r = 0	0.139	17.913*	0.003
1878-2001	r = 1	0.001	0.073	0.787
France	r = 0	0.284	35.940*	0.000
1899-2001	r = 1	0.036	3.574	0.059
Italy	r = 0	0.189	28.478*	0.000
1872-2001	r = 1	0.015	1.928	0.165
Netherlands	r = 0	0.204	37.874*	0.000
1850-2001	r = 1	0.029	4.376	0.379
Norway	r = 0	0.284	49.400*	0.000
1865-2001	r = 1	0.039	5.259	0.279
Spain	r = 0	0.138	14.535*	0.020
1908-2001	r = 1	0.010	0.908	0.341
Sweden	r = 0	0.183	39.139*	0.000
1820-2001	r = 1	0.019	3.331	0.529
Switzerland	r = 0	0.210	34.144*	0.001
1876-2001	r = 1	0.044	5.461	0.286

* denotes significance at 5%.

Table 3: Life Expectancy (LE) and total GDP

Long-run coefficients of the VECM

	ECT = β_1 GDP + β_2 LE		Speed-of-adjustment (α) of the ECT in the equation for:	
	β_1 (GDP) [1]	β_2 (LE)	dGDP	dLE
Australia 1921-2001	1	-8.828* (-3.054)	0.007* (3.472)	0.002* (5.415)
Belgium 1846-2001	1	-4.238* (-11.482)	-0.033* (-7.479)	-0.012* (-2.524)
Canada 1921-2001	1	-9.286* (-13.648)	-0.020* (-2.292)	-0.009* (-6.135)
Denmark 1835-2001	1	-6.452* (-22.009)	-0.043* (-8.919)	-0.005 (-1.200)
England/Wales 1841-2001	1	-2.679* (-2.291)	0.003* (3.977)	0.006* (6.168)
Finland 1878-2001	1	-5.760* (-27.769)	-0.010 (-0.625)	0.088* (4.178)
France 1899-2001	1	-5.920* (-15.645)	-0.055* (-3.085)	0.045* (2.689)
Italy 1872-2001	1	-4.245* (-16.961)	-0.059* (-5.561)	0.010 (0.858)
Netherlands 1850-2001	1	-5.134* (-10.255)	-0.037* (-6.771)	-0.007* (-2.027)
Norway 1865-2001	1	-9.284* (-13.900)	-0.028* (-7.313)	-0.003 (-1.047)
Spain 1908-2001	1	-8.022* (-6.183)	-0.005 (-1.060)	0.016* (3.460)
Sweden 1820-2001	1	-6.518* (-14.562)	-0.025* (-6.449)	-0.000 (-0.085)
Switzerland 1876-2001	1	-3.250* (-3.960)	-0.019* (-4.714)	-0.008* (-3.476)

[1] β coefficients are all normalised on GDP for ease of comparison.
* denotes significance at 5%. *t*-values are given in brackets below each coefficient.

Table 4: Life Expectancy (LE) and GDP per capita (GPC) *Long-run coefficients of the VECM*				
	ECT = β_1 GPC + β_2 LE		Speed-of-adjustment (α) of the ECT in the equation for:	
	β_1 (GPC) [1]	β_2 (LE)	dGPC	dLE
Australia 1921-2001	1	-4.954* (-4.012)	0.012* (2.381)	0.006* (5.998)
Belgium 1846-2001	1	-3.487* (-8.772)	-0.031* (-6.560)	-0.014* (-2.855)
Canada 1921-2001	1	-6.653* (-13.742)	-0.093* (-3.618)	0.002 (0.590)
Denmark 1835-2001	1	-4.950* (-14.302)	-0.037* (-8.354)	-0.007 (-1.868)
England/Wales 1841-2001	1	-6.437* (-1.963)	-0.001* (-3.842)	-0.002* (-4.935)
Finland 1878-2001	1	-4.743* (-18.756)	-0.024 (-1.504)	0.065* (3.131)
France 1899-2001	1	-4.846* (-15.891)	-0.056* (-2.646)	0.063* (3.016)
Italy 1872-2001	1	-3.520* (-13.750)	-0.058* (-5.429)	-0.009 (0.776)
Netherlands 1850-2001	1	-2.773* (-8.130)	-0.053* (-5.977)	-0.017* (-2.957)
Norway 1865-2001	1	-7.432* (-11.483)	-0.029* (-7.238)	-0.005 (-1.865)
Spain 1908-2001	1	-7.722* (-5.388)	-0.005 (-1.135)	0.015* (3.408)
Sweden 1820-2001	1	-5.024* (-14.702)	-0.033* (-6.280)	-0.002 (-0.231)
Switzerland 1876-2001	1	-2.397* (-4.859)	-0.028* (-4.348)	-0.015* (-3.882)

[1] β coefficients are all normalised on GPC for ease of comparison.
* denotes significance at 5%. *t*-values are given in brackets below each coefficient.

Table 5: Life Expectancy (LE) and total GDP *Short-run coefficients of the VECM*		
	Short-run coefficients significant at 5% in the equation for dGDP	Short-run coefficients significant at 5% in the equation for dLE
Australia 1921-2001	*dGDP*: lags = 1 and 2. *dLE*: none	*dGDP*: lags = 1. *dLE*: lags = 1 and 2.
Belgium 1846-2001	*dGDP*: lags = 2 and 5. *dLE*: none.	*dGDP*: none. *dLE*: lags= 1, 2, 3 and 4.
Canada 1921-2001	*dGDP*: lags =1. *dLE*: none.	*dGDP*: lags = 1, 2 and 4. *dLE*: lags = 1 and 2.
Denmark 1835-2001	*dGDP*: lags = 1 and 2. *dLE*: none.	*dGDP*: none. *dLE*: lags = 1, 2 and 3.
England/Wales 1841-2001	*dGDP*: lags = 1. *dLE*: none.	*dGDP*: lags = 1 and 2. *dLE*: lags = 1, 2, 3, and 4.
Finland 1878-2001	*dGDP*: lags = 1, 2, 3 and 4. *dLE*: none.	*dGDP*: lags= 1. *dLE*: none.
France 1899-2001	*dGDP*: lags = 2 and 5. *dLE*: lags = 3, 4 and 5..	*dGDP*: none. *dLE*: none.
Italy 1872-2001	*dGDP*: none. *dLE*: none.	*dGDP*: lags = 2. *dLE*: lags = 1 and 2.
Netherlands 1850-2001	*dGDP*: lags = 2. *dLE*: lags = 1.	*dGDP*: lags = 1. *dLE*: lags = 1, 2, 3 and 4.
Norway 1865-2001	*dGDP*: lags = 2. *dLE*: lags = 1 and 4.	*dGDP*: lags = 1 and 2. *dLE*: lags = 1, 3 and 4.
Spain 1908-2001	*dGDP*: lags = 1. *dLE*: none.	*dGDP*: lags = 1. *dLE*: lags = 1.
Sweden 1820-2001	*dGDP*: lags= 2. *dLE*: lags = 1 and 2.	*dGDP*: lags = 1. *dLE*: lags = 1, 2, 3 and 4.
Switzerland 1876-2001	*dGDP*: none. *dLE*: none.	*dGDP*: none. *dLE*: lags = 1, 2 and 3.

Table 6: Life Expectancy (LE) and GDP per capita (GPC) *Short-run coefficients of the VECM*		
	Short-run coefficients significant at 5% in the equation for dGPC	Short-run coefficients significant at 5% in the equation for dLE
Australia 1921-2001	*dGPC*: lags = 1 and 2. *dLE*: none	*dGPC*: lags = 1. *dLE*: lags = 1 and 2.
Belgium 1846-2001	*dGPC*: lags = 2 and 5. *dLE*: none.	*dGPC*: none. *dLE*: lags = 1, 2, 3 and 4.
Canada 1921-2001	*dGPC*: lags = 1. *dLE*: none.	*dGPC*: lags = 1and 2. *dLE*: lags = 1 and 2.
Denmark 1835-2001	*dGPC*: lags = 1 and 2. *dLE*: none.	*dGPC*: none. *dLE*: lags = 1, 2, and 3.
England/Wales 1841-2001	*dGPC*: lags = 1. *dLE*: none.	*dGPC*: lags= 1 and 2. *dLE*: lags = 1, 2, and 3.
Finland 1878-2001	*dGPC*: lags = 1, 2, 3, and 4. *dLE*: lags = 1.	*dGPC*: lags = 1. *dLE*: lags = 1.
France 1899-2001	*dGPC*: lags = 2 and 5. *dLE*: lags = 3, 4 and 5.	*dGPC*: none. *dLE*: none.
Italy 1872-2001	*dGPC*: none. *dLE*: none.	*dGPC*: lags = 2. *dLE*: lags = 1 and 2.
Netherlands 1850-2001	*dGPC*: lags = 2. *dLE*: lags = 1.	*dGPC*: lags = 1. *dLE*: lags = 1, 2, 3 and 4.
Norway 1865-2001	*dGPC*: lags = 2. *dLE*: lags = 1 and 4.	*dGPC*: lags = 1 and 2. *dLE*: lags = 1, 3 and 4.
Spain 1908-2001	*dGPC*: lags = 1. *dLE*: none.	*dGPC*: lags = 1. *dLE*: lags = 1.
Sweden 1820-2001	*dGPC*: lags = 2. *dLE*: lags = 1 and 2.	*dGPC*: lags = 1. *dLE*: lags = 1, 2, 3 and 4.
Switzerland 1876-2001	*dGPC*: none. *dLE*: none.	*dGPC*: none. *dLE*: lags = 1, 2 and 3.