A Structural Model of Social and Economic Development

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Abstract

In this paper we estimate a model of the determinants of economic and social development that takes seriously three of the criticisms of panel data models in the existing growth literature: that long run coefficients are biased because the lagged dependent variable is not strictly exogenous; that they are biased because of slope coefficient heterogeneity; and that they are biased because of explanatory variable endogeneity. The model indicates that there are strong causal relationships in both directions between on the one hand, economic development, and on the other, social and political development.

JEL categories: O1, O4

1. Economic Growth and Social Development

The interaction between social and economic development is of interest both to economists and to social scientists in other disciplines. However, there has not as yet been that much cross-fertilisation between the two groups. This paper models economic and social development in a way that draws on insights from several areas of development studies.

Recent contributions by economists to the interaction of social and economic development have been dominated by the estimates of cross-country growth models surveyed by Levine and Zervos (1993) and Temple (1999). These models employ international panel data to estimate regression equations of the form:

$$\Delta y_{it} = a_0 - a_1 \cdot y_{it-1} + a_2 \cdot x_{it} + u_{it} \qquad (1)$$

where y_{it} is per capita income in country i in period t, x_{it} is a set of social and economic variables, and u_{it} a residual. These "growth" models are really dynamic models of the level of income, since they can be re-parameterized as:

$$y_{it} = a_0 + [1 - a_1] \cdot y_{it-1} + a_2 \cdot x_{it} + u_{it} \qquad (1a)$$

The components of x_{it} vary widely across different studies. Physical capital usually enters in some form, as the neoclassical core to a production function that also includes variables intended to capture the determinants of factor efficiency. These determinants can include measures of or proxies for "social capital", such as ethnic homogeneity, measures of civic spirit and education (Knack and Keefer, 1997; Johnson and Temple, 1998). They can also include measures of government policy performance such as debt-GDP ratios or black market forex premia (Easterly and Rebelo, 1993; Easterly and Levine, 1997), or measures of financial development, captured by the ratios of various types of asset holding to GDP (King and Levine, 1993; Levine, 1997).

Correspondingly, there is a literature in political science investigating the determinants of measures of social and political development. The dependent variable can be a measure of democracy or political / civil rights (Park, 1987; Henderson, 1991, 1993; Poe and Tate, 1994; Diamond, 1996), or the probability of the outbreak of violence and civil disorder (Bremer, 1992; Maoz and Russet, 1993; Mansfield and Snyder, 1995; Collier, 1998). Most of these papers estimate cross-section or panel data regressions, and often include indicators of economic development, such as the level or growth rate of per capita income, as explanatory variables.

Comparison of these two groups of papers indicates a fundamental drawback in the interpretation of the estimation results. The economists' papers use single equation estimation techniques and assume the exogeneity of social development, whilst the political scientists' papers assume the exogeneity of economic development. "Cross-country growth regressions do not resolve causal issues; [they] should be viewed as evaluating the strength of partial correlations, and not as behavioural relationships" (Levine and Zervos, 1993).[1]

Further problems arise from the use of panel datasets to estimate the determinants of social and economic development. First, since the lagged dependent variable is not strictly exogenous, single-equation techniques will not deliver consistent estimates of the coefficient a_1 in equation (1), and therefore of the long run effects of x_{it} on income: some Instrumental Variables technique (as in Caselli et al., 1996) is necessary. Second, the a_2 parameters will vary across countries, unless each country exhibits identical tastes and technology. The goal of pooled regression analysis is then to estimate the mean of the distribution of a_2; but if there is any serial correlation in the explanatory variables, then a panel data regression that imposes common a_2 values across countries will induce serial correlation in u_{it}. As a result, the fitted a_2 will not represent consistent estimates of the cross-country average of the true parameter values (Pesaran and Smith, 1995; Lee et al., 1998).

In this paper, we will estimate a cross-country model of social and economic development that takes all three of these problems seriously. Section 2 describes the modeling strategy, and Section 3 the results. Section 4 concludes.

2. The Model of Development

[1] Some papers use lags of explanatory variables in order to achieve weak exogeneity; but unless the explanatory variables are strictly exogenous the regression results cannot be interpreted in a counterfactual way (Engle and Hendry, 1993), which limits their interest for the policy-maker.

The main purpose of our model is to determine to what extent economic development is a consequence of social development, and to what extent the reverse is true. In order to produce consistent estimates of the impact of social factors on economic development, and of economic factors on social development, our estimation technique needs to deal with the three sources of parameter bias:

(a) Bias due to the endogeneity of the lagged dependent variable in a panel.

(b) Bias due to slope parameter heterogeneity in a panel.

(c) Bias due to the endogeneity of the key indicators of social and economic development. Instruments must be found to identify equations for each of the indicators of interest, so that a structural model may be estimated.

Problem (a) could be dealt with by instrumenting the lagged dependent variable, for example by using a GMM estimator as in Caselli et al. (1996). But the Pesaran and Smith (1995) results mean that when problem (b) is present such estimation techniques cannot deliver consistent estimates of mean slope parameters. However, consistency in the estimates of mean long run slope parameters can be achieved by averaging the data over time, and estimating the model on a pure cross-section.[2] It is this approach that we will follow below. The main drawback of the approach is that lags can no longer be used as instruments in dealing with problem (c), as they are in the Caselli et al. paper; so we need to find "real" instruments in order to identify the model.

Existing papers in the growth literature contain dozens of potentially endogenous variables, and it would be heroic in the extreme to attempt to identify all of the interactions between them using cross-section data. Instead, we will identify equations for four key indicators of development, and leave the rest of the model in reduced form.

The four variables are per capita income, education, health and democracy (i.e., the degree of openness in competition for legislative and executive power). First we present a theoretical model to show how equations for these four variables might be identified; then we deal with the question

[2] This is proven in Pesaran and Smith (1995). The caveat here is that the parameters will provide estimates only of the impact of x_i on y_i. Any cross-country effects of x_j on y_i will not be captured. The consistency result applies to any cross-section, whatever the period of averaging; but averaging over a longer period will reduce the variance in the estimate errors.

of measurement.

2.1 Theoretical model

The model consists of nine equations. Greek characters are parameters and Roman characters are variables; endogenous variables are written in bold. The variables are:

y: log per capita income

e: a measure of the average education level

h: a measure of the average level of health

k: the log per capita physical capital stock

a: factor efficiency

d: the degree of democracy

c_e: the cost of investment in education, net of its consumption benefits

c_h: the cost of investment in health, net of its consumption benefits

r: the interest rate

n: the log per capita natural resource stock

v: a measure of ethno-linguistic diversity

s: country size

t: an indicator variable for whether the country has a maritime coastline

m: a vector of variables capturing cultural characteristics

x: mean annual temperature

The equations are:

The aggregate production function:

$$y = a + \alpha_1 \cdot e + \alpha_2 \cdot h + \alpha_3 \cdot k + \alpha_4 \cdot n \qquad (2)$$

$1 > \alpha_1, \alpha_2, \alpha_3, \alpha_4 > 0$

The determinants of factor efficiency:

$$a = \beta_0 + \beta_1 \cdot v + \beta_2 \cdot s + \beta_3 \cdot t + \beta_4 \cdot d \qquad (3)$$

$\beta_0, \beta_3 > 0 > \beta_1, \beta_2$

A resource constraint:

$$\theta \cdot y = \pi_0 + \pi_1 \cdot e + \pi_2 \cdot h + \pi_3 \cdot k \qquad (4)$$

$1 > \pi_1, \pi_2, \pi_3 > 0 > \pi_0$

The public education decision:

$$e = \ln(\alpha_1) + y - c_e \qquad (5)$$

The cost of education (net of consumption benefits):

$$c_e = \gamma_0 - \gamma_1 \cdot v - \gamma_2 \cdot s - \gamma_3 \cdot t - \gamma_4 \cdot m - \gamma_5 \cdot d - \gamma_6 \cdot y - \gamma_7 \cdot h + r \qquad (6)$$

$\gamma_1, \gamma_3, \gamma_5, \gamma_6, \gamma_7 > 0$

The public health decision:

$$h = \ln(\alpha_2) + y - c_h \qquad (7)$$

The cost of health (net of consumption benefits):

$$c_h = \delta_0 - \delta_1 \cdot v - \delta_2 \cdot s - \delta_3 \cdot t - [\delta_4 - \delta_4' \cdot x] \cdot x - \delta_5 \cdot d - \delta_6 \cdot y - \delta_7 \cdot e + r \qquad (8)$$

$\delta_0, \delta_4, \delta_4', \delta_5, \delta_6, \delta_7 > 0$

The private investment decision:

$$k = \ln(\alpha_3) + y - r \qquad (9)$$

The determinants of the degree of democracy:

$$d = \zeta_0 + \zeta_1 \cdot v + \zeta_2 \cdot s + \zeta_3 \cdot t + \zeta_4 \cdot m + \zeta_5 \cdot e + \zeta_6 \cdot y + \zeta_7 \cdot h \qquad (10)$$

$\zeta_2, \zeta_3, \zeta_5, \zeta_6 > 0$

Equation (2) is a log-linear aggregate production function. The two human capital terms (e and h) are to be thought of as stock variables: there is constant depreciation of the stock through mortality, disease and forgetfulness. Higher levels of health and education can increase the productivity of the population for two reasons. First, they can increase the inherent productivity of the average worker. Second, they may be associated with lower fertility rates, and so a reduction in the proportion of the population below working age. In the absence of an instrument for a fertility equation, it is not possible to separate these two effects.

Equation (3) expresses the idea that the efficiency of resource use might depend on social and cultural factors. On the basis of the evidence in Easterly and Levine (1997), we allow for the possibility that greater ethno-linguistic diversity (v) reduces efficiency. We also allow for the possibility that more democracy (d) affects efficiency. This effect could work through the formation of social capital (Hardin, 1992; Knack and Keefer, 1997), or through a link between democracy and (good or bad) policy choices, or through a link between democracy and peace (Bremmer, 1992; Maoz and Russet, 1993). In the absence of appropriate instruments, these links will remain unidentified in our model. The causal chain from polity to policy to economic performance is captured in reduced form, in the parameter β_4. In addition, we allow for the possibility that country size (s) affects efficiency: larger countries might be more difficult to manage (country size is one of the variables included in the data set of King and Levine, 1993). Finally, the variable t is included to test the hypothesis that countries with access to the sea are more efficient, because costs of international trade are lower.

Equation (4) is a resource constraint. Letting capitals represent levels rather than logs, the constraint is:

$$S = Y^{\theta} = \lambda_e \cdot E + \lambda_h \cdot H + \lambda_k \cdot K \tag{4a}$$

where S is total saving, θ is the elasticity of saving with respect to income and the λ_i are rates of depreciation for the three types of capital: in equilibrium, investment will be equal to the depreciation rate times the capital stock. Letting π_1 represent the share of education investment in total investment, π_2 the share of investment in health, π_3 the share of physical capital investment, and $\pi_0 = \ln(\lambda_e)\cdot\pi_1 + \ln(\lambda_h)\cdot\pi_2 + \ln(\lambda_k)\cdot\pi_3$, the constraint can be written as equation (4).[3]

Equation (5) states that public education expenditure is at the level at which the marginal return to

[3] Since the λ_i are less than unity, and the $\ln(\lambda_i)$ are less than zero, π_0 is less than zero.

eduction equals its perceived marginal cost, c_e.[4] (In almost all countries it is the government that decides the level of education expenditure, at least at the margin.) This marginal cost is net of any consumption benefits that are perceived to arise from education: education is both a consumer good and a capital good. Equation (6) allows for the perceived consumption benefits to vary across countries. Higher levels of democracy might increase the value attached to education: it certainly increases observance of rights to personal integrity (Poe and Tate, 1994) which might plausibly be positively correlated with education levels; governments which do not value human rights are unlikely to value education. More openness to trade might also increase the value attached to education consumption ("travel broadens the mind"). As long as the income elasticity of demand for education is positive, higher levels of y ought to lead to higher levels of e. A more healthy population might value education more, because education and health are complements in consumption. Moreover, a higher degree of ethno-linguistic diversity might cause more worth to be attached to education, because second-language literacy will be more valuable. We also allow for a set of cultural factors (m) to affect the value placed on education. m includes indicators for whether the country has been colonized by Britain or France: Henderson (1991; 1993) argues that a country's colonial experience can influence the development of the degree of observance of rights to personal integrity and other measures of social development. m also includes the fraction of the population reporting adherence to Islam and Christianity: Poe and Tate (1994) and Park (1987) argue that religious adherence is equally important in determining the degree of observance of human rights. If there are no consumption benefits of education, then c_e will equal the interest rate, r.

Equation (7) expresses an equivalence between the marginal return to health expenditure and its marginal cost net of consumption benefits, c_h. Equation (8) indicates the possible determinants of c_h, and is analogous to equation (6). The one difference is that we assume that the value placed on health is not affected by cultural factors; but the cost of delivering a certain level of health does depend on the average temperature in the country, x. If extremes of temperature are unhealthy, then $c_h(.)$ will be non-monotonic in x, and the parameters δ_4 and δ_4' allow for this.

[4] Note that in a log-linear production function, the log of the marginal product of e is equal to the log of the average product, (y - e) plus the log of the elasticity of output with respect to e, $\ln(\alpha_1)$.

Equation (9) states an equivalence between the marginal cost of physical capital (r) and the marginal return. This equation could be modified by an efficiency expression similar to equation (3), driving a wedge between marginal product and marginal cost, to capture the possibility that some countries have less efficient capital markets than others; but this would leave unaltered the general form of the final equations to be estimated.

The final equation in the model, equation (10), indicates the potential determinants of democracy. It may be the case that higher material income promotes democracy (Park, 1987), or that more highly educated societies are more democratic. The existence of a coastline may encourage the democratic process, because it makes it easier for residents to flee from authoritarian governments. Cultural factors could influence the evolution of a democratic process because of their association with human rights observance, discussed above. Country size could also have an effect: larger countries might be more difficult for an authoritarian regime to manage, ceteris paribus. Ethno-linguistic diversity might promote democracy, because it makes it more difficult for a single party to acquire the unconditional support of a large fraction of the population; or it might promote authoritarianism, because of a lack of social capital.

Equations (2-10) can be solved in a partially reduced form that permits us to investigate the links between four of the key factors in social and economic development: income (y), education (e), health (h) and democracy (d). The four equations are shown below.

Income:

$$y = \{\beta_0 + \beta_1 \cdot v + \beta_2 \cdot s + \beta_3 \cdot t + \beta_4 \cdot d + [\alpha_1 - \alpha_3 \cdot \pi_1 / \pi_3] \cdot e + [\alpha_2 - \alpha_3 \cdot \pi_2 / \pi_3] \cdot h + \alpha_4 \cdot n\} \times \{\pi_3 / [\pi_3 - \theta \cdot \alpha_3]\} \qquad (11)$$

Education:

$$e = \{\ln(\alpha_1/\alpha_3) - \gamma_0 + \gamma_5 \cdot \zeta_0 - \pi_0/\pi_3 + [\gamma_1 + \gamma_5 \cdot \zeta_1] \cdot v + [\gamma_2 + \gamma_5 \cdot \zeta_2] \cdot s + [\gamma_3 + \gamma_5 \cdot \zeta_3] \cdot t + [\gamma_4 + \gamma_5 \cdot \zeta_4] \cdot m + [\gamma_6 + \gamma_5 \cdot \zeta_6 + \theta/\pi_3] \cdot y + [\gamma_7 + \gamma_5 \cdot \zeta_7 - \pi_2/\pi_3] \cdot h\} \div [1 - \gamma_5 \cdot \zeta_5 + \pi_1/\pi_3] \qquad (12)$$

Health:

$$h = \{\ln(\alpha_2/\alpha_3) - \delta_0 - \pi_0/\pi_3 + \delta_1 \cdot v + \delta_2 \cdot s + \delta_3 \cdot t + [\delta_4 - \delta_4' \cdot x] \cdot x + \delta_5 \cdot d + [\delta_6 + \theta/\pi_3] \cdot y$$
$$+ [\delta_7 - \pi_1/\pi_3] \cdot e\} \div [1 + \pi_2/\pi_3] \qquad (13)$$

Democracy:

$$d = \{\zeta_0 + \zeta_5 \cdot [\ln(\alpha_1/\alpha_3) - \gamma_0 - \pi_0/\pi_3] + [\zeta_1 + \zeta_5 \cdot \gamma_1] \cdot v + [\zeta_2 + \zeta_5 \cdot \gamma_2] \cdot s + [\zeta_3 + \zeta_5 \cdot \gamma_3] \cdot t$$
$$+ [\zeta_4 + \zeta_5 \cdot \gamma_4] \cdot m + [\zeta_6 + \zeta_5 \cdot [\gamma_6 + \theta/\pi_3]] \cdot y + [\zeta_7 + \zeta_5 \cdot [\gamma_7 - \pi_2/\pi_3]] \cdot h\}$$
$$\div [1 - \gamma_5 \cdot \zeta_5] \qquad (14)$$

y is identified by n; h is identified by x;[5] e and d are identified by m (which represents more than one variable). e cannot be identified in equation (14), nor can d in equation (12). Otherwise, there are three endogenous variables on the right hand side of each equation. Note that the effect of changes in e and h on other variables is ambiguous: education and health are inherently good for income, but in this partially reduced form an increase in e or h also has crowding out effects. More expenditure on human capital means less expenditure on physical capital.

Assuming that the realized values of each dependent variable in the i^{th} country are determined by equations of the form of (11-14) plus some idiosyncratic residual effect u_i, the system can be estimated on a cross-section of countries. We will do this using the data described in the next section.

2.2 Measurement of variables in the model

Following previous papers on growth, income is measured by the per capita GDP figures reported in the Penn World Tables (Heston and Summers, 1991). As discussed above, these figures are not used in panel data form, but are averaged over time. y is measured as the logarithm of the 30-year average of PWT GDP from 1960. Since this long run average might be interpreted as a measure of permanent income, we will compare the results of using the PWT figures with an alternative measure of permanent income: the wealth dataset presented in Dixon and Hamilton (1996). This is an attempt to measure the current present discounted value of human, physical and natural resource capital in each country of the world. A caveat to the comparison of the two sets of results reported

[5] As long as n, the value of natural resources (including land fertility), is measured accurately enough, temperature ought not to affect output independently of n.

below is that the wealth figures are not the result of averaging over time, the original data being reported as a pure cross-section, not a panel.

The measure of democracy is taken from the Polity-IIId dataset (McLaughlin et al., 1998), which is a revision of the Polity-II dataset (Gurr, 1997). These datasets provide information on Gurr's measure of democracy for each country in each year, which we average over time. For each year, democracy is measured on a ten-point scale. Countries are awarded up to three points for the competitiveness of political participation, that is, "the extent to which alternative preferences for policy and leadership can be in the political arena".[6] Polities in which opposition parties are harassed, suppressed or banned from participating in elections are awarded lower scores. Up to two points are awarded for the competitiveness of executive recruitment, that is, "the extent that prevailing modes of advancement give subordinates equal opportunities to become superordinates". Polities in which the electorate have more say in the choice of the chief executive are awarded higher scores. Countries are awarded up to one point for the openness of executive recruitment (measuring any limits on who can stand for election to the executive), and up to four points for constraints on executive decision-making. Polities in which the chief executive is not accountable for his actions (for example, by having to answer to a legislature) are awarded lower scores. Although the weighting implicit in the aggregate democracy index is arbitrary, the Polity-II dataset has been employed effectively in a wide range of contexts in political science (McLaughlin et al., 1998).[7]

A number of alternatives are available in measuring the stock of education. Barro and Lee (1993) provide the most sophisticated measure based on years in school, but for a limited range of countries, and with strong assumptions about the relative quality of schooling across the world. We use a more basic measure instead: the fraction of the adult population that is literate. This measure has the advantage that it is available for a wider range of countries, and it is a direct measure of an

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[6] Quotations are from Gurr (1997).

[7] With the averaging, the distribution of the democracy measure is approximately continuous, but censored: dividing the score by ten, observations all lie on the interval [0,1]. We estimated both linear and logit regressions for the democracy equation, and found very little difference in the effects of explanatory variables at the mean. The main tables report the linear regression results, but the logit regression results are available on request. The same goes for the literacy measures discussed next.

output, rather than an input-based measure. The data are taken from UNESCO (1998). The adult literacy rate is a stock of human capital built up over many years; one difficulty in using it alongside income in a structural model is that adult literacy in 1960 is unlikely to depend on income in 1960, but income in 1960 is likely to depend on literacy in 1960. If we were interested solely in the [literacy → income] part of the model, we should want to average the literacy data in the same way as the income data; but this is not true when the [income → literacy] part of the model is also of interest. Having tried both past averaged and current literacy rates, we report the results of using the latter, though the choice does not make a great deal of difference to the outcome. The same remarks are true of the measure of health used in the model, (log) life expectancy at birth. The life expectancy figures used to generate the results reported below are taken from the Dixon and Hamilton dataset.

The other stock variable used in the estimated model is the measure of the value of natural resources. The only consistent measure available for a wide range of countries is the one in Dixon and Hamilton dataset, which is reported just once for each country; ideally, we would use an average for the same period as income. A caveat to the use of the Dixon and Hamilton data is that there may be some measurement error, if in some countries there has been a great deal of variation in the value of natural resources over time.

The measure of ethno-linguistic diversity is the most recent and comprehensive one we are aware of, presented in Krain (1997). This measures the probability that two individuals selected randomly from a country's population will speak the same native language. Country size figures (log thousands of km^2) are taken from CIA (1997), and temperature data (tenths of degrees centigrade) from Hoare (1998). For large countries, the temperature figures used are averages over several large population centres, and for small countries the temperature in the capital city; further details are available on request. For the cultural variables, information on colonisation by Britain or France is taken from CIA (1997), and the fraction of the population adhering to Christianity or Islam from Grimes (1996).

With data drawn from these disparate sources, there are 114 countries in our dataset using the PWT measure of income ("Model 1"), and 120 countries in the dataset using the Dixon and Hamilton measure of wealth ("Model 2"). These are listed in Appendix 1. The sample means and standard deviations of all continuous variables are reported in Table 1. The measures of each variable are summarized as follows.

y: log per capita GDP in $ (Model 1); log wealth in $ (Model 2)
e: the fraction of the adult population that is literate
h: log years' life expectancy
d: Polity-IIId democracy index, scaled to the interval [0,1]
n: the log per capita natural resource stock in $
v: Krain's measure of ethno-linguistic diversity
s: log country size in 1000 km^2
t: dummy for whether the country has a maritime coastline
m: GBR (dummy for British colonies); FRA (dummy for French colonies); CHR (the fraction of the population that is Christian; MUS (the fraction of the population that is Muslim)
x: mean annual temperature in 0.1 degrees centigrade

Table 1: Descriptive Statistics

Variable	mean	std. dev.
y (Model 1)*	7.809	0.991
y (Model 2)	10.450	1.667
e	0.767	0.227
h	4.145	0.168
d	0.433	0.355
CHR	0.520	0.385
MUS	0.227	0.355
v	0.415	0.273
n	8.712	1.792
x/100	1.921	0.737
s	5.320	1.891

* The statistics for this variable are based on a sample of 114 countries; for other variables the sample size is 120.

In addition to measuring the variables in equations (11-14), we ought to allow for the possibility that the u_i for each equation are spatially correlated. The regression equations include the regional dummies EUR (Europe), SAM (South and Central America), AFR (Africa), MDE (Western Asia) and ASP (the rest of Asia and the Pacific); the baseline intercept in the equations including regional dummies is for North America. Dummies at a greater degree of geographical disaggregation were insignificant.

3. Estimation Results

The unrestricted reduced form OLS estimates on which the structural model in equations (11-14) is based are reported in Appendix 2. The full model corresponding to equations (11-14) is not reported here, but is available on request. Tables 2-3 below report the result of imposing those restrictions on the model that minimize the Hannan-Quinn model selection criterion, when the model is estimated by FIML.[8] (The model resulting from minimizing the Schwartz criterion is similar, but omits a few explanatory variables significant at the 5% level. The model resulting from using the Akaike criterion is less restrictive than the one reported here; standard errors are higher than those in Tables 1-2, but coefficient magnitudes are similar. None of the additional coefficients in the Akaike-based model is statistically significant.) Table 4 reports some corresponding diagnostic statistics, including White's test for heteroskedasticity. The null of homoskedasticity can be rejected at the 10% level in Model 1 and at the 1% level in Model 2, so the t-ratios in Tables 2-3 are based on White-corrected standard errors ("H.C.S.E."); the uncorrected standard errors ("std. err.") are also shown for comparison. In order to give an impression of the relative importance of different effects, the final column in Tables 2-3 reports the product of the estimated coefficients and the variables' standard deviations from Table 1.

The first equation in Tables 2-3 is for the variable y, measured as *per capita* GDP and wealth respectively. The y equations in the two tables are qualitatively similar, but with higher elasticities in the second, wealth-based regression. By far the strongest relationship in the

[8] For the purposes of model selection country location is treated as a single variable, so individual equations include either all or none of the regional dummies.

Table 2: Model 1 Parameter Estimates

y equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-20.0450	3.40260	3.63790	-5.51005	▯▯▯▯▯▯▯
n	0.21588	0.03461	0.04101	5.26408	0.38686
s	-0.06551	0.02551	0.02972	-2.20424	-0.12388
d	0.17984	0.22980	0.24052	0.74771	0.06384
e	-2.43770	0.81680	0.77601	-3.14133	-0.55336
h	6.78100	0.94523	1.02220	6.63373	1.13921

σ = 0.4714

e equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-2.39410	0.79874	0.86844	-2.75678	▯▯▯▯▯▯▯
FRA	-0.06402	0.02646	0.02644	-2.42133	▯▯▯▯▯▯▯
MUS	-0.17887	0.03175	0.03470	-5.15476	-0.06350
v	0.02417	0.04585	0.04909	0.49236	0.00660
y	0.07445	0.03802	0.04349	1.71189	0.07378
h	0.63223	0.25422	0.28218	2.24052	0.10621

σ = 0.1032

h equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	3.61320	0.10963	0.12268	29.45223	▯▯▯▯▯▯▯
EUR	-0.02456	0.02308	0.01467	-1.67416	▯▯▯▯▯▯▯
SAM	-0.04879	0.02388	0.01637	-2.98045	▯▯▯▯▯▯▯
AFR	-0.12375	0.03059	0.02835	-4.36508	▯▯▯▯▯▯▯
MDE	-0.02540	0.02790	0.02101	-1.20895	▯▯▯▯▯▯▯
ASP	-0.04386	0.02408	0.01785	-2.45714	▯▯▯▯▯▯▯
s	-0.00575	0.00285	0.00322	-1.78571	-0.01087
t	0.03181	0.00986	0.01238	2.56947	▯▯▯▯▯▯▯
$x/100$	0.05106	0.02625	0.02044	2.49804	0.03763
$x^2/100$	-0.19018	0.07420	0.06832	-2.78367	-0.00103
v	-0.02584	0.01714	0.01686	-1.53262	-0.00705
y	0.04312	0.01587	0.01720	2.50698	0.04273
e	0.32889	0.07156	0.07181	4.58000	0.07466

σ = 0.0562

d equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-1.71770	0.37430	0.43955	-3.90786	▯▯▯▯▯▯▯
EUR	0.31898	0.13713	0.14031	2.27339	▯▯▯▯▯▯▯
SAM	0.12208	0.13869	0.14624	0.83479	▯▯▯▯▯▯▯
AFR	0.18427	0.15290	0.16793	1.09730	▯▯▯▯▯▯▯
MDE	-0.30775	0.15308	0.16441	-1.87184	▯▯▯▯▯▯▯
ASP	0.28012	0.14860	0.16234	1.72551	▯▯▯▯▯▯▯
CHR	0.13470	0.08047	0.10144	1.32788	0.05186
GBR	0.24390	0.05266	0.04861	5.01749	▯▯▯▯▯▯▯
FRA	0.13736	0.06606	0.06087	2.25661	▯▯▯▯▯▯▯
y	0.23190	0.04155	0.04986	4.65102	0.22981

σ = 0.2203

Table 3: Model 2 Parameter Estimates

y equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-27.3030	4.96270	4.10820	-6.64598	□□□□□□□
n	0.46425	0.04902	0.05723	8.11200	0.83194
s	-0.12023	0.03167	0.03434	-3.50116	-0.22735
d	1.30230	0.36259	0.33262	3.91528	0.46232
e	-3.93820	1.18100	0.99591	-3.95437	-0.89397
h	8.88030	1.38410	1.14740	7.73950	1.49189

σ = 0.7015

e equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-3.39350	0.51423	0.59127	-5.73934	□□□□□□□
FRA	-0.04390	0.01975	0.02148	-2.04376	□□□□□□□
MUS	-0.15427	0.02680	0.03130	-4.92875	-0.05477
v	0.06876	0.03864	0.04086	1.68282	0.01877
y	0.02028	0.01233	0.01426	1.42216	0.03381
h	0.95655	0.14522	0.16864	5.67214	0.16070

σ = 0.0979

h equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	3.74180	0.07812	0.07542	49.6128	□□□□□□□
EUR	-0.01568	0.02790	0.01338	-1.17190	□□□□□□□
SAM	-0.03223	0.02796	0.01384	-2.32876	□□□□□□□
AFR	-0.11940	0.03387	0.02367	-5.04436	□□□□□□□
MDE	-0.00419	0.03243	0.02062	-0.20320	□□□□□□□
ASP	-0.03321	0.02842	0.01747	-1.90097	□□□□□□□
s	-0.00623	0.00263	0.00271	-2.29889	-0.01178
t	0.03195	0.01079	0.01321	2.41862	□□□□□□□
$x/100$	0.05233	0.03088	0.02396	2.18406	0.03857
$x^2/100$	-0.20226	0.08795	0.07968	-2.53840	-0.00110
v	-0.04604	0.02157	0.02185	-2.10709	-0.01257
e	0.35083	0.07655	0.07455	4.70597	0.07964
y	0.01852	0.00762	0.00808	2.29208	0.03087

σ = 0.0580

d equation

Variable	coeff.	std. err.	H.C.S.E.	t ratio	co × sd
Intercept	-1.10610	0.25016	0.27290	-4.05313	□□□□□□□
EUR	0.21667	0.12379	0.12834	1.68825	□□□□□□□
SAM	0.02042	0.12299	0.12457	0.16392	□□□□□□□
AFR	0.06972	0.13056	0.13199	0.52822	□□□□□□□
MDE	-0.31632	0.13709	0.13790	-2.29384	□□□□□□□
ASP	0.17533	0.12955	0.13113	1.33707	□□□□□□□
CHR	0.12899	0.06874	0.08336	1.54738	0.04966
GBR	0.21218	0.04863	0.04962	4.27610	□□□□□□□
FRA	0.09231	0.05603	0.05081	1.81677	□□□□□□□
y	0.12475	0.01954	0.02268	5.50044	0.20796

σ = 0.2189

Table 4: Diagnostic and Descriptive Statistics for Models 1-2

A. Residual Correlation

Model 1

	d	y	e
y	-0.27707		
e	-0.07197	0.12977	
h	0.16400	-0.76210	-0.34637

Model 2

	d	y	e
y	-0.50250		
e	-0.18549	0.47873	
h	0.11887	-0.56276	-0.62906

B. Log-Likelihoods

Model 1	
Unrestricted	869.361
Restricted	858.364
Restrictions test ($\chi^2(29)$)	21.9945 [0.8204]
Model 2	
Unrestricted	861.692
Restricted	849.803
Retrictions test ($\chi^2(29)$)	23.7795 [0.7397]

C. Model Selection Criteria

	Restr.	Unrestr.
Model 1		
Schwartz	-13.605	-12.593
Hannan-Quinn	-14.104	-13.506
Akaike	-15.059	-14.252
Model 2		
Schwartz	-12.767	-11.808
Hannan-Quinn	-13.250	-12.691
Akaike	-14.163	-13.362

D. Heteroskedasticity Tests

Model 1	
Restricted	$F(210,703)$ = 0.9901 [0.0599]
Unrestricted	$F(210,630)$ = 0.9901 [0.5277]
Model 2	
Restricted	$F(210,757)$ = 1.3872 [0.0011]
Unrestricted	$F(210,685)$ = 1.2726 [0.0131]

E. Unrestricted Reduced Form R^2(LM)s

Model 1	0.6445
Model 2	0.6645

regression is the effect of higher life expectancy. A one standard deviation increase in log life expectancy leads to a *per capita* GDP level 114% higher, and a *per capita* wealth level 149% higher. Whilst part of this substantial effect might be attributable to the beneficial impact of health on worker productivity, a large part may to be due to an unidentified relationship between health and fertility. (The magnitude of the effect is less surprising when one bears in mind that the maximum observation of GDP is 47 times greater than the minimum, and the maximum observation of wealth is 596 times greater than the minimum: there is a lot of variance to be explained.)

Education also has a significant effect on income, but the effect is negative. This is consistent with the theoretical model, implying that in the typical country $\alpha_1 \cdot \pi_3 < \alpha_3 \cdot \pi_1$. The reduced productivity resulting from the crowding out of physical capital investment when education expenditure rises more than offsets the benefits to productivity of the better average education levels. This is consistent with rational behaviour because education also has consumption benefits. *Ceteris paribus*, a one standard deviation reduction in literacy is associated with a *per capita* GDP level that is 55% higher and a *per capita* wealth level that is 89% higher. The net effect of education on income can still be positive, however, if education influences health levels. This possibility will be addressed in the discussion of the h regression, and later in the discussion of general equilibrium effects. The education effects estimated here are difficult to compare directly with those in previous studies, which include educational attainment and physical capital stock measures as independent variables. But with the negative education coefficient in the income equation and the positive income coefficient in the education equation below, it is not surprising that most previous studies using single equation techniques have found no strong overall correlation between the two variables (Temple, 1999).

Income is also influenced positively by the stock of natural capital, and negatively by country size, although the second effect is relatively small in both versions of the model. In Model 2 there is a significant positive coefficient on the democracy variable, d, implying that a one standard deviation increase in the democracy index leads to a 46% increase in income. This squares with other papers which have also found a positive relationship by using measures of political development such as the infrequency of coups d'état (Easterly and Levine, 1997). However, the result is fragile: the democracy coefficient is insignificant in both Model 1 in

Table 2, and in the specification of Model 2 selected using the Akaike criterion, which includes (insignificant) region dummies.

The most striking aspect of the second equation, for education *qua* the literacy rate, is that although there is a positive coefficient on income, it is quite small. The coefficient is significant at only the 10% level in Model 1 and is insignificant in Model 2. On average, higher income appears neither to increase the consumption demand for education, nor to generate financial resources for investment in education. However, the impact of health on education is highly significant; a one standard deviation increase in life expectancy is on average associated with an 11 percentage point increase in the literacy rate in Model 1 and a 16 percentage point increase in Model 2. The sum of the income and life expectancy effects are very similar in the two models, and one interpretation of the figures is that life expectancy and GDP / wealth are competing measures of the index of material well-being that is the true determinant of education demand. Conventional measures of material well-being have little direct effect on education, though they may have an indirect effect through a positive relationship between health and wealth. To put it another way: increases in *per capita* GDP are not associated with increases in the demand for basic education unless they deliver a higher general quality of life.

Aside from income and life expectancy, the only other significant determinants of education are cultural factors. There is a significantly negative coefficient on the French colonisation dummy: *ceteris paribus*, former French colonies have a literacy rate estimated to be six percentage points lower in Model 1 and four percentage points lower in Model 2.

The third equation, for life expectancy, is the one in which effect of the region dummies are both large and significant. South America, the Asia-Pacific region and Africa all have life expectancy rates that are *ceteris paribus* significantly lower than those in North America. By far the strongest effect is in Africa: in both models being African instead of North American reduces life expectancy by 12%; being Asian or South American reduces life expectancy only by 3-4%.[9] Recall that life expectancy is significant in the two income equations, but the regional

[9] The sample standard deviation of log life expectancy is much lower than that of log income (see Table 1); and likewise the estimated effects of explanatory variables in terms of percentage changes are much lower in the life expectancy equation.

dummies are not. Africa's "growth tragedy" (Easterly and Levine, 1997) appears to be a health tragedy. Africa's problem is not that it is a particularly inefficient continent, but that it is a particularly disease-ridden one. Similarly, it is in the life expectancy equation that the measure of ethno-linguistic fractionalisation appears with a negative coefficient; but the coefficient is significant at the 5% level only in Model 2. A one standard deviation increase in this variable is estimated to reduce life expectancy by just over 1% in Model 2 and just under 1% in Model 1. It is unclear why the negative impact of ethno-linguistic fractionalisation works through life expectancy rather than directly in the income equation.

Both income and education have large, positive, significant effects on life expectancy. A one standard deviation increase in literacy increases life expectancy by 7-8%; for income the figure is 3-4%. Since both education and income depend positively on health, this means that the equilibrium impact of income on education will be greater than the small direct effect discussed above, and that the negative direct impact of education on income will be offset by a positive equilibrium effect. These net effects will be evaluated later.

Health is also influenced by climatic factors. There is a significant quadratic relationship between life expectancy and annual average temperature, with the maximum life expectancy at around 13^{o} centigrade in both models; and countries with a coastline have a life expectancy that is around 3% higher than similar countries with no coastline. Size matters too: a one standard deviation increase in log country size is associated with a 1% reduction in life expectancy. This may reflect a lower level of efficiency of public healthcare provision in large countries, for a given income level.

The equation for democracy indicates that income levels have a strong and highly significant impact on polity. In Model 1 a one standard deviation increase in log income is associated with a 23 percentage point increase in the democracy score; in Model 2 the figure is 21%. At the national level, democracy (and the quality of life from the human rights that go with it) are a luxury item. As in other studies, we find that patterns of colonialisation affect present-day polities. Former British colonies have a democracy score that is *ceteris paribus* 21-24 percentage points higher than other countries; for former French colonies the figure is 9-14%. There is also one strong significant regional effect: countries in the Mid-East (including both

Israel and its Arab neighbours) have a democracy score that is *ceteris paribus* 32 percentage points lower than the score for North America; the gap relative to other parts of the world is even greater.

Having estimated the structural model, it is possible to compute the equilibrium impact of an exogenous shock to each of the dependant variables on all of the variables in the system.[10] These effects are listed in Table 5 for both Model 1 and Model 2, and are presented in the following way. Each column represents the impact of a shock to one of the four equations (11-14) on each of the four dependant variables. The magnitude of the shock is one standard deviation of the column variable, and the impact is measured in standard deviations of the row variable. For example, the second figure in the first column for Model 1 (1.659) indicates the impact on e of a shock to the y equation equal to one standard deviation of y, the impact being measured in standard deviations of e. The results for the two models are broadly similar (so we have some confidence in their robustness), but care should be taken in comparing the two sets of results because the standard deviation of the income measure (and hence the normalisation) in Model 1 is rather different from that in Model 2.

The figures on the main diagonal are the multiplier effects, all of which are positive. The largest multiplier effect is for h (estimated at 2.08 in Model 1 and 1.86 in Model 2); the smallest is for d (1.06 and 1.23). The only negative figures are for the impact of shocks to the e equation on y, and via y on d; these figures are quite small, however, because the negative direct impact of e on y (Tables 2-3) is largely offset by the positive impact of e on h, and of h on y. Otherwise, the equilibrium impact of a shock to one variable on others in the system is large and positive. In many cases a positive shock of one standard deviation to the equation for a variable leads to increases in other variables greater than one standard deviation, so there are many virtuous spirals in the system.

[10] The impact of shocks to exogenous variables is given in the reduced form coefficients reported in Appendix 2.

Table 5: Normalized Effects of Exogenous Shocks

The columns show the normalized equilibrium impact on each of the four dependent variables of an exogenous shock in each of the four equations. For example, the second figure in the first column (1.659) indicates the impact on e of a shock to the y equation equal to one standard deviation of y, the impact being measured in standard deviations of e.

Model 1

	Equation			
	y	e	h	d
Variable				
y	1.452	-0.086	1.623	0.094
e	1.659	1.216	1.487	0.052
h	0.726	0.519	2.080	0.130
d	1.052	-0.056	1.055	1.061

Model 2

	Equation			
	y	e	h	d
Variable				
y	1.398	-0.235	0.926	0.366
e	0.586	1.410	1.454	0.154
h	0.548	0.625	1.863	0.143
d	0.872	-0.215	0.576	1.227

A "shock" in this cross-section context is an idiosyncratic effect making the level of income, education, health or democracy of a country greater or less than what one might expect, given the country's other socio-economic characteristics. Since the model we have estimated is a partially reduced form, it would be incautious to read too much into the regression residuals; we cannot attribute the appearance of certain countries in either tail of a residual distribution to a particular reason.[11] However, the figures in Table 5 could be interpreted as the potential impact on a country's development of idiosyncratic effects (including idiosyncratic government policy) which raised the level of income, education, health or democracy above the level one would expect.[12] Policy initiatives related to one variable will have a different impact on development

[11] Moreover, the identity of the countries appearing in the tails varies between Model 1 and Model 2.

[12] Of course policy is implicitly endogenous in the model; but there will always be a stochastic component in the determinantion of policy variables that reflects the individual country's genius.

from policy initiatives related to another. In the absence of a social welfare function converting values of of y, e, h and d into a single metric (and of estimates of the resource costs of implementing a certain kind of policy) it is impossible to say which kind of initiative will be most valuable. But it is striking that the figures in the h columns in Table 5 are generally larger than those in other columns: idiosyncratic health improvements have more impact on the system than other idiosyncrasies.

4. Conclusion

This paper has examined the long run relationship between indicators of social and economic development taking seriously the potential econometric problems encountered in estimating cross-country regressions, in particular the endogeneity of the different development indicators. Our results suggest that there exist a number of virtuous spirals in the process of social and economic development. Economic growth promotes democratic development, and *vice versa*; education is good for health, and health is good for education. Perhaps the most interesting result to appear is the role of health (measured in terms of life expectancy) in the development process. First, many of the key explanatory variables used in previous economic growth studies, such as ethno-linguistic fractionalisation and the "Africa dummy", impact on the economy just through their effect on health. Second, the shocks to the system that have the largest impact on development indicators are those to the level of health. Small improvements in life expectancy can have a large effect on income, education and democracy. The value of good public health policy and health-promoting foreign aid may be even greater than one might anticipate.

Moreover, the inclusion of a democracy index in the model reinforces a point made *inter alia* by Collier (1998), that foreign aid - income transfers from wealthy countries to poorer ones -can generate Pareto improvements. As is well documented in the political science literature cited above, democratic countries are less prone to engage in internal or external conflict. Aid that improves the level of income and health of a country will, on average, make it more democratic in the long run, and so less prone to violence. Since it is the industrialized world that bears the brunt of the cost of policing and mediating intra- and international conflicts, aid payments could be motivated by enlightened self-interest.

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Appendix 1: Countries Included in the Sample

* indicates inclusion in Model 2 only

Ethiopia	Senegal	Turkey	Portugal
Nepal	Cote d'Ivoire	Thailand	Greece
Burundi	Egypt	Cuba*	Cyprus
Malawi	Zimbabwe	P. N. G.	Namibia
Uganda	Indonesia	Iraq	Saudi Arabia
Tanzania	Zambia	Costa Rica	Botswana
Viet Nam*	Cameroon	Iran	New Zeland
Sierra Leone	Burma	Congo	Ireland
Niger	Mauritania	Fiji	Israel
Cambodia*	Philippines	Panama	Spain
Burkina Faso	Liberia	Jamaica	Singapore
Gambia	Romania	Brazil	Britain
Kenya	Guatemala	Mauritius	Finland
Mali	Morocco	Swaziland	Italy
Nigeria	C. A. R.	Poland	Netherlands
India	Peru	Czech Republic	Belgium
Madagascar	Ecuador	Mongolia	Austria
Haiti	Dominican Republic	Malaysia	Germany
Benin	Jordan	Venezuela	Kuwait
Sudan	El Salvador	South Africa	France
Togo	Syria	Uruguay	U. S. A.
China	Bolivia	Hungary	Norway
Laos	Bulgaria	Chile	Denmark
Pakistan	Lithuania*	Trinidad	Iceland
Ghana	Paraguay	Mexico	Sweden
Yemen	Colombia	Guyana	Japan
Nicaragua	Algeria	Argentina	Switzerland
Comoros	Tunisia	Oman	Luxembourg
Sri Lanka	Albania*	South Korea	Canada
Honduras	Slovakia*	Bahrain	Australia