

**The Impact of Human Capital on Non-Market Outcomes
and Feedbacks on Economic Development**

**Techniques for Measurement and Estimates of Impacts of Education
in OECD Member Countries**

Technical Appendix

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This Technical Appendix explains in some detail the 38 equation structural model that lies behind the simulations. The logical rationale for most of the equations and brief references to the microeconomic research as it relates to each social outcome has been presented in the main paper keyed to the numbering of the equations in the model and will not be repeated here. This Technical Appendix includes the more precise definition of the variables, the data source for each, a summary of the statistical properties of each of the major structural equations together with some brief references to the results of alternative specifications (presented in much more detail in the book, McMahon 2000), and a discussion of various issues that surround such an analysis. These include an appraisal of the quality of the data, and the ways in which the endogenization of the Solow constants and use of data specific to each OECD member country to set the initial conditions for each variable takes ‘cultural differences’ into account. The background paper available from OECD addresses other issues such as when and how causation can be inferred in this multivariate context containing lags (as distinguished from correlations alone which can be spurious). It also presents simulations in graphs and tables of both total and indirect effects for all of the 22 OECD member nations for which the model is operational.

For a thoughtful recent survey of research relevant to these and related issues the reader is referred to Temple (1999). He concludes that, with eyes wide open to all of the problems, there are still significant insights that can be gained by observing what inter-country data has to reveal that cannot be gained in any other way. For a more comprehensive discussion of the rationale and other research related to each economic and social outcome of education, the statistical properties and alternative specifications of each equation, the indirect effects, externalities, and valuation of outcomes, and discussion of further applications to East Asia, Latin America, and Africa, see McMahon (2000).

I. Definitions of Variables and Data Sources

The major variables and data sources, numbered to correspond to the numbering of the equations in the complete model which follows are:

1. *Life Expectancy*, LEXP, index of health of the population (World Bank, 1997, p.214, Col 9).
2. *Infant Mortality*, IMR, another measure of health status (World Bank, 1997, p.224)
3. *Total Fertility Rate*, TFR, live births per female during child bearing years (ibid., p.224)
4. *Crude Birth Rate* CBR, (ibid)
5. *Crude Death Rate* CDR, (ibid)
6. *Population (POP.)* (ibid)
7. *Population Growth Rate*, POPNGR (ibid.)
8. *Democratization*, DEM, Scale of 1 to 8 (8 is highest), (Freedom House, 1996, p.539-41)
9. *Human Rights*, HR, Scale of 1 to 8 (8 is highest), (Freedom House, 1996, p. 539-41)
10. *Political Stability*, PS, Scale of 1 to 100, (Intern'tl Country Risk Guide, 1995, Composite,S8)
11. *Poverty*, POV, % of income received by poorest 20% of the population, (World Bank '99,p196)

12. *Inequality*, GINI, inequality in the income distribution, World Bank (1999, *ibid.*, p.206)
13. *Environmental Deforestation & Wildlife Destruction*, DEF, the rate of reforestation (often negative), (World Bank, 1999, p.206)
14. *Water Pollution*, WATER, Water Pollution, (World Bank, World Development Indicators, '98)
15. *Air Pollution*, AIR, Percent of population not having clean air, World Bank (*ibid.*)
16. *Homicide Rates*, HOMICIDE, (International Crime Statistics, INTERPOL,1998)
17. *Property Crime Rates (C-H)*, Total Crime less Homicide, (*ibid.*, INTERPOL 1998)
18. *GER1F*, *Gross Enrollment Rates, Primary, Female*, (World Bank 1998, & UNESCO 1999)
19. *GER1M*, *Gross Enrollment Rates, Primary, Male* (*ibid.*)
20. *GER1T*, *Gross Enrollment Rates, Primary, Total*; $(GER1F+GER1M)/2$
21. *GER2F*, *Gross Enrollment Rates, Secondary, Female* (*ibid.*)
22. *GER2M*, *Gross Enrollment Rates, Secondary, Male* (*ibid.*)
23. *GER2T*, *Gross Enrollment Rates, Secondary, Total* (Eq. 23)
24. *GER3T*, *Gross Enrollment Rates, Higher Education, Total* (*ibid.*)
25. *PEDCF*, *Fifth Grade Completion Rates, Female*, (UNESCO, 1999)
26. *PEDCM*, *Fifth Grade Completion Rates, Male*, (UNESCO, 1999)
27. *LAGRI*, *Proportion of Labor Force in Agriculture*, (ILO, 1997), Low in OECD; hence this variable does not have much effect of the outcome
28. *LFPRF*, *Labor Force Participation Rate, 1995, Female* (World Bank, 1999, p.234, & *ibid.*), not strictly comparable across countries because women who work on farms are not always counted.
29. *LFPR*, *Labor Force Participation Rate, 1995, Total*, $(PFPRF+LFPRM)/2$
30. *AGEMARR*, *Age at Marriage*, (UNESCO, 1999)

31. *N*, Employment (LFPR/100) x POP
32. *U*, Underutilization of Labor, 1-LFPR/100
33. *UT*, Long Run Average Underutilization
34. *GN*, Growth of per capita GNP, in real terms, computed endogenously by Eq. 34. For the endogenous development scenario, '85-95 from World Bank, 1997
35. *GROWTH*, Growth Rate of GNP (Computed endogenously as GN+POPGR)
36. *GNP*, Gross National Product (Eqs. 35&36. Initial GNP 1995,US \$, World Bank, 1997)
37. *GNPPC*, Gross National Product Per Capita. (Computed endogenously, Eq. 37.)
38. *Investment in Physical Capital as a % of GNP*, GDIG, (World Bank ,1997, p.238)
- MILX*, Military Expenditures as % of Central Government Budget, (World Bank, 1997)
- SSX/100*, Social Security Expenditures as a percent of GDP (Summers and Heston, 1993)
- FPSCORE*, Family Planning Score, Level of support for family planning (Population Crisis Committee, 1987 and other years)
- AFRICA*, *ASIA*, *LAC*, *EMENA*, Dummy variables for African, Asian, Latin American, and European and Middle Eastern countries respectively in the regressions.

II. The Model

The complete model follows in Table 1A. All equations dealing with non-market outcomes, but not the production and investment functions, were estimated from worldwide data generally for 78 countries, providing the necessary perspective on the long run processes involved. These countries include the OECD member countries, but not any centrally planned

economies given their differences from market economies and the lack of comparable data on key variables. Data is not available for a few variables for all 78 countries, especially for inequality, the environment, and crime. So these equations were estimated for all countries for which data exists.

This model then was programmed for the purpose of computer simulations following a change in one of six education policy variables, including investment in education as a percent of GNP (EDSH) which is the main policy change whose effects are traced in this paper. To do this the initial condition for each endogenous variable is taken to be the actual value of that variable in each country which in the case of OECD member countries is as given below in Table 2A.

Practically speaking this means that the constant term in each equation is adjusted so that the 'prediction' of each equation is forced to be the value given by the real world data for that country for 1995, the initial year. Therefore the reader should not pay much attention to constants in the equations that follow since they essentially are replaced with the actual data for each country in the simulations. In cases where actual data is missing on key variables (e.g. Iceland) no simulations could be run. But where values for a particular variable is missing it was sometimes possible to get a predicted value as a starting point for that variable (e.g. the Gini) if all of the other explanatory variables in that equation were known. Occasionally even that was not possible and if that variable did not affect anything else in the model (e.g. AIR pollution) simulations are computed for that country but no outcomes were run for that variable in that country.

The t-statistics are shown below each coefficient in each equation. Other statistical properties of each equation are discussed following Table 1A. Generally, all regressions were

corrected for heteroscedasticity, and there are many other variables that were tested for each equation that did not prove to be significant. They are shown in more extensive tables in McMahon (2000, Chapters 3-10). Occasionally the t-statistics reach only the 90% level of confidence, although most reach the 95% level or higher, but these were retained because they were judged to have predictive capacity since they also have a theoretical logical or causal connection to the outcome in question. Occasionally explanatory variables were rejected from the equation chosen to appear in the final model even though their coefficient might have been statistically significant because the correlation was judged to be spurious given that there was no conceivable theoretical logical or causal connection to the potential outcome.

Per capita GNP is always retained as a control even though not significant wherever the objective is to measure non-market outcomes. The model with variables as defined above follows.

Table 1A

Equations in the Complete Model

Non-Market Impacts of Education on Health: Life Expectancy and Infant Mortality

$$(1) \text{ LEXP} = -.185 \text{ IMR}(-1) + .073 \text{ GER2T}(-20) - 2.932 \text{ AFRICA} - 2.464 \text{ ASIA}$$

(-26.24)	(3.23)	(6.45)	(4.88)
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Environment: Deforestation and Destruction of Wildlife : DEF

$$(13) \text{ DEF} = + 5.42\text{E-}07 \text{ GNPPC} - .413 \text{ POPGR} - .0002 \text{ GER2T}(-20) + .00926$$

(1.52) (-3.30) (-1.82) (1.85)

Environment : Water Pollution (WATER)

$$(14) \text{ WATER} = 2.92 \text{ GNPPC} + 707040 \text{ POPGR} + 557 \text{ POVU} - 1,117 \text{ GER3T} - 23051$$

(1.96) (2.08) (2.15) (-2.11) (-1.92)

Environment: Air Pollution (AIR)

$$(15) \text{ AIR} = -.00062 \text{ GNPPC} - 6.531 \text{ NEWDEM} - 1,745 \text{ POPGR} + 1.481 \text{ GER1T}(-20)$$

(-1.00) (-1.61) (-2.26) (3.09)

$$+ 441.4 \text{ GROWTH} - 61.74$$

(2.33) (-2.93)

Crime; Homicide Rates (HOMICIDE)

$$(16) \text{ HOMICIDE} = 1,447 \text{ lnGNP} - 15.9 \text{ GER2T} + 59.2 \text{ U}(-2) - 1.23$$

(5.76) (-2.55) (3.05) (-5.20)

Property Crime (CH)

$$(17) \text{ CH} = + 22612 \text{ lnGNPPC} + 1.04 \text{ GNPPC} + 93,893 \text{ GINI} - 974 \text{ GER2T}(-20) + 647 \text{ POVU} - 188$$

(2.15) (.34) (2.39) (-2.11) (1.79) (-2.39)

The Education Sector in the Model**Enrollment Rates (GER)**

$$(18) \text{ GER1F} = 1858 \text{ EDSH}(-1) \times \text{PEXP}(-1) - 324 \text{ XPSP}(-1) - .362 \text{ LAGRI}(-5) + 119.9$$

(5.50) (8.06) (-3.03) (15.08)

$$(19) \text{ GER1M} = 1600 \text{ EDSH}(-1) \times \text{PEXP}(-1) - 291 \text{ XPSP}(-1) - .205 \text{ LAGRI}(-5) + 119.3$$

.02 (-9.19) (2.18) (19.05)

$$(20) \text{ GER1T} = (\text{GER1F} + \text{GER1M}) / 2$$

Quality of the Data

A word is needed about the quality of the cross country data since some persons, often those oriented to using only microeconomic data, do tend to raise questions about that. It should be kept carefully in mind that microeconomic data is also subject to various kinds of sampling bias and other kinds of measurement errors. Microeconomic studies are extremely useful, but they are not the only source of truth, and they have the inherent disadvantage of dealing with isolated subsets of the population or of the topic being studied, with results that are often partial as well as sometimes offsetting, and that do not always reveal nationwide totals or impacts.

First, and relevant to the fact that cross country data is being used, why use per capita real growth rates, GN, as the dependent variable instead of real GNP per capita? This is for two reasons. The theory which involves differentiating a standard production function such as Eq. (1) in the main paper with respect to time calls for the *per capita growth rate* (after dividing through by GNP and converting to per capita terms), not the *level* of GNP per capita. For the level of

Table 2A
OECD Data

	Economic Growth			Education Enrollments and Investment											
	GN(PC 85-95	GNP95 gnpp95*pop95	GNPPC 95	GER1F 90	GER1F 95	GER1M 90	GER1M 95	GER2F 90	GER2F 95	GER2M 90	GER2M 95	GER3T 90	GER3T 95	EDSH 90	EDSH 95
Australia	0.014	334451520	18720	107	107	108	108	83	86	80	83	35.5	42	5.4	6.2
Austria	0.019	216330050	26890	102	103	102	103	100	104	107	109	35.2	43	5.5	5.6
Belgium	0.022	250238170	24710	101	100	100	99	103	104	103	103	40.2	49	5.1	5.7
Canada	0.004	569810760	19380	102	104	104	106	101	103	101	104	97.7	103	7.4	7.2
Czech Rep.	-0.018	39717810	3870	99	100	99	99	90	88	86	85	14.6	16	4.6	6.1
Denmark	0.015	156115470	29890	98	98	98	97	110	115	108	112	36.5	41	7.5	8.4

Finland	-0.002	105102060	20580	99	100	99	100	127	130	106	110	48.9	63	6.2	8
France	0.015	1452018960	24990	108	105	109	107	101	107	96	104	39.6	50	5.4	6.7
Germany	0.024	2244650940	27510	100	98	98	97	99	100	101	101	35	56	4.1	6
Greece	0.013	85827340	8210	98	94	97	95	98	96	100	96	25.5	42	3	3.7
Hungary	-0.01	41640840	4120	95	95	95	95	79	82	78	79	14	17	6.1	6.5
Iceland				102	97	104	99	97	102	103	105	24.8	35	6	7.2
Ireland	0.052	52161660	14710	103	103	103	103	105	110	96	101	29.3	34	6	6
Italy	0.018	1088039100	19020	97	99	97	98	79	82	79	81	30.8	37	5	4.8
Japan	0.029	4957695520	39640	100	102	100	102	98	97	96	95	29.1	30	6	4.9
Korea	0.077	435617300	9700	105	102	105	100	88	92	91	93	38.6	48	3.6	6.2
Mexico	0.001	302601400	3320	114	110	117	114	55	58	55	57	14.1	14	4.1	5.9
Netherlands	0.019	371568000	24000	104	99	101	96	115	120	124	126	39.8	45	6.4	6
NewZealand	0.008	48196740	14340	105	101	106	102	90	104	88	103	38.7	58	6.4	6.7
Norway	0.017	135375000	31250	100	99	100	99	105	114	101	118	42.3	54	7.9	8.3
Poland	0.012	107574030	2790	98	97	99	98	83	87	80	82	21.7	26	4.9	5.5
Portugal	0.036	95598100	9740	115	125	120	131	74	111	63	102	22.6	36	5.1	5.7
Spain	0.026	538134660	13580	108	105	107	104	109	120	101	107	36.7	41	4.2	6.4
Sweden	-0.001	208738750	23750	100	100	100	100	92	100	88	99	32	38	7.7	9
Switzerland	0.002	291154580	40630	103	102	101	100	87	89	83	93	25.7	31	5	5.5
Turkey	0.022	169129640	2780	106	98	115	107	42	48	66	74	12.9	16	3.4	4.2
UK	0.014	1086077300	18700	105	113	104	112	88	94	85	91	29.1	37	4.7	4.8
USA	0.013	7206762700	26980	104	106	106	107	93	97	92	98	74.1	81	5.3	6.8
OECD Mean	0.0163	836678829.6	18659.3	103	102	103	103	93	97.9	91.3	97	34.5	42.3	5.4	6.2

Table 2A (Cont.)
OECD Data

	LEXP		Health						Population		Democracy				
	90	95	IMR		TFR		CBR		CDR		POP		DEM HR		PS
			90	95	90	95	90	95	90	95	90	95	95	95	
Australia	77	78	8	6	1.9	1.8	15	15	7	7	16888	17866	7	7	82
Austria	76.5	77	8	5	1.5	1.4	12	12	11	11	7705	8045	7	7	85
Belgium	76.5	76.5	8	7	1.6	1.5	13	12	11	11	9951	10127	7	7	83
Canada	77.5	79	7	6	1.7	1.7	14	15	7	7	27791	29402	7	7	83
Czech Rep.	71.5	73.5	12	6	2	1.2	14	13	11	13	10306	10263	7	6	80.5
Denmark	75.5	75.5	8	6	1.7	1.8	11	12	12	12	5140	5223	7	7	86
Finland	76	77	6	4	1.8	1.8	13	13	10	10	4986	5107	7	7	83.5
France	77	78	7	5	1.8	1.7	13	13	10	10	56718	58104	7	6	82
Germany	76.5	76.5	7	5	1.5	1.3	11	10	11	11	79365	81594	7	6	84.5
Greece	77	78	11	8	1.5	1.4	11	10	9	10	10238	10454	7	5	72
Hungary	71	70	15	11	1.8	1.5	12	12	13	15	10365	10107	7	6	73
Iceland											255	269	7	7	
Ireland	74.5	76.5	7	5	2.2	1.9	16	15	9	9	3503	3546	7	7	81.5

Italy	77.5	78	9	6	1.3	1.2	10	10	9	10	57024	57205	7	6	76.5
Japan	79	80	5	4	1.6	1.4	11	10	7	8	123527	125068	7	6	87
Korea	70	72.5	17	9	1.8	1.7	16	16	16	6	42869	44909	6	6	81.5
Mexico	69.5	72	39	32	3.3	2.9	27	27	5	5	84511	91145	4	4	73.5
Netherlands	77	77.5	7	5	1.6	1.5	12	13	9	8	14952	15482	7	7	85.5
New Zealand	75.5	76	10	6	2	2	16	17	8	8	3361	3361	7	7	83.5
Norway	77.5	78	8	4	1.8	1.9	13	14	10	11	4242	4332	7	7	86
Poland	71	72.5	16	12	2.1	1.6	15	13	10	11	38119	38557	7	6	76
Portugal	75	75.5	12	7	1.6	1.4	12	12	9	11	9868	9815	7	7	79.5
Spain	76	77	8	5	1.5	1.2	11	10	9	9	39272	39627	7	6	76
Sweden	78	79	6	4	1.9	1.7	15	14	12	11	8559	8789	7	7	82
Switzerland	78.5	78.5	7	5	1.7	1.5	12	13	10	9	6834	7166	7	7	89.5
Turkey	66.5	68.5	60	42	3.5	2.6	28	27	7	7	56098	60838	3	3	62.5
UK	75.5	77	8	6	1.8	1.7	13	13	11	11	57561	58079	7	6	79
USA	76.5	77	9	7	1.9	2.1	17	16	9	9	249924	267115	7	7	84
OECD Mean	75.1	76.1	12	8.4	1.9	1.7	14	14	10	9.6	37140	38628	6.71	6	80.67

* Cells with missing data are not included in the means.

Table 2A Cont.
OECD Data

	Poverty Inequality		Environment			Crime			Investment in	
	20%	GINI	DEF	WATER	AIR	HOM.	Total	C-H	Physical Capital	
		95	95	95	95	95		95	/GNP= GDIG 95	
Australia	4.4	0.337	0	173.5	11	3.45	4166.98	4163.5	0.23	
Austria		0.231	0	86.6	14	2.19	6057.91	6055.7	0.27	
Belgium	7.9	0.25	0	113.4	20	3.88	7106.29	7102.4	0.18	
Canada	5.7	0.315	-0.1	300.1	13.6	5.13	9162.7	9157.6	0.19	
Czech Rep.	10.5	0.266	0	171.2	32				0.25	
Denmark	5.4	0.247	0	87.2	7	1.13	10333.55	10332	0.16	
Finland	6.3	0.256	0.1	68.2	4	0.78	7929.74	7929	0.16	
France	5.6	0.327	-1.1	609.9	14	4.42	6316.54	6312.1	0.18	
Germany	7	0.281	0	1046.1	12.3	4.86	8178.6	8173.7	0.21	
Greece			-2.3	59.7	34	2.78	3207.73	3205	0.19	
Hungary	9.5	0.279	-0.5	151.3	39	3.95	4884.57	4880.6	0.23	

Iceland		0.3			5				
Ireland		0.359	-2.7	33.4	20	1.65	2911.51	2909.9	0.13
Italy	6.8	0.312	-0.1	313.9	31	4.9	3993.6	3988.7	0.18
Japan	8.7		0.1	1548	44.3	1.02	1485.77	1484.8	0.29
Korea			0.2	358.6	61.6	1.5	1181.41	1179.9	0.37
Mexico	4.1	0.344	0.9	167.3	74				0.15
Netherland	8.2	0.315	0	136.1	10	17.6	7928.38	7910.8	0.22
New Zealand	5.1		-0.6	45.8	3	3.13	14144.5	14141	0.24
Norway	6.2	0.252	-0.2	47.5	8	2.2	9166.66	9164.5	0.23
Poland	9.3	0.272	-0.1	365.6	40	3.05	2526.57	2523.5	0.17
Portugal			-0.9	77.4	8	3.99	942.83	938.84	0.28
Spain	18.1	0.325	0	318.5	11	2.43	2303.25	2300.8	0.21
Sweden	8	0.25	0	102.3	5	9	12982	12973	0.14
Switzerland	5.2	0.361	0	38.2	11	2.29	4980.68	4978.4	0.23
Turkey			0	168.5	67.5			5000	0.25
UK	4.6	0.326	-0.5	680.9	20	1		6787	0.16
USA	4.7	0.401	-0.3	2447.8	16.3	8.22	5277.59	5269.4	0.16
OECD Mean	7.20476	0.300273	-0.3	359.889	22.736	3.945963	885	5954.5	0.20962963

* Cells with missing data are not included in the means.

GNP per capita to be dependent, the regression should then contain the levels of the capital stocks on the right, not new investment, and national balance sheet data is not yet available for most of the countries in the model. Furthermore using the growth rate gets away from most of the distortions introduced by exchange rates when converting GNP in domestic currencies to US dollars, so this does not require use of the Summers and Heston data (which also tries to get away from that) and permits use of growth rates of real GNP per capita as measured in domestic currencies which is largely independent of exchange rates. For the same important reason, the rate of investment in physical capital *as a percent of GNP* is what is called for theoretically by differentiating levels with respect to time and dividing through by Y . It is also a pure number, largely free of the need to convert using exchange rates and the attendant problems.

Second, the use of Gross Enrollment Rates, GER, is called for more logically by the theory of the problem than is average educational attainment or even changes in average

educational attainment. Gross enrollments are logically related to gross investment in human capital formation through education which is what must be financed by education budgets. This is important since education investment (as a percent of GNP) is a key policy variable we are using in the complete model. Also, after differentiating the production function with respect to time, this theoretically calls for the *change in* the human capital stock, as mentioned above, not the *level of* that stock as measured by educational attainment. Furthermore, although measures of the latter have been greatly improved in work by Psacharopoulos, Barro, and others recently, the level of educational attainment still is not available for all of the 78 countries in our model, whereas gross enrollments are readily available extending into past years to allow for the lags. Finally, gross enrollment is equivalent to gross investment in the sense that it includes replacement investment. Replacement investment (and not just net investment) theoretically embodies the new knowledge and technologies in human capital as a key means of disseminating new knowledge which is an important part of the rationale of this paper and of the book. It is gross investment which includes replacement investment for the society that must be financed from total savings in part by earnings forgone by parents, which are often ‘in kind’, as enrollment by children in school induces this additional domestic total saving by families. This is another important part of the rationale. (See McMahon 2000, especially Chapter 2, pp, 26-31 for more extensive discussion of the total saving and total investment concepts common to the ‘total accounts’ and consistent with Becker’s “full income”). Apart from this rationale, at a purely statistical level the measures of average educational attainment and changes in average educational attainment were tried in several contexts. But they proved to be less significant, perhaps in part for the reasons mentioned.

The other kind of question about Gross Enrollment Rates relates to measurement error. GER's do reflect the fact that education is less efficient in some countries than in others, with more repeaters. Nevertheless, this is what must be financed, and it is the impacts of enrollments, not of increments to test scores, that we seek to measure. More serious, opening fall enrollments generally overstate Average Daily Attendance in some countries. But this source of error in measurement is normally higher in the poorer countries of the world than in the OECD member countries where the educational systems are more mature and attendance requirements are more adequately enforced. The returns to education which the simulations deal with here are *average* returns. The author is seriously interested in improving the internal efficiency of education systems which would operate to *increase* these average returns. But that is the subject of another paper (e.g. Boediono, McMahon and Adams, 1992). Finally, there are a few places where the data on gross enrollment rates appear to be distorted. This is mostly for higher education where there are part time and returning students and where postgraduate students can inflate the totals (e.g. Canada). So caution needs to be used in interpreting simulations that involve these levels in these places. The literature about the bias introduced by errors in measurement of the education variable due to self reporting also concludes that it generally leads to underestimates in the true return to schooling, (e.g. Carnoy, 1997, McMahon 2000a).

Beyond this, some variables in the cross country data are measured more accurately than others. For example, the international crime data is poor, especially on total crimes other than homicide. Non-homicide 'property crime' rates might be reflecting, in part, better reporting as economic development occurs. So simulations are sometimes not shown for 'property' crime and where they are they are treated with caution. The same can be said for inadequacies in the data

for the Gini coefficient, water, and air pollution, although for all of these it is steadily improving. The remedy, in the author's opinion, is not to throw up one's hands and reject everything that can be learned from cross country data. Instead a more constructive approach is to explore and make more specific judgments as one goes along and then place wider error margins on any findings concerning particular variables and sometimes for particular countries where the data is less adequate. Temple (1999) is of the same opinion.

IV. Statistical Properties of the Estimates

This section will review the essentials of the statistical properties of the equations following the same numbering system as for equations 1-38 in Table 1A above.

Health Equations

Life Expectancy (1). With a sample size of 78 and $R^2=.973$, the t-statistics for infant mortality rates and secondary education total gross enrollment rates are both significant at the .01 level. This is after controlling with dummy variables for AFRICA and ASIA which is an indirect control for per capita income and also insures that the regression coefficients apply more directly to the OECD countries by controlling for other cultural differences if they are significant.

Some have questioned the relation of education to illness and life expectancy on the grounds that it is affected by marital status. But as pointed out by Grossman and Kaestner

(1997, section 4.2) ‘the lack of schooling effects may reflect causality from schooling to marital status’. The studies in question also often exclude the intergenerational effect of education on the health of children, and hence on the infant mortality rate, which we find to be extremely important. Barro and Sala-I-Martin (1995, p. 453) report results for life expectancy very comparable to those reported here. Linear specification was superior to log specification suggesting that for advanced levels of development increases in educational participation at more advanced levels continue to remain important to longevity.

Infant Mortality (2). With a sample size of 83, and $R^2=.839$, secondary education enrollment of females after a lag of 20 years is a very highly significant determinant of infant mortality ($t=8.55$). Primary education enrollment of females also lagged 20 years is less significant ($t=1.53$), but we retain the latter to show that primary education has been controlled for, that its effects can reasonably be expected to be positive, and because it nevertheless does have some predictive capacity. GNP per capita controls for the market returns to education so that these can be said to be non-market impacts of education over and above the effects of rising living standards. Average female age at marriage, the level of urbanization, and geographic region were tested but they make negligible contributions and were removed. The log linear specification produced a fit superior to the linear specification, suggesting that the effect of education on reducing infant mortality diminishes in those OECD countries that have higher income levels and higher enrollment rates. Male enrollment rates made insignificant contributions when both male and female enrollments were tested in the same equation. Barro and Sala-I-Martin (1995, p.453) obtain less significant results but this is almost surely due to the inclusion of $\ln \text{GNP}^2$ which dominates everything and captures unexplained effects at high

income levels including those due to the no-monetary returns to education. The scatter diagrams that include the regional means in McMahon (2000, p. 85) are quite suggestive. Because of the diminishing effects as female secondary enrollments get high, it would be useful to introduce GER3F(t-20) and test for the strength of continuing effects from higher education enrollments.

Fertility Rates (3). The sum of primary and secondary enrollments lagged 20 years multiplied by the level of financial support for family planning (FP as developed by the Population Crisis Committee, 1987) is a highly significant determinant reducing the number of births per woman during her child bearing years ($t = -9.80$). The $R^2 = .787$, but the sample size is smaller ($n=44$) because of the limitations of the nationwide data on family planning. But the result is interesting in that it shows that more female education reduces fertility rates at given levels of family planning efforts, but that both working together so that females have access to the available technologies results in augmented effects. This is consistent with earlier work by Wheeler (1984) who also finds that female education has its greatest impact on fertility when combined with support for family planning. The AFRICA regional dummy is an indirect control for per capita income and largely removes cultural and other differences unique to Africa.

Population Growth Rates (4-7). In Eq. (4), crude birth rates are very significantly determined by fertility rates ($t=10.8$), with a sample size of 160 and $R^2=.959$. Crude death rates (5) are determined largely by life expectancy ($t=11.4$, $n=151$, and $R^2=.977$) which together, in turn, determine population levels (6) and population growth rates (7) by definition. A plotting of these life expectancy and infant mortality effects as they raise population growth and fertility effects as they lower population growth, all with female secondary education enrollment rates on the horizontal axis, is quite suggestive (see McMahon, 2000, p.89). As fertility rates continue

to fall in the OECD member countries, this effect on population growth would appear to continue to dominate. This structural approach is judged to be far superior to a single regression equation explaining population growth with female education enrollment rates after controlling for GNP per capita, although even here female education is still highly significant (ibid., p. 90).

Democratization Equations

Democratization (8). After controlling for per capita income in a way that allows for the non-linearity at the higher income levels, secondary education enrollments after a lag of 15 years make a highly significant additional contribution ($t=2.20$). High military expenditure as a percent of the government budget makes a very significant negative contribution ($t=-4.73$). The sample size is 75, and the R^2 is .494. The simple correlation of GER2T with $\ln\text{GNPPC}$ is .78, but there is no other multicollinearity in the regression above .08. This regression (and all other equations discussed) has been corrected for heteroscedasticity if it was found to be significant. The lag structure was chosen based on the rationale that requires graduates to be in the labor force a while before they are able to exercise significant economic and political influence, plus experimentation with slightly longer or shorter lags to see which works the best.

An identical specification, but using the average percent of the labor force with at least secondary education from Psacharopoulos and Arrigadu (1992) instead of gross enrollment rates, was tried but it does not reach the .05 level of significance (see McMahon, 2000, Model 2, p.98). The sample size is smaller because of the unavailability of this variable for all countries in the model. Other independent variables that were tried, but not found to be significant, in addition to those selected, are primary education enrollments, urbanization, and communication (newsprint used and radios, both per 1000 persons). BRITISH heritage was found to be very

significant, in addition to literacy, but MUSLIM heritage is insignificant in similar regressions by Clague et. al (1996) but these were not tried here. They also may be less relevant within the OECD context. Countries were sorted by those below and those above \$3,000 per year per capita income but this did not lead to significantly different results.

Human Rights (9). With a sample size of 75 and an $R^2=.87$, democratization is the major determinant of human rights ($t = 11.88$) after controlling for per capita income. But secondary education enrollment rates again make an additional contribution at a lower level of significance, whereas the percent of the labor force with secondary education in an alternative specification again does not. (For the latter see McMahon, model 2, p.103). Military Expenditure that is relatively high again makes a highly significant negative contribution to human rights ($t = -3.13$). Other explanatory variables such as urbanization and communications were tried but were not found to be significant. Again the log of GNPPC takes the non-linearity into account. There are of course particular political leaders with unique personalities that emerge from time to time that have effects on both democratization and human rights which are revealed by an analysis of the residuals.

Political Stability (10). With a sample size of 62 and $R^2=.98$, after controlling for per capita income (which is significant), political stability is determined by secondary education enrollment rates (10% confidence level) which are more relevant to the OECD countries, or alternatively by primary education enrollment rates (.01 level) which are more relevant in Africa and South Asia (from Model 3 and Model 1 respectively in McMahon, 2000, p.107). Democratization contributes positively at the 10% level, and relatively high military expenditure again makes a significantly negative contribution to stability ($t = -2.23$).

In alternative specifications that exclude democratization, social security expenditure as a percent of GNP has a significant positive relationship to stability ($t=2.27$), but urbanization is never significant at the .05 level. The zero order correlation matrix reveals some multicollinearity between urbanization and GNPPC ($=.72$) as between urbanization and social security expenditure ($=.67$) and social security expenditure and GER2 ($.72$) which has suggested that urbanization and social security be dropped. There is some that remains in Model 3 between GER2T and GNPPC, but we must retain GNPPC for theoretical reasons to control for market returns to education. There is little or no other multicollinearity among the variables in Model 3 which is the democratization equation shown in Table 1A.

Poverty and Inequality

Poverty (11). Although the focus of the simulations as it relates to equity considerations is on inequality since the fact that it is rising makes it a significant problem within the OECD countries, a few comments will be made about absolute poverty. The regression equation shown is somewhat less satisfactory since this is a pattern that is different from a worldwide perspective where primary and secondary enrollments are not universal as it is within OECD. However with a sample size of 40, and $R^2=.30$, it does suggest that less poverty is associated with faster growth ($t=2.12$) and marginally with higher primary, higher secondary, and lower higher education enrollments. Four other specifications are shown other than the one chosen (which is Model 3, McMahon 2000, p. 115) all of which reveal the same pattern and none of which are better. Democratization is one of the other variables tried but it is not associated with reduced poverty and instead has a positive and significant sign after controlling for GNP per capita. This suggests that sometimes authoritarian regimes do move to reduce poverty, whereas

sometimes democratic processes are not very egalitarian but instead associated with ruling elites. It is clear that more widespread access to good quality higher education by low income groups in those OECD nations where basic education is universal reduces inequality, as indicated in the main paper, and it's relation to absolute poverty in the OECD nations would be an interesting hypothesis to test.

Inequality (12). Inequality as measured by the Gini Coefficient, after controlling for growth of GNP per capita, is reduced primarily by expanding secondary enrollments after a lag of 20 years (significant at the 10% level) and by slower population growth (also significant at the 10% level). The sample size is 40 and the $R^2=.44$, from Model 2, McMahon (2000, Table 8.3, p. 122). The regression was limited by the number of countries for which data was available. But these were largely middle income and higher income OECD countries and data is rapidly becoming available for more countries following the World Bank's very recent emphasis on this (e.g. World Bank 1999, pp. 238-9). Democratization again is an insignificant determinant of inequality. Primary enrollment rates are not relevant in the OECD context, and they were also less significant and multicollinear with secondary enrollment rates in the data for this equation ($r=.638$), so primary enrollment rates have been dropped in the Model 2 specification chosen. There is some negative multicollinearity remaining between population growth and secondary enrollment rates as might be expected from the earlier discussion of health effects, but there is no other substantial multicollinearity in this Gini equation.

Environmental Impacts

Deforestation Rates (13). The average rate of destruction of forests and wildlife in the OECD countries is .3 of a percent per year, from Table 2A above. With a sample size of 75, and

an $R^2=.25$, this Model 3 (ibid, p. 129) and all other specifications suggest that it is not higher GNP per capita that makes the rate of destruction of forest lands worse, but instead rapid population growth ($t = 3.30$). After controlling for both of these, then higher secondary education rates also make things worse (at the 10% significance level). But this does not take into account the indirect effects of education in contributing to economic growth and to slower population growth which eventually dominate as discussed in the main paper.

Other variables tried include higher education reducing destruction of forests or supporting national and provincial park systems (not significant), primary education (not significant), and changes in the land devoted to agriculture (not significant when the variables shown in Eq. 13 were taken into account). The latter, however, was highly significant in the Latin American countries (ibid., p. 130)

Water Pollution (14). Water pollution has a sample size of 22 and $R^2=.458$ (Model 3 p.134). This is not ideal since the degrees of freedom are so small, but it is the number of countries for which consistent data were available. This hopefully will improve with time. Nevertheless the significance of the determinants is consistently high and the effects shown are very robust in many alternative specifications (see ibid, p. 134). Lower population growth rates, less poverty, and increased higher education enrollment rates emerge as consistently related to lower water pollution at the .05 significance level. Other variables tried were secondary education enrollments and democratization; the signs of both are consistently negative (i.e. in the direction of reducing pollution) but they are only occasionally significant. Political stability was not significant.

Air Pollution (15). This equation is Model 1 (ibid., p.137) where 6 different specifications testing other variables are shown. These other variables cannot all be put into the same regression because of the small sample size, given the lack of data for a sufficient number of countries. But the outcomes of water and air pollution do not affect anything else in the model and, on a tentative basis, some things can be learned.

Controlling for GNP per capita, air pollution is higher with economic growth ($t=2.33$), and with universal primary education ($t = 3.09$) but lower with democratization although the latter is not significant ($t = -.161$). High population growth is probably a proxy for and hence also a control for poor agrarian nations and hence should be ignored since concern is with the OECD countries. Since the sample size is only 19, these t statistics should not be interpreted literally but only taken to be suggestive. The $R^2=.507$.

Many other variables were tried and other data sources sought. Secondary education enrollments have a consistently negative relation to air pollution that is significant at the .05 level in models 4 and 6, and at lower 10% levels in models 2 and 3. The democratization coefficient is always negative and significant at the .05 level in model 3 only. When population growth is dropped in model 5, then higher GNP is related to higher air pollution, but air pollution is significantly lower with increased higher education and greater political stability. Multicollinearity is highest between population growth and many of the other variables discussed, so dropping it helps.

Crime Rates

Homicide (16). The international data for homicide is adequate for 30 countries. Homicide rates fall significantly with higher per capita income ($t= -2.53$), and with lower

inequality (10% level of significance). With these two determinants only, the R^2 is .17 (ibid., model 2, p.144). The sample size is much larger, $n=55$, when it is not required that the sample contain only countries for which there is both data on the Gini and on homicide. The higher GNP per capita relationship to significantly lower homicide rates remains very robust, although there are individual country exceptions within the OECD (ibid., model 1).

Additional insights are offered by examining data for the US, the OECD member country with one of the highest homicide rates. These are 8.2 per 100,000 persons in the US, as compared to 1-3 in all other OECD countries except France, Hungary, and Portugal where they are 4, Canada, Germany, and Italy where they are 5, Sweden 9, and the Netherlands where they are 17 (Table 2A). When the Gini is replaced with a measure of poverty in the 50 states and the District of Columbia, it has a similarly large positive and highly significant coefficient with $t=5.96$, $R^2=.54$ (ibid., model 5). Even more interesting, continuing to control for per capita income, when poverty is replaced with both unemployment rates lagged two years and secondary education completion rates, the coefficient for unemployment is 59.2 ($t = -2.55$) and for secondary education is -15.9 ($t = -2.55$), $n = 51$, $R^2 = .43$ (ibid., model 6). This is fully consistent with the rationale in the main paper.

Property Crime Rates (17). “Property crime” is used in this paper as a shorthand term for all crime reported other than homicide. It therefore includes some violent crime, specifically forcible rape, robbery, and aggravated assault as well as burglary, larceny, theft, motor vehicle theft, and arson “as known to the police” from INTERPOL (1995). This last phrase is important, because at higher per capita income levels, ‘property crime’ is significantly higher ($t=2.15$), which may in part be a phenomenon due to better reporting. Homicide was treated separately

because it was judged to be a more cleanly defined crime among countries and probably not as subject to this possible reporting error. Nevertheless, controlling for \ln GNPPC, which should remove some of this reporting error bias as well as focus attention on the non-market returns to education, inequality ($t=2.39$), poverty ($t=1.79$ reaching the 10% level), and secondary education enrollment rates ($t= -2.11$) again show up as the key factors. The sample size is 30, and $R^2 = .31$ (ibid., model 1, p.148). GNPPC is shown to demonstrate that the latter is insignificant although when the latter is dropped in model 2 (ibid.), the other coefficients are not much affected.

It is useful to turn again to the US data in order to cross check these hypotheses in an OECD member country but also to increase the sample size, given the large number of countries for which INTERPOL does not report adequate data. In the US, poverty rates remain a highly significant determinant of 'property crime' rates after controlling for GNP per capita. The coefficient for \ln GNPPC however remains positive and highly significant ($t=3.47$), $n=51$, $R^2 = .20$ (ibid., model 6). Alternatively, unemployment rates lagged two years are significantly related to property crime, just as they were to homicide.

Those regressions based on intercountry data which includes many OECD nations were used in the simulation model because we do not want the results to be interpreted as specific to the US. There is high inequality in the education system in the US, which contributes to large migrations of unskilled poor people to large urban centers (e.g. from rural Mississippi to the urban Chicago ghettos), a situation that is somewhat unique, although it also occurs in Brazil and some other countries where crime rates are high

The Education Sector

Enrollment and Primary Education Completion Rates (18-27). The model is structured so that policy simulations can be run by changing relative enrollment rates directly, a type of policy that can be implemented largely within Ministries of Education, or by changing rates of investment in education to increase all enrollment rates; a policy that generally requires the involvement of the national or provincial chief executives and legislative bodies. The latter is the focus of this paper since significant increases in investment expenditure as a percent of GNP are required if larger percentages of the population are to be accommodated in school systems for longer periods of time. Reforms of various kinds are also of interest, but they must be the subject of a different paper.²

It is only as universal secondary education is approached in each OECD member country, which requires a gross enrollment rate of 115-118 percent of the secondary school age population for a sustained period, that additional resources are funneled disproportionately through the structure of the education sector in the model to the accelerated expansion of higher education enrollments in that country. After time passes, these gross enrollment rates always drift back down toward 100 as the educational level of the population catches up and the internal efficiency of the education system improves. At the secondary level, most OECD nations have quite a ways to go since many students still drop out after 10th grade. For higher education, the rates of return tend to be the highest at the 2 and 4 year levels, so it is reasonable that the enrollments would expand there the fastest at first (For recent US social rates of return at high school, and 2, 4, and postgraduate college levels see Arias and McMahon, 2000, and for other OECD member countries see Healy, 1998). The higher education gross enrollment rates in recent years in Canada are very high, in a way apparently inconsistent with other countries. So

GER3T was capped somewhat artificially at 70 percent. This, however, affects simulations for none of the countries in the model except those for Canada and the US.

The *primary education enrollment* equations (18-20) can be ignored since all OECD member countries have universal primary education and the determinants in these equations do not affect anything in this paper. *Secondary education enrollment* determinants for females and males are very similar except for slight differences in the size of the coefficients so these two equations will be discussed together. For GER2F $n=52$ and $R^2=.798$, and for GER2M $n=52$ and $R^2=.665$, from McMahon (2000, p.164). The key policy variable in this paper, education expenditure as a percent of GNP (EDSH), is highly significant in both equations in determining enrollment rates ($t=2.83$ and 2.97). A constant EDSH implies that the real expenditure on secondary education grows at a rate about the same as the rest of the economy in part as teachers salaries keep up with the rest of the economy in real terms, (i.e. a unitary income elasticity of effective demand for secondary education). This roughly unitary income elasticity of effective demand is typical of the historical experience of primary and secondary education in the US and elsewhere (developed in detail in McMahon, 1970). Since EDSH is constant unless explicitly changed by policy, this implicit unitary income elasticity illustrates one key way in which investment in education is endogenous in OECD countries in the model.

Higher education enrollment rates, GER3T, have a higher income elasticity given their additional degree of dependence on GNPPC in Eq. 24 ($t=3.23$, $n=22$ OECD countries, $R^2 = .993$) and the interaction of EDSH with secondary education enrollment rates. At the secondary level, there is additional endogeneity since these equations contain primary education completion rates, PEDCF and PEDCM, which are also dependent on GNPPC which is

determined within the model. In the secondary education equations the percent of the labor force in agriculture, LAGRI, is also endogenous as determined by Eq.27. But since this is low and no longer changing rapidly in most OECD countries, this variable will have little effect on secondary education enrollment rates. The regional dummies EMENA and LAC act as controls for economic and cultural differences in the OECD countries as compared to other countries in the complete model, although their influence is displaced as the constant terms are automatically adjusted to the starting data points specific to each country in the simulations. Finally, it is important to keep in mind that all of these determinants of enrollment rates have as their primary purpose the determination of the 'endogenous development' base line scenario, and essentially little else. This is the base line scenario for the other social outcomes in the model from which the effects from education impacts following policy changes are measured.

Labor Force Participation Rates (28-33)

Female labor force participation has been increasing in all of the OECD member countries. The sources of this are useful to study, although their practical effects on social outcomes are only through the relatively broadly defined labor utilization rates in Eqs. 31-3 that enter the production function (34). They depend exponentially on the rising age of marriage ($t=1.67$) after interactive controls using regional dummies for cultural differences. The international comparability of female labor force participation rates is poor, as was indicated in the main paper, so it was thought that these regional dummies would help to correct for that.

This equation does not pick up the effects of increasing female education on labor force participation rates directly, although it does to some extent through the effects of education in raising the age of marriage, ($t=4.22$ for the primary education completion rate in equation 30).

These two equations are as originally estimated by Louis Crouch et. al. (1992, and endnote 1).³ When the latter equation was reestimated using secondary and higher education enrollment rates instead, they also were significant if used alone.

The Growth Equation (34)

The rationale of the growth equation is that of a reduced form related to the Lucas (1998) production function shown in the main paper and also related to augmented Solow-type growth models. The solutions refer, however, to the medium term, a period of 45 years or so, during which human and physical capital deepening continues to occur (more human and physical capital per worker in the OECD, less per worker in Africa), and not to the long run steady state where this process is assumed to have ended. As indicated in the main paper, the production function stresses investment in human capital and knowledge dissemination via education, as well as investment in physical capital, which are factors related primarily to the supply side, given this medium term context. There are, however, controls for underutilization which can still occur, as well as for energy shocks, as shown in Col 1 of Table 3A below. These as well as the rates of investment (and saving) in both physical and human capital reflect those cultural factors that are empirically significant, as does the rate of population growth and political stability which are related to per capita growth, per capita capital deepening, and the rate of investment. These are also endogenous in the model reflecting all of the cultural factors influencing these other equations as well as explained in the main paper.

This growth equation (and the investment function to follow) are the only two equations in the model that were not newly estimated specifically for this model. The variables in the production function were scaled differently in the published article from which the coefficients

were drawn (McMahon, 1984, p.306, Table 1, Col 1 is identical to Col. 1 in Table 3A below). So for these to be appropriate for the simulations, the ratio of the means for the OECD countries in the regressions from the original computer print out for the article to the means of the corresponding variable in the model for the OECD member countries (data for which is in the bottom row of Table 2A above) are used to adjust the coefficients in the article to relate them to the scaling of the variables used in the simulations. These ratios of the OECD means for each variable shown in Col. 2 of Table 3A below are multiplied by the coefficients in Col. 1 to obtain the coefficients in Col. 3 for Eq. (34) of the model. The regression coefficients that result for this relatively homogeneous set of countries and the relatively short (postwar) time periods for which time series data is available are so sensitive to the choice of period and also

Table 3A

The Growth Equation: Scaling, and Comparisons to Similar Specifications

(t-statistics in parens below coefficients; Cols 4-5 *=10%, **=5%, & ***= 1% level)

	<u>Coefficients</u> <u>Used as a Basis</u> From McMahon 1984,p.306,Cols. 1 & 2 (1)	<u>Ratio of</u> <u>Means of</u> <u>Variables</u> (Col. 1 to Col.3) ^a (2)	<u>Equation</u> <u>(34) as</u> <u>in Model</u> <u>Table 1A</u> Cols(1)x(2) (3)	<u>Mingat and Tan</u> <u>(1996,p.9)</u> <u>Middle</u> <u>High</u> <u>Income</u> <u>Income</u> <u>Countries</u> <u>Countries</u> (4) (5)		<u>Five</u> <u>Largest</u> <u>Countries</u> <u>1955-80</u> (6)
Human Capital	.05	<u>1.17</u>	.0002			.08
Deepening	(2.02)	241.9	(2.02)			(3.71)
GER1T(60)				.03*	-	
GER2T(60)				.07***	-.008	
GER3T(60)				-.10	.06**	
Physical Capital	.81	<u>.182-.14</u>	.19	.085*	.073**	.21
Deepening (I/Y)-n	(3.38)	.209	(3.38)			(.81)
Average Under- utilization	-1.23 (-1.52)	<u>.044</u> 10.82	.005 (-1.52)	-	-	-4.48 (-11.56)

(Y/N) ₆₀	-11.23	<u>8292/100</u>	-.1076	-.07	-.02**	12.74
GNPPC(60)	(-2.62)	8654	(2.62)			(5.82)
Energy change per worker	0.00 (.38)					001 (.03)
Pop. Growth (R&D)/Y				-.029	.024	.04 (1.42)
Constant	.14 (1.70)					
No. of Obs.	45			19	20	10
R ²	.57			.55	.49	.99

a.. In Row 1, Col 2 the OECD mean in the computer print out is 1.17, whereas the OECD mean for 1995 from Table 2A for GER1+GER2+GER3 is $1.2.5+97.45+42 = 241.9$. In Row 2, the investment ratio mean must be net of the growth in the employed labor force, n, given the way this variable was defined in the published paper. In the model n is defined more broadly than just the standard unemployment rate and is generated endogenously, where it is affected in part by changes in the female labor force participation rate and the age at marriage (Eqs 28,30). In Row 3 this labor force participation rate also affects the way the percent of underutilization is defined in the simulations.

to the other variables included in the regression that the numerical values must be regarded as approximate. However the pattern and consistency with which variables are significant is important, and can be compared both to the corresponding coefficients obtained recently by Mingat and Tan (1996) for “middle” and “high” income countries in Cols. 4 and 5, as well as to those obtained for the five largest OECD nations by the author in Col. 6 from the article cited. The specification used is almost identical to that used by Mingat and Tan (1996, and Table 3A) as well as in the East Asian Miracle, World Bank (1993), in Barro (1992), and in Barro and Sala-I-Martin (1995, pp.425-30, 448). In the Barro regressions there are many additional explanatory variables which are sometimes suggestive, but they also can sometimes be quite misleading since so many of them are highly collinear. Nevertheless, although the coefficients for human capital tend to be somewhat larger in Mingat and Tan, and in the Five largest OECD

countries (Cols 4-6) and the coefficients for physical capital somewhat smaller in Mingat and Tan, human and physical capital investment are both consistently significant. The same can be said about Barro's regressions (too much detail to show them here), although he does get a very strange negative result for female secondary education. This is very likely because Barro includes public expenditure on education as a percent of GNP among the explanatory variables which heavily overlaps these enrollment rates. See McMahon (1998b) for a serious effort to separate the effects of this investment in education as a percent of GNP from enrollment rates, and also consider see the specification of the education sector in the structural model in Table 2A above which includes both. But Barro's negative result for female education may also be due in part to his inclusion of the positive and highly significant effect of life expectancy in the production function to which female secondary education enrollments are also closely related structurally. For other comparisons, the same rationale and statistical approach using region specific panel data underlies separate production function estimates for East Asia, Latin America, and Africa done specifically for the model and with more sophisticated statistical tests (given that the book was designed to focus primarily on the developing countries, see McMahon, 2000, Chapters 3-5 and for East Asia, 1998c)⁴. The estimates for these other regions also reveal a similar pattern to that shown in Table 3A for the OECD countries. As one might expect, the lower levels of education tend to be more significant and have larger coefficients than higher education in the poorer countries in these regions, as is also suggested by the pattern in Table 3A⁵. In Africa for example the indirect effects relating to political instability and rapid population growth loom relatively more important (ibid).

Several more detailed comments can be made about the properties of these estimates. First, the regression in Col.1 was estimated from panel data for 15 OECD member countries using 5 year periods for 1955-70 to avoid the 1972 and 1979 oil shocks and productivity slowdown which disturbed productivity growth in the medium term and have not been repeated in the 90's. As seen in Col.1, this energy shock term has a zero coefficient and also is not significant so it can be ignored. After allowing for 10 year lags the sample size is 45, or 3 five year periods times 15 countries. Second, it is assumed that the growth equation coefficients for these 15 countries is reasonably typical of the other 7 OECD countries not included in the regression in Col. 1. However this is not likely to be far from the truth, given the patterns and comparisons discussed above, and the starting values for all variables, furthermore, are specific to each country, including these 7. These starting values shown in Table 2A are a major way specific conditions in these 7 as well as in the other countries are taken into account. In programming for the simulations, this is done by adjusting the constant term in each equation so that the prediction made by the equation for the initial year in each country is identical to the data for that variable for each country as given in Table 2A. The result is that the constant term in Table 3A as well as in all of the equations in the model in Table 1A can be ignored.

Finally, as a cross check on the outcomes of the simulations involving economic growth (as distinguished from those for non-market returns) the social rate of return to education was calculated from simulations of the model in Table 2A for the US only. To be comparable to the rates of return calculated for samples of identical twins, where there are strong controls for "ability" bias and corrections for measurement error, only the *direct* effects from the simulations are considered. The results of this simulation, which appears together with an explanation of the

method for making the simulations in McMahon (1998c) is virtually identical to the rate of return to education obtained in the most recent studies based on large samples of identical twins. For comparisons to the results of identical twin studies, Rouse (1999, p.126) reports a rate of return to education of 10%. This is essentially the same result as the 10.4% rate of return that Behrman and Rosenzweig (1999, p.166) obtain using an even larger 1,440 identical twin sample. Although the identical twin data is for the United States only, given the technologies and education levels in common, this check of US simulations would seem to be a relatively meaningful cross check of the cross-country panel estimates of the growth equation based on panel data for 15 OECD nations and used for the simulations as shown in Table 2 Col. 3.⁶

Investment in Physical Capital

Gross Domestic Investment as a percent of GNP in physical capital is the dependent variable as used in the model. Its determinants are as estimated by Barro (1991, p. 426, Table III) from worldwide data for 76 countries of the 78 used in the model as shown in McMahon, (2000, p.160, Table 11.1). The R^2 Barro obtains is .58, and the t-statistics as shown are all significant at the .05 level. In particular, the control for initial GNP per capita is negative ($t=-2.04$) consistent both with diminishing returns to physical capital that would otherwise occur and with conditional convergence⁷. Secondary education positively offsets these diminishing returns ($t=2.12$), but also contributes to attracting investment from abroad and limits the dependence on domestic saving while earning foreign exchange by aiding exports (see Wood, 1994). Political stability (PS) had to be re-scaled from Barro's REV (the number of revolutions or coups per year and the number of assassinations per million in the population per year) between 1960 and 1985, by reversing the sign of REV and dividing by 10, the ratio of the mean of REV to the OECD mean for PS in

Table 2A. So this coefficient and the t statistic ($t=-2.62$) are approximate. But they are the channel that reflects the indirect feedback from education via its contribution to political stability and hence to rates of investment. Finally, social security expenditure as a percent of GNP ($SSX/100$) reflect government support of consumption, as in Barro (1991, p. 426) since he removes defense expenditure from this ratio. $SSX/100$ is negatively related to rates of investment in physical capital ($t=$ approximately 2.01) as expected.⁸

V. Conclusion

It is hoped that this technical appendix has made the model used for the numerical comparative-dynamic time paths and graphical presentations for 22 OECD countries in the background paper as straightforward and transparent as is possible in the short space available here. Nevertheless, serious misinterpretations are still possible. Almost any equation can be continually refined and improved with continuing effort and as new data becomes available. Extreme precision is not claimed, and should not be expected. Every economist, furthermore, knows that long range predictions are not very useful, and that therefore most forecasting is focused on an 18 month time horizon. However the simulations are not predictions or forecasts in any sense for any country, but instead they seek to be suggestive of approximate net policy impacts under predetermined conditions.

This said, it is hoped that this first effort to trace the impacts of human capital formation on social outcomes, the nature of their interaction, and the effects of feedback externalities on the growth and development process, has been suggestive. As such it has implications for all OECD member countries.

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¹ The author is deeply indebted to Thomas Healy and to his colleagues at OECD who offered many useful comments and suggestions on prior drafts that have now been incorporated. He is also indebted to Louis Crouch who was a co-principal investigator during earlier stages of this project. Parts of the health sector equations which entered into the model from the beginning are based on Crouch, Spratt, and Cubbeddu (1992, pp.14-18). OECD and the persons mentioned are not responsible for the end result. The author alone is fully responsible for any errors and all interpretations.

² The types of structural reforms that can be simulated include changing the ratio of female to male enrollments at any level, changing the percent of the education budget allocated to primary, secondary, and higher (although some of this occurs automatically as the system expands), changing the level of teachers' salaries relative to GNPPC in any given country, and changing the student/teacher ratio which relates to effectiveness and but is also a major cost factor.

³ As an agenda for future research, it could be fruitful to reestimate the female labor force participation and higher education enrollment equations with updated data for the OECD, and then re-program the simulation model with these for refinements to the simulations. See also #4.

⁴ With several months and additional resources the production and investment functions could be updated, reestimated by simultaneous equation methods, and additional precision achieved..

⁵ Recent independent estimates of a growth equation using cross-country panel data for the OECD countries for 1995-96 have also been done by Petrakis and Stamatakis (1999). They find highly significant t- statistics for positive effects from both secondary and higher education gross enrollment rates, as we do here. Although they do have controls for investment in physical capital, the variables are not measured in a way identical to Table 2, so closer comparisons cannot be made. Nevertheless, this is a second more general cross check of the OECD production function.

⁶ Mingat and Tan (1996) estimate the social rate of return to be 52% for secondary for middle income countries and 20% for higher education in high income countries. These higher rates are not surprising given the higher coefficients they obtain as shown in Table 3A Cols 4 and 5.

⁷ Barro uses GDP, whereas our model calls for GNP. But the difference is not large or likely to have significant effects.

⁸ Although the following should not have any meaningful effects on the simulation outcomes, the constant term is the same as Barro's (1991, p.426, Eq.20), and two variables that are in Barro's equation that are both related to the price levels for capital goods , PP160, and PP160DEV which is not significant, are dropped. The data on these two variables necessary for simulations is not available. Furthermore, as they become part of the constant term for each country, which is then replaced to force the equation to start at the data point given by Table 2A for that country, their deletion should not affect the outcomes.