UNIVERSITY OF BIRMINGHAM | BIRMINGHAM BUSINESS SCHOOL

Assessment and Feedback: Student Template

Student ID Number(s): 2244195

Programme: Economics

Module: LI Econometrics

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Assignment Title: Stata Assignment

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Extension: N **Extension Due Date:**

I do wish my assignment to be considered for including as an exemplar in the **School Bank of Assessed Work. ***

delete as appropriate

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Section Two: In this assignment, I have attempted to act on previous feedback in the following ways (3 bullet points) • add more details • develop the issue more clearly • appropriate reference

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- clarity
- logic
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Augmented Solow Model for Economic Growth

Introduction to the Methodology

I. Introduction:

Economic growth has been a broad yet researchable issue for centuries. To find out and interpret the underlying factors leading to economic growth, researchers have developed various models to clarify them. Among all these, Solow model is one of the most popular ones and many subsequent researches (Mankiw, Romer and Weil, 1992) have enriched it since its appearance in 1956. This paper adds educational and medical ingredient into Solow model to make it better fit the reality and find out how education and medicine will improve the performance of economy.

II. Building model:

We assume production function:

$$Y = K^{\alpha} E^{\beta} M^{\gamma} (AL)^{1-\alpha-\beta-\gamma} \qquad 0 < \alpha, \beta, \gamma, \alpha+\beta+\gamma < 1 \tag{1}$$

where Y is output, K physical capital, E educational capital, M medical capital, A level of technology and L labor force. Compared with Cobb-Douglas production function which only incorporates capital, labor and technology, it adds educational and medical components into it. By dividing AL on both sides, we get:

$$y = k^{\alpha} e^{\beta} m^{\gamma} \qquad y = \frac{Y}{AL}, k = \frac{K}{AL}, e = \frac{E}{AL}, m = \frac{M}{AL} \tag{2}$$

which defines a relationship between output per effective labor and three kinds of capital per effective labor.

Then we assume a proportion of output is invested in physical, educational, and medical capital respectively for next stage of production, represented by s_k, s_e and s_m. Level of technology grows at g; labor grows at n; depreciation rate is δ. With these assumptions, we can derive the change in physical, educational and medical capital per effective labor:

$$\begin{aligned} \Delta k &= s_k y - (n+g+\delta)k \\ \Delta e &= s_e y - (n+g+\delta)e \\ \Delta m &= s_m y - (n+g+\delta)m \end{aligned} \tag{3}$$

By setting that physical, educational, and medical capital per effective labor converges to k^*, e^*, m^* (i.e., $\Delta k = 0, \Delta e = 0, \Delta m = 0$), we get:

$$k^* = \left(\frac{s_k^{1-\beta-\gamma} s_e^{\beta} s_m^{\gamma}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$$

$$e^* = \left(\frac{s_k^{\alpha} s_e^{1-\alpha-\gamma} s_m^{\gamma}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}} \tag{4}$$

$$m^* = \left(\frac{s_k^{\alpha} s_e^{\beta} s_m^{1-\alpha-\beta}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$$

which is the steady-state physical, educational and medical capital per effective labor.

After that, we substitute the result into (1) and take the logarithm of both sides, from which we get the following equation:

$$\ln\left(\frac{Y}{L}\right) = \ln A - \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta-\gamma}\ln(s_k) + \frac{\beta}{1-\alpha-\beta-\gamma}\ln(s_e) + \frac{\gamma}{1-\alpha-\beta-\gamma}\ln(s_m) \tag{5}$$

This equation indicates that output per capita is determined by level of technology, population growth rate, efficiency of labor, depreciation rate and the three kinds of capital as a percentage of GDP respectively. Then we shall conduct regression analysis on the substance of the equation.

III. Empirical Analysis

To proceed our study, data from the World Bank in 2015 shall be used. On country level, GDP per capita is used to represent Y/L, consumption of fixed capital divided by GDP (called "physical_pct") s_k, education expenditure divided by GDP (called "edu_pct") s_e, health expenditure divided by GDP (called "medical_pct") s_m. Meanwhile, $g + \delta$ is assumed to be 0.05 as was assumed by previous studies, so we use population growth rate plus 0.05 (called "ngdelta") as $n + g + \delta$. In selecting countries, we use all countries for which data is available as this can increase the sample size, totaling 134.

We first run the regression according to equation (5). However, the regression

displays heteroskedasticity as p-value of the white test is 0.0197. Therefore, robust regression should be performed instead. Then we test whether the sum of the coefficients of the variables is zero as is demonstrated by the equation to show the substance of the model.

IV. Why This Methodology

This methodology is chosen because it is based on Solow model with rich theoretical background. Meanwhile, it can display the role of educational and medical capital in economic growth just like physical capital, in line with what we want to study.

Results

TABLE: Regression Result of the Augmented Solow Model

	Normal regression	Robust regression
Unrestricted regression:		
CONSTANT	7.46***	7.46***
	(2.24)	(2.65)
ln(physical_pct)	1.01***	1.01***
	(0.23)	(0.23)
ln(ngdelta)	-2.31***	-2.31***
	(0.60)	(0.69)
ln(edu_pct)	0.50**	0.50**
	(0.24)	(0.21)
ln(medical_pct)	0.54*	0.54*
	(0.27)	(0.28)
observations	134	134
R^2	0.39	0.39
Restricted regression:		
CONSTANT	8.20***	
	(0.22)	
ln(physical_pct) – ln(ngdelta)	1.04***	
	(0.21)	
ln(edu_pct) – ln(ngdelta)	0.52**	
	(0.24)	
ln(medical_pct) – ln(ngdelta)	0.57**	
	(0.25)	
observations	134	
R^2	0.39	

* "***" denotes significance at 1% level; "**" denotes significance at 5% level; "*" denotes significance at 10% level. The restricted regression displays homoskedasticity, so there is no result in the "Robust regression" column.

The result indicates that all the variables are statistically significant, though at different levels. Also, the VIF test shows result of 1.22, 1.21, 1.16, 1.13 and 1.49, 1.48, 1.29 in the two tests respectively, implying that there is no multicollinearity.

It also suggests that one percent increase in physical capital proportion of GDP will increase GDP per capita by about 1.01%. For the variables we are interested in, educational capital and medical capital increases GDP per capita by 0.5% and 0.54% with one percent increase in their proportion of GDP respectively.

The restricted regression result supports that the coefficients of the variables sum zero.

R square are both 0.39 in the two tests, showing satisfying competence in fitting the data.

Policy Recommendation

I. Policy recommendation

The result indicates positive influences of educational and medical investment and implies some policy recommendations, both fiscal and monetary.

On the fiscal side, the government shall invest more to education, like subsidizing rural schools to employ high quality teaching or supervising and regulating educational activities to increase their efficiency. Besides, the government can't neglect expenditure in medical care. For example, it can promote telemedicine services, saving patients' precious time.

On the monetary side, the central bank can encourage the commercial banks to lend more to educational and medical fields, like decreasing interest rate particularly for the companies in those fields.

However, these policies shall be based on adequate investment in physical capital as physical capital displays the highest return of the three kinds of capital.

II. Limitations

There exist some limitations of the data used. The data we use only represents the situation in 2015 and may not apply to other years. Also, our estimate and policy recommendation may not apply to countries that are neglected by us for lack of data. The method we use has some limitations as well because we assume $0 < \alpha + \beta + \gamma < 1$ and the model we use can't solve situations where $\alpha + \beta + \gamma \geq 1$.

Appendix

I. Stata code:

```
import excel "C:\Users\Administrator\Desktop\econometric_final_data.xlsx", sheet("Sheet1") firstrow

reg ln_GDP_per_capita ln_physical_pct ln_ngdelta ln_edu_pct ln_medical_pct

imtest, white

estat vif

gen ln_physical_pct_minus_ngdelta = ln_physical_pct - ln_ngdelta

gen ln_edu_pct_minus_ngdelta = ln_edu_pct - ln_ngdelta

gen ln_medical_pct_minus_ngdelta = ln_medical_pct - ln_ngdelta

reg ln_GDP_per_capita ln_physical_pct_minus_ngdelta ln_edu_pct_minus_ngdelta ln_medical_pct_minus_ngdelta

imtest, white

estat vif
```

II. Data name and description (from the World Bank):

Data Name	Data Description
GDP per capita (current US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.
Adjusted savings: consumption of fixed capital (current US$)	Consumption of fixed capital represents the replacement value of capital used up in the process of production.

Data Name	Data Description
Adjusted savings: education expenditure (current US$)	Education expenditure refers to the current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment.
GDP (current US$)	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars. Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used.
Current health expenditure (% of GDP)	Level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT and stocks of vaccines for emergency or outbreaks.
Population growth (annual %)	Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.

Source: the World Bank

III. Specific Data used in Stata:

Number	CountryName	ln_GDP_per_capita	Ln_physical_pct	ln_ngdelta	ln_edu_pct	ln_medical_pct
1	Algeria	8.339861	-2.42945	-2.6528	-3.13759	-2.66234
2	Argentina	9.531631	-2.16891	-2.80049	-2.96543	-2.43173

Number	CountryName	ln_GDP_per_capita	Ln_physical_pct	ln_ngdelta	ln_edu_pct	ln_medical_pct
3	Armenia	8.190714	-2.01817	-2.90946	-3.57344	-2.29089
4	Australia	10.94651	-1.68225	-2.74276	-3.01492	-2.37357
5	Austria	10.69598	-1.71079	-2.79345	-2.96478	-2.26647
6	Bahamas, The	10.35122	-2.03751	-2.8202	-3.29217	-2.86218
7	Bahrain	10.02721	-2.74667	-2.57145	-3.59198	-3.00073
8	Bangladesh	7.129661	-2.50813	-2.79405	-4.18234	-3.70374
9	Belarus	8.690996	-1.91673	-2.96437	-3.088	-2.80258
10	Belgium	10.62113	-1.67637	-2.88608	-2.77903	-2.27496
11	Belize	8.471349	-1.86577	-2.64243	-2.80742	-2.82967
12	Benin	6.981747	-1.83906	-2.55468	-3.22027	-3.22092
13	Bhutan	7.920325	-2.45595	-2.77754	-2.76522	-3.30823
14	Bolivia	8.018287	-2.03992	-2.73138	-2.83492	-2.71553
15	Botswana	8.824659	-1.55756	-2.72948	-2.38797	-2.8601
16	Brazil	9.084097	-2.13354	-2.84064	-2.81431	-2.42247
17	Brunei Darussalam	10.34704	-2.48487	-2.77322	-3.25767	-3.7351
18	Bulgaria	8.861624	-1.90629	-3.13226	-3.28538	-2.5007
19	Burkina Faso	6.482078	-2.35755	-2.53332	-3.18842	-2.84296
20	Burundi	5.722113	-1.99134	-2.50631	-2.96176	-2.72135
21	Cambodia	7.058676	-2.1148	-2.71754	-3.97312	-2.78154
22	Cameroon	7.191055	-1.87874	-2.56632	-3.63358	-3.05771
23	Canada	10.68248	-1.74492	-2.85661	-3.02527	-2.25278
24	Chile	9.515924	-2.0358	-2.78422	-3.11624	-2.48859
25	Colombia	8.728406	-1.89023	-2.78592	-3.39831	-2.61765
26	Comoros	7.124964	-2.46836	-2.61087	-3.69407	-2.55423
27	Congo, Dem. Rep.	6.209228	-3.11119	-2.48857	-3.95892	-3.23348
28	Congo, Rep.	7.808524	-1.49161	-2.59246	-4.02549	-3.37689
29	Costa Rica	9.332482	-2.88919	-2.79902	-2.68927	-2.54812
30	Cote d'Ivoire	7.58708	-3.91122	-2.58733	-3.09106	-3.11858
31	Croatia	9.374306	-1.9547	-3.17584	-3.10733	-2.69002
32	Cyprus	10.05765	-1.99662	-2.85559	-2.79802	-2.68692
33	Czech Republic	9.788621	-1.48711	-2.95717	-2.93756	-2.62517
34	Denmark	10.88284	-1.82485	-2.86358	-2.6437	-2.28012
35	Dominican Republic	8.84239	-3.12001	-2.79042	-3.72335	-2.81634
36	Ecuador	8.720051	-1.82444	-2.71539	-3.25409	-2.45475
37	Egypt, Arab Rep.	8.178339	-2.96366	-2.63011	-3.12837	-2.93059
38	El Salvador	8.217595	-2.1189	-2.90491	-3.30592	-2.57304
39	Estonia	9.771226	-1.82033	-2.98271	-3.05571	-2.75101
40	Eswatini	8.210614	-2.10117	-2.84376	-2.67724	-2.64129

Number	CountryName	ln_GDP_per_capita	Ln_physical_pct	ln_ngdelta	ln_edu_pct	ln_medical_pct
41	Ethiopia	6.462315	-1.90699	-2.55669	-3.48611	-3.23274
42	Finland	10.66394	-1.67603	-2.93194	-2.74047	-2.33262
43	France	10.50885	-1.74579	-2.92703	-2.98737	-2.16639
44	Gabon	8.907168	-1.84616	-2.4847	-3.57345	-3.62781
45	Gambia, The	6.493336	-1.9052	-2.52467	-3.66823	-3.47378
46	Georgia	8.29759	-2.25177	-2.96472	-4.06277	-2.53422
47	Germany	10.62344	-1.7451	-2.83605	-3.10482	-2.19931
48	Ghana	7.463851	-1.64263	-2.62158	-3.17295	-3.0744
49	Greece	9.807405	-1.74903	-3.13703	-3.47239	-2.51456
50	Guatemala	8.292708	-2.04439	-2.70434	-3.56024	-2.82002
51	Guinea	6.645424	-2.35766	-2.59164	-3.81359	-2.84573
52	Guinea-Bissau	6.402582	-3.09721	-2.57564	-4.43304	-2.45444
53	Guyana	8.626376	-3.19326	-2.89509	-3.81753	-3.09708
54	Haiti	7.236425	-2.78712	-2.75208	-4.75392	-2.4501
55	Honduras	7.741621	-2.88643	-2.69689	-2.83079	-2.56214
56	Hungary	9.4499	-1.7507	-3.04447	-3.15496	-2.66342
57	Iceland	10.86979	-1.87017	-2.80645	-2.64261	-2.50686
58	India	7.381256	-2.24144	-2.79416	-3.49191	-3.32544
59	Indonesia	8.111237	-1.65249	-2.7698	-3.45512	-3.50263
60	Ireland	11.03482	-1.27421	-2.82265	-3.35256	-2.6124
61	Israel	10.48505	-2.02746	-2.66194	-2.93416	-2.64698
62	Italy	10.3166	-1.70107	-3.0152	-3.24971	-2.40928
63	Jamaica	8.498521	-2.51432	-2.8912	-2.93213	-2.87262
64	Japan	10.44942	-1.52488	-3.01719	-3.51717	-2.21774
65	Jordan	8.334257	-2.60965	-2.42914	-3.35018	-2.57792
66	Kazakhstan	9.260156	-1.997	-2.73931	-3.61486	-3.49142
67	Kenya	7.198096	-2.0286	-2.59134	-3.02045	-2.95279
68	Kiribati	7.341209	-3.12556	-2.74933	-2.07496	-2.52721
69	Korea, Rep.	10.26577	-1.63566	-2.89547	-3.06761	-2.65284
70	Kyrgyz Republic	7.02205	-1.7172	-2.65086	-2.9864	-2.63816
71	Lao PDR	7.666087	-1.72149	-2.73095	-3.6901	-3.70759
72	Latvia	9.530582	-1.43264	-3.17453	-3.10591	-2.86284
73	Lebanon	8.941748	-1.67939	-2.38323	-3.87402	-2.56664
74	Lesotho	7.049376	-2.07495	-2.85428	-2.57259	-2.47675
75	Liberia	6.565805	-2.72925	-2.58324	-3.39997	-2.27402
76	Lithuania	9.56509	-1.97657	-3.20417	-3.2993	-2.7372
77	Luxembourg	11.5266	-1.70336	-2.60912	-3.3338	-2.90425
78	Madagascar	6.146833	-1.98121	-2.5647	-3.90638	-2.861
79	Malawi	5.941741	-1.97427	-2.55626	-2.89341	-2.37158
80	Malaysia	9.205855	-1.60647	-2.75751	-3.05893	-3.2455
81	Mali	6.622038	-2.63746	-2.53376	-3.30874	-3.1914

Number	CountryName	ln_GDP_per_capita	Ln_physical_pct	ln_ngdelta	ln_edu_pct	ln_medical_pct
82	Malta	10.12349	-2.06738	-2.60553	-3.13932	-2.38193
83	Marshall Islands	8.075221	-2.60703	-2.90888	-2.43619	-1.7378
84	Mauritania	7.329142	-2.39347	-2.53912	-3.55981	-3.04845
85	Mauritius	9.133508	-1.75447	-2.96959	-2.9614	-2.86471
86	Mexico	9.171251	-1.78404	-2.774	-2.98194	-2.84782
87	Moldova	7.912957	-2.1516	-3.1672	-2.8484	-2.45835
88	Mongolia	8.273484	-2.3886	-2.66434	-3.17559	-3.161
89	Morocco	7.963898	-2.18953	-2.75375	-2.97582	-2.98149
90	Mozambique	6.379884	-2.40425	-2.54659	-2.94127	-2.94342
91	Namibia	8.490722	-2.22749	-2.68709	-3.54559	-2.30904
92	Nepal	6.675259	-2.36712	-2.91859	-3.41211	-2.77752
93	Netherlands	10.7183	-1.78611	-2.9108	-3.04931	-2.27071
94	New Zealand	10.56142	-1.92193	-2.76429	-2.64352	-2.37212
95	Niger	6.182578	-3.01055	-2.42119	-2.93909	-2.63973
96	Nigeria	7.896359	-2.19684	-2.5708	-4.7785	-3.32926
97	North Macedonia	8.484726	-1.71924	-2.9809	-3.4529	-2.75793
98	Norway	11.21661	-1.76613	-2.81423	-2.71436	-2.29176
99	Oman	9.682131	-2.0256	-2.22649	-3.04017	-3.14553
100	Pakistan	7.212787	-3.02417	-2.64682	-3.88022	-3.6167
101	Panama	9.520051	-2.6767	-2.702	-3.64147	-2.68709
102	Paraguay	8.595395	-1.79489	-2.75784	-3.32414	-2.69607
103	Peru	8.736987	-2.34353	-2.7716	-3.47703	-2.99057
104	Philippines	8.006714	-2.46486	-2.72123	-3.8872	-3.1416
105	Poland	9.439744	-2.12794	-3.00915	-3.11105	-2.7492
106	Portugal	9.86487	-1.73065	-3.08219	-3.06811	-2.41108
107	Romania	9.101546	-1.71416	-3.09446	-3.58162	-3.00726
108	Russian Federation	9.139168	-2.10493	-2.95794	-3.33621	-2.93838
109	Rwanda	6.622257	-1.98692	-2.58459	-3.39284	-2.72961
110	Saudi Arabia	9.934401	-2.09242	-2.58272	-2.60694	-2.81369
111	Senegal	7.10599	-2.18101	-2.54997	-3.06776	-3.12753
112	Serbia	8.628552	-1.80581	-3.09993	-3.29263	-2.42823
113	Sierra Leone	6.377115	-3.00969	-2.63364	-3.62045	-1.58898
114	Singapore	10.92678	-1.88386	-2.78282	-3.66061	-3.16901
115	Slovak Republic	9.699594	-1.58758	-2.9769	-3.23445	-2.68142
116	Slovenia	9.946632	-1.55009	-2.98081	-3.09957	-2.46559
117	South Africa	8.654279	-1.95267	-2.72893	-2.85911	-2.50093
118	Spain	10.15549	-1.85414	-3.01137	-3.20797	-2.39588
119	Sri Lanka	8.254212	-2.64298	-2.82687	-4.0178	-3.24678

Number	CountryName	ln_GDP_per_capita	Ln_physical_pct	ln_ngdelta	ln_edu_pct	ln_medical_pct
120	Sudan	7.554722	-2.72914	-2.60272	-3.84162	-2.63348
121	Sweden	10.85022	-1.79383	-2.80388	-2.63605	-2.20694
122	Switzerland	11.31547	-1.60151	-2.79062	-3.08388	-2.12995
123	Tanzania	6.854284	-2.0592	-2.52541	-3.30794	-3.31054
124	Thailand	8.672494	-1.71428	-2.91837	-3.22618	-3.30555
125	Timor-Leste	7.195024	-3.41811	-2.68039	-2.89079	-3.35405
126	Togo	6.347232	-2.14294	-2.58217	-2.99974	-2.77269
127	Turkey	9.306219	-1.90885	-2.70814	-3.28721	-3.18483
128	Uganda	6.737713	-1.74272	-2.46556	-3.92833	-2.73592
129	Ukraine	7.661368	-2.08988	-3.0494	-2.95932	-2.6671
130	United Kingdom	10.71386	-1.9228	-2.84863	-2.90724	-2.3344
131	United States	10.94798	-1.85868	-2.85934	-3.0987	-1.78142
132	Uruguay	9.655908	-2.40621	-2.92998	-3.10341	-2.40704
133	Vietnam	7.642573	-2.41186	-2.80611	-3.12915	-2.87305
134	Zimbabwe	7.275914	-2.3494	-2.70848	-4.06265	-2.59668

* “ln_GDP_per_capita” is the logarithm of “GDP per capita (current US$)”; “ln_physical_pct” is the logarithm of “Adjusted savings: consumption of fixed capital (current US$)” divided by “GDP (current US$)”; “ln_ngdelta” is the logarithm of “Population growth (annual %)” plus 0.05; “ln_edu_pct” is the logarithm of “Adjusted savings: education expenditure (current US$)” divided by “GDP (current US$)”; “ln_medical_pct” is the logarithm of “Current health expenditure (% of GDP)”.

Reference

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