Complementarities in development

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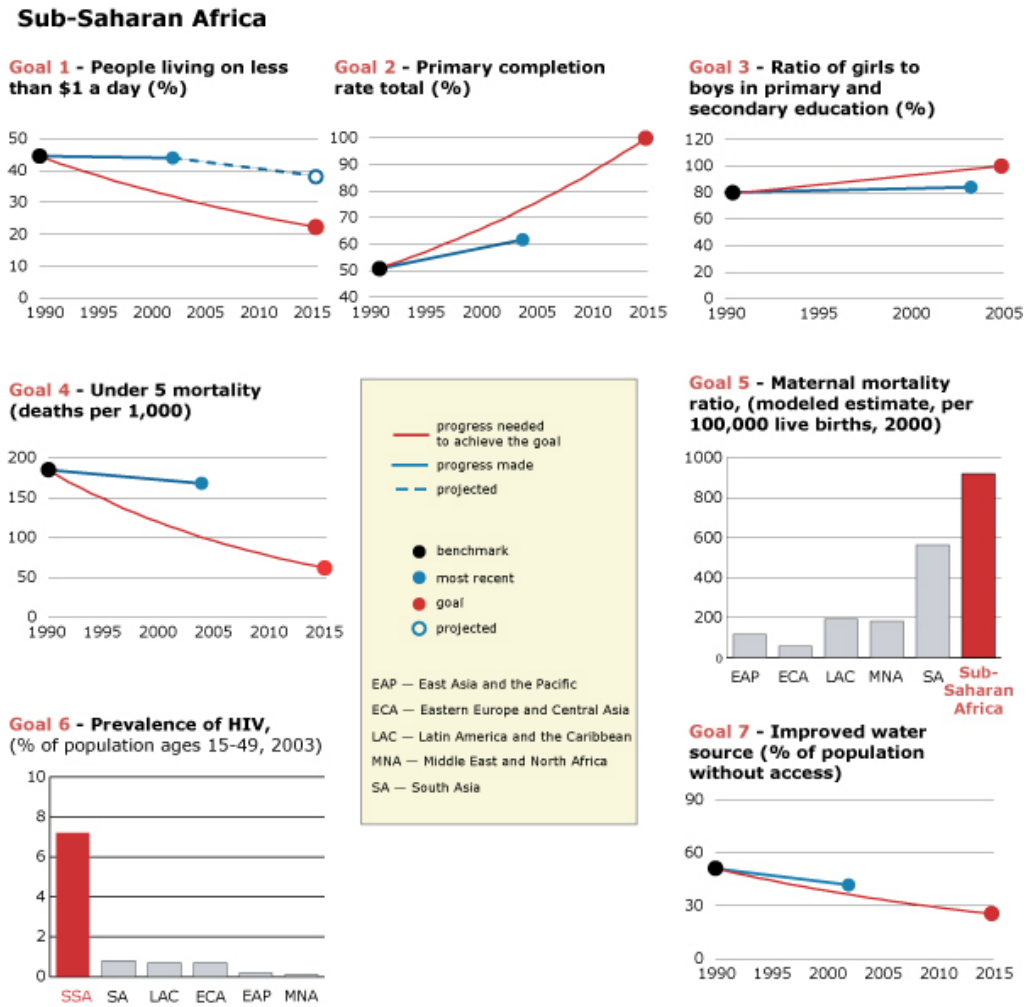
Outline



http://devdata.worldbank.org/gmis/mdg/images/ssa2006.jpg

Development progress in Sub-Saharan Africa

- Sub-Saharan African (SSA) countries are among the least developed in the world
- Development progress in SSA is very slow
- Millennium Development Goals (MDGs) will not be reached in 2015

Measures of development

- MDGs
  - set in 2000 by the UN General Assembly
  - 10 goals with sub-targets
  - poverty, health, education, environmental protection
- Human Development Index (HDI)
  - developed in 1990 by the UN Human Development Report Office
  - composite indicator of 3 aspects of development
  - per capita income,
- World Development Indicators

Dimensions of development

Standard-of-living

gdpc GDP per capita (HDI)

hceh Household consumption expenditures per capita

tpec Total primary energy consumption per capita (IEA[1])

Health

life Life expectancy at birth (HDI)

u5sr Under-5 mortality rate (MDG) $\rightarrow$ under-5 survival rate

Education

litr Literacy rate (HDI)

pscr Primary school completion rate (MDG)

[1] International Energy Agency

Research question

Why is there so little development progress in SSA?

Are the different dimensions of development mutually reinforcing or not compatible with each other?

Complementarity Theory

Two approaches in complementarity theory

- Conditional correlations
- **Productivity analysis**

Amir (2003), p.2:

"If in a maximization problem, the objective reflects a complementarity between an endogenous variable and an exogenous parameter, in the sense that **having more of one increases the marginal return to having more of the other**, then the optimal value of the former will be increasing in the latter. In the case of multiple endogenous variables, then all of them must also be complements so as to guarantee that their increases are mutually reinforcing."

Complementarity Theory

Lokshin *et al.* (2007):
s_i and s_j are complements in $f(s_i, s_j)$ if and only if $\frac{\partial^2}{\partial s_i \partial s_j} = \alpha_{ij} \geq 0$

Miravete and Pernías (1998):
estimate the interaction coefficient α_{ij} of s_i and s_j from the first order conditions

Development objective

$$
\begin{aligned}
d \quad = \quad & \alpha_{10} s_{1t} + \alpha_{20} s_{2t} + \alpha_{30} s_{3t} \\
& + \frac{1}{2} \left[\alpha_{11} (s_{1t})^2 + \alpha_{22} (s_{2t})^2 + \alpha_{33} (s_{3t})^2 \right] \\
& + \alpha_{12} s_{1t} s_{2t} + \alpha_{13} s_{1t} s_{3t} + \alpha_{23} s_{2t} s_{3t}
\end{aligned} \tag{1}
$$

- d Development measure
- s_1 Logarithm of standard-of-living indicator
- s_2 Logarithm of health indicator
- s_3 Logarithm of education indicator

First order conditions

$$
\begin{aligned}
s_{1t}^{\star} &= -\frac{1}{\alpha_{11}}\left[\alpha_{10} + \alpha_{12}s_{2t}^{\star} + \alpha_{13}s_{3t}^{\star}\right] = a_{10} + a_{12}s_{2t}^{\star} + a_{13}s_{3t}^{\star} \\
s_{2t}^{\star} &= -\frac{1}{\alpha_{22}}\left[\alpha_{20} + \alpha_{12}s_{1t}^{\star} + \alpha_{23}s_{3t}^{\star}\right] = a_{20} + a_{21}s_{1t}^{\star} + a_{23}s_{3t}^{\star} \qquad (2) \\
s_{3t}^{\star} &= -\frac{1}{\alpha_{33}}\left[\alpha_{30} + \alpha_{13}s_{1t}^{\star} + \alpha_{23}s_{2t}^{\star}\right] = a_{30} + a_{31}s_{1t}^{\star} + a_{32}s_{2t}^{\star}
\end{aligned}
$$

$s_{it}^{\star}$ Optimal level of development of s_i at time t

Partial adjustment model

As development in Sub-Saharan African countries is far from optimal, but taking first order conditions assumes optimality, it is necessary to extend the model with partial adjustment coefficients b_i for each dimension i of development

$$s_{it} - s_{it-1} = b_i \left(s_{it}^{\star} - s_{it-1} \right). \tag{3}$$

Final equation system

$$\Delta s_{1t} = a_{10}b_1 + \frac{a_{12}b_1}{b_2}\Delta s_{2t} + \frac{a_{13}b_1}{b_3}\Delta s_{3t} - b_1 s_{1t-1} + a_{12}b_1 s_{2t-1} + a_{13}b_1 s_{3t-1} + k_1 x_1$$
$$\Delta s_{2t} = a_{20}b_2 + \frac{a_{21}b_2}{b_1}\Delta s_{1t} + \frac{a_{23}b_2}{b_3}\Delta s_{3t} + a_{21}b_2 s_{1t-1} - b_2 s_{2t-1} + a_{23}b_2 s_{3t-1} + k_2 x_2 \quad (4)$$
$$\Delta s_{3t} = a_{30}b_3 + \frac{a_{31}b_3}{b_1}\Delta s_{1t} + \frac{a_{32}b_3}{b_2}\Delta s_{2t} + a_{31}b_3 s_{1t-1} + a_{32}b_3 s_{2t-1} - b_3 s_{3t-1} + k_3 x_3$$

x_i Exogenous control variable for development dimension i

Calculating results

1. Estimate equation system (4) with 2SLS

Model I	*gdpc*, *u5sr*, *pscr*
Model II	*hceh*, *u5sr*, *pscr*
Model III	*tpec*, *u5sr*, *pscr*
Models a/b	differ w.r.t. exogenous control variables

2. Calculate a_{ij}'s and b_i's from estimated coefficients
3. Check if coefficients fulfill restrictions
   - $a_{ij} * a_{ji} \geq 0$
   - $a_{12}a_{23}a_{31} = a_{13}a_{32}a_{21}$
   - $0 \leq b_i \leq 1$

Table: Complementarity and partial adjustment coefficients *gdpc*

	$a_{ij} = -l_{ij}/l_{ii}$				$a_{ij} = -c_{ij}l_{jj}/l_{ii}$				$a_{ij} = -l_{ij}/l_{ii}$				$a_{ij} = -c_{ij}l_{jj}/l_{ii}$			
	Model Ia								**Model Ib**							
	Coef.	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**	
a_{12}	21.805	18.681	1.167		19.632	41.511	0.473		-90.348	295.319	-0.306		-99.225	275.596	-0.360	
a_{21}	0.042	0.025	1.653	'	0.038	0.044	0.864		-0.006	0.023	-0.244		-0.005	0.015	-0.354	
a_{13}	-3.080	1.883	-1.636	'	-3.240	1.965	-1.649	'	8.150	26.954	0.302		7.487	27.301	0.274	
a_{31}	-0.301	0.214	-1.404	'	-0.272	0.329	-0.827		0.061	0.249	0.243		0.059	0.165	0.358	
a_{23}	0.128	0.088	1.446	'	0.131	0.109	1.206		0.080	0.061	1.326	'	0.075	0.079	0.952	
a_{32}	6.990	4.241	1.648	'	6.854	7.295	0.940		11.144	3.344	3.332	***	10.762	6.042	1.781	*
b_1	-0.107	0.098	-1.102						-0.043	0.071	-0.607					
b_2	0.251	0.128	1.967	*					0.140	0.041	3.408	***				
b_3	0.345	0.113	3.054	***					0.390	0.138	2.834	***				
$a_{12}a_{23}a_{31}$	-0.840				-0.700				-0.441				-0.439			
$a_{13}a_{32}a_{21}$	-0.904				-0.844				-0.545				-0.403			

Signif. codes: *** 0.01, ** 0.05, * 0.10, ' 0.20, 1.00

Table: Complementarity and partial adjustment coefficients *hceh*

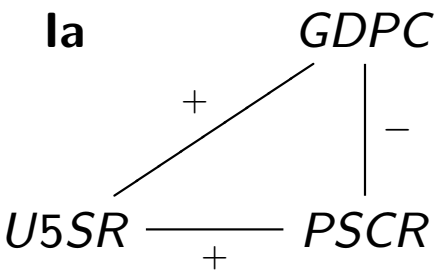
	$a_{ij} = -l_{ij}/l_{ii}$			$a_{ij} = -c_{ij}l_{jj}/l_{ii}$			$a_{ij} = -l_{ij}/l_{ii}$			$a_{ij} = -c_{ij}l_{jj}/l_{ii}$		
	Model IIa						**Model IIb**					
	Coef.	**SE**	**t-stat**	**Coef.**	**SE**	**t-stat**	**Coef.**	**SE**	**t-stat**	**Coef.**	**SE**	**t-stat**
a_{12}	376.958	7616.144	0.049	379.991	7929.621	0.048	-26.400	114.999	-0.230	-28.354	110.781	-0.256
a_{21}	0.002	0.065	0.035	0.003	0.056	0.046	-0.015	0.063	-0.235	-0.028	0.096	-0.295
a_{13}	-55.691	1137.833	-0.049	-54.915	1140.985	-0.048	5.464	19.682	0.278	5.856	21.844	0.268
a_{31}	-0.018	0.338	-0.052	-0.019	0.471	-0.041	0.056	0.276	0.204	0.121	0.432	0.280
a_{23}	0.144	0.647	0.223	0.143	0.618	0.232	0.163	0.186	0.875	0.185	0.224	0.825
a_{32}	6.766	6.042	1.120	6.983	32.466	0.215	4.929	4.057	1.215	4.680	6.360	0.736
b_1	-0.005	0.097	-0.048				0.050	0.152	0.329			
b_2	0.078	0.151	0.515				0.066	0.063	1.045			
b_3	0.261	0.676	0.386				0.292	0.166	1.756 *			
$a_{12}a_{23}a_{31}$	-0.977			-1.032			-0.241			-0.635		
$a_{13}a_{32}a_{21}$	-0.754			-1.150			-0.404			-0.767		

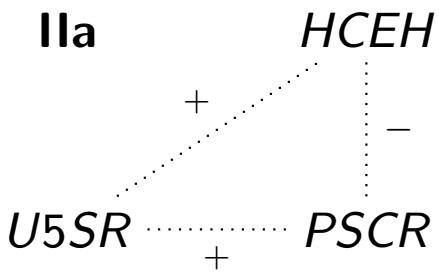
Signif. codes: *** 0.01, ** 0.05, * 0.10, ' 0.20, 1.00

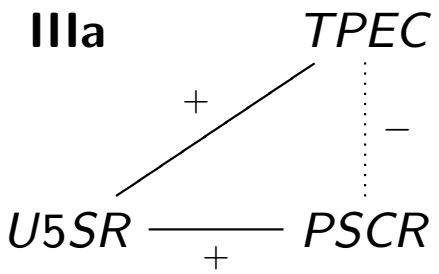
Table: Complementarity and partial adjustment coefficients *tpec*

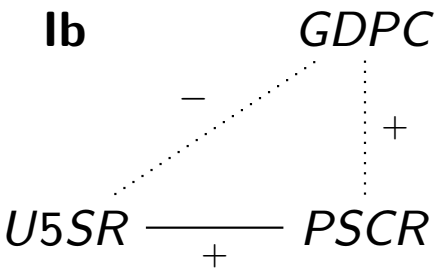
	$a_{ij} = -l_{ij}/l_{ii}$				$a_{ij} = -c_{ij}l_{jj}/l_{ii}$				$a_{ij} = -l_{ij}/l_{ii}$				$a_{ij} = -c_{ij}l_{jj}/l_{ii}$			
	Model IIIa								**Model IIIb**							
	Coef.	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**		**Coef.**	**SE**	**t-stat**	
a_{12}	86.548	228.728	0.378		54.907	83.563	0.657		-36.569	70.132	-0.521		-39.267	62.695	-0.626	
a_{21}	0.017	0.009	1.878	*	0.001	0.010	0.139		-0.014	0.027	-0.532		-0.012	0.019	-0.621	
a_{13}	-3.398	14.751	-0.230		-1.764	27.541	-0.064		3.507	8.144	0.431		2.665	8.177	0.326	
a_{31}	-0.146	0.123	-1.182		-0.004	0.052	-0.067		0.084	0.233	0.359		0.052	0.174	0.298	
a_{23}	0.076	0.068	1.110		0.079	0.090	0.878		0.077	0.082	0.937		0.060	0.104	0.582	
a_{32}	7.972	5.853	1.362	'	8.250	6.229	1.324	'	9.325	3.331	2.800	***	8.276	5.239	1.580	'
b_1	0.025	0.160	0.158						-0.069	0.051	-1.356	'				
b_2	0.181	0.039	4.572	***					0.127	0.042	3.043	***				
b_3	0.390	0.111	3.511	***					0.386	0.122	3.152	***				
$a_{12}a_{23}a_{31}$	-0.960				-0.017				-0.237				-0.123			
$a_{13}a_{32}a_{21}$	-0.461				-0.015				-0.458				-0.265			

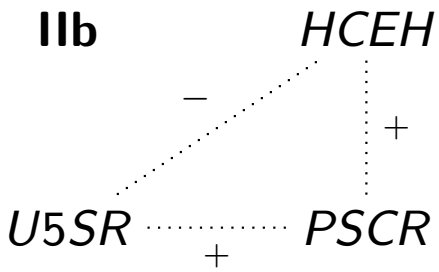
Signif. codes: *** 0.01, ** 0.05, * 0.10, ' 0.20, 1.00

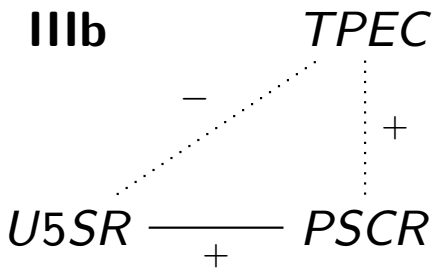












— significant coefficient, . . . insignificant coefficient

Model validity

- restrictions on coefficients are fulfilled
  - except $b_1 < 0$
  - possible explanation: reflecting decreasing production and income in many Sub-Saharan African countries during the 1990s
- significant positive coefficients a_{23} and a_{32}

$\Rightarrow$ Complementary relation between health and education

- sign of a_{12}, a_{21} and a_{13}, a_{31} depending on included exogenous variables

$\Rightarrow$ Relation of standard-of-living indicators with health and education unclear

Policy conclusion

Good health and education outcomes, measured by the number of children surviving to the age of five (out of one thousand life births) and the primary school completion rate, respectively, are mutually reinforcing. A clear relation of these with living standards, measured with three different indicators, however is not apparent. Development policies that aim at increasing both health and education outcomes at the same time will have a higher effect on a country's overall development than policies aiming at either one individually.

Bibliography

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