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Article

Complementarities in development

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Abstract: This paper applies econometric complementarity analysis to three dimensions of sustainable social developmen: standard-of-living, education and health. From a development objective function, the corresponding first order conditions are calculated and extended using a partial adjustment model. The system is estimated for a panel of 42 Sub-Saharan African countries. There exist significant complementarities between some of the development objectives, whereas there seems to be no significant relation for others. Using these results it is possible to identify mutually reinforcing and conflicting policy targets. The most significant relations were found between the under-5 survival rate and the primary school completion rate.

Keywords: Complementarity analysis; Sustainable development indicators; Sub-Saharan Africa

1. Introduction

Two thirds of the time span to achieve the Millennium Development Goals (MDGs) have passed and only very few countries seem to be on track in reaching the targets set in 2000 by the UN General Assembly. The natural question to ask is "Why?". There are most probably many different reasons and hence also many different answers as well as possibilities to deduce answers. A very basic question that should be answered first is: Can all MDGs actually be achieved simultaneously? Are they compatible? Or can only a subset of the MDGs be reached at a time? Or, to pose a more positive question: Are the MDGs complementary to each other, i.e. does a positive development in reaching one goal have positive externalities on reaching another goal? Does in addition to this, the economic development of a country have an influence on the attainment of the MDGs? And does a good performance with respect to the MDGs enhance economic growth?

McGillivray *et al.* [1] state in the introduction to their book on the MDGs (p. 2) that

> No one goal can be looked at in isolation from the others, nor from key macroeconomic outcomes not built directly into or recognized within the MDGs. Central to achieving the MDGs is a recognition of these interdependencies, and any robust and insightful analysis of them must take this into account.

The literature on these possible interdependencies is not conclusive: The European Report on Development [2], which was published in September 2008, states (on p. 9) that:

> The correlation between GDP per capita growth and the non-income MDGs is practically zero, thus confirming the limited linkage found between these indicators and poverty reduction.

The Stern Review [3] on the other hand states (on p. 125) that

> There is also a close relationship between growth and many non-income indicators of development, ranging from under-5 mortality to educational attainment and peace and security.

The Millennium Development Goals cover very different aspects of living: poverty, health, education and environmental sustainability. These dimensions of development are also reflected in the Human Development Index (HDI), which is a composite indicator of a standard of living, a health and an education index.The HDI aims at measuring a country's overall development. The three indicators which constitute the HDI can be seen as development outcomes, while the MDG indicators, though of course development outcomes in itself, also reflect development inputs. The objective of this paper is to find complementarities between the three dimensions of development: standard of living, health and education.

According to [1] no structural modeling approach has been applied to this issue before. The authors use simultaneous equation modeling to analyze interdependencies between some MDG related indicators, aid and material wellbeing. The approach applied here is similar, but additionally uses methods from firm productivity analysis of finding complementarities. There are two main types of this complementarity/substitutability analysis, productivity analysis (PROD) and correlation analysis (CORR) as described by Mohnen and Röller [4]. While the former compares the productivity of following two strategies simultaneously versus following each of the strategies individually, the latter identifies the correlation between outcomes of following different strategies after controlling for other variables.

This paper will apply the PROD approach, testing whether the three dimensions of development, standard-of-living, education and health, are complements with respect to each other. The paper is organized as follows: the next section will shortly summarize some of the relevant literature on development indicators and econometric analyses of their interdependencies. Section 2.2 introduces econometric complementarity analysis. The model applied here is developed in Section 3. After presenting results, Section 4 gives some conclusions.

2. Methodological background

2.1. Empirical analysis of development

There exists a broad literature relating income, health and education measured by different indicators; But, as also noted by Fielding and Torres [5], most of the empirical literature focuses on analyzing relations between two indicators only. According to McGillivray *et al.* [1] a comprehensive view on the interdependencies between different dimensions of development should involve a model that looks at more than one relationship simultaneously. Some of the papers, referred to by Fielding and Torres [5, p. 39], do not even consider a two-way relation between pairs of indicators, but rather only the effect of education on income (e.g. [6]) or of income on education (e.g. [7]), the effect of health on income (e.g. [8]) or of income on health (e.g. [9]).

One example for the investigation of the two-way relation between GDP per capita growth and life expectancy at birth is Azomahou *et al.* [10], who observed for 18 different countries between 1820 and 2005 a co-evolution of per capita income and life-expectancy at birth. The estimation results confirm their assumption of a non-linear relationship between the two data series. While it is a strictly positive relationship, the curvature depends on the values of life expectancy: for low values, the relation is strictly convex, while for higher values it is concave. In Azomahou *et al.* [11] the authors investigate the impact of AIDS on economic growth. The empirical investigation is based on a general equilibrium model in which two scenarios, low and high AIDS prevalence rates, are implemented. They find that via increasing mortality rates, and decreasing life expectancy and employment there is a negative long-run impact of AIDS on the economy in Sub-Saharan Africa.

Health is further negatively affected by environmental pollution, see for example [12], and by low income, which negatively affects health through malnutrition; van Zon and Kiiver [13] summarize the relevant empirical literature on this issue. The literature argues that inadequate nutrition not only negatively affects health and general mental development, but also that children with low health spend less time in school and hence do not have the chance to obtain a good education. Low education leads into low-paid jobs or even unemployment, so that the children's children also grow up in poverty. This problem is called intergenerational poverty trap. They further state that "even with the current speed of improvement of nutritional standards, about 1 billion children will be impaired in their mental development in 2020 due to the compound effect of malnutrition of parents and children" [13, p.3]. Health affects economic growth via different channels, e.g. low health leading to lower accumulation of human capital and hence to lower economic growth or low health leading to lower life expectancy and hence to lower growth.

These chains already link the three dimensions of development, which are the focus of this work. For earlier empirical work on the link between education and economic growth Aghion and Howitt [14] refer to Barro and Sala-i Martin [15] and Benhabib and Spiegel [16]. The main findings are that a high level of education and public spending on education positively influence economic growth. The positive influence can be explained by a high stock of human capital that increases the rate of innovations and technological diffusion, which in turn increase growth.

Ranis and Stewart [17] show a positive impact of per capita income growth, health and education expenditures as well as education itself. These authors did look at the two-way interaction between human development, that is health and education, and economic growth. They found that the level of education and health is still significant in determining per capita income growth after introducing investment and income. This shows a significant positive dependence of income development on education and health.

The literature most relevant to the question at hand is quite limited. Most authors in this field also contributed to [1]: David Fielding and Sebastian Torres (e.g. 5,18–20), Mark McGillivray [20,21], Howard White and Nina Blöndal [22,23], and Stephan Klasen and various coauthors (e.g. 24,25). In this book about the Millennium Development Goals (MDGs), they apply different empirical techniques to analyze progress toward the MDGs based on different development indicators. To start with [21] shortly describes the Millennium Development Goals and the progress that has been made since their announcement in 2000. [23] gives an overview over existing methods to project the path towards the MDGs. The authors differentiate between "naïve" projections only based on time trends, outcome-income projections based on international forecasts of GDP and GDP growth, and more sophisticated multi-equation models.

The analysis in [20] belongs to the latter category. It is a similar approach as in [18] and [19] to analyze the link between aid, material wellbeing, and some MDG related indicators including the under-5 mortality rate, educational attainment, access to piped water (as a proxy for access to improved water sources and sanitation), and fertility. The authors set up a structural model including one equation per MDG indicator and additionally an equation for aid. All the indicators appear on both sides in this system of equations, once as a dependent variable, and also as an explanatory variable in the other equations (not necessarily in all). Additionally, a set of exogenous variables covering geographic factors and population structure is included. This system of equations is then estimated using the simultaneous equation method 3-stage least squares (3SLS). They infer on the relationship between the indicators directly from the coefficients, that is how proportional changes in the explanatory variables translate into proportional changes in the dependent variables.

Fielding and Torres [5] also use this approach of developing the partially reduced form system of equations from a system of structural equations, but when estimating they distinguish between different income quintiles to explicitly consider the effect of inequality. All of these papers reduce the number of endogenous variables to include some measure of wealth (GDP per capita, material wellbeing), education (literacy rate, primary school completion rate), health (life expectancy at birth, under-5 mortality rate), and one or two other measures of development, e.g. fertility, democracy, inequality, access to piped water or aid transfers, treating the remaining indicators as exogenous. This can be done because the endogenous indicators can be seen as development outcomes whereas the remaining indicators rather are development inputs. Szirmai [26] discusses different development inputs and outcomes.

The econometric development literature summarized here finds significant relations between different development indicators. The interdependencies between the different development indicators will be put in a new context in the following analysis by explicitly applying complementarity analysis.

2.2. Complementarity analysis

Let a 'strategy' be representing an indicator of a policy measure itself or the measure of the outcome of a policy. Then, an informal definition of complementarity between two strategies is:

> Two strategies are complementary if following both strategies simultaneously has a higher payoff than following each strategy separately.

or as stated by Amir [27], 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."

This definition clearly corresponds to what is called the productivity apporach (PROD) of complementarity analysis [4]. Milgrom and Roberts [28,29] derive their theory of complementarity from the mathematics of supermodularity. This theory gives a more formal definition of complementarity. Given strategies s,$s' \in R^n$, a function $f : R^n \rightarrow R$ is supermodular if

$$f\left(\min(s, s')\right) + f\left(\max(s, s')\right) \geq f\left(s\right) + f\left(s'\right) \tag{1}$$

which is equivalent to

$$f\left(\max(s, s')\right) - f\left(s'\right) \geq f\left(s\right) - f\left(\min(s, s')\right). \tag{2}$$

where $f\left(\max(s, s')\right)$ is such that $s, s' \geq s_i, s'_i$ for all i and $f\left(\min(s, s')\right)$ is such that $s, s' \leq s_i, s'_i$ for all i. The LHS of the inequality shows the change in payoff of increasing s to its maximum value given that s' is higher than its minimum value, while the RHS shows the payoff of increasing s to a value higher than minimum, given that s' has its minimum value. If the above inequality holds, raising s on the LHS has a higher payoff than raising it on the RHS. Amir [27] calls this property 'increasing differences'. It implies that s and s' are complementary, if the function $f\left(s, s'\right)$ is supermodular in s and s'. This formal definition corresponds exactly to the informal definition given above.

There are only few papers applying complementarity theory to macro-economic data, the most famous being those on capital-skill complementarity, e.g. [30] or [31], complementarity of agent activities, e.g. [32], money-capital complementarity, e.g. [33], or the effects of private and public capital aggregate output and productivity as in [34]. What is common to all of these papers is the use of an aggregate production function and the PROD complementarity methodology based on the supermodularity theory. To conduct a complementarity analysis using this theory, an objective function measuring the payoff of adopting strategy s and/or strategy s' is needed.

In short, the PROD approach works as follows: first estimate an objective function and then test whether the cross elasticities are positive or negative. The actual procedure is more involving, starting with the choice of the appropriate functional form of the objective. It is necessary to use a flexible form that does not impose too strong *a priori* restrictions on the elasticities of substitution. Hence, it is not possible to use any of the linear, the Cobb-Douglas, the Leontief or the constant-elasticity-of-substitution (CES) production function. Then it has to be ensured that there is no endogeneity problem in the data; choosing the appropriate estimation technique is therefore an important step in the analysis. The last step is to calculate the cross elasticities from the estimated parameters.

This method was pioneered by Griliches [35], where he tested capital-skill complementarity using a nested CES function. The approach is followed up more recently in for example [30] on the same subject, or [36], testing complementarity between the three production factors capital, labor and energy. Duffy *et al.* [30] test the hypothesis that physical capital is more complementary to skilled than to unskilled labor. For that they need to show that the elasticity of substitution of capital and unskilled labor is greater than the elasticity of substitution of capital and skilled labor. The nested CES function however requires separability of inputs. A functional form not assuming this is for example the translog specification, which has been widely applied in empirical studies, *inter alia* in studies on energy-capital complementarity as in [37] or [38].

Lokshin *et al.* [39] use a slightly different approach. Rather then comparing substitution elasticities, they define s and s' to be substitutes (complements) in the function $f(s, s')$ if and only if (the interaction term) $\frac{\partial^2 f}{\partial s \partial s'} \leq 0$ (≥ 0) for all values of $(s_1, ..., s_n)$, with the inequality holding strictly for at least one value. This goes back to Topkis' Monotonicity Theorem, see Lemma 1 in [27]. This Lemma states that if we have a problem in $\mathbb{R}^2$, then if $f(s, s')$ is twice differentiable, increasing differences, as defined in Equation (2), are equivalent to $\partial f(s, s'))/(\partial s \partial s') \geq 0$. Now, assume

$$\frac{\partial^2 f}{\partial s \partial s'} = \alpha_{ss'}; \tag{3}$$

to conclude that there is complementarity between s and s', it is therefore sufficient to show that the coefficient of the interaction term $\alpha_{ss'}$ is positive (and significant).

As there does not exist one single measure of development, the PROD approach as such is not directly applicable, though it does give the background for what is explained in the next section. As shortly described by Mohnen and Röller [4], who refer to Miravete and Pernías [40], the approach of the latter is to "estimate the correlation in choice variables from the first order conditions". That is, they simultaneously estimate the system of structural equations that result from taking the first derivatives of the profit function (they aim at finding complementarities between different innovation strategies) and setting those to zero. This can be done because it is assumed that firms maximize their profits when choosing output level and deciding about engagement in innovation practices. This means, rather than actually having an objective, i.e. dependent, variable as in the PROD approach, for this the objective variable only needs to be there theoretically, to set up such an objective function.

When applying this PROD *without objective value* approach it is sufficient to assume that some aggregated development measure indeed exists, without having actual data on it. To follow the argumentation in [40], it would be necessary to assume that a country's policies aim at an optimal overall development of the country. There exist different superordinate development policy goals in for example the EU Sustainable Development Strategy [41]: economic prosperity, social equity and cohesion, and environmental protection; or as defined by the Human Development Report Office: "a long and healthy life, knowledge and a decent standard of living"[1]. Even though these policy goals exist, the optimality of development is, at least in Sub-Saharan African countries, not given. Including a partial adjustment model into the first order conditions allows us to still follow this approach.

[1]http://hdr.undp.org/en/statistics/indices/

3. Development complementarities

3.1. The model

The model developed in this section aims at finding complementarities between the three dimensions of development: standard-of-living, health, and education. The corresponding indicators are listed in Table 5. While using GDP per capita as a measure of a countries development or of the living conditions in a country is criticized by e.g. [42], it well reflects the economic dimension of development. GDP can be seen as a measure of production, whereas household consumption expenditures per capita might better reflect people's disposable income. Additionally, in light of the 2009 IEA World Energy Outlook's theme on energy poverty, total primary energy consumption is used as a measure of standard-of-living.

Life expectancy at birth summarizes the health status of a population and additionally is an indicator for which data is readily available for many countries. Alternatively, we measure the health status with the reciprocal value of the under-5 mortality rate, i.e. the share of children born within one year that survive at least until the age of five. This is indicator also is one of the indicators with which the progress toward Millennium Development Goal (MDG) 4 "Reduce child mortality" is measured. The education indicator "school enrollment rate" can be directly influenced by policies or policy makers, e.g. by enacting a law that all children have to go to school as is done in most industrialized countries, or by reducing school fees and providing enough capacities at state schools. Therefore the school enrollment rate is rather seen as an input into development than an output. The development output in education can be measured by the literacy rate, though this is of course only a proxy indicator of what the actual education level of a country is. An alternative indicator is the primary school completion rate. This indicator relates to MDG 2 "Achieve universal primary education".

These indicators, GDP per capita ($gdpc$), household consumption expenditures per head ($hceh$) or total primary energy consumption per capita ($tpec$), life expectancy at birth ($life$) or under-5 survival rate ($u5sr$), and the literacy rate ($litr$) or primary school completion rate ($pscr$) are modeled as development outcomes and hence relate to the three endogenous variables S_1, S_2, and S_3 that together constitute the overall development D of a country. As mentioned before, there does not exist an overall development measure D, so that the approach followed here is the *PROD without objective value*.

The model developed here combines the approach of [39] and [43]. That is, S_i and S_j are definned to be complements (substitutes) if $\partial^2 D/(\partial S_i \partial S_j) > 0$ ($\partial^2 D/(\partial S_i \partial S_j) < 0$). By using the approach of [43], it is possible to assume that a measure of a country's overall development exists, without actually having data on it. When taking the first order conditions, the objective variable drops out of the system that is to be esitmated.

Let D be the general (non-existent) development measure and vector $\mathbf{S}$ contain the endogenous variables. The number of endogenous variables is three, which corresponds to the number of development dimensions considered. The *development production function* is set up using a translog specification as in [37] with variables S_1, S_2, and S_3. Let d denote $\ln D$ and s_i denote $\ln S_i$.

$$\begin{aligned} d &= \alpha_{10} s_{1t} + \alpha_{20} s_{2t} + \alpha_{30} s_{3t} \\ &\quad + \frac{1}{2} \left[\alpha_{11} (s_{1t})^2 + \alpha_{22} (s_{2t})^2 + \alpha_{33} (s_{3t})^2 \right] \\ &\quad + \alpha_{12} s_{1t} s_{2t} + \alpha_{13} s_{1t} s_{3t} + \alpha_{23} s_{2t} s_{3t}. \end{aligned} \tag{4}$$

Strategies s_i and s_j are complements if the corresponding coefficient of the interaction term $s_i s_j$, that is α_{ij} is positive. The derived first order conditions are:

$$\begin{aligned}\frac{\partial d_t}{\partial s_{1t}} &= \alpha_{10} + \alpha_{11}s_{1t} + \alpha_{12}s_{2t} + \alpha_{13}s_{3t} \ \hat{=}\ 0\\ \frac{\partial d_t}{\partial s_{2t}} &= \alpha_{20} + \alpha_{12}s_{1t} + \alpha_{22}s_{2t} + \alpha_{23}s_{3t} \ \hat{=}\ 0\\ \frac{\partial d_t}{\partial s_{3t}} &= \alpha_{30} + \alpha_{13}s_{1t} + \alpha_{23}s_{2t} + \alpha_{33}s_{3t} \ \hat{=}\ 0\end{aligned} \tag{5}$$

Solving these for s_{1t}, s_{2t}, and s_{3t}, the conditions for the optimal levels of development of s_i at time t, $s^\star_{it}$ follow:

$$\begin{aligned}s^\star_{1t} &= -\frac{1}{\alpha_{11}}\left[\alpha_{10} + \alpha_{12}s^\star_{2t} + \alpha_{13}s^\star_{3t}\right] = a_{10} + a_{12}s^\star_{2t} + a_{13}s^\star_{3t}\\ s^\star_{2t} &= -\frac{1}{\alpha_{22}}\left[\alpha_{20} + \alpha_{12}s^\star_{1t} + \alpha_{23}s^\star_{3t}\right] = a_{20} + a_{21}s^\star_{1t} + a_{23}s^\star_{3t}\\ s^\star_{3t} &= -\frac{1}{\alpha_{33}}\left[\alpha_{30} + \alpha_{13}s^\star_{1t} + \alpha_{23}s^\star_{2t}\right] = a_{30} + a_{31}s^\star_{1t} + a_{32}s^\star_{2t}\end{aligned} \tag{6}$$

with coeffcients a_{ij} fulfilling $a_{12}a_{23}a_{31} = a_{13}a_{32}a_{21}$. This follows from the six conditions imposed on the six unknown α's:

$$\begin{aligned}&(a)\ \ a_{12} = -\frac{\alpha_{12}}{\alpha_{11}} \qquad &&(b)\ \ a_{13} = -\frac{\alpha_{13}}{\alpha_{11}}\\ &(c)\ \ a_{21} = -\frac{\alpha_{12}}{\alpha_{22}} \qquad &&(d)\ \ a_{23} = -\frac{\alpha_{23}}{\alpha_{22}}\\ &(e)\ \ a_{31} = -\frac{\alpha_{13}}{\alpha_{33}} \qquad &&(f)\ \ a_{32} = -\frac{\alpha_{23}}{\alpha_{33}}\end{aligned} \tag{7}$$

Solving (a) and (b) for α_{11} gives $\alpha_{12} = \alpha_{13}a_{12}/a_{13}$, solving (c) and (d) for α_{22} gives $\alpha_{12} = \alpha_{23}a_{21}/a_{23}$, so that $\alpha_{13}a_{12}/a_{13} = \alpha_{13}a_{21}/a_{23} \Leftrightarrow \alpha_{13} = \alpha_{23}a_{21}a_{13}/(a_{12}a_{23})$. Solving (e) and (f) for α_{33}, we have that $\alpha_{13} = \alpha_{23}a_{31}/a_{32}$, so that the coefficient restriction is $\alpha_{23}a_{21}a_{13}/(a_{12}a_{23}) = \alpha_{23}a_{31}/a_{32} \Leftrightarrow a_{12}a_{23}a_{31} = a_{13}a_{32}a_{21}$[2]. Additionally, coefficients a_{ij} and a_{ji} have to be of the same sign, that is they have to fulfill $a_{ij}a_{ji} > 0$. Assuming that the objective function is indeed maximized, the corresponding Hessian has to be negative definite, that is the entries on the diagonal, α_{ii}, should be negative to ensure that the objective function is concave in s_i.

Using first order conditions assumes optimality in the strategies, that is that the level of development is optimal. As development in the Sub-Saharan African countries is by no means optimal, the optimal strategies here are approximated using a partial adjustment model [44] for each strategy s_i:

$$s_{it} - s_{it-1} = b_i\left(s^\star_{it} - s_{it-1}\right). \tag{8}$$

Here, $s^\star_{it}$ is the desired optimal level of, in this case, development in either one of the three dimensions, whereas s_{it} is the actual observed level of development. The fraction b_i, $0 < b_i < 1$, is the speed of adjustment of the actual level to the desired level. Solving this for the optimal level gives

$$s^\star_{it} = \frac{1}{b_i}s_{it} + \left(1 - \frac{1}{b_i}\right)s_{it-1} = \frac{1}{b_i}\Delta s_{it} + s_{it-1}. \tag{9}$$

[2]For four endogenous variables this single restriction becomes six different conditions (all possible combinations of multiplying three and four variables) that the coefficients need to fulfill.

Now replacing the optimal $s^\star_{it}$ in system (6) by (9) gives

$$\begin{aligned}
\Delta s_{1t} &= a_{10}b_1 + \frac{a_{12}b_1}{b_2}\Delta s_{2t} + \frac{a_{13}b_1}{b_3}\Delta s_{3t} - b_1 s_{1t-1} + a_{12}b_1 s_{2t-1} + a_{13}b_1 s_{3t-1} \\
\Delta s_{2t} &= a_{20}b_2 + \frac{a_{21}b_2}{b_1}\Delta s_{1t} + \frac{a_{23}b_2}{b_3}\Delta s_{3t} + a_{21}b_2 s_{1t-1} - b_2 s_{2t-1} + a_{23}b_2 s_{3t-1} \\
\Delta s_{3t} &= a_{30}b_3 + \frac{a_{31}b_3}{b_1}\Delta s_{1t} + \frac{a_{32}b_3}{b_2}\Delta s_{2t} + a_{31}b_3 s_{1t-1} + a_{32}b_3 s_{2t-1} - b_3 s_{3t-1}
\end{aligned} \tag{10}$$

This system shows that development, i.e. the first difference, in each of the three dimensions theoretically depends on development in the other two dimensions and the previous level (at time $t-1$) of each of the three dimensions. Directly estimating this system is not possible because it is not identified. It is therefore necessary to add at least one[3] exogenous variable to each equation that does not influence development in the other two dimensions, denoted x_i. These exogenous variables also act as control variables that at least partly take care of country heterogeneities. The choice of exogenous variables is explained in the results section.

3.2. *Results*

From the model derived in the previous section we get the following system of structural equations including exogenous variables x_i:

$$\begin{aligned}
\Delta s_{1t} &= c_{10} + c_{12}\Delta s_{2t} + c_{13}\Delta s_{3t} + l_{11}s_{1t-1} + l_{12}s_{2t-1} + l_{13}s_{3t-1} + k_1 x_{1t-1} + \varepsilon_1 \\
\Delta s_{2t} &= c_{20} + c_{21}\Delta s_{1t} + c_{23}\Delta s_{3t} + l_{21}s_{1t-1} + l_{22}s_{2t-1} + l_{23}s_{3t-1} + k_2 x_{2t-1} + \varepsilon_2 \\
\Delta s_{3t} &= c_{30} + c_{31}\Delta s_{1t} + c_{32}\Delta s_{2t} + l_{31}s_{1t-1} + l_{32}s_{2t-1} + l_{33}s_{3t-1} + k_3 x_{3t-1} + \varepsilon_3
\end{aligned} \tag{11}$$

This system of structural form equations is estimated with two-stage least squares using data on the different development outcome indicators for a panel of five-year average data[4] for the past three decades for about 40 Sub-Saharan African countries. These indicators represent three dimensions of development: standard-of-living (SoL), health (HEA) and education (Edu). The indicators chosen for each of the dimensions are GDP per capita ($gdpc$), household consumption expenditure per capita ($hceh$) and total primary energy consumption per capita ($tpec$) for SoL, under-five survival rate ($u5sr$) and life expectancy at birth ($life$) for health and primary school completion rate ($pscr$) and literacy rate ($litr$) for education. It turned out that no significant relations were found for $life$ and $litr$, so these results are not reported here.[5]

In time series econometrics or if there are more observations in time in panel data, testing the series for their order of integration is important. As in this data set there are at most six observations in time per

[3]This is the minimum number that is necessary to satisfy the order condition for identifying equations as explained in [44], Ch. 15, p. 392.

[4]The average for time t is taken from all available years in the period from t-2 to t+2, that is for example the average of all available years between 1978 and 1982 for the data point labeled 1980. This method has been applied in the literature before and proven to be useful, see for example Adler *et al.* [45].

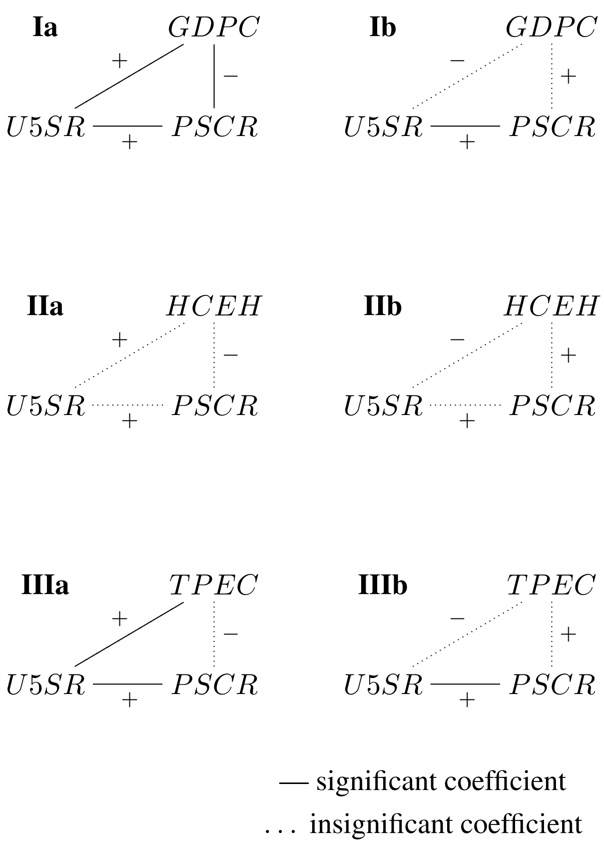
[5]This insignificance might be due to the fact that both life expectancy at birth and the literacy rate change rather slow compared to the changes in the other indicators, under-5 survival rate or primary school completion rate. To find significant relations of these indicators, longer time series might be necessary.

variable per country, and only about four on average, testing the data for stationarity is almost impossible. Existing panel unit root tests as developed for example in [46], which is referred to as a test for small samples by Breitung and Peseran [47], only give the necessary test statistics for 25 or more observations in time. As at least part of the individual country effects are taken care of by taking the first differences, hence controlling for level effects, and by using exogenous control variables, estimating a pooled model is sufficient.

In short, the main result, which is confirmed by all specifications, is that the primary school completion rate ($pscr$) and the under-5 survival rate ($u5sr$) are complements. The relation between these two is always positive, and significant in almost all specifications. Having more children completing primary school and reducing child mortality therefore are mutually reinforcing.

Figure 1 summarizes these results, the dotted lines representing insignificant relations and the full lines significant relations, with a '+' sign next to the line connecting two variables s_i and s_j indicating that α_{ij} is positive, that is s_i and s_j are complements, and a '−' sign indicating that α_{ij} is negative. A negative α_{ij} does not necessarily imply that s_i and s_j are substitutes. Rather, applying both s_i and s_j at the same time does not increase the return to either of these two. The total impact on development d of applying both strategies can still be positive depending on the size of α_{i0} and α_{j0} and the actual level of s_i and s_j.

Figure 1. Complementarities



A more detailed look at the results includes a description of the size, sign and significance of the coefficients at the different levels of the model: the structural form coefficients and those relating to the partial adjustment model and the first order conditions, that is the coefficients defining complementarity.

For each of the three combinations of endogenous variables (Model I: $gdpc$, $u5sr$, $pscr$; Model II: $hceh$, $u5sr$, $pscr$; Model III: $tpec$, $u5sr$, $pscr$), two specifications are presented in Tables 1 through 3, differing in the choice of exogenous variables. Note that a subscript 1 always refers to the standard-of-living indicator, subscript 2 to the health indicator and 3 to the education indicator. These tables display the 2SLS estimation results for structural coefficients, c_{ij} and l_{ij} from equation system (11).

The coefficients in the standard-of-living (SoL) equations are not very significant in any of the model specifications, i.e. the variables chosen here do not necessarily explain development of GDP, household consumption expenditures or total primary energy consumption per capita very well. This does not make the exercise obsolete as the aim of this paper is to identify the relation between the endogenous variables and not to perfectly explain development in the different dimensions of development. The reason three different endogenous SoL indicators are analyzed here is to show that this insignificance does not depend on how standard-of-living is measured, rather it seems that no complementarity relation between this and the other two dimensions exist.

Both development in health, measured by the number of children that survive at least until the age of five, and education, measured by the primary school completion rate, are significantly influenced by their own lagged variables as well as those of the other dimensions in models I and III. The coefficients of the respective own lags (l_{22} and l_{33}) are always negative. This on the one hand results in positive partial adjustment coefficients b_2 and b_3 and on the other hand indicates that for lower previous levels of health and education the increase, i.e. the first difference, in the respective variable is higher (when looking at this effect alone, without considering the influence of the other independent variables). Health is positively influenced by the lagged education indicator. The coefficient of the lagged SoL indicator is significant at 10% and 20% in models Ia and IIIa, respectively. The coefficient however is negative resulting in negative a_{31} as displayed in Table 4. The corresponding coefficients in models Ib and IIIb are positive but not significantly different from zero.

The coefficient of the lagged primary school enrollment rate in the health equations is always positive, though not necessarily significant. The coefficient of the health indicator in the education equation is positive and significant for models I and III, defining the significant complementarity relation between health and education via coefficient $a_{32} = -l_{32}/l_{33}$. Recall that the a_{ij}'s are overidentified. This significant relation is also confirmed for $a_{32} = c_{32}l_{33}/l_{22}$, as all of these coefficients are significant in models Ib, IIIa and IIIb. Models IIa and IIb have fewest significant coefficients, but both c_{23} and c_{32} are positive and significant at 10%, again confirming the complementarity relation found between the health and education indicators.

The exogenous control variables are generally not significant. Possible variables for education and health dimensions are selected on the basis of a short correlation analysis[6]. Therefore specifications including the immunization rate of two-year olds against either measles ($immu$) or diphtheria ($dpti$) as the exogenous variable in the health equation and the primary ($sepn$) or total ($gser$) school enrollment rates in the education equation were estimated. For the standard-of-living equation different indicators

[6] For more information please contact the author.

relating to the economic structure such as the share of trade ($trad$), industry ($eind$) or manufacturing ($eman$) in GDP, or actual value added in manufacturing ($manh$) or industry ($indh$) per capita, or to the population structure, such as the share of population living in rural areas ($rptp$) were used. The exogenous variables enter the model in lagged logarithms. Interestingly, in models II and III, where GDP per capita could be used as an exogenous control variable in the SoL equation, it turned out to not be significant at all.

Including either one of the immunization rate of two-year olds against measles ($immu$) or diphtheria ($dpti$) as the exogenous control variable in the health equation gives similar results, with those of $dpti$ being slightly more significant. The coefficient of $dpti$ is always positive, but very close to zero. That means that immunizing infants against diphtheria has a very small but positive impact on their survival rate until the age of five. In models I and III the coefficient of the lagged primary school enrollment rate is positive, while that of the total school enrollment rate is negative. These control variables however are not significant at the 20% level.

The estimation results of the structural model indicate the outcome of the overall analysis, that is the coefficients identifying complementarity, a_{ij} and corresponding α_{ij}. Table 4 displays the a_{ij} coefficients from the set of first order conditions (6) and the b_i coefficients resulting from the use of the partial adjustment model. Coefficients a_{ij} and b_i are calculated from the estimated structural form coefficients c_{ij} and l_{ij}, compare systems (10) and (11). b_i is exactly defined as $b_i = -l_{ii}$ for all i. a_{ij} however can be either calculated from the coefficient of lagged variable j in equation i as $a_{ij} = -l_{ij}/b_i = -l_{ij}/l_{ii}$, reported in the first columns of each model in Table 4, or from the coefficient of the first difference of variable j in equation i as $a_{ij} = c_{ij}l_{jj}/l_{ii}$, reported in the fourth column. Columns 2 and 3 and 5 and 6 contain the corresponding approximated standard errors[7] and t-statistics.

For each of model I, II and III, two specifications differing in the choice of exogenous variables are displayed in Table 4. These results well represent the overall findings from different specifications with regard to the exogenous control variables: There is no significant complementarity relations between the standard-of-living indicators and both education and health indicators. This can be seen from the insignificance of the respective coefficients (a_{12} and a_{21}, and a_{13} and a_{31}), and the contradicting signs of the coefficients when comparing specifications a and b for each of model I, II, and III. Coefficient a_{12} however, if significant at the 12% level as in Model Ia and IIIa, is positive, which might indicate that there could be a complementary relation between standard-of-living and health.

Coefficient a_{32} (and partly also coefficient a_{23}) is the most significant of the complementarity coefficients in all model specifications. Further, a_{32} and a_{23} are positive in all specifications tested (as a robustness check), not only those displayed here. These two coefficients determine sign and significance of α_{23}, which is the coefficient of the interaction term of the health and education indicator in the de-

[7] The standard errors are approximated using Taylor series expansion: for $a_{ij} = -l_{ij}/l_{ii}$

$$SE\,(a_{ij}) = \left(\left(\frac{\partial a_{ij}}{\partial l_{ij}}\right)^2 SE(l_{ij})^2 + \left(\frac{\partial a_{ij}}{\partial l_{ii}}\right)^2 SE(l_{ii})^2 + 2\frac{\partial a_{ij}}{\partial l_{ij}}\frac{\partial a_{ij}}{\partial l_{ii}}Cov(l_{ij}, l_{ii})\right)^{1/2} = \left(\left(\frac{1}{-l_{ii}}\right)^2 SE(l_{ij})^2 + \left(\frac{l_{ij}}{l_{ii}^2}\right)^2 SE(l_{ii})^2 + 2\frac{1}{-l_{ii}}\frac{l_{ij}}{l_{ii}^2}Cov(l_{ij}, l_{ii})\right)^{1/2}$$

and for $a_{ij} = c_{ij} * l_{jj}/l_{ii}$

$$SE\,(a_{ij}) = \left(\left(\frac{\partial a_{ij}}{\partial c_{ij}}\right)^2 SE(c_{ij})^2 + \left(\frac{\partial a_{ij}}{\partial l_{jj}}\right)^2 SE(l_{jj})^2 + \left(\frac{\partial a_{ij}}{\partial l_{ii}}\right)^2 SE(l_{ii})^2 + 2\frac{\partial a_{ij}}{\partial c_{ij}}\frac{\partial a_{ij}}{\partial l_{ii}}Cov(l_{ij}, l_{ii}) + 2\frac{\partial a_{ij}}{\partial c_{ij}}\frac{\partial a_{ij}}{\partial l_{jj}}Cov(c_{ij}, l_{jj}) + 2\frac{\partial a_{ij}}{\partial l_{jj}}\frac{\partial a_{ij}}{\partial l_{ii}}Cov(l_{jj}, l_{ii})\right)^{1/2} =$$

$$\left(\left(\frac{l_{jj}}{l_{ii}}\right)^2 SE(c_{ij})^2 + \left(\frac{c_{ij}}{l_{ii}}\right)^2 SE(l_{jj})^2 + \left(\frac{c_{ij}l_{jj}}{l_{ii}^2}\right)^2 SE(l_{ii})^2 + 2\frac{l_{jj}}{l_{ii}}\frac{c_{ij}l_{jj}}{l_{ii}^2}Cov(c_{ij}, l_{ii}) + 2\frac{l_{jj}}{l_{ii}}\frac{c_{ij}}{l_{ii}}Cov(c_{ij}, l_{jj}) + 2\frac{c_{ij}}{l_{ii}}\frac{c_{ij}l_{jj}}{l_{ii}^2}Cov(l_{jj}, l_{ii})\right)^{1/2}$$

with $Cov(l_{ij}, l_{ii})$, $Cov(c_{ij}, l_{ii})$, $Cov(c_{ij}, l_{jj})$ and $Cov(l_{jj}, l_{ii})$ given by the coefficient covariance matrix of the 2SLS estimation.

velopment objective. α_{23} is therefore significantly different from zero and positive, which indicates that there is a complementary relation between health and education.

The very last row of the table checks the restriction on the a_{ij} coefficients that is developed from the six conditions in system (7). Using this system it is possible to calculate α_{12}, α_{13} and α_{23}. Given that we normalize either one of α_{11}, α_{22} or α_{33} to -1, we have that α_{12}, α_{13} and α_{23} have the same sign as the corresponding a_{ij} and a_{ji}. To conclude whether or not s_i and s_j are complements it is therefore sufficient to consider the sign of a_{ij} and a_{ji}, which should be the same. Additionally, as the α_{ij}'s are overidentified from the first order conditions, it should hold that $a_{12}a_{23}a_{31} = a_{13}a_{32}a_{21}$, as derived in the previous section. In practice the coefficient products are not the same but sufficiently close together in order to conclude that the restrictions on the model coefficients are indeed fulfilled.

The b_i coefficients entered the overall development model through the partial adjustment model, Equation (9). These coefficients relate to the speed of adjustment of the current level of development to the optimal level of development and should therefore take values between zero and one. This is not the case for b_1, that is the adjustment coefficient of the standard-of-living indicator. This is due to the fact that these indicators decreased during most part of the late 1980s and the 1990s in many African countries, only attaining 1980's level after 2000. The remaining b_i's are significant and between 0.02 and 0.4 showing that there is some progress towards the 'optimal' level of development, but that it is very slow. According to these results, the primary school completion rate has a higher rate of adjustment, represented by coefficients b_3, than the under-5 survival rate with adjustment rates b_2.

4. Conclusion

This paper takes the approach from productivity analysis of finding complementarities between innovation strategies and adapts it to find complementarities between three dimensions of development, standard-of-living, education and health. Analysis at the firm level however can use the assumption of profit optimizing strategies, which is not transferable to the problem at hand. The model was therefore extended to also include a partial adjustment approach that identifies the deviation from the optimal development path. The more dimensions are included in such a model the more important are testable restrictions. The restrictions on the coefficients of the model are twofold relating to the multiplicity and the signs of the complementarity coefficients in the first order conditions and relating to the partial adjustment coefficients. The former are verified by the empirical analysis, while for the latter a negative partial adjustment coefficient appeared. This however can be explained by the nature of the underlying data. The negative partial adjustment coefficient in the standard-of-living dimension reflects the period of decreasing production and income in large parts of Sub-Saharan Africa during the 1990's. Hence, the empirical results support the theoretical considerations that serve as the background of the model. The difference to the development models of David Fielding and others is the derivation of the structural model, the interpretation of the coefficients (as indications of complementarity), the inclusion of lagged development indicators and the explicit consideration of non-optimal development.

The main result is that 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.

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Table 1. Estimation results Model I

		Model Ia			Model Ib		
		Coef.	**SE**	**t-val.**	**Coef.**	**SE**	**t-val.**
SoL Equation		$\Delta\log(\mathbf{gdpc})_\mathbf{t}$			$\Delta\log(\mathbf{gdpc})_\mathbf{t}$		
c_{10}	$Intercept$	13.938	24.253	0.575	-25.838	66.387	-0.389
c_{12}	$\Delta\log(u5sr)_t$	-8.395	23.354	-0.359	30.745	66.223	0.464
c_{13}	$\Delta\log(pscr)_t$	1.009	1.001	1.007	-0.831	2.521	-0.33
l_{11}	$\log(gdpc)_{t-1}$	0.107	0.098	1.102	0.043	0.071	0.607
l_{12}	$\log(u5sr)_{t-1}$	-2.343	3.776	-0.621	3.913	10.373	0.377
l_{13}	$\log(pscr)_{t-1}$	0.331	0.398	0.832	-0.353	0.962	-0.367
k_1	$\log(eind)_{t-1}$	0.02	0.182	0.111			
	$\log(trad)_{t-1}$				0.049	0.19	0.26
Hea Equation		$\Delta\log(\mathbf{u5sr})_\mathbf{t}$			$\Delta\log(\mathbf{u5sr})_\mathbf{t}$		
c_{20}	$Intercept$	1.518	0.723	2.1 **	0.911	0.249	3.661 ***
c_{21}	$\Delta\log(gdpc)_t$	-0.089	0.097	-0.916	0.017	0.036	0.466
c_{23}	$\Delta\log(pscr)_t$	0.095	0.099	0.958	0.027	0.027	0.981
l_{21}	$\log(gdpc)_{t-1}$	0.01	0.011	0.963	-0.001	0.003	-0.259
l_{22}	$\log(u5sr)_{t-1}$	-0.251	0.128	-1.967 *	-0.14	0.041	-3.408 ***
l_{23}	$\log(pscr)_{t-1}$	0.032	0.031	1.037	0.011	0.009	1.305 ’
k_2	$\log(dpti)_{t-1}$	0.001	0.011	0.108	0.001	0.006	0.187
Edu Equation		$\Delta\log(\mathbf{pscr})_\mathbf{t}$			$\Delta\log(\mathbf{pscr})_\mathbf{t}$		
c_{30}	$Intercept$	-14.519	7.29	-1.992 **	-28.195	13.058	-2.159 **
c_{31}	$\Delta\log(gdpc)_t$	0.875	0.527	1.661 ’	-0.531	1.304	-0.407
c_{32}	$\Delta\log(u5sr)_t$	9.414	7.984	1.179	30.05	21.063	1.427 ’
l_{31}	$\log(gdpc)_{t-1}$	-0.104	0.056	-1.853 *	0.024	0.102	0.232
l_{32}	$\log(u5sr)_{t-1}$	2.412	1.123	2.147 **	4.35	1.888	2.304 **
l_{33}	$\log(pscr)_{t-1}$	-0.345	0.113	-3.054 ***	-0.39	0.138	-2.834 ***
k_3	$\log(sepn)_{t-1}$	0.019	0.178	0.104			
	$\log(gser)_{t-1}$				-0.032	0.165	-0.196
	No. Obs.	291			342		
	DoF	270			321		
	Log.Lik	717			656		
	AIC	-1390			-1268		

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

Table 2. Estimation results Model II

		Model IIa			Model IIb		
		Coef.	**SE**	**t-val.**	**Coef.**	**SE**	**t-val.**
SoL	**Equation**	$\boldsymbol{\Delta}\log(\mathbf{hceh})_\mathbf{t}$			$\boldsymbol{\Delta}\log(\mathbf{hceh})_\mathbf{t}$		
c_{10}	$Intercept$	11.217	21.686	0.517	8.319	15.025	0.554
c_{12}	$\Delta\log(u5sr)_t$	-22.983	30.057	-0.765	-21.597	24.539	-0.88
c_{13}	$\Delta\log(pscr)_t$	0.988	1.32	0.749	1.004	1.099	0.914
l_{11}	$\log(hceh)_{t-1}$	0.005	0.097	0.048	-0.05	0.152	-0.329
l_{12}	$\log(u5sr)_{t-1}$	-1.771	3.38	-0.524	-1.319	2.376	-0.555
l_{13}	$\log(pscr)_{t-1}$	0.262	0.325	0.804	0.273	0.275	0.993
k_1	$\log(rptp)_{t-1}$	0.001	0.211	0.005			
	$\log(manh)_{t-1}$				0.027	0.126	0.21
Hea	**Equation**	$\boldsymbol{\Delta}\log(\mathbf{u5sr})_\mathbf{t}$			$\boldsymbol{\Delta}\log(\mathbf{u5sr})_\mathbf{t}$		
c_{20}	$Intercept$	0.493	1.05	0.469	0.415	0.397	1.046
c_{21}	$\Delta\log(hceh)_t$	-0.043	0.192	-0.221	-0.037	0.03	-1.227
c_{23}	$\Delta\log(pscr)_t$	0.043	0.071	0.604	0.042	0.025	1.684 $\star$
l_{21}	$\log(hceh)_{t-1}$	0	0.005	0.036	-0.001	0.003	-0.283
l_{22}	$\log(u5sr)_{t-1}$	-0.078	0.151	-0.515	-0.066	0.063	-1.045
l_{23}	$\log(pscr)_{t-1}$	0.011	0.031	0.367	0.011	0.009	1.178
k_2	$\log(dpti)_{t-1}$	0	0.021	0.005	0.001	0.006	0.188
Edu	**Equation**	$\boldsymbol{\Delta}\log(\mathbf{pscr})_\mathbf{t}$			$\boldsymbol{\Delta}\log(\mathbf{pscr})_\mathbf{t}$		
c_{30}	$Intercept$	-11.165	35.423	-0.315	-9.119	7.606	-1.199
c_{31}	$\Delta\log(hceh)_t$	1.071	11.284	0.095	0.707	1.053	0.672
c_{32}	$\Delta\log(u5sr)_t$	23.463	39.14	0.599	20.793	10.478	1.984 $\star$
l_{31}	$\log(hceh)_{t-1}$	-0.005	0.085	-0.054	0.016	0.077	0.213
l_{32}	$\log(u5sr)_{t-1}$	1.766	4.79	0.369	1.437	1.181	1.217
l_{33}	$\log(pscr)_{t-1}$	-0.261	0.676	-0.386	-0.292	0.166	-1.756 $\star$
k_3	$\log(sepn)_{t-1}$	-0.009	1.684	-0.005	0.05	0.254	0.196
	No. Obs.	234			231		
	DoF	213			210		
	Log.Lik	861			551		
	AIC	-1679			-1058		

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

Table 3. Estimation results Model III

		Model IIIa			Model IIIb		
		Coef.	SE	t-val.	Coef.	SE	t-val.
SoL Equation		$\mathbf{\Delta}\log(\mathbf{tpec})_\mathbf{t}$			$\mathbf{\Delta}\log(\mathbf{tpec})_\mathbf{t}$		
c_{10}	$Intercept$	-14.234	53.519	-0.266	-16.691	29.248	-0.571
c_{12}	$\Delta\log(u5sr)_t$	7.693	49.365	0.156	21.473	32.635	0.658
c_{13}	$\Delta\log(pscr)_t$	-0.114	2.477	-0.046	-0.48	1.447	-0.332
l_{11}	$\log(tpec)_{t-1}$	-0.025	0.16	-0.158	0.069	0.051	1.356 '
l_{12}	$\log(u5sr)_{t-1}$	2.19	8.366	0.262	2.541	4.581	0.555
l_{13}	$\log(pscr)_{t-1}$	-0.086	0.872	-0.099	-0.244	0.558	-0.437
k_1	$\log(eman)_{t-1}$	-0.092	0.075	-1.228	-0.069	0.083	-0.837
Hea Equation		$\mathbf{\Delta}\log(\mathbf{u5sr})_\mathbf{t}$			$\mathbf{\Delta}\log(\mathbf{u5sr})_\mathbf{t}$		
c_{20}	$Intercept$	1.164	0.268	4.348 ***	0.832	0.249	3.348 ***
c_{21}	$\Delta\log(tpec)_t$	0.01	0.036	0.281	0.022	0.027	0.821
c_{23}	$\Delta\log(pscr)_t$	0.037	0.037	0.977	0.02	0.036	0.552
l_{21}	$\log(tpec)_{t-1}$	0.003	0.002	1.685 *	-0.002	0.003	-0.623
l_{22}	$\log(u5sr)_{t-1}$	-0.181	0.039	-4.572 ***	-0.127	0.042	-3.043 ***
l_{23}	$\log(pscr)_{t-1}$	0.014	0.011	1.213	0.01	0.011	0.855
k_2	$\log(dpti)_{t-1}$	0.002	0.006	0.405	0.003	0.006	0.475
Edu Equation		$\mathbf{\Delta}\log(\mathbf{pscr})_\mathbf{t}$			$\mathbf{\Delta}\log(\mathbf{pscr})_\mathbf{t}$		
c_{30}	$Intercept$	-19.878	14.386	-1.382 '	-22.992	11.983	-1.919 *
c_{31}	$\Delta\log(tpec)_t$	-0.054	0.733	-0.074	-0.288	1.004	-0.287
c_{32}	$\Delta\log(u5sr)_t$	17.822	12.01	1.484 '	25.128	18.677	1.345 '
l_{31}	$\log(tpec)_{t-1}$	-0.057	0.043	-1.326 '	0.032	0.096	0.336
l_{32}	$\log(u5sr)_{t-1}$	3.11	2.164	1.437 '	3.598	1.745	2.062 **
l_{33}	$\log(pscr)_{t-1}$	-0.39	0.111	-3.511 ***	-0.386	0.122	-3.152 ***
k_3	$\log(sepn)_{t-1}$	0.07	0.163	0.429			
	$\log(gser)_{t-1}$				-0.069	0.13	-0.526
	No. Obs.	291			324		
	DoF	270			303		
	Log.Lik	406			507		
	AIC	-768			-969		

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

Table 4. Complementarity and partial adjustment coefficients

	$a_{ij} = -l_{ij}/l_{ii}$			$a_{ij} = -c_{ij}l_{jj}/l_{ii}$			$a_{ij} = -l_{ij}/l_{ii}$			$a_{ij} = -c_{ij}l_{jj}/l_{ii}$		
	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		
	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		
	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

Table 5. Abbreviations

Short	Long name	Source
SoL	**Standard-of-living**	
$gdpc$	GDP per capita	WDI
$hceh$	Household consumption expenditures per capita	WDI
$tpec$	Total primary energy consumption	IEA
$trad$	Share of trade in total value added	WDI
$eind$	Share of industry in total value added	WDI
$eman$	Share of manufacturing in total value added	WDI
$manh$	Manufacturing value added per capita	own calculations based on $eman$
$rptp$	Share of rural population in total population	WDI
Hea	**Health**	
$u5sr$	Under-5 survival rate	own calculations based on $u5mr$
$u5mr$	Under-5 mortality rate	WDI
$life$	Life expectancy at birth	WDI
$dpti$	Immunization rate of 2-year olds against diphtheria	WDI
$immu$	Immunization rate of 2-year olds against measles	WDI
Edu	**Education**	
$pscr$	Primary school completion rate	WDI
$litr$	Literacy rate	HDRO
$sepn$	School enrollment, primary (net)	WDI
$gser$	Gross school enrollment rate, total	HDRO
WDI	*World development intdicators*	
HDRO	*UN Human Development Report Office*	
IEA	*International Energy Agency*	