

The Interaction of Human and Physical Capital Accumulation: Evidence from Sub-Saharan Africa*

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I. INTRODUCTION

While East Asian economic performance has given rise to a large literature studying its growth 'miracle,' Sub-Saharan Africa has attracted attention for exactly the opposite reason: the failure of the majority of the countries in the region to sustain per-capita income growth after the 1970s¹. Several studies of economic development in Sub-Saharan Africa (hereafter SSA) attribute low factor accumulation as a major cause of the 'growth disaster.' Collier and Gunning (1999) show that the stock of private capital per worker has fallen by twenty percent since 1980 and is now less than one half the level in South Asia, which they classify as the 'next most capital scarce region in the world'. Human capital accumulation has also been slow in SSA; average educational attainment levels are consistently lower in SSA than in other developing regions².

The problem with blaming the SSA growth disaster on meager factor accumulation is that it begs the question of why factor accumulation has been so low. To a large extent, low levels of investment are a rational response to economic and political problems in the region, such as war, inflation, closed markets with distorted exchange rates, and a general lack of infrastructure. For example, Devarajan, Easterly, and Pack (2001) claim that the investment climate is so bad in the region that one could reasonably argue that investment is too high rather than too low. From this perspective, capital accumulation may be both low and optimal, given the negative incentives that investors face in the region.

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1. See Block (2001) for an excellent analysis of African economic growth.
2. Barro and Lee (2001) report that the average years of schooling of the population over fifteen years old was only 3.52 in SSA in 2000, while it was 6.06 for the Latin American and Caribbean region, 6.71 in East Asia and Pacific, and 4.57 in South Asia.

On the other hand, factor accumulation may be lower than optimal if human and physical capital have spillover effects. That is, if a higher stock of physical capital raises the return to acquiring education, and capital owners cannot appropriate those returns, then the stock of physical capital will be under supplied from a societal perspective. Likewise, if higher levels of human capital raise the return to investing in physical capital, which in turn cannot be appropriated by those making the education decision, then human capital will be lower than the socially optimal level.

Given the lack of consistent data on the return to human and physical capital for a panel of countries in SSA, I examine the relationship between the two types of capital with data on the accumulation of capital, which can be used to make inferences about the return to capital. That is, if the return to investing in human or physical capital was low in the past, then we would expect that current levels of capital would also be low. More specifically, I estimate a simultaneous model of the evolution of human and physical capital in SSA from 1970–2000 using lagged measures of political instability, regime type, ethnic diversity, trade openness, and geography as exogenous explanatory variables³.

I show that the human and physical capital are jointly endogenous in the region: the quantity of physical capital positively and significantly affects the quantity of human capital, and the quantity of human capital positively affects the quantity of physical capital. This result indicates the possibility of spillover effects, where individual investors will not be able to appropriate the full benefit of their investment. Thus, my results imply that the low levels of investment that we observe in SSA may be perfectly optimal from the individual investor's perspective and too low from a societal one.

In addition, I build on a tradition of studies which investigate the relationship between effective institutions, policies, and subsequent economic development (some early examples include Weede 1983, Kormendi and Meguire 1985, Pourgerami 1988, Scully 1988, and Grier and Tullock 1989). I find several other interesting results. First, I find support for the hypotheses that economic and political instability are negatively related to the physical capital stock. Specifically, I show that coups d'état and inflation variability both have a negative and significant effect on the accumulation of physical capital. Second, unlike many recent papers which claim that SSA is underdeveloped because of factors like climate, location, and ethnic diversity, my results show that these variables do not have a negative effect on capital stocks. In fact, I find no significant effect of tropical climates or being land-locked on human or physical capital. In addition, I uncover a positive relationship between human capital accumulation and ethnic diversity.

3. See *Appendix 1* for a list of the countries included in the sample.

The paper is organized as follows. Section II discusses models where the accumulation of human and physical capital have important spillover effects, while Section III constructs a simultaneous model of human and physical capital for a panel of 21 SSA countries. Section IV presents GMM estimates of the model and examines the coefficient significance of the right-hand side variables and their long-run equilibrium effects on investment and education. Section V concludes.

II. THE INTERACTION OF HUMAN AND PHYSICAL CAPITAL

Many papers argue that human and physical capital are significantly related. Nelson and Phelps (1966) claim that better educated people are more likely to innovate and assimilate new technology than poorly educated ones. Fishlow (1966) argues that high education levels in the 1900s helped to speed the accumulation of physical capital and the creation of new technology in the US. More recently, Romer (1993) formalizes the argument that a more educated populace is better able to integrate new technologies.

Caballe and Santos (1993) and Graca, Saqib, and Philippopoulos (1995) demonstrate that an increase in the stock of physical capital should have a positive effect on the accumulation of human capital, since increased physical capital means human capital will be more productive in the future⁴. In Lucas (1993) and Greiner (1999), any increase in physical capital must be matched by increases in human capital in order to sustain per-capita income growth. Upadhyay (1994), while recognizing the possibility that new technology may destroy existing human capital, constructs a model where innovation increases the derived demand for new types of human capital.

Empirical work on the joint endogeneity of human and physical capital is considerably less extensive. In a cross-country regression of 78 countries, Benhabib and Spiegel (1997) find support for the Nelson and Phelps hypothesis that more educated countries grow faster. They show that increases in human capital bring about significantly higher growth in the stock of physical capital. To date, Grier (2002) is the only paper to empirically study the simultaneous determination of human and physical capital. In a panel of 21 Latin American countries from 1965–1990, Grier finds that the two types of capital are indeed jointly endogenous.

4. Caballe and Santos (1993) also discuss the possibility that increased physical capital has no effect on human capital, or even a negative effect. People may have more incentive to invest in human capital with an increased capital stock, but they also have more incentive to work, as the opportunity cost of labor has increased.

III. A SIMULTANEOUS MODEL OF HUMAN AND PHYSICAL CAPITAL IN SUB-SAHARAN AFRICA

In this section, I estimate a model of human and physical capital for 21 SSA countries from 1970–2000, using lagged measures of political instability, regime type, ethnic diversity, trade openness, and geography as exogenous explanatory variables. All variables and their sources are discussed in more detail in *Appendix 3*. Whenever possible, data are averaged into five-year intervals, which allows me to capture information from both average cross country differences and fluctuations over time⁵.

Given the strong theoretical reasons for believing that human and physical capital are jointly related, I use a GMM estimator that controls for the joint endogeneity of the two types of capital, the contemporaneous correlation of the error terms in the two equations, and heteroskedasticity. Using this estimator also allows me to test the validity of the over-identifying restrictions that I impose on the model.

As stated above, I would ideally like to use data on the returns to human and physical capital in the model. Unfortunately, there is no consistent panel data on returns to capital across countries in SSA. For that reason, I use the accumulation of both types of capital as a proxy⁶. Specifically, I measure physical capital as the per-capita stock of physical capital (in U.S. dollars), using the same methodology as Nehru and Dhareshwar (1993)⁷. The data is averaged over five-year intervals. Human capital is measured as the average years of primary schooling in the population aged fifteen and over⁸. Data on educational attainment is from Barro and Lee (2001), which are available every five years. Since the education data is not continuous over the thirty year sample, I take the average of the two closest observations (e.g. for the period 1970–74, education is measured as the average of 1970 and 1975 levels).

5. See Grier and Tullock (1989) for a justification of using 5 year intervals instead of averaging over long periods.
6. If the return to human or physical capital increases, then we would expect the accumulation of that type of capital to also increase.
7. Nehru and Derwarshwar (1998) present a method of estimating the stock of physical capital and provide estimates for a panel of 92 countries. Unfortunately, matching their data with Barro and Lee's (2001) data on educational attainment results in observations for only fifteen SSA countries. I use their methodology and Heston, Summers and Aten's (2002) data on real GDP and investment to expand the sample to 25 countries. The correlation coefficient between my capital stock data and the Nehru and Derwarshwar data is .74.
8. Berthélemy and Söderling (2001), in a study on capital accumulation and economic take-off in Africa, emphasize the role of primary education since it makes up over 90 percent of total educational attainment in the region. Likewise, in my sample, over 80 percent of total education consists of primary schooling.

In the paragraphs below, I discuss the various independent variables used in the specification and identification issues involved in estimating the model.

1. Political and Economic Instability

The literature on economic development provides many reasons for why capital stocks are so low in SSA. One of the largest deterrents to the accumulation of physical capital is thought to be the prevalence of political and economic instability in the area⁹. Since investments are often irreversible, investors will want to delay undertaking any new investment during periods of uncertainty¹⁰. As Collier and Gunning (1999) document, there are very few secondary markets for capital goods, making investments even more irreversible in Africa than other developing regions. Empirically, Berthélemy and Söderling (2001) show that political instability, as measured by the number of coups and revolutions, negatively and significantly affects investment levels in Africa, although this significance disappears when they control for total factor productivity.

The empirical evidence on a relationship between political instability and education levels is more mixed. For instance, Fedderke and Klitgaard (1998) find that regime-threatening political instability is negatively correlated with education levels, while non-regime threatening instability is positively correlated with education. The rank correlation between regime threatening political instability and education ranges from -0.21 to -0.65 , while the correlation between non-regime threatening instability and educations ranges from 0.20 to 0.61 .

I construct two dummy variables to measure political instability. The first is a dummy equal to one if the country has experienced a coup d'état in the previous five year period and zero if not. The second dummy is equal to one if a country has been at war in the previous five year period and equal to zero if there has been no civil war. I measure economic instability as the average standard deviation of inflation in the previous five years. As the theoretical literature

9. Fischer (1991, 1993) finds that unstable macro environments, evidenced by inflation and inflation variability, budget deficits, and black market premiums, significantly reduce economic growth by lowering investment and productivity. Easterly (2003), on the other hand, argues that macroeconomic policy is probably only economically harmful at extreme levels and that moderate rates of inflation and budget deficits are not very correlated with real GDP growth. See Tabellini (2005) for an excellent survey of the role of policy and institutions in economic development.
10. See McDonald and Siegel (1986), Majd and Pindyck (1987), Bernanke (1983) and Cukierman (1980), Benhabib and Spiegel (1997), Edwards (1996), Gyimah-Brempong and Traynor (1996), and Alesina and Perotti (1996) for more on the negative relationship between economic performance and instability. Londregan and Poole (1990), on the other hand, find no evidence of a relationship between political instability and investment.

overwhelmingly emphasizes the relationship between instability and physical capital accumulation, and the empirical evidence of a link between instability and education is weak, I exclude these variables from the human capital equation.

2. *Trade Policy*

A general lack of openness of SSA markets to international trade may also help explain the low level of physical capital in the sample countries. In support of Bloom and Sach's (1998) claim that trade openness is important to economic development in the SSA region, Collier (1998) argues that African regimes have hindered international trade both directly, with explicit barriers and exchange rate policies, and indirectly by failing to invest in the infrastructure that would facilitate trade¹¹.

There is less evidence that trade openness directly affects the accumulation of human capital. Sachs and Warner (1995) find no significant relationship between closed economies and primary education levels, and Harrison (1996) argues that any relationship between trade policy and education is not robust. For this reason, I do not include the measure of openness (the average ratio of exports and imports to GDP in the previous five year period) in the human capital equation.

3. *Democracy*

Just as the relationship between instability and development has been widely researched, so has the potential link between government type and development. Specifically, much work has been done on whether democracy is significantly related to growth, especially through its effect on education rates. One reason for this focus on education and democracy is the problem that much of the empirical work on economic growth and democracy finds a negative relationship between the two. Giavazzi and Tabellini (2004) argue that the sequencing of political and economic reforms is important and that countries that tackle economic liberalization before political liberalization perform better than those that democratize first. In addition, Helliwell (1994) argues that a negative relationship between democracy and subsequent economic growth may be at least partially offset by democracy's positive effect

11. Frankel and Romer (1999) and Alesina, Spolaore, and Wacziarg (2004) find a positive relationship between trade and economic growth, while Wacziarg and Welch (2003) and Giavazzi and Tabellini (2004) show that trade liberalization results in more trade and high levels of investment. Rodriguez and Rodrik (2001), on the other hand, find no significant empirical relationship between trade integration and capital accumulation in a panel of 80 countries.

on education levels. He finds that democracy in 1960 is a positive and significant determinant of subsequent education rates.

Along the same lines, Barro (1996) argues that democracy may influence growth indirectly through the promotion of female education, which in turn tends to reduce fertility rates and raise per-capita income growth¹². Fedderke and Klitgaard (1998) show a positive correlation between the level of education and democracy that ranges from 0.22 to 0.80, depending on how democracy is measured. To investigate the relationship between democracy and human capital accumulation, I construct a dummy variable for countries with high levels of democracy in the previous five year period. As the relationship between democracy and capital accumulation seems to be primarily through the education, I do not include this variable in the physical capital equation.

4. *Ethnic Heterogeneity*

Ethnic diversity is often hypothesized to have a negative effect on the provision of education and on development in general. While homogeneous societies with a common language and culture may agree more easily on the provision of schooling, it is unlikely that more diversity has a monotonically negative effect on education¹³. It may be easier to reach consensus about educational goals in societies that are on either end of the diversity spectrum; that is, countries which are extremely homogeneous or extremely heterogeneous. In the case of high diversity societies, it may be that no single ethnic group is large enough to dominate, and decisions have to be made by compromises between groups. Such decisions are more likely to be inclusive of other groups than decisions made where a dominant ethnic group can impose its will on educational policy.

The effect of ethnic diversity on the overall growth and development is less clear cut. Lian and Oneal (1997), in a study 98 countries for the period 1960–1985, find no relationship between ethno-linguistic diversity and per-capita income growth. More recently, Nettle (2000) finds a negative relationship between linguistic heterogeneity and economic development, but argues that there is no strong evidence that one directly causes the other.

When we also control for political instability in the form of coups and war, ethnic diversity is more likely to have a direct impact on education than on the

12. From a theoretical perspective, Saint-Paul and Verdier (1993) construct a model where democratization leads to more income redistribution, which results in increased expenditures on public education. On a negative note, Barro (1996) finds no significant support for a relationship between education, fertility, and democracy in a sample of 100 countries.

13. Alesina, Baqir, and Easterly (1997) show in a sample of U.S. cities that ethnically divided communities are less likely to agree on the location of schools and the language of instruction, with the end result being less public schooling. Easterly and Levine (1997), in a study of GDP growth in SSA, show that more diverse countries also have lower average levels of education.

accumulation of physical capital. To study the effect of diversity on capital accumulation, I use data from Posner (2004) to construct three dummy variables representing countries with high, medium, and low levels of diversity¹⁴. Posner's measure of diversity improves on earlier measures in that it uses more than just language to define ethnicity and also moves over time¹⁵.

5. *Geography and Colonial History*

Bloom and Sachs (1998) argue that variables such as climate and location have important effects on disease and child mortality rates, agricultural productivity, openness to external trade, and economic growth¹⁶. To control for such geographic factors, I create two dummy variables: one for countries which are landlocked and one for those with tropical climates. Finally, Grier (1999) shows that British colonies in SSA had higher stocks of human capital at the time of independence than colonies of other European countries¹⁷. I control for this colonial effect by including a dummy variable for countries which were once British colonies.

IV. RESULTS

1. *Model Specification Tests*

One of the difficulties in estimating any simultaneous system, and especially one where the two dependent variables are different types of capital, is finding variables to identify the system (that is, variables that are correlated with one dependent variable but not the other). As discussed above, theory suggests that economic and political instability and trade openness would affect physical capital in a more direct fashion than human capital, while colonial history and ethnic diversity might directly affect the stock of human, but not physical, capital. So, the key over-identifying assumptions of the model are that instability and trade openness affect the stock of physical capital but not

14. The high (low) dummy is equal to one for countries with diversity rankings that are one standard deviation above (below) the sample average.
15. Most other papers in the growth literature use the Soviet measure (ELF) developed in the 1960s, which means that my findings on the relationship between ethnic diversity and education will not be strictly comparable. On the other hand, the benefits of using Posner's variable over the problematic ELF are numerous. See Posner (2004) for a critique of ELF and other commonly used measures of diversity and a more detailed description of PREG (Politically Relevant Ethnic Groups).
16. Rodrik, Subramanian, and Trebbi (2002) argue instead that geography plays at best an indirect role in economic development.
17. See Acemoglu, Johnson, and Robinson (2001) for an excellent study of colonialism and subsequent development.

educational attainment, while colonial history and ethnic diversity directly affect the stock of human, but not physical, capital.

Since GMM minimizes a criterion function that is itself a function of the correlation between the instruments and the errors of the equation, I can construct a test of the overall validity of the over identifying restrictions in each model. The minimized value of the GMM criterion function times the sample size is distributed as a χ^2 with degrees of freedom equal to the number of over identifying restrictions. Model 1 of *Table 1* presents the results of an initial estimation, while Model 2 re-estimates the system of equations with the exclusion of insignificant variables (defined as ones with a t-statistic below 1.0). The calculated test statistics, which are provided at the bottom of the estimations, indicate that I cannot reject the null hypothesis that the over identifying restrictions are valid in either model, even at the 0.10 level¹⁸. While over identifying restrictions are always to a certain degree debatable, the data do not reject the validity of the restrictions I impose on the model.

2. Coefficient Signs and Significance

The results of Model 1 show that human and physical capital are jointly endogenous. The per capita stock of physical capital is a positive and significant determinant of educational attainment at the 0.05 level, and education is a positive and significant determinant of physical capital at the 0.01 level¹⁹. This result has important implications for policymakers, since policies which stimulate investment in human capital will also affect physical capital (and vice versa).

I find that economic and political instability negatively affects the accumulation of physical capital. The coefficient on lagged inflation variability is negative and significant at the 0.01 level, while the coefficient on lagged *coups d'état* is negative but only significant at the 0.10 level. The variable representing lagged civil war is negative but not significant at any conventional level²⁰. The finding of a negative relationship between coups and physical capital is similar

18. There are 8 over identifying restrictions in Model 1 and the critical value at the 0.10 level is 13.36. See Greene (2000, p. 302) for a good description of the test (variously called a J-test, Sargan test, or a Hansen test).

19. It is important to note that the results are also not sufficient to prove that the accumulation of human and physical capital has external effects. It is possible that returns are fully internalized and the two forms of capital still positively affect one another. Since it is unlikely that the entrepreneur investing in physical capital is the same person who is deciding to invest in new human capital, it is probably safe to assume that there are externalities involved in factor accumulation.

20. A simple correlation test between the variables representing civil war and democracy show the two to be highly negatively correlated. When the democracy variable is removed from the physical capital equation, the coefficient on lagged civil war becomes negative and significant at the 0.05 level.

Table 1

Simultaneous models of human and physical capital in Sub-Saharan Africa

Variable	Model 1		Model 2	
	<i>Physical Capital</i>	<i>Human Capital</i>	<i>Physical Capital</i>	<i>Human Capital</i>
Constant	6.74 (20.9)	-1.24 (1.8)	6.69 (28.9)	-1.47 (2.7)
Log (Human Capital)	0.47 (2.0)	*	0.49 (2.4)	*
Log (Physical Capital)	*	0.19 (1.8)	*	0.22 (2.9)
Lag (Standard Deviation of Inflation)	-1.57 (2.4)	*	-1.56 (3.1)	*
Lag (war dummy)	-0.42 (1.1)	*	-0.36 (1.1)	*
Lag (coup dummy)	0.41 (1.7)	*	0.42 (2.1)	*
Lag of openness	0.01 (1.9)	*	0.007 (0.93)	*
Lag (democracy dummy)	0.90 (3.8)	0.14 (0.7)	0.93 (3.4)	*
Lag (High diversity dummy)	*	0.68 (4.9)	*	0.63 (4.7)
Lag (Low diversity dummy)	*	-0.05 (0.3)	*	*
British colony dummy	*	0.92 (5.2)	*	0.87 (5.3)
Climate dummy	-0.008 (0.0)	-0.08 (0.8)	*	*
Landlocked dummy	-0.005 (0.0)	0.05 (0.4)	*	*
R ²	0.492	0.679	0.492	0.680
N, J-test	125, 0.0738		125, 0.0552	

Notes: The numbers in parentheses are t-statistics. Time dummies were estimated in both equations, but are not reported for reasons of space. The number reported for the J-test is the minimized value of the GMM criterion function times the sample size. It is distributed as a χ^2 with degrees of freedom equal to the number of over-identifying restrictions. The critical value at the .10 level for 3 degrees of freedom is 6.25.

to the results in Grier (2002), who shows that both coups and civil war have a strong negative effect on the accumulation of physical capital in Latin America.

Unlike Grier (2002) though, who reports a statistically insignificant relationship between trade openness and physical capital in Latin America, the coefficient on lagged openness in Model 1 is positive and significant at the 0.05 level, indicating that SSA countries which have opened their economies in the past have higher subsequent stocks of physical capital than closed-economy countries.

I do not find evidence that high levels of ethnic diversity reduce the accumulation of human capital. Specifically, Model 1 shows that the dummy variables representing high diversity are positive and significant at the 0.01 level, while the low diversity dummy is insignificantly different from zero. Thus,

the results indicate that high diversity countries (such as Cameroon, Kenya, Malawi, and Uganda) will have higher educational levels than averagely diverse countries, *ceteris paribus*²¹.

Like Grier (1999), who showed that ex-British colonies had higher education levels on average, I find that the British colonial dummy is positively and significantly related to primary educational attainment at the 0.01 level.

Democracy has a direct and significant effect on the stock of physical capital in SSA. The coefficient on lagged democracy is positive and significant at the 0.01 level in the physical capital equation, meaning that countries which have had more experience with democracy also have higher stocks of per-capita physical capital. Unlike Grier's (2002) finding that past democratic experience is positively and significantly related to primary educational attainment in Latin America, I find that the democracy dummy is positive but insignificant in the human capital equation.

Model 1 also shows that the geographic dummies (representing tropical climates and land-lockedness) are not significantly related to the accumulation of either physical or human capital. This result supports Rodrik, Subramanian, and Trebbi (2002), who argue that geography does not have a direct, significant effect on economic development, and to a certain extent, Grier (2002), who shows that these geographic variables do not have a direct negative effect on the accumulation of physical capital.

Model 2 shows the results of estimating the system of equations without the insignificant variables. Specifically, the geographic variables are dropped from both equations, while the low diversity dummy and the lagged democracy dummy are eliminated from the human capital equation. In this pared down system, I find even stronger support for the argument that human and physical capital are jointly endogenous. The per capita stock of physical capital is a positive and significant determinant of educational attainment at the 0.01 level, and education is a positive and significant determinant of physical capital at the 0.01 level. Many of the other independent variables are also more statistically significant. Lagged inflation variability and lagged openness are now related to the accumulation of physical capital at the 0.01 level, while the lagged coup variable is significant at the 0.05 level.

3. *Equilibrium Quantitative Effects*

Since human and physical capital are jointly determined in my model, any right-hand side variable has a direct effect on at least one type of capital and either a direct or indirect effect on the other. That is, even though the civil war

21. I employ a different measure of ethnic diversity than Alesina, Baqir, and Easterly (1997) and Easterly and Levine (1997), so the results reported here are not directly comparable.

variable is not included in the education equation, it still affects education levels through its effect on the stock of physical capital. To properly measure the long-term equilibrium effects of all of the exogenous variables on human and physical capital, I calculate the structural reduced-form of the model. All quantitative effects discussed below are constructed using the coefficients of model 2.

While democracy was not statistically significant in the human capital equations above, it does have a long run economic effect on education levels. Democracy has a strong quantitative effect on the stock of physical capital, which in turn raises the stock of human capital. More specifically, countries in the high democracy grouping have 93% higher stocks of physical capital on average (and 23% higher stocks of human capital) than countries with less democracy, *ceteris paribus*.

Economic and political instability also have important quantitative effects on the accumulation of capital. Countries which have experienced at least one coup in the previous 5 year period have 42% lower average stock of physical capital, *ceteris paribus*, than countries with no *coup d'état*. The indirect effect of instability on human capital is weaker: countries which have had coups have 10% lower stocks of human capital. The results also show that an increase in inflation variability by one standard deviation is associated with a 20.3% lower stock of physical capital and a 5% lower stock of human capital, *ceteris paribus*.

Ethnic diversity and a British colonial heritage both have strong and direct quantitative effects on the accumulation of human capital. Specifically, countries with high ethnic diversity have levels of primary education that are 51% higher than less diverse countries while ex-British colonies have 82% higher educational attainment on average than the other countries in the sample, *ceteris paribus*²².

These variables also have an indirect effect on physical capital accumulation through their initial effect on education. Countries with high levels of ethnic diversity have 34.5% higher stocks of physical capital, on average, than less diverse countries, while ex-British colonies have 48% higher physical capital accumulation than other countries.

V. DISCUSSION

The relationship between human and physical capital is complex. Some argue that increases in physical capital should significantly increase the accumulation

22. The average years of primary school attainment for former British colonies is 2.47, while it is only 1.03 for the other countries in the sample.

of human capital, while others argue the reverse; namely, that increases to human capital raise the level of physical capital. Very few theoretical or empirical papers model the accumulation of the two types of capital jointly. I test and find in a panel of SSA countries that human and physical capital are jointly endogenous in the region, indicating that increases to the stock of human capital raise the level of physical capital, and vice versa. This is an important finding for both the academic literature on capital accumulation and for policymakers in SSA. With respect to the literature, my results indicate that the two forms of capital should be modelled in a simultaneous system. Theoretical and empirical models which focus solely on the effect of one type of capital or the other may be mis-specified.

The implications of the findings are also important for policymakers. Governments can work to break the vicious circle of low capital accumulation by stimulating private investment in human or physical capital. Any policy that increases educational levels will do more than raise the overall skill level of the society, but will also have a positive effect on the stock of physical capital.

The results are also optimistic in what they do not show. That is, many recent papers argue that climate and geography, the ultimate in exogenous factors, are important reasons for the low incomes of the region. However, I find no evidence that geography has a negative impact on the evolution of either type of capital.

Further work could investigate other ways in which governments in the region can provide the incentives for private investors to accumulate human or physical capital. One example is the effect of political stability on capital accumulation. My results indicate a potentially large dividend to stability for the region, as the incidence of coups d'état significantly lower the stock of physical capital, which in turn lowers primary educational levels.

APPENDIX 1 COUNTRIES IN THE SAMPLE

Benin	Malawi	Sierra Leone
Botswana	Mali	South Africa
Cameroon	Mauritius	Togo
Central African Republic	Mozambique	Uganda
Ghana	Niger	Congo, Democratic Republic
Kenya	Rwanda	Zambia
Lesotho	Senegal	Zimbabwe

APPENDIX 2 SUMMARY STATISTICS

Variable	Mean	Standard Deviation
Log of human capital	0.38	0.76
Log of physical capital	7.32	1.17
Lag (standard deviation of inflation)	0.09	0.13
Lag (war dummy)	0.10	0.29
Lag (democracy dummy)	2.03	3.23
Lag (openness)	66.6	37.3
Lag (ethnic diversity)	0.43	0.22
British colony dummy	0.57	0.49
Lag (coup dummy)	0.19	0.39
Climate dummy	0.52	0.50
Landlocked dummy	0.48	0.50

APPENDIX 3 VARIABLE DESCRIPTION AND SOURCES

Physical Capital the log of per capita stock of physical capital (Nehru and Dhareshwar 1993, Heston, Summers, and Aten 2002).

Human Capital the log of the average years of primary schooling in the population age fifteen and over (Barro and Lee 2001).

War dummy variable equal to one if a country was at war during the five-year period (war is defined by Azam and Hoeffler as 'internal wars which resulted in at least 1,000 battle related deaths per year'.) (Azam and Hoeffler 2002, Small and Singer 1982, Collier and Hoeffler 2004).

Coups equal to one if there was a coup d'état in five-year period (Bates 2000, Banks 1994).

Standard Deviation of Inflation equal to the standard deviation of inflation over five-year period (Heston, Summers, and Aten 2002).

Open equal to exports + imports as a percentage of GDP; averaged over five-year period (Heston, Summers, and Aten 2002).

Tropical equal to one if a country is predominantly tropical (CIA Factbook 2001).

Landlocked equal to one if a country has no ocean coastline (CIA Factbook 2001).

British equal to one if the country is an ex-British colony (CIA Factbook 2001).

Democracy equal to one for countries which averaged an eight or higher on democracy Ranking (Azam and Hoeffler 2002, Jagers and Gurr 1995).

Diversity a measure of ethnic diversity for forty-two Sub-Saharan African countries from 1960–1990; 1990 figures are used for the 1990–2000 period (Posner 2004).

REFERENCES

- Acemoglu, Daron, Simon Johnson and James A. Robinson (2001). The Colonial Origins of Comparative Development: An Empirical Investigation, *American Economic Review*. 91: 1369–1401.
- Alesina, Alberto, Reza Baqir and William Easterly (1997). Public Goods and Ethnic Divisions, *Quarterly Journal of Economics*. CXIV: 1243–1284.
- Alesina, Alberto and Roberto Perotti (1996). Income Distribution, Political Instability, and Investment, *European Economic Review*. 40: 1203–1228.
- Alesina, Alberto, Enrico Spolaore and Romain Wacziarg (2004). Trade, Growth, and the Size of Countries, in: Philippe Aghion and Steven Durlauf (eds.), *Handbook of Economic Growth*. Amsterdam: North Holland.

THE INTERACTION OF HUMAN AND PHYSICAL CAPITAL ACCUMULATION

- Azam, Jean-Paul and Anke Hoeffler (2002). Violence Against Civilians in Civil Wars: Looting or Terror?, *Journal of Peace Research*. 39: 461–485.
- Banks, Arthur S. (1994). Cross-National Time-Series Data Archive. Center for Social Analysis, State University of New York at Binghamton. Binghamton, New York. <http://www.databanks.sitehosting.net>.
- Barro, Robert J. (1996). Democracy and Growth, *Journal of Economic Growth*. 1: 1–27.
- Barro, Robert and Jong-Wha Lee (2001). International Data on Educational Attainment, *Oxford Economic Papers*. 3: 541–563.
- Bates, Robert (2000). African Research Program, Harvard University, Boston, MA. <http://www.gov.harvard.edu/research/rbates/>.
- Benhabib, Jess and Mark Spiegel (1997). Growth and Investment Across Countries: Are Primitives All that Matter? Working paper. New York University.
- Bernanke, Ben (1983). Irreversibility, Uncertainty and Cyclical Investment, *Quarterly Journal of Economics*. 98: 85–106.
- Berthélemy, Jean-Claude and Ludvig Söderling (2001). The Role of Capital Accumulation, Adjustment and Structural Change for Economic Take-Off: Empirical Evidence from African Growth Episodes, *World Development*. 29: 323–343.
- Block, Steven A. (2001). Does Africa Grow Differently?, *Journal of Development Economics*. 65: 443–467.
- Bloom, David E. and Jeffrey D. Sachs (1998). Geography, Demography, and Growth in Africa, *Brookings Papers on Economic Activity*. 2: 207–289.
- Caballe, Jordi and Manuel S. Santos (1993). On Endogenous Growth with Physical and Human Capital, *Journal of Political Economy*. 101: 1042–1067.
- Central Intelligence Agency (CIA), The World Factbook 2001 (Washington D.C.), <http://www.cia.gov/cia/publications/factbook/>.
- Collier, Paul (1998). Comment, *Brookings Papers on Economic Activity*. 2: 207–289.
- Collier, Paul and Jan Willem Gunning (1999). Explaining African Economic Performance, *Journal of Economic Literature*. XXXVII: 64–111.
- Collier, Paul and Anke Hoeffler (2004). Greed and Grievance in Civil War, *Oxford Economic Papers*. 56: 363–595.
- Cukierman, Alex (1980). The Effects of Uncertainty on Investment under Risk Neutrality with Endogenous Information, *Journal of Political Economy*. 88: 462–475.
- Devarajan, Shatayanan, William R. Easterly and Howard Pack (2001). Is Investment in Africa Too High or Too Low? Macro and Micro Evidence, *Journal of African Economies*. 10: 81–108.
- Easterly, William R. (2003). *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics*. Cambridge: MIT Press.
- Easterly, William R. and Levine Ross (1997). Africa's Growth Tragedy: Policies and Ethnic Divisions, *Quarterly Journal of Economics*. 112: 1203–1250.
- Edwards, Sebastian (1996). Why Are Latin America's Savings Rates So Low? An International Comparative Analysis, *Journal of Development Economics*. 51: 5–44.
- Fedderke, Johannes and Robert Klitgaard (1998). Economic Growth and Social Indicators: An Exploratory Analysis, *Economic Development and Cultural Change*. 46: 455–489.
- Fischer, Stanley (1991). Macroeconomics, Development, and Growth, in: Olivier Jean Blanchard and Stanley Fischer (eds.), *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press for NBER, 392–364.
- Fischer, Stanley (1993). The Role of Macroeconomic Factors in Growth, *Journal of Monetary Economics*. 32: 485–512.
- Fishlow, Albert (1966). The Common School Revival: Fact or Fancy?, in: Rosovsky Henry (ed.), *Industrialization in Two Systems*. New York, NY: Wiley.

- Frankel, Jeffrey and David Romer (1999). Does Trade Cause Growth?, *American Economic Review*. 89: 379–399.
- Freeman, Richard and David Lindauer (1999). Why Not Africa?, NBER Working Paper No. 6942.
- Giavazzi, Francesco and Guido Tabellini (2004). Economic and Political Liberalizations. Working Paper, IGER.
- Graça, Job, Jafarey Saqib and Apostolis Philippopoulos (1995). Interaction of Human and Physical Capital in a Model of Endogenous Growth, *Economics of Planning*. 28: 93–118.
- Greene, William H. (2000). *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall.
- Greiner, Alfred (1999). Endogenous Growth Through Externalities of Investment: A Different Approach, *Atlantic Economic Journal*. 27: 86–90.
- Grier, Kevin B. and Gordon Tullock (1989). An Empirical Analysis of Cross-National Economic Growth: 1951–1980, *Journal of Monetary Economics*. 24: 259–276.
- Grier, Robin M. (1999). Colonial Legacies and Economic Growth, *Public Choice*. 98: 317–335.
- Grier, Robin M. (2002). On the Interaction of Human and Physical Capital in Latin America, *Economic Development and Cultural Change*. 50: 891–913.
- Gurr, Ted Robert, Keith Jagers and Will H. Moore (1991). The Transformation of the Western State: The Growth of Democracy, Autocracy, and State Power since 1800, in: Alex Inkeles (ed.), *On Measuring Democracy: Its Consequences and Concomitants*. New Brunswick, CT: Transaction Publishers.
- Gyimah-Brempong, Kwabena and Thomas L. Traynor (1996). Political Instability and Savings in Less Developed Countries: Evidence from Sub-Saharan Africa, *Journal of Development Studies*. 32: 695–714.
- Harrison, Ann (1996). Openness and Growth: A Time Series-Cross Country Analysis for Developing Countries, *Journal of Development Economics*. 48: 419–447.
- Helliwell, John F. (1994). Empirical Linkages between Democracy and Economic Growth, *British Journal of Political Science*. 24: 225–248.
- Heston, Alan, Robert Summers and Bettina Aten (2002). Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP).
- Jagers, Keith and Ted R. Gurr (1995). Tracking Democracy's Third Wave with the Polity III Data, *Journal of Peace Research*. 32: 469–482.
- Kormendi, Roger C. and Philip G. Meguire (1985). Macroeconomic Determinants of Growth: Cross-Country Evidence, *Journal of Monetary Economics*. 16: 141–163.
- Lian, Brad and John R. Oneal (1997). Cultural Diversity and Economic Development: A Cross-National Study of 98 Countries, 1960–1985, *Economic Development and Cultural Change*. 46: 61–78.
- Londregan, John and Keith Poole (1990). Poverty, the Coup Trap, and the Seizure of Executive Power, *World Politics*. 42: 151–183.
- Lucas, Robert E. (1993). Making a Miracle, *Econometrica*. 61: 251–272.
- Majd, Saman and Robert S. Pindyck (1987). Time to Build, Option Value, and Investment Decisions, *Journal of Financial Economics*. 18: 7–27.
- McDonald, Robert and Daniel R. Siegel (1986). The Value of Waiting to Invest, *Quarterly Journal of Economics*. 101: 707–728.
- Nehru, Vikram and Ashok Dhareshwar (1993). A New Database on Physical Capital Stock: Sources, Methodology and Results, *Revista de Análisis Económico*. 8: 37–59.
- Nelson, Richard R. and Edmund S. Phelps (1966). Investment in Humans, Technological Diffusion, and Economic Growth, *American Economic Review*. 56: 69–75.
- Nettle, Daniel (2000). Linguistic Fragmentation and the Wealth of Nations: The Fishman-Pool Hypothesis Reexamined, *Economic Development and Cultural Change*. 48: 335–348.
- Posner, Daniel (2004). Measuring Ethnic Fractionalization in Africa, *American Journal of Political Science*. 48: 849–863.

THE INTERACTION OF HUMAN AND PHYSICAL CAPITAL ACCUMULATION

- Pourgerami, Abbas (1988). The Political Economy of Development: A Cross-National Causality Test of Development-Democracy-Growth Hypothesis, *Public Choice*. 58: 123–141.
- Rodriguez, Francisco and Dani Rodrik (2001). Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence, in: Ben Bernanke and Kenneth S. Rogoff (eds.), *Macroeconomics Annual 2000*. Cambridge, MA: MIT Press for NBER.
- Rodrik, Dani, Arvind Subramanian and Francesco Trebbi (2002). Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development. NBER Working Paper No. 9305.
- Romer, Paul (1993). Idea Gaps and Object Gaps in Economic Development, *Journal of Monetary Economics*. 32: 543–573.
- Sachs, Jeffrey D. and Andrew Warner (1995). Economic Reform and the Process of Global Integration, *Brookings Papers on Economic Activity*. 1: 1–95.
- Saint-Paul, Gilles and Thierry Verdier (1993). Education, Democracy and Growth, *Journal of Development Economics*. 42: 399–407.
- Scully, Gerald W. (1988). The Institutional Framework and Economic Development, *Journal of Political Economy*. 96: 652–662.
- Small, Melvin and J. David Singer (1982). *Resort to Arms: International and Civil Wars, 1816–1980*. Beverly Hills, CA: Sage Publications.
- Tabellini, Guido (2005). The Role of the State in Economic Development, *Kyklos*. Vol. 58, No. 2, 283–303.
- Upadhyay, Mukti P. (1994). Accumulation of Human Capital in LDCs in the Presence of Unemployment, *Economica*. 61: 355–378.
- Wacziarg, Romain and Karen Horn Welch (2003). Trade Liberalizations and Growth: New Evidence. NBER Working Paper No. 10152.
- Weede, Erich (1983). The Impact of Democracy on Economic Growth: Some Evidence from Cross-National Analysis, *Kyklos*. 36: 21–39.

SUMMARY

In this paper, a simultaneous model of the evolution of human and physical capital in Sub-Saharan Africa is estimated. It can be shown that the two types of capital are jointly endogenous, in that increases in human capital significantly raise the per-worker physical capital stock, and increases in the physical capital significantly raise primary education levels. Unlike the implications of other recent papers, there is no evidence that tropical climates and ethnic diversity have a negative effect on the accumulation of capital in the region.