Paper I

A Resource-Based Approach to Development Policy Analysis A Cross-Country Analysis

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Abstract

Development is a complex transformation process. Some countries undergo such process rapidly and successfully, while others do not. We apply a resource-based approach to the analysis of growth and development, with the aim of understanding differences in growth patterns across countries and indentifying effective policies to stimulate growth. Based on existing theory and empirical evidence, we identify a set of key resources for growth, and develop a database for such resources covering 100 countries for the period 1960-2005. We then divide the countries into six groups based on their initial output and growth performance, and develop a System Dynamics model that provides a resource-based, endogenous explanation of differences in performance across groups. Results indicate that better performance results from initial advantages in terms of output and resources, but also due to different propensity to invest in such resources. We simulate alternative policy runs retrospectively. The results indicate that areas for effective intervention differ among the different groups of countries: Investment in human capital is particularly effective in low-income countries; investment in infrastructure is most effective in high income countries; while a broader investment in all key resources is effective in the case of mid-income countries. Significant diversity exists across countries within each group. Therefore our results do not apply equally well to all the countries considered. We suggest that country-specific models be developed to support the identification of effective country-specific policies. Nevertheless, our results provide an alternative, resource-based perspective on growth and development issues, and points to some possible effective areas for interventions.

Keywords: Cross-Country Analysis, Growth, Development, Resource-Based Approach, System Dynamics, Policy Analysis.

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1. Introduction

1.1 Background and objectives

Over the last fifty years, many countries underwent dramatic socio-economic development, while in other countries we observed stagnation and even worsening of living condition (WB 2007). The strategic choices of a government can fundamentally alter a country's development path, by shifting key resources across sectors, and providing effective regulatory environments (WB 1997). The objective of this study is to analyze the possible causes of the different development performances observed across countries as seen from a resource perspective and to identify those public policies that facilitate a favorable development.

Development policy analysis aims at identifying those public sector interventions that can speed up sustainable socio-economic development in a country. In order to be effective, development policy analysis must be based on a solid understanding of the mechanisms that drive the development process. Development is inherently a process that extends across disciplines, and a highly complex one. In order to provide a broad and realistic picture of the development process, a variety of approaches, theories, and models have been developed. Each of these allows policy-makers to consider development from a different angle, with a different objective, and a different time frame. With this analysis, we aim at further enriching this variety of analytical tools by extending the resource-based approach, which has proven successful for strategic management at the firm's level, to development policy analysis.

The resource-based approach (or resource-based view) has been a fertile area of research in the field of strategic management in the private sector. Although the concept of an economic resource has been broadly used in economics, a formal analysis of the role of resources for firms' growth was first presented in 1959 (Penrose 1959). Building on this foundation, over the last twenty-five year, research on the subject has flourished, leading to a formalization of a new theory of the firm, now known as the resource-based view (RBV) (Wernerfelt 1984; Barney 1991; Peteraf 1993). Most of the research in the field has focused on the characteristics of the resources that can lead to a sustained competitive advantage and to monopoly or quasi-monopoly rents. More recently, Warren has proposed a more quantitative and dynamic perspective, focusing to the resources accumulation processes over time, and on the feedback mechanisms that drive their build-up or depletion (Warren 2002).

As for individual firms, economic performance at the country level also depends on the type and amount of strategic resources accumulated. While at the firm level, resources are generally intended as the total means available to a company for increasing production or profit, at the aggregated national level, resources are generally intended as the total means available for economic and political development (HMC 2000). Specifically, in the context of development policy analysis, we define as key resources those stocks, assets, or levels that provide fundamental services in support of economic activities. We believe that a dynamic resource-based approach, as that developed by Warren, would provide a strategic perspective on development that may serve as a basis for effective development policy analysis.

In a world in rapid development, focusing development strategies on a country's existing key resources is insufficient, and must be complemented by a dynamic perspective on resources' growth. Fierce competition and fluctuation of commodity prices may turn competitive advantages into disadvantages, and specialization into a trap that is difficult to escape (Hassink 2007). In this context, development plans need to focus not only on exploiting the existing sources of performance, but also on continuously developing them and indentifying new ones. The overall level of capital, education and health of a country, its public infrastructure and natural resources, its level of governance, among others, are strategic resources that shape its economic performance. The way such resources are created and maintained, and how this influences development, is the focus of our investigation.

After identifying, in the next section, the dynamic behavior of the issues being analyzed, the remaining of the paper provides a description of some fundamental characteristics of the resource-based approach as we apply it to the analysis of the development process; and it illustrates through a cross-country analysis the type of insights that the approach can provide. In particular, in section 2 we identify key categories of resources involved in the development process, and discuss how they contribute to production; in section 3 we introduce the key feedback mechanisms that are underlying the growth in resources and development; in section 4 we illustrate and discuss the results arising from a resource-based cross-country development analysis; and finally, in section 5 we draw some general conclusions.

1.2 A Reference mode of behavior

During the last fifty years of economic development we have witnessed incredible improvements at both country-level and on a global scale. Never before had wellbeing improved so fast for so many people, and the average levels of education and health reached so high. These improvements, perhaps unbelievable only 50 years ago, could mark our times as a golden age of human development. Nevertheless, development processes that seemed to work well in several countries did not in others, so that many today are still not enjoying such high quality of life. Our research revolves around the understanding of such processes, and of the reasons for the substantial differences in development performance across countries.

In order to have a more precise and dynamic representation of the issue being analyzed, we portray, in this section, a *reference mode* of behavior for the key variables. A reference mode is a set of descriptive data highlighting the development of the issue of interest over time (Sterman 2000). In our case, we select as primary indicator of the level of development the amount of economic output per worker. This is primarily an indicator of a country's economic performance rather than of its broader level of development. Nevertheless, given the close interrelation between economic growth and development, we consider the output per worker a satisfactory initial proxy for the level of development.

Economic growth and development are two intertwined processes. Economic production generates the means that are necessary for development, including goods and services, but also employment and participation in social life. At the same time, economic production depends on a country's level of development, as the amount of key resources such as human capital, infrastructure, etc., determines the country's production frontier. Although by itself not sufficient to generate development at large, economic growth is therefore a fundamental process that enables development (Ranis et al. 2000). While we retain here as single indicator of development a country's output per worker, throughout the analysis we will discuss how economic growth emerges from, and is determined by, different mixes of resources, i.e. different types of development.

The last five decades have also been especially important for the advance of the field of economic growth theory, as new and more sophisticated theories have been developed and tested. But even more importantly, these last fifty years have been crucial to our field because for the first time measures of production and income have been recorded on a systematic basis, providing now valuable insights into the economic growth and development processes that led us where we are today. An excellent example of such data on income and output are the University of Pennsylvania's tables, best known as Penn Tables (UPENN 2007). Among other indicators, these tables provide measures of output in purchasing power parity, and in U.S. constant (2000) dollars: This is a reliable dataset that allows comparing economic production across countries. Based on the Penn tables, we constructed a database containing figures of output per unit of labor (for simplicity "**Y**" in the following) for 100 countries, for the period 1960 – 2005. Countries were selected based on data availability only, and the resulting 100 provide a diverse spectrum of experiences: Based on the 2005 World Banks's classification (WB 2005), the database includes 28 low income countries, 45 middle income countries, and 27 high income countries, covering all the five continents and major economic regions. The full list of countries and their international codes are reported in Table 1.

Table 1: List of countries included in the analysis and respective country codes.

Country	Code	Country	Code	Country	Code	Country	Code
Algeria	DZA	Egypt, Arab Rep.	EGY	Kenya	KEN	Portugal	PRT
Argentina	ARG	El Salvador	SLV	Korea, Rep.	KOR	Romania	ROM
Australia	AUS	Equatorial Guinea	GNQ	Lesotho	LSO	Rwanda	RWA
Austria	AUT	Ethiopia	ETH	Luxembourg	LUX	Senegal	SEN
Barbados	BRB	Finland	FIN	Madagascar	MDG	Singapore	SGP
Belgium	BEL	France	FRA	Malawi	MWI	South Africa	ZAF
Benin	BEN	Gabon	GAB	Malaysia	MYS	Spain	ESP
Bolivia	BOL	Gambia, The	GMB	Mali	MLI	Sri Lanka	LKA
Brazil	BRA	Ghana	GHA	Mauritius	MUS	Sweden	SWE
Burkina Faso	BFA	Greece	GRC	Mexico	MEX	Switzerland	CHE
Burundi	BDI	Guatemala	GTM	Morocco	MAR	Syrian Arab Rep.	SYR
Cameroon	CMR	Guinea	GIN	Mozambique	MOZ	Taiwan	TWN
Canada	CAN	Guinea-Bissau	GNB	Namibia	NAM	Tanzania	TZA
Cape Verde	CPV	Honduras	HND	Nepal	NPL	Thailand	THA
Chad	TCD	Hong Kong	HKG	Netherlands	NLD	Togo	TGO
Chile	CHL	Iceland	ISL	New Zealand	NZL	Trinidad & Tobago	TTO
China	CHN	India	IND	Nicaragua	NIC	Tunisia	TUN
Colombia	COL	Indonesia	IDN	Niger	NER	Turkey	TUR
Comoros	COM	Iran, Islamic Rep.	IRN	Nigeria	NGA	Uganda	UGA
Congo, Rep.	COG	Ireland	IRL	Norway	NOR	United Kingdom	GBR
Costa Rica	CRI	Israel	ISR	Pakistan	PAK	United States	USA
Côte d'Ivoire	CIV	Italy	ITA	Panama	PAN	Uruguay	URY
Denmark	DNK	Jamaica	JAM	Paraguay	PRY	Venezuela, RB	VEN
Dominican Rep.	DOM	Japan	JPN	Peru	PER	Zambia	ZMB
Ecuador	ECU	Jordan	JOR	Philippines	PHL	Zimbabwe	ZWE

Collecting these data into a single database provides an immediate overview of how varied the development landscape is. Ample diversities in points of departure and growth rates make it challenging to identify similarities in such a large sample. For the purpose of producing a clearer picture of the various growth patterns, we first divide the countries considered into three groups based on the countries' initial **Y**: Group [L], consisting of the countries that in 1960 had a **Y** below $1,500; group [M], including the countries that in 1960 had a **Y** between

$1,500 and $5,000; and group [H], including the countries that in 1960 had a **Y** higher than $5,000. We then compare the average economic performance of each group, to identify any possible similarities. The average performance is obtained as a weighted average of the performance of all countries within a group, using as weight the relative size of a country's labor force compared to the total for the group.

Figure 1 illustrates the growth in the output per unit of labor (**Y**) for the three groups for the period 1960-2005: we use the same absolute scale in order to compare the respective growth paths. The three curves have quite different growth patterns, and exhibit different average growth rates. The [L] group (green line) grows on average of about 4% per year, faster than the [M] group (red line, growing at about 2.6% per year), and than the slowest [H] group (blue line, growing at about 2.3% per year). However, growth for each group is far from smooth: Growth rates are increasing for the [L] group; declining for the [M] group; and quite stable for the [H] group. There seem to be no clear evidence of a monotonic relationship between the level of income of a group, and its growth rate.

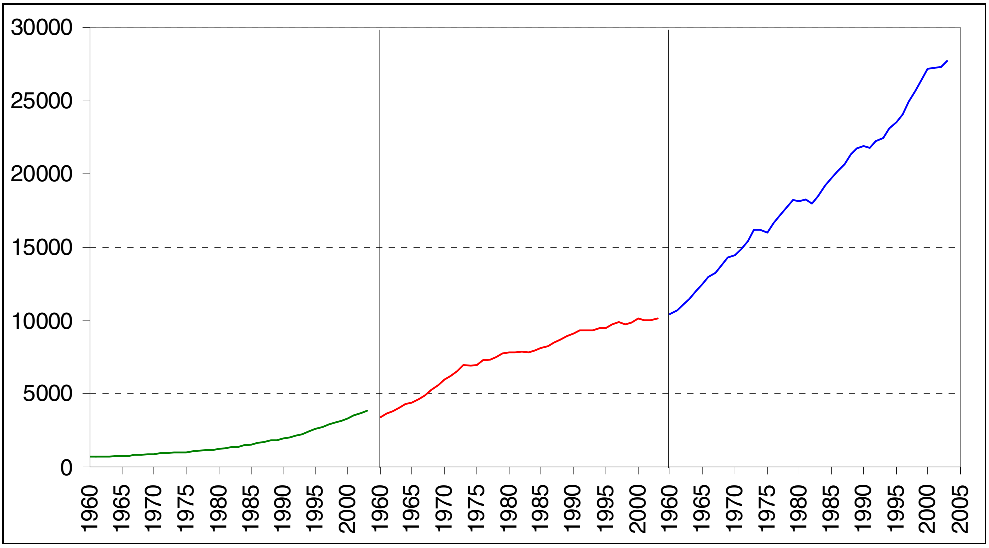

Figure 1: Output per unit of labor (Y), period 1960 – 2005, for the [L] group (left, green line); the [M] group (center, red line); and the [H] group (right, blue line).

Although it is useful to compare growth rates among the three groups, observing the change in output obtained by the three subgroups in absolute terms leads to a different appreciation of the subgroups' performances. For example, the 5 fold change in output per labor obtained by the [L] group is a much smaller step than that obtained by the [M] group over the same period, which is substantially smaller than that obtained by the [H] group.

The three lines in Figure 1 can also be interpreted as if they represent the performance of a single group over three consecutive periods of time – i.e. the three phases in the development of this synthetic group of nations. Using such a perspective highlights how the growth trajectories of the three groups seem to lie on a same, almost continuous growth path. The output per unit of labor (**Y**) for the [L] group in 2005 matches remarkably well that for the [M] group in 1960; and similarly **Y** for the [M] group in 2005 well matches that of the [H] group in 1960. Also, this perspective allows for a better appreciation of the long-term exponential growth pattern that these groups follow on the average.

The graph presented in Figure 1, should not lead to the conclusion that development is an inevitable process, and that all countries will inevitably follow the same growth path. Although, on the average, the three groups of countries considered all exhibit positive economic performances, substantial differences in performance exist between the countries in each group. In order to analyze the different development performances observed within each of the three groups ([L], [M], and [H]), we further classify the countries by their growth performance over the period 1960-2005. This allows us to distinguish between countries characterized by faster or slower development, as our eventual objective is to identify the underlying reasons for such different performances. Specifically, we divided the [L] group into [L_0], including the countries in the group whose **Y** less than doubled over the period analyzed, and [L_1], including the countries in the [L] group whose **Y** more than doubled during that period. We follow the same procedure for the [M] group, and for the [H] group, although in the latter case we include in the [H_0] group the countries whose **Y** grew of less than 2.5 times in the period analyzed, and in the [H_1] group those whose **Y** grew of more than 2.5 times. We did so to obtain a more even subdivision of the [H] group. The resulting groupings are summarized in Table 2.

Table 2: Classification of countries based on initial output per unit of labor (Y) and growth performance over the period 1960-2005.

Group	Income Growth	Nr. of Countries
[L_0]	Less than doubled	23
[L_1]	More than doubled	15
[M_0]	Less than doubled	20
[M_1]	More than doubled	16
[H_0]	Less than 2.5 times	11
[H_1]	More than 2.5 times	15

Based on this new subdivision, we calculate the average growth performance for each sub-group, to analyze within-group growth differences. Figure 2 provides an overview of how the output per unit of labor (**Y**) developed over time for the period 1960-2005 for each sub-group. Values for the [L_0] sub-group are represented by a dark green line, while those for the [L_1] sub-group by a brighter green line. Values for the [M_0] sub-group are represented by a purple line, while those for the [M_1] sub-group by a brighter pink line. Values for the [H_0] sub-group are represented by a dark blue line, while those for the [H_1] sub-group by a brighter blue line. The same color conventions are used for the subsequent graphs. All the values are normalized using as reference the output per unit of labor in the U.S.A. in the year 2000.

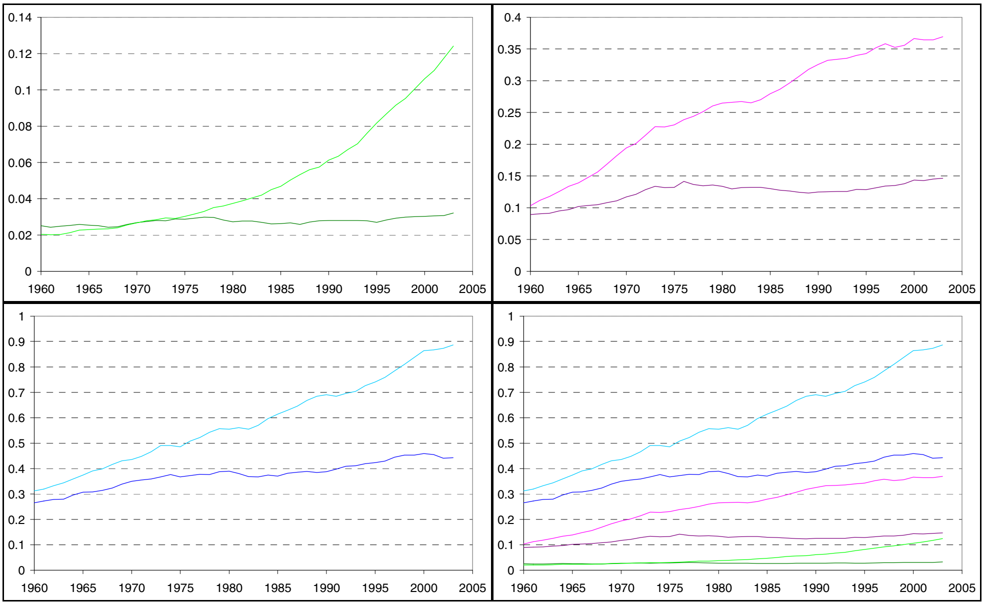

Figure 2: Average output per unit of labor for the sub-groups within each group: Top left: [L_0] and [L_1] groups (respectively, dark green and light green lines); Top right: [M_0] and [M_1] groups (respectively, purple and pink lines); Bottom left: [H_0] and [H_1] groups (respectively, dark blue and light blue lines); Bottom right: summary of the three groups using the same scale.

The graph in the upper-left corner of the figure illustrates the dynamics of the output per unit of labor (**Y**) for the [L_0] and [L_1] sub-groups, over the 45-year period analyzed. The graph highlights how initially the [L_0] sub-group enjoys a larger **Y** than the [L_1] subgroup. Specifically, in 1960 [L_0] has a **Y** about 19% higher than [L_1] (see Table 3). Such difference, however, is rapidly reduced, the [L_1] sub-group growing substantially faster than the [L_0] sub-group. Eventually, by 2005 **Y** of [L_1] is nearly 300% higher than that of [L_0]. Also in the case of the subgroups within the [M] and [H] groups (graphs in the upper-right and bottom-left corners of Figure 2), **Y** is initially quite similar, but eventually we observe a large gap opening up during the period analyzed (see Table 3).

Table 3: Differences in output per unit of labor (Y) between fast and slow growers, in 1960 and in 2005

Group	**Difference in Y (%) in 1960 fast/slow growers**	**Difference in Y (%) in 2005 fast/slow growers**
[L]	-19%	287%
[M]	+15%	152%
[H]	+18%	100%

Such trajectories highlight how, within each group, some countries grew substantially faster and some slower than the average. Initially, fast growers and slow growers in each group have similar **Y**, and a large gap is gradually built up from an initially quite even situation. Embarking on a rapid growth path is thus a success that only some of the countries achieve, and our objective is to study the reasons for such differences in performance among sub-groups. Such differences cannot be explained by an initial advantage in the output per unit of labor (**Y**) alone, as the case of the [L_0] and [L_1] sub-groups clearly exemplifies. We investigate such differences in performance as seen from a resource perspective, focusing on the contribution of the existing resources, and of a country's ability to build them up, to economic growth. Our eventual aim is that of identifying policies that are potentially effective in that they stimulate growth and development.

2. Resources for Growth

2.1 Seven types of resources

Identifying the key resources that are essential for economic development is one of the central themes of investigation in the development field. Countless growth accounting and growth regressions exercises have been run in the attempt at establishing a relationship between growth and a variety of possible causes underlying growth. This section reviews the existing literature on the subject, and, on that basis, identifies seven categories or types of resources that play an essential role in determining the economic performance in a country. In addition, we provide a brief review of the formulations commonly used to represent the contribution of resources to production.

A first resource influencing economic development is physical capital. Physical capital represents the amount of durable physical man-made items that are used in the production process (machinery, equipment and buildings). Virtually none of the goods and services that we buy today could be produced without appropriate machinery, and even the most rural production processes involve using some types of tools. The classics already identified physical capital as a factor of production, and distinguished it from circulating capital for its different use and purpose (Smith 1776). Neoclassic growth models also stressed physical capital as the major driver of output per capita (Solow 1956). Since then, a large number of empirical studies validated the concept of capital as one of the main drivers of production (Bosworth et al. 1995; Senhadji 1999).

Together with capital, the labor force is among the most essential resources for production. The labor force contributes to production by providing labor, which represents the quantity of human work involved in the production process. Smith already referred to labor as one of the key determinants of value added (Smith 1776), and the intuitive necessity of labor as an input to production has since never been questioned. Nevertheless, in modern cross-country growth analysis, labor is often not treated explicitly: For reasons of comparability across countries, inputs and outputs of production are expressed per unit of labor. The focus of such analysis is therefore on the quality of labor available (see for example (Mankiw et al. 1992)), including education and health, rather than on its quantity, as discussed in the paragraph below.

A third resource relevant to economic development is human capital. Human capital is the stock of knowledge, skills, techniques, strengths, and capabilities embodied in labor. These qualities are important for the workers to understand and perform their tasks, to properly use the available tools, and to efficiently organize the production process. The importance of what we now call human capital was also already recognized by the classics (Smith 1776). The relevance of human capital – education and training in particular – for economic development was further theorized and empirically explored by many researchers in recent times, such as Becker (Becker 1975), Lucas (Lucas 1988), and Mankiw (Mankiw et al. 1992; Mankiw et al. 1995). Other have extensively demonstrated how health as part of human capital contributes to economic development, as Howitt (Howitt 2005), López-Casanovas (López-Casasnovas et al. 2005), and Bloom (Bloom et al. 2001).

A fourth type of resource, essential for economic development, is infrastructure. Infrastructure is a form of physical capital that is built to provide essential services to firms and households. Basic infrastructure can be either owned by the public or the private sector, and include, for example, structures for the transportation of goods and people (i.e. roads, railways, harbors); structure to support telecommunications (i.e. telephone lines, internet cables); and power generation and distribution facilities (i.e. power transmission networks, power plants). Efficient and extended infrastructure allows faster and cheaper access to the market, broader access to information, and reliable access to the inputs required for production. In the late 1980s, the role of infrastructure as a vehicle for economic development was broadly recognized, thanks to a series of theoretical and empirical studies focused on the return to public investment (Aschauer 1989; Aschauer and Holtz-Eakin 1993). The 1994 World Development Report (WB 1994) summarized the evidence on the role of infrastructure for development, with a focus on developing countries. More recently, Calderon and others have done further detailed analysis on this subject, focusing in particular on the role of telecommunications, roads and energy in economic growth (Canning 1999; Calderón and Servén 2003; Calderón and Servén 2004).

Governance is a fifth resource that has recently been indicated as one of the key determinants of production. Governance in a country represents the traditions and institutions by which authority is exercised (Kaufmann et al. 1999). This includes the processes by which the governments are selected, monitored, and replaced; the ability of the government to effectively formulate and implement sound policies; and the respect of citizens and state for the institutions governing their social and economic interactions. The concept of governance thus brings together a variety of aspects of the socio-economic environment in a country that are important for economic activities to be established and operated in a competitive setting. These also include the regulations of markets for goods and services, and of financial markets and institutions. Empirical evidence of the importance of governance to development have emerged from both cross-country analyzes (Kaufmann et al. 2002) and from broad surveys on the investment environment (WB 2005).

Natural resources also play an important role in the development process. Historically, some countries have been able to effectively support their economic growth through the use of their natural resources (Cypher and Dietz 2004). Some of these resources enter the production process as raw materials (e.g. minerals, wood, water, wild animals); others are used to produce energy (e.g. coal, oil, wind, sunlight); while others provide essential services to support the process (e.g. agriculture land, water bodies as supporting environment for fish farming, landscape and wilderness as drivers of tourism, forests for their ability to absorb CO2 emissions). Based on the definition introduced in the previous section, we here consider as key resources for the development process only the latter: In addition to land, which was already considered a key resource for production by the classics (Smith 1776; Malthus 1798), we consider as key those resources that provide ecosystem services that are important for production (Costanza et al. 1998). Such resources play a different role in the production process than the resources considered so far: Although their contribution to production is recognized, they can hardly be developed, and the policy focus is often on maintaining them at their *natural* level, for reasons that extend beyond supporting growth and development.

A final category of key resources for production includes the more qualitative aspects of a country's society, including its culture, its traditions, and the characteristics of the country's social networks. Recently, the concept of social capital has emerged as a notion embedding several dimension of social structures (Coleman 1988), although the concept still escapes a unique definition, and its use for growth analysis is arguable. The difficulty in relating such a type of resource to production relies in the fact that they are hardly measurable, and that they contribute to production in a complex way. Specifically, different types of social capital have different and contrasting effects on development (Annen 2003). In addition, the development of social capital, through an alteration of the characteristics of a country's social network, although might be beneficial for production, might not yield a desirable social outcome.

For the cross-country analysis reported in this study, we analyze the impact of a broad variety of resources on growth and development, covering nearly all the categories described above. However, we do not explicitly consider in our analysis the contribution of social capital and natural resources to the development process. Social capital is not included in this analysis because of the inherent difficulties in identifying a satisfying definition for it, and of the debatable issue of whether this type of capital should be subject to public policy at all. Natural resources are not explicitly included in the analysis because of the scope of our study and because of an issue of data availability. First, our study focuses on the mechanisms that drive growth and development, and on how public policy can affect them. Natural resources cannot be built up through human activity, i.e. they cannot be accumulated as part of the development process, but they can at best be preserved or restored in some cases. This implies that the accumulation of natural resources is not a process underlying growth. Instead, the depletion of natural resources is a process that can slow down growth: Natural resources play a key role in defining the long term environmental sustainability of growth, which we do not address in this study. Still, a large endowment of natural resources can provide an advantage for a country, as the use of such resources can increase production and thus facilitate investment in other resources. We consider such phenomenon in our analysis assuming that a country's ability to profit of its natural resources depends on its other key resources, e.g. physical and human capital, good governance and infrastructure. In other words, we emphasize the importance for development of a country's ability to exploit its natural resources, and assume that on average the various groups of countries considered have a similar potential in terms of natural resources. Second, estimating the value of natural resources across countries is impractical, because of the very different forms that such resources can take on, and because their value is inherently determined by the ability of the country to exploit them. In summary, we do not further analyse the role of social capital and natural resources in the development process, although we believe these to be important areas for future research.

2.2 A Database

Based on the types of resources identified above, we have developed an extensive database collecting relevant proxies for such resources for the 100 countries considered in the analysis and over the period 1960 – 2005[1]. In particular, we collected and organized data for seven key variables, in addition to the data for output per unit of labor (**Y**), presented in section 1.2. The seven additional variables considered are: (1) physical capital (**K**); (2) average years of schooling (**E**); (3) average life expectancy (**H**); (4) extension of the roads network (**R**); (5) power generation capacity (**P**); (6) extension of the telephone network (**T**); and (7) type of governance (**G**). The average years of schooling and life expectancy represents proxies for human capital, while **R**, **P**, and **T** aim at giving a broad overview of a country's basic infrastructure. All variables are measured per unit of labor, so as to control for differences in the size of the labor force.

Table 4 provides a summary of the units and the ranges used for the variables considered. As mentioned in section 1.2, data on the output per unit of labor (**Y**) has been collected from the University of Pennsylvania's Penn Tables (UPENN 2007). **Y** data is expressed in real (base year 2000) U.S. Dollars, per unit of labor (person), per year. The data have been normalized so that a value of one corresponds to the actual **Y** measured in the U.S. in the year 2000. The

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[1] Data for some of the variables in the database is available only until the year 2000.

same type of normalization is used for all the variables in the database, for the purpose of making the data more easily comparable against a clear benchmark (the U.S. value in 2000). We chose as benchmark the U.S. because it is a large and diversified economy, well integrated in the global markets, and has the second highest **Y** worldwide (the highest **Y** is actually that of Luxemburg, which however has a rather small and non-representative economy). We chose as benchmark year the year 2000 because most data are available for that year, and it is also the base year for the currency.

Table 4: Variables in the database, units, and ranges

Variable	Symbol	Unit	0% level	100% level
Output per Unit of Labor	Y	$2000PPP/person/yr	0	as USA 2000
Physical Capital	K	$2000PPP/person	0	as USA 2000
Years of Schooling	E	Year	0	as USA 2000
Life Expectancy	H	Year	30	as USA 2000
Roads Network Extension	R	Km/person	0	as USA 2000
Power Generation Capacity	P	KW/person	0	as USA 2000
Telephone Network Extension	T	Line/person	0	as USA 2000
Governance	G	Dimensionless	0	as USA 2000

Data on physical capital (**K**) is primarily drawn from studies performed at the World Bank (Nehru and Dhareshwar 1993; King and Levine 1994; Easterly and Levine 2001), but also integrated with other studies and estimates (Marquetti 2004). Some of these estimates are derived using a perpetual inventory method (Dey-Chowdhury 2008), that is, by reconstructing **K** level based on an existing estimate for one year, and subtracting the recorded investment and adding depreciation. The units used for **K** is U.S. Dollar per unit of labor, that is, **K** measures the actual capital/labor ratio. Data on education (**E**) is mainly obtained from the World Bank's *edstats* (WB 2006), and is integrated with data from Barro's study on educational attainment (Barro and Lee 1993). The unit used for this variable is year. Data on life expectancy (**H**) is obtained form the United Nations Population Division (UN 2003), and is also expressed in years. Data on the extension of road networks (**R**) is obtained from the International Road Federation (IRF 2006), from the World Development Indicators (WB 2005), and from Calderón's study on infrastructure and growth (Calderón and Servén 2004). Data in particular refers to the extension of the network of paved roads in a country, and is expressed in Km per unit of labor. Data on power generation capacity (**P**) is also based on Calderón's study, and is complemented with data from the Energy Information Administration (EIA 2004). Power generation capacity is expressed in Kw per unit of labor. Data on the extension of telephone network (**T**) is also derived from Calderón's study and from the World Development Indicators, and is complemented with data from the International Telecommunications Union, as reported on the UN database (UN 2007). In particular, we consider as a proxy for the network's extension the number of telephone lines and cellular subscribers, expressed with the unit line per unit of labor. Finally, data on governance (**G**) is derived from the Polity IV database (Marshall and Jaggers 2006), and more specifically we use as proxy of the form of governance the Polity2 indicator (dimensionless), which classifies countries based on their level of democracy.

2.3 Dynamics of Resources

In order to analyze how different levels of resources and different accumulation patterns contributed to the different development performances observed, we calculate for each sub-group (see Table 2) the average growth trajectory of each of the resources considered**.** In this section, we illustrate first the developments for the key resources that are traditionally associated with economic growth in endogenous growth theory (Romer 1990) – physical capital, and human capital – for the subgroups within the [L] group. We then describe the dynamics of the other resources considered in the analysis, which might contribute less directly, but equally importantly, to production. A similar analysis is then carried out for the subgroups within the [M] and [H] groups.

Figure 3 provides an overview of how the output per unit of labor (**Y**), physical capital (**K**), education (**E**), and life expectancy (**H**) have developed for the [L_0] and [L_1] sub-groups over the period 1960-2005. All the values are normalized as indicated in Table 4 (the scale differs across the graphs). The graph for **Y**, in the upper-left corner of the figure, has already been discussed in section 1.2, and is replicated here to facilitate the visual comparison of the pattern growth of **Y** with those of other resources. The graph in the upper-right corner of the figure illustrates how the accumulation of **K** developed over time for the [L_0] and the [L_1] sub-groups. The pattern of behavior for **K** is similar to that of **Y**, in line with the neo-classic assumption of a strong relationship between the two variables. Also in the case of **K**, the initial values for the subgroups are quite close, but eventually the [L_1] sub-group is able to accumulate **K** substantially faster than the [L_0] sub-group, so that the gap between the two becomes much larger by 2005 (see Table 5).

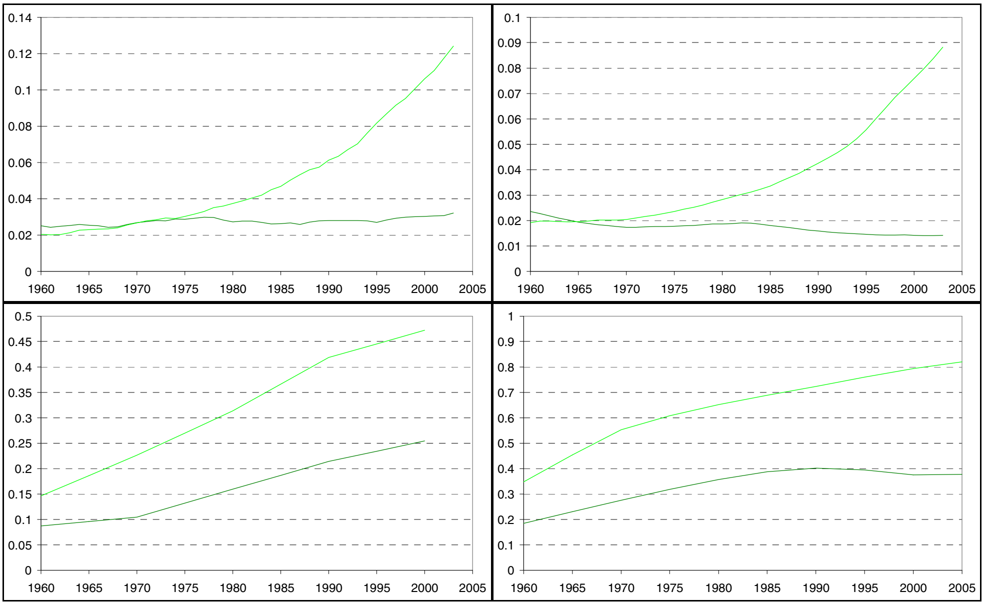

Figure 3: Output per unit of labor (Y), physical capital (K), education (E), and life expectancy (H) for the [L_0] and [L_1] sub-groups (respectively, dark green and light green lines). From the upper left corner, clockwise: Y, K, H, E.

The initial situation for education (**E**) and life expectancy (**H**) is significantly different. For both **E** and **H,** the [L_1] sub-group has a substantial advantage compared to the [L_0] sub-group, and such gaps then tend to expand over the period. This indicates that, although the two sub-groups started from similar levels of **K** and **Y**, the fast growers had a substantial advantage in terms of **E** and **H**, a gap that they have been able to increase over time.

Table 5: Differences in output per unit of labor (Y), physical capital (K), education (E), life expectancy (H), extension of the road network (R), power generation capacity (P), extension of the telecommunication network (T), and governance (G) between [L_0] and [L_1], in 1960 and in 2005.

Variable and Group	Difference (%) in 1960 fast/slow growers	Difference (%) in 2005 fast/slow growers
Y [L]	-19%	+287%
K [L]	-19%	+521%
E [L]	+68%	+86%
H [L]	+88%	+117%
R [L]	+25%	+207%
P [L]	+86%	+449%
T [L]	+101%	+282%
G [L]	-17%	-16%

Figure 4 illustrates the dynamics for four other key resources for the [L_0] and [L_1] sub-groups: road network extension (**R**), power generation capacity (**P**), telecommunication network extension (**T**), and governance (**G**). Regarding infrastructure (**R**, **P**, and **T**) the [L_1] sub-group has an initial advantage compared to the [L_0] sub-group (see Table 5), and in all the three cases the gap tends to increase over time. In the case of **R** and **P** in particular, it appears that from the eighties the [L_0] sub-group has suffered a net loss of resources. This does not happen in the case of **T** which grows rapidly towards the end of the period: the sudden improvement in telecommunication technologies observed in the 1990s – and the associated reduction in costs – also benefits the [L_0] sub-group. However, the data highlights how the fast growers have been able to adopt the new technology faster than the slow growers, eventually building up a substantial advantage in this sense. In summary, the fast growers in the [L] group have in average benefited from an initial advantage in terms of infrastructure, and have been able to further increase such initial gap.

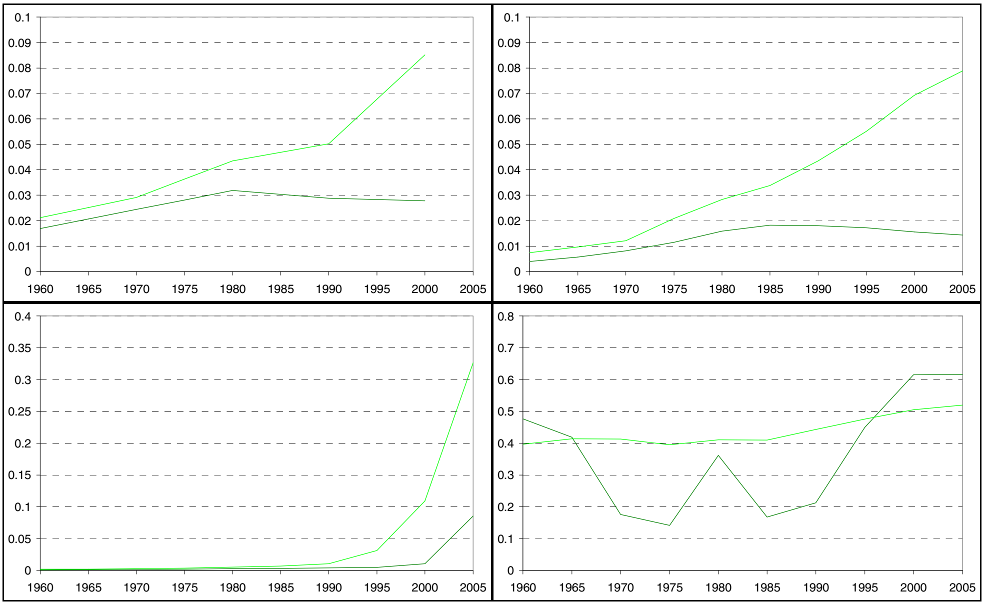

Figure 4: Road network extension (R), power generation capacity (P), telecommunication network extension (T), and governance (G) for the [L_0] and [L_1] sub-groups (respectively, dark green and light green lines). From the upper left corner, clockwise: R, P, G, T.

In the case of **G,** dynamics are significantly different from those observed for infrastructure. [L_0] has an initial advantage in terms of **G**, and despite some significant oscillations throughout the period, also ends up having a higher **G** than the [L_1] sub-group in 2005. Still, for most of the period considered, **G** for the [L_1] sub-group is higher than that of the [L_0] sub-group.

Following the same procedure adopted above for the sub-groups within the [L] group, in the following paragraphs we discuss the dynamics of the key resources for the fast and slow growers within the [M] and [H] groups. Figure 5 illustrates the dynamics of the output per unit of labor (**Y**), physical capital (**K**), education (**E**), and life expectancy (**H**) for the [M_0] and [M_1] sub-groups (in purple and pink respectively), and for the [H_0] and [H_1] sub-groups (in dark and light blue respectively).

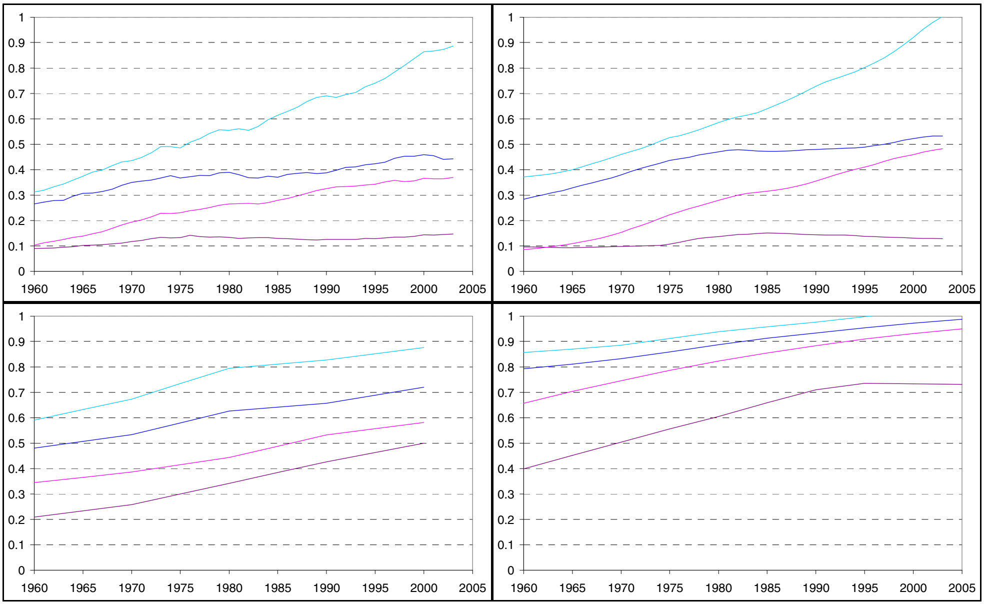

Figure 5: Output per unit of labor (Y), physical capital (K), education (E), and life expectancy (H) for the [M_0] and [M_1] sub-groups (respectively, purple and pink lines), and for the [H_0] and [H_1] sub-groups (respectively, dark blue and light blue lines). From the upper left corner, clockwise: Y, K, H, E.

In the case of **K,** within the [H] group fast growers have an advantage on slow growers, while within the [M] group slow growers have an initial advantage on fast growers (see Table 6). Divergence in the accumulation of **K** between fast and slow growers is rapid (graph in the top right corner of Figure 5) and, as also observed for the [L_0] and the [L_1] sub-groups, the growth in **K** well matches that in **Y**. The development of **E** for each subgroup is illustrated in the graph in the bottom-left corner of Figure 5. In this case there is a significant difference in the initial levels of **E** between fast and slow growers, particularly marked for the sub-groups within the [M] group. The gap tends to decrease over time for the [M] group, and roughly remain the same for the [H] group. The initial conditions for **H** (bottom-right corner graph) are similarly unequal, and in this case, the gaps tend to close during the period of the analysis. Overall, fast growers within the [M] group have significant initial advantages in terms of **E** and **H**, while such advantages are smaller for fast growers within the [M] group. In all cases, the advantages tend to decrease in relative terms over the period analyzed.

Table 6: Differences in output per unit of labor (Y), physical capital (K), education (E), life expectancy (H), extension of the road network (R), power generation capacity (P), extension of the telecommunication network (T), and governance (G) between [M_0] and [M_1], and between [H_0] and [H_1], in 1960 and in 2005.

Variable and Group	Difference (%) in 1960 fast/slow growers	Difference (%) in 2005 fast/slow growers
Y [M]	+15%	+152%
K [M]	-11%	+275%
E [M]	+65%	+16%
H [M]	+65%	+30%
R [M]	+6%	+147%
P [M]	+23%	+144%
T [M]	+90%	+92%
G [M]	+48%	+31%
Y [H]	+18%	+100%
K [H]	+30%	+89%
E [H]	+22%	+22%
H [H]	+8%	+5%
R [H]	+230%	+148%
P [H]	+67%	+103%
T [H]	+67%	+38%
G [H]	+24%	+8%

Figure 6 provides an overview of the development of four other key resources for the sub-groups within the [M] and [H] groups: Extension of the road network (**R**), power generation capacity (**P**), governance (**G**), and extension of the telecommunication network (**T**), over the period 1960-2005. The graph for **R** (in the upper left corner of Figure 6) highlights a large gap in initial conditions for the sub-groups within the [H] group, and a smaller gap for those within the [M] group. Within the [H] group, the initial gap in **R** shows a tendency to reduce over time, while the opposite is true for the sub-groups within the [M] group. Initial conditions for **P** (graph in the upper right corner of Figure 6) also indicate a gap in favor of the fast growers within the [H] and [M], gap that tends to expand through the period, in particular for the sub-groups within the [M] group. In the case of **T** (graphs in the bottom-left corner of Figure 6), there are also consistent initial gaps in favor of the fast performers in the [H] and [M] groups. Starting from small initial levels, growth in **T** is dramatic for all the sub-groups, particularly starting form the IT revolution in the 1990's. Overall, fast growers within the [H] group have a substantial initial advantage in terms of infrastructure, while such advantage is less dramatic for fast growers within the [M] group. The advantages for fast growers in the [H] group tend mostly to decrease in relative terms over the period analyzed, while those for fast growers in the [M] group tend to increase.

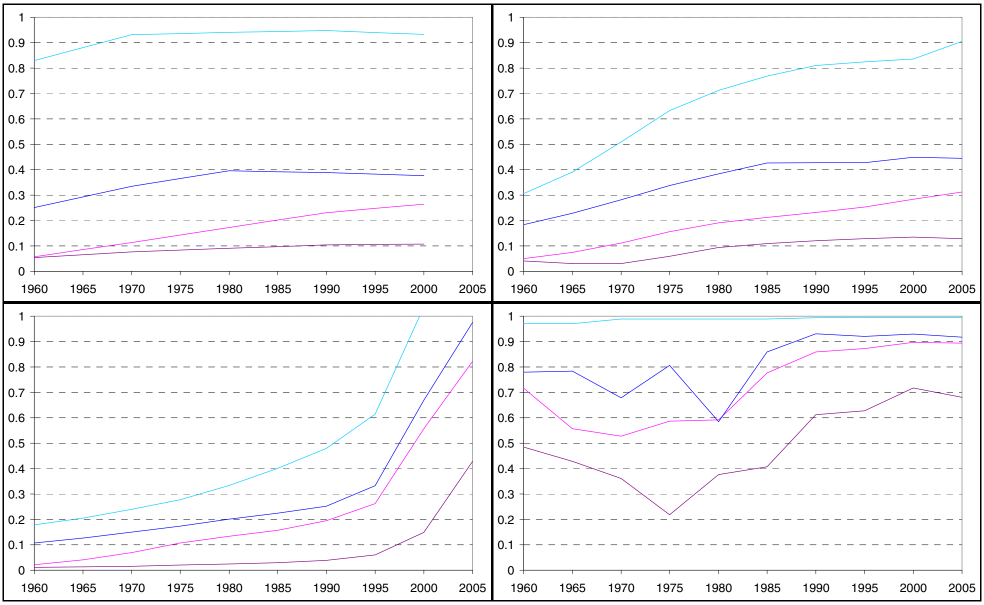

Figure 6: Road network extension (R), power generation capacity (P), telecommunication network extension (T), and governance (G) for the [M_0] and [M_1] sub-groups (respectively, purple and pink lines), and for the [H_0] and [H_1] sub-groups (respectively, dark blue and light blue lines). From the upper left corner, clockwise: R, P, G, T.

For most sub-groups in the [H] and [M] groups, growth of **G** (graph in the bottom-right corner of Figure 6), is less smooth than that of other resources. We observe some significant discrepancies in the initial levels between the different sub-groups: **G** for [H_1] and [M_1] are initially higher than those for [H_0] and [M_0]. Such gaps tend to close throughout the period, despite the significant reductions in **G** observed for most of the sub-groups towards the middle of the period analyzed.

In summary, data collected for the seven key resources considered highlights that fast growers across the groups, although starting from a similar level of output per unit of labor (**Y**) and physical capital (**K**) compared to slow growers, had a substantial initial advantage in terms of human capital and infrastructure. It is our hypothesis that such an advantage, only partially reflected in the initial **Y**, led to faster development throughout the period as it facilitated a more effective accumulation of **K**. The role of **G** in facilitating investment in **K** appears also to be important, particularly in the cases of the [H] and [M] groups. In the next section we develop a simulation model to test this hypothesis and in section 4 we derive some preliminary insights about the effectiveness of alternative development strategies.

3. The model

Based on the types of resources identified and on the data analysis carried out in the previous section, we develop a System Dynamics (SD) model with the aim of understanding how different initial levels and patterns of accumulation of such resources can explain differences in development performances across countries. The SD method is well suited to implement our resource-based approach to development policy analysis, as it allows representing explicitly the processes of resources accumulation, and the underlying feedback mechanisms (Richardson 1991). Also, the SD method enables us to properly represent the elements of dynamic complexity, including delays and non-linearity that characterize the development process (Forrester 1994).

In our model, we assume that resources take part in the development process in two ways. More directly, the level of a resource can influence the overall amount of economic output in a country, which in turn can generate an increase in the investment in such resource. This creates a positive, or reinforcing, feedback loop, which drives growth and development through the accumulation of resources. Less directly, the level of a resource can affect the volume and effectiveness of investment in other resources, which in turn can affect the economic output. Also in this case, changes in economic output can affect the amount of investment, closing another positive feedback loop. Sections 3.1 and 3.2 will present and discuss these mechanisms in more detail.

3.1 Accumulation processes and basic feedback loops

Resources grow by way of a flow of investment, and are depleted by way of a flow of loss or depreciation. This is evident for resources such as physical capital (**K**) or infrastructure, but less simple to visualize for other, less tangible, resources. In the case of resources such as education (**E**) or governance (**G**), for example, the inflow represents the slow process of adding to such resources through investment in the education sector and in measures to improve governance. Depreciation takes place over time, as knowledge is forgotten or educated workers leave the labor force, in the case of **E**; and as good governance mechanisms become obsolete or incentives to apply them fade out, in the case of **G**. Also, there exist other flows affecting a resource beyond investment and normal depreciation. For example, a rapid deterioration of life expectancy (**H**) could be generated by the spread of an infectious disease, and not necessarily by a scarce public support to the health sector. We do not explicitly consider and analyze such flows, which we implicitly include in our investment flow. In the example illustrated above, the spread of an infectious disease would result in a smaller than normal investment flow.

In the cases of investment and depreciation, such flows are influenced by the state of the resource itself, through feedback loop mechanisms. Some of these mechanisms drive growth and development, while others tend to counteract them. Figure 7 provides a stock and flow representation of the generic mechanisms driving a resource growth and depletion. Variables inside a box are stocks; variables represented as double arrows are flows; and variables represented otherwise are auxiliaries, that is, they are intermediate calculations to determine the flow rates. Feedback loop mechanisms are highlighted with a capital letter (either R or B) and a number within a circular arrow symbol. A legend to interpret the figure is reported to the right of the stock and flow diagram.

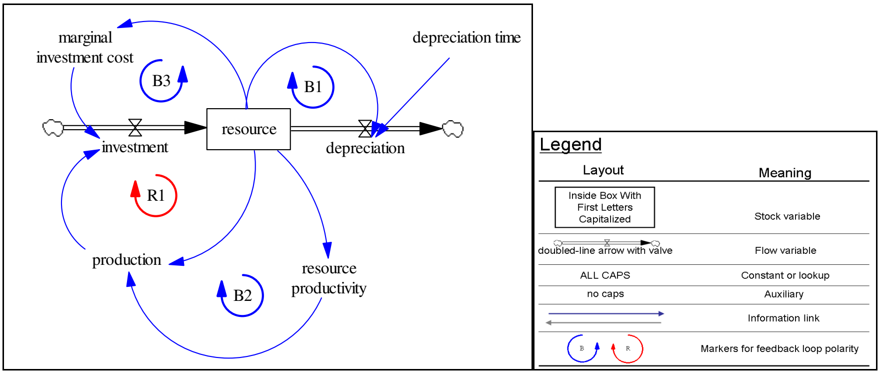

Figure 7: Generic stock and flow structure of the mechanisms driving resources' growth and depletion.

In our model, we assume that the level of a generic resource positively affects production: Ceteris paribus, the larger the amount of the resource available, the larger is the production. Production, in turn, has a positive effect on the amount of investment in the resource: The larger the production, the larger the income and, therefore, the larger the amount of investment that can be made in the resource. Equation 1 illustrates the relationship between investment in a generic resource and **Y**, where *m* is a constant multiplier:

Investment = **Y** * m / marginal investment cost

Equation 1

The relationship between the resource, production, and investment forms a positive, or reinforcing, feedback loop (R1 in Figure 7), which generates growth in production through growth in the resource: An increase in the resource level tends to be amplified through this mechanism, which leads to an exponential growth in production, i.e. the type of behavior observed for successful countries in Figure 2. If it was to be driven by this mechanism only, development in all countries would follow a pure exponential path, and the economy would grow unbounded. In reality, there exist mechanisms that tend to counteract such growth.

First, in our model we assume that the level of a resource also positively affects its depreciation: Ceteris paribus, the larger the amount of the resource accumulated, the larger is the depreciation. Depreciation, in turn, depletes the resource stock, creating a negative, or balancing, feedback loop (B1 in Figure 7): The more resource is depleted, the less is left to be depleted. This loop tends to slow down growth, by discarding an increasing amount of resource as the stock increases, as highlighted in Equation 2:

Depreciation = resource / depreciation time

Equation 2

A second mechanism counteracting growth is related to the marginal contribution of a resource to production. We follow the common assumption in neo-classic economics (Cobb and Douglas 1928) that such a contribution tends to decrease as the level of the resource available increases, based on the rationale that resources are allocated first to their most productive use. Therefore, the larger the amount of resource accumulated, the smaller is its marginal productivity, the smaller production and thus investment. This creates another balancing feedback loop (B2 in Figure 7), which also contributes to slowing down growth. Equation 3 illustrates the relationship between a generic resource level, and its productivity, where *a* is a fixed coefficient between 0 and 1. Such formulation is in line with the neoclassic assumption of decreasing marginal returns, as by multiplying the resource level by its productivity we obtain **Y**= resource^*a*.

Resource productivity = resource ^ (a-1)

Equation 3

Finally, we assume that, as the level of the resource increases, the cost of investing in such a resource increases: We assume that investments are first directed to develop the resource in the most cost-effective of contexts, and then in gradually less cost-effective circumstances. This forms another balancing feedback loop (B3 in Figure 7) that slows down growth: As the resource is accumulated, further accumulation becomes more difficult. Equation 4 illustrates the relationship between a generic resource's level and its depreciation flow, where *g* is a constant, positive coefficient. Although a minimum critical threshold level for investment to be effective might exist, for simplicity we do not consider such a phenomenon, and assume that we operate beyond such a minimum level.

Marginal investment cost = resource ^ g

Equation 4

The relationship in Equation 4 does not apply to physical capital (**K**), as discussed in section 3.2 below, nor to governance (**G**). **G** is estimated based on an indicator that, by definition, cannot grow beyond 100%, and we thus use a different formulation (see Equation 5) to ensure that as **G** approaches 1, the marginal investment cost grows indefinitely.

Marginal investment cost **G** = 1/(**G**^(-g) – 1)

Equation 5

The feedback loops illustrated in Figure 7 do not work equally fast for all resources. We assume that resources such as **K**, and light infrastructure such as telephone lines, can be rapidly built-up under favorable conditions. Other resources, such as roads and power capacity, have longer implementation times. Human resources require even longer time to build up, in the order of a few decades. For simplicity, we do not indicate such delays explicitly in the previous equations. Still, delays are among the factors that essentially define a country's development possibilities, and their type and duration are described in section 4.

The interaction of the mechanisms presented above influence the rate of development in a country. We apply the stock and flow structure in Figure 7 to all the resources considered in our model, although we assume that some of those resources do not affect the production level directly, but only indirectly through other resources. This creates another type of feedback loop, which we present in the next paragraphs, and which, in combination with those presented above, can give raise to a variety of growth and development patterns such as those identified as our reference mode of behavior.

3.2 Cross-resource feedback loops

Based on the analysis of the data collected for **Y** and for the different resources, and on recent growth theory, we assume that production is a function of physical capital (**K**), education (**E**), and life expectancy (**H**). In order to determine production based on the level of such resources, we assume a production function of the form indicated in Equation 6, where *a*, *b*, and *c* are fixed coefficients between 0 and 1 (i.e. the function exhibits diminishing marginal returns to each individual resource), *p* is a fixed multiplier, and *Init Y* is a constant. Such function assumes a form similar to an extended Cobb-Douglas production function (Romer 1990), with **E** and **H** as proxies for human capital[2].

Y= p* **K**^a * **E**^b * **H**^c + Init Y

Equation 6

The relationship between **K**, **E**, **H**, and **Y**, is therefore of the type illustrated in Figure 7, while we assume that the other resources considered have a less direct, although equally important, impact on production. More specifically, we assume that investment in **K** does not only depend on **K** and on the level of production (as illustrated in Equation 1), but also on the investment environment. Equation 7 represents the formulation used to determine investment in **K**: Each component of the equation is explained below.

Investment **K** = m * **Y** * effect of income on investment * effect of capital intensity on investment * effect of investment environment on investment

Equation 7

As in Equation 1 (which represents investment for a generic resource), investment in **K** depends on **Y** and a multiplier *m*. However, in this case we assume that investment in **K** grows more than proportionally relative to **Y**, as a larger income might imply a larger propensity to invest. This effect is represented by the "effect of income on investment", calculated as described by Equation 8, where *d* and "**Y** ref" are positive constants. Such an effect further strengthens the relationship between production and investment, reinforcing the action brought about by the R1 loop.

effect of income on investment = (**Y**/**Y** ref)^d

Equation 8

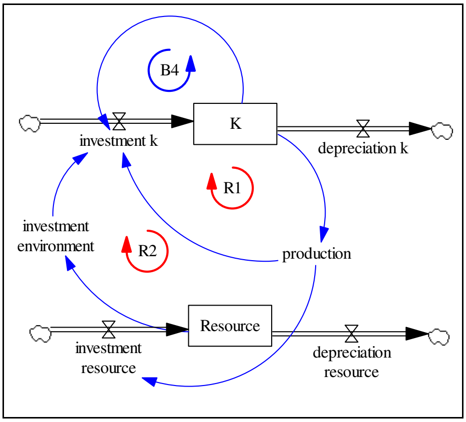

Figure 8: Generic stock and flow structure of the accumulation process for K, and cross-resource FB loops.

We also consider the effect of capital intensity on investment: We assume that a large **K/Y** ratio discourages investment, as it indicates low productivity of **K**. Equation 9 describes such relationship, where *e* is a negative constant. This relationship between capital and investment forms another balancing feedback loop (B4 in Figure 8) which tends to slow down capital accumulation when capital grows too rapidly compared to production.

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[2] Note that all the variables in this formulation are intended *per unit of labor*.

effect of capital intensity on investment = (**K**/**Y**)^e

Equation 9

The last component used in Equation 7 is the effect of the investment environment on investment. The investment environment is an indicator of the overall attractiveness for investment of the local economy. Over the last few years, an increasing amount of studies have analyzed the importance of the investment environment (or investment climate) for investment and the resulting growth. A recent World Bank's report reviewing a large portion of such studies (WB 2005) indicates as key determinants of the investment environment resources such as education, health, infrastructure, and governance. We thus assume that education (**E**), life expectancy (**H**), governance (**G**), the extension of the road network (**R**), power generation capacity (**P**) and the extension of the telecommunication network (**T**), all contribute to the determination of the investment environment. Lacking a clear evidence of the relative importance of each resource, which is likely to vary from country to country, we assume that all resources are equally important in the formation of the investment environment (InvEnv in Equation 10):

InvEnv = (**E**+**H**+**G**+**R**+**P**+**T**)/6

Equation 10

We then determine the effect of investment environment on investment as illustrated in Equation 11, where *f* is a positive constant. "InvEnvRef" represents the reference level of investment environment to which the levels of each sub-groups is compared. We assume that such reference level changes over time: As the overall investment environment improves, so do investors' expectations. Specifically, we calculate the InvEnvRef as the average of the InvEnv for [M_0] and [M_1]. We chose not to use the values for the [L] and [H] groups as they are more extreme.

effect of investment environment on investment = (InvEnv/InvEnvRef)^f

Equation 11

The assumption regarding the investment environment illustrated above implies that investment can only take place with an adequate amount of resources in place. The investment environment not only provides an indication of the current profitability of investment, but also of the feasibility of investing in more advanced technologies. Increasing the amount of **K** invested per unit of labor can indicate that more of the same tools, machines and buildings are employed in the production process; or that more technologically advanced and efficient capital is used. In either case, this implies a modification of the technology in use, and therefore a higher **K** per unit of labor also implies a higher technological level. In this perspective, the investment environment defines the potential level of technology that a country can adopt, which can then be realized through investment in **K**. This process is known as the Salter effect (Cypher and Dietz 2004).

The relationship described above between the investment environment and investment in **K** closes an additional reinforcing feedback loop that drives growth (R2 in Figure 8): The more resources accumulated, the more the investment in **K**, the larger the production, and the more the investment in all resources next time around. We define such reinforcing feedback loops that circuit through two resources as "cross-resource" feedback loops.

Cross-resource feedback loops are important drivers of growth, and also further increase the complexity of the process. Investment in a resource depends more directly on the level of the other resources than would be the case if resources were only connected through production. This implies that policies aiming at strengthening a resource can have a direct positive effect on the accumulation of other resources. In the next section we present the results of the model and highlight some initial policy insights.

4. Analysis of Results

Based on the basic structure described in the previous section, we develop a simulation model representing development and growth processes for each of the six sub-groups identified in section 2.2. The model is implemented using the System Dynamics method and the Vensim[3] software, is initialized based on historical conditions in 1960, and is simulated over the time horizon 1960-2005. We use the optimization capabilities of Vensim to identify a set of parameters that generates a good replication of historical data for the six sub-groups, and that are consistent with our knowledge about the development process. In sections 4.1 and 4.2 we discuss the values obtained for the critical parameters, the simulated results of the model, and the policy implications.

4.1 Base Run and Validation

The model contains a large number of parameters, and most of them can be grouped into three categories: (1) Those that define the strength of the contribution of resources to production; (2) those that define the strength of the contribution of the investment environment to investment in physical capital (**K**); and (3) those that define the strength of the contribution of production to the investment in resources. In our analysis, we use a two-stage estimation process: We first estimate a unique set of values for the parameters in the first two of these categories for all the sub-groups, i.e. we treat them as fundamental structural characteristics of the growth process that all groups share. Then, for the last category of parameters – those influencing how intensively production affects the accumulation of resources – we estimate different values for each sub-group. Such parameters can be influenced by policy choices that differ across sub-groups (e.g. the amount of value generated by production that is reinvested in education), and which we intend to compare and study. Although production, the investment environment, and resources are dynamically interdependent in the model, for clarity we first present in the next paragraphs the values used for the parameters in the first two categories and we discuss the simulation results obtained for **Y** and **K**, for each subgroup, in the "Base" run. We then present the values used for the parameters in the third category, and the results obtained for the each of the resources considered.

Parameters and results for the output per unit of labor (Y) and physical capital (K)

The production function presented in Equation 6 is implemented using as values for the three elasticities (a, b, and c) 0.6, 0.2, and 0.2 respectively. These estimated values reflect the relatively stronger contribution of **K** to **Y**, compared to that of life expectancy (**H**) and education (**E**). We use a value for p of 0.83, to scale production to data. In addition, we use representative values of *Init Y* for each sub-group in order to initialize production in line with the long-term trend. This parameter assumes generally small values (i.e. smaller than 10% of **Y**), with the exception of [M_1] (18%) and [H_1] (11%). These parameters do not determine the strength of the relationship between production and resources, but only affect the initial **Y** of each sub-group.

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[3] www.vensim.com

The functions relating investment in **K** with **Y**, **K**, and the investment environment (Equations 7-10) are implemented using the same parameter values for all sub-groups. For *d*, *e*, and *f* we use values of respectively about 0.05; -2; and 1.4. These values, which are obtained via optimization, indicate a rather weak effect of income on investment in **K**, compared to the stronger effects of capital intensity and investment environment. The significant strength of the effect of investment environment on investment in **K** is in line with our hypothesis on the role of the existing resources in facilitating investment in **K**.

The resulting behavior for **Y** for the six-subgroups matches well the historical data available. The graphs in Figure 9 compare the model simulation results (continuous lines) with historical data (dotted lines). We use dark green for the [L_0] group, and light green for the [L_1] group; purple for the [M_0] group and pink for the [M_1] group; dark blue for the [H_0] group and light blue for the [H_1] group. Although the model does not capture the short and medium term oscillations observed in the data, it captures well the overall trends. Such trends are more evident for the fast growers, and less so for the slow growers, particularly in the [M] and [L] groups. The graph in the bottom-right corner of Figure 9 display the model's results for all the groups for **K**, compared to historical data. Also in this case, the model is able to capture the large differences in growth of **K** between fast growers and slow growers.

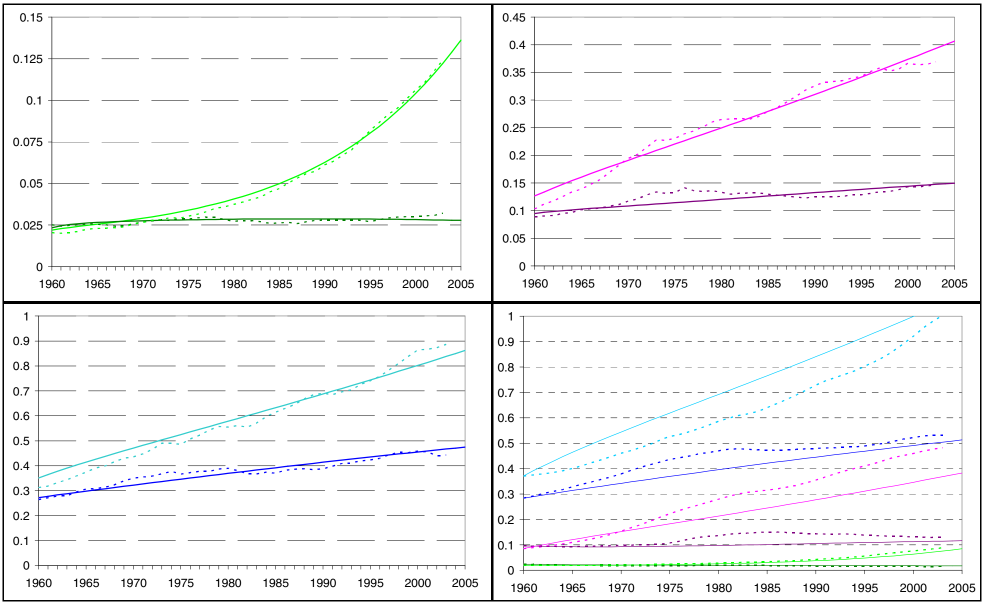

Figure 9: Simulation results (continuous lines) and historical data (dashed lines) for the output per unit of labor (Y): Y the sub-groups [L_0] and [L_1] (top-left corner, dark green lines and light green lines respectively); [M_0] and [M_1] (top-right corner, purple lines and pink lines respectively); [H_0] and [H_1] (bottom-left corner, dark blue lines and light blue lines respectively). Graph in the bottom-right corner: physical capital (K) for all sub-groups.

Table 7 provides summary statistics for **Y**, for each group, including the coefficient of determination (R2), the root mean square percent error (RMSPE), and its decomposition by way of the Theil's inequality statistics. Theil's statistics are appropriate to estimate the historical fit of a system dynamics model (Sterman 1984), and they decompose the error into a bias component (Um), an unequal variation component (Us), and an unequal covariation component (Uc). The R2 is above 0.9 for all groups, with the exception of the [L_0] and [M_0] groups. Nevertheless, the error decomposition for [M_0] and [L_0] indicates that most of the error for these variables is of non systematic nature (i.e. Uc), that is, is due to the inability of the model to capture short-term fluctuations, while the trend is well represented.

Table 7: Summary statistics: comparison of model's behavior with historical data for the output per unit of labor (Y), for the six sub-groups.

Variable	RMSPE	Um	Us	Uc	R2
Y [L_0]	0.058	0.041	0.192	0.767	0.305
Y [L_1]	0.084	0.424	0.434	0.142	0.999
Y [M_0]	0.079	0.041	0.000	0.959	0.611
Y [M_1]	0.082	0.004	0.081	0.916	0.973
Y [H_0]	0.046	0.001	0.119	0.879	0.912
Y [H_1]	0.068	0.171	0.639	0.190	0.992

For all sub-groups, the simulated behavior shows a strong divergence between fast and slow growers. While the R1 and R2 loops presented in Figure 8 generate fast exponential growth among the fast growers, the slow growers are not able to make use of these mechanisms in the same manner. Fast growers were able to invest more abundantly in their resources, and they have developed through growth in such resources. On the other hand, slow growers were only able to mobilize a limited amount of resources, barely sufficient to compensate for the action of the balancing loops B1-B4 (or insufficient in the case of the [L_0] sub-group). There are principally three reasons for this. First, some of the fast growers, such as [M_1] and [H_1], had an initial income higher than the slow growers in their group. This implies a possibility to invest more, and thus to grow more rapidly. Second, all the fast growers had initially a substantially larger amount of resources (beyond **K**) than the slow growers. Given such an advantage, the fast growers were able to stimulate investment in **K** faster than what the slow growers did, so that [M_1] and [L_1] rapidly eliminated their initial deficiency in **K**. Finally, overall the fast growers were able to invest more, even in proportion to their production, than slow growers did in nearly all resources. The amount of investment in each resource may be significantly affected by governmental policies, and represent, therefore, an important area of development policy analysis. The next paragraphs illustrate the parameter values used to determine the strength of the relationship between production and the accumulation of resources, and their policy implications.

Parameters and results for key resources

The values we identified for the parameter *g*, indicating the strength of the relationship between a resource level and its marginal investment cost, are the same across all sub-groups, but differ between the resources. The values we obtain through optimization for the g parameter are reported in the second row of Table 8. Overall, the values for *g* are substantially higher for life expectancy (**H**), education (**E**), and governance (**G**), than for the other three resources[4]. This indicates that, for human capital and governance, investment becomes rapidly more expensive as the amount of the accumulated resource increases. For **H**, this phenomenon is intrinsic to the fact that biological limits exist to the possibility of increasing life expectancy. For **E**, the value we estimate for *g* indicates that costs per student are significantly higher at higher educational levels: For example, a university education requires substantially more funds per students than primary education. For **G**, the value we estimate also indicates that it is significantly more expensive to improve governance when close to its maximum level, than when starting from a very poor initial situation. For the power generation capacity

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[4] Note that the formulation used to determine the marginal investment cost for **G** (Equation 5) is different from that used for the other resources, and the parameter "g" in this case indicates a sharper decrease in relative terms than it would produce using the standard formulation in Equation 4.

(**P**) and the extension of the road network (**R**), the values of *g* are relatively small, indicating that the cost of building new roads and power plants increases only slowly as such resources increase. Finally, for the extension of the telecommunication network (**T**) we obtain a value of zero, indicating that the cost of investing in telecommunications does not tend increase as the network extends. This could also be due to the fact that the new telecommunication technologies that emerged in the 90's substantially cut the marginal costs of investment in this sector, compensating the naturally tendency of marginal cost to increase as the service is extended to more remote areas.

Table 8: Parameters *g*, and *m* for the six sub-groups.

Parameter	H	E	G	R	P	T
g	2.05	0.39	0.23	0.04	0.12	0
m [L_0]	1.6	6.3	47.8	0.045	0.009	0.03
m [L_1]	7.1	10.8	48.4	0.078	0.039	0.10
m [M_0]	2.2	3.8	25.0	0.043	0.024	0.05
m [M_1]	2.6	2.2	41.3	0.064	0.044	0.10
m [H_0]	1.9	2.0	47.8	0.072	0.039	0.07
m [H_1]	1.6	1.9	610.1	0.112	0.056	0.07

For each resource, we also estimate various delays, representing the time lag between the moment investment takes place and the moment this impacts on the resource's level as well as various depreciation times. For human resources and governance, investment delays and depreciation times are combined into the same formulation. Specifically, for **H** we assume that the resource level adjusts to investment with a first-order delay of 20 years. We use a similar formulation for **E** and **G**, using delays of respectively 50 and 25 years. For the infrastructure, we use separate investment implementation delays and depreciation times. Investment implementation delays for **T**, **P**, and **R** are, respectively, 3 years, 5 years, and 5 years. Depreciation times are, respectively, 25 years, 50years, and 20 years. For **K**, we use a depreciation time of 30 years.

The values we use for the *m* parameters are different for each resource and for each sub-group. The *m* parameters indicate the strength of the contribution of production to the investment in a resource. Such a contribution can be affected through public policy, e.g. by way of public investment or through incentives to private investment, but it can also be affected by other social and cultural factors. For example, although a government might allocate a large amount of funds to the education sector, the actual investment in **E** might be small, because it is a part of the local culture to use children as labor. Also, as mentioned in section 3.1, a smaller investment might results from other losses in the resource stock beyond the normal depreciation. Table 8 reports the values for *m* we estimate using optimization. Such values should not be compared across resources, as each resource has different marginal costs, and different implementation times. Instead, the values may be compared, for each resource, across sub-groups.

Starting from education (**E**), within the [L] group fast growers are investing proportionally more than slow growers, while the opposite is true for the [M] group. As a consequence, the gap in **E** between [L_0] and [L_1] tends to expand, while that between [M_0] and [M_1] tends to reduce (left-hand graph in Figure 10). Within the [H] group, *m* is very similar for the two sub-groups. Eventually, the gap in **E** tends to increase as the larger **Y** for [H_1] leads to a larger investment in absolute terms. These results reflect well the available data, and we obtain an R2 above 0.9 for all the sub-groups.

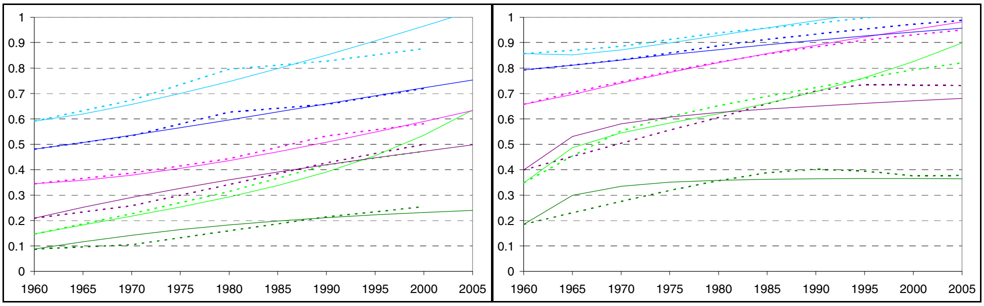

Figure 10: education (E) (left-hand graph) and life expectancy (H) (right-hand graph): Simulation results (continuous lines) and historical data (dashed lines) for the groups [L_0] (dark green lines); [L_1] (light green lines); [M_0] (purple lines); [M_1] (pink lines); [H_0] (dark blue lines); [H_1] (light blue lines).

For life expectancy (**H**), the fast growers in the [L] group have invested in **H** proportionally much more of their production than the slow growers did. The result is a large increase in the gap in **H** between the two groups, as highlighted in the right-hand graph in Figure 10, illustrating simulation results and historical data. In the [M] group, the difference in *m* is smaller, and in the [H] group the slow growers actually invested more in **H** than the fast growers did. Combined with the increase in cost that the fast performers are experiencing, this causes the slow performers in the [M] and [H] groups to gradually catch up. These performances replicate well the trend in the historical data: For all sub-groups, we obtain an R2 higher than 0.9, except for the [M_0] group (0.78), in which case most of the error is of a non-systematic nature (Uc=0.72).

For the extension of road network (**R**) (left-hand graph in Figure 11), fast growers have invested proportionally more than slow growers across the groups. This has led to an increasing gap in **R** for the [L] and [M] groups. For the [H] group, however, the large initial gap in favor of the [H_1] group implied also a much larger marginal cost of investment, so that overall the smaller investment of the [H_0] group produced an increase in **R** faster than that of the [H_1] group, eventually leading to a smaller gap. Overall the model replicates well the trends observed in the historical data. We obtain an R2 above 0.65 for all subgroups, with the exception of the [H_1] group (0.24). For this group, the error is mostly concentrated in the unequal variation (Us=0.54) and unequal covariation (Uc=0.27).

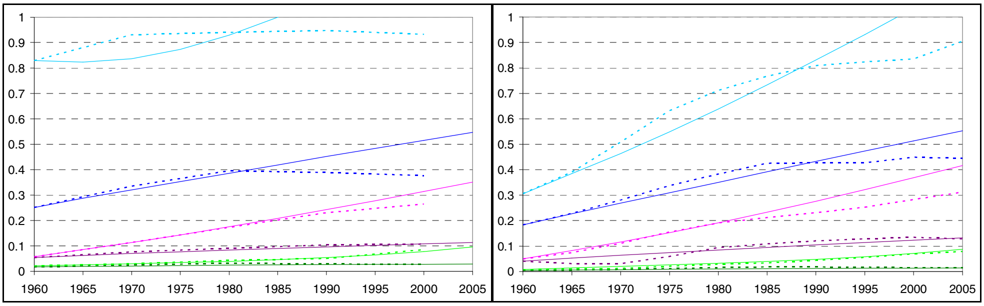

Figure 11: Extension of the road network (R) (left-hand graph) and power generation capacity (P) (right-hand graph): Simulation results (continuous lines) and historical data (dashed lines) for the groups [L_0] (dark green lines); [L_1] (light green lines); [M_0] (purple lines); [M_1] (pink lines); [H_0] (dark blue lines); [H_1] (light blue lines).

Also in the case of power generation capacity (**P**) (right hand graph in Figure 11), in each group fast growers have invested proportionally more than slow growers. However, differently from the case of **R**, in this case all sub-groups started from relatively small levels of **P**, and thus a small marginal cost of investment. Consequently, the gap in **P** increased in all the groups. The trends in the historical data are well replicated by the model, and we obtain an R2 above 0.7 for all the sub-groups.

For the extension of the telecommunication network (**T**) (left-hand graph in Figure 12), investment in the [L_1] group is larger than that in the [L_0] group, leading to an increasing gap. Investment for the [M_1] group is also larger than that for the [M_0] group, so that, on the average, the gap tends to increase throughout the period. Within the [H] group, investment in **T** was roughly the same, so that the gap remained quite constant throughout the period. In the case of **T**, the model is able to replicate the average growth observed in the period, but not the difference between the initial slow development before the 1990s, and the subsequent dramatic acceleration. Such a phenomenon could be due to the emergence of modern telecommunication technologies during the 1990's, which we do not represent in the model. We obtain R2 above 0.4 for all the sub-groups, with the exception of the [L_0] group, for which the error is mostly concentrated in the unequal variation component (Us=0.73).

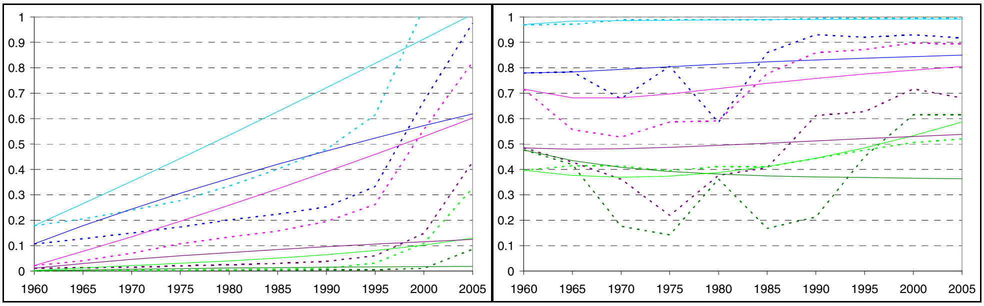

Figure 12: Extension of the telecommunication network (T) (left-hand graph) and governance (G) (right-hand graph): Simulation results (continuous lines) and historical data (dashed lines) for the groups [L_0] (dark green lines); [L_1] (light green lines); [M_0] (purple lines); [M_1] (pink lines); [H_0] (dark blue lines); [H_1] (light blue lines).

Finally, for governance (**G**) (right-hand graph in Figure 12), across the groups, fast growers have invested more than slow growers. However, the gap in **G** expands only for the [L] group, were the initial levels of [L_0] and [L_1] are roughly similar, and, consequently, the marginal costs of investment are also similar. Within the [M] group, marginal costs of investment are substantially different, so that despite the larger investment made by the [M_1] sub-group, the gap tends to reduce. For the [H] group, for similar reasons, the gap tends to remain stable, despite a substantially larger investment of the [H_1] group. In the case of **G**, the high variability in the data substantially decreases our measures of the model's statistical fit. Overall, we obtain an R2 above 0.7 for most groups, but substantially lower for the [H_0] (0.4) and [L_0] (close to zero). In the latter case, the error is concentrated in the unequal variation (Us=0.59) and unequal covariation (Uc=0.38) components, while the bias component is small.

In summary, for the eight key variables considered (**Y**, **K**, **E**, **H**, **G**, **R**, **P**, and **T**) we obtain a good overall replication of historical trends. In particular, the model endogenously generates the observed increasing divergence in **Y**. Such divergence is generated by the initial advantages in favor of fast growers, in terms of **Y** in some cases, and in terms of other resources in other cases; but also by proportionally different amounts of investment in the key resources. In most cases, fast growers have invested in the key resources proportionally more than slow growers. In the next session, through a retrospective analysis, we explore alternative development path that slow growers could have embarked upon by investing proportionally more in some key resources.

4.2 Policy Analysis

Based on the results of the "Base" run illustrated in the previous section, in this section we test various alternative investment policies, and report their results. Such tests are run retrospectively, as if different investment policies were introduced back in 1960, and we analyze the alternative growth patterns these would have generated. In particular, we test alternative investment policies in all resources, with the exception of physical capital (**K**). In our analysis, we consider investment in **K** endogenously, as a decision of investors on the market. On the other hand, we consider that investment in all other resources can be influenced by the government, and we study how the level of such resources can facilitate investment in **K**.

We run three "Policy" simulations, each aiming at increasing the speed of development of one of the three slow growing sub-groups. Table 9 illustrates the *m* parameters values used for the "Policy" simulations, and those used in the "Base" run. Such parameters values are the only changes we introduce to the model in order to run the "Policy" simulations. In the following paragraphs we discuss the changes introduced for each sub-group individually, and the corresponding results.

Table 9: *m* parameters for the "Policy" run, compared to the "Base" run, for the slow growing groups.

Parameter	***H***	***E***	***G***	***R***	***P***	***T***
m [L_0] Base	*1.6*	*6.3*	*47.8*	*0.045*	*0.009*	*0.03*
m [L_0] Policy	*3.5*	*10.8*	*47.8*	*0.045*	*0.009*	*0.03*
m [M_0] Base	*2.2*	*3.8*	*25.0*	*0.043*	*0.024*	*0.05*
m [M_0] policy	*3.5*	*4.0*	*55.0*	*0.090*	*0.050*	*0.10*
m [H_0] Base	*1.9*	*2.0*	*47.8*	*0.072*	*0.039*	*0.07*
m [H_0] policy	*1.9*	*2.5*	*47.8*	*0.130*	*0.060*	*0.09*

In the "Base" run, the [L_0] sub-group starts with an advantage in terms of **Y** and **K** compared to the [L_1] sub-group, but with an important disadvantage in terms of other resources, **H** and **E** in particular. The advantage in **Y** and **K** is rapidly lost, as investment in **K** and other resources is larger in the [L_1] sub-group, which has a better investment environment. We run an alternative simulation focusing in particular on investment in education (**E**) and life expectancy (**H**) for the [L_0] to catch-up on the initial gap in these resources. Specifically, we set the *m* parameters so that the [L_0] group invests proportionally as much as the [L_1] group in **E**, and about half than the [L_1] in **H**.

The upper-left graph in Figure 13 illustrates the results for **Y** for the [L_0] group in the Base run (continuous line), compared to the Policy run (dotted line). Thanks to the larger investment in **E** and **H**, in the Policy run **Y** for [L_0] grows substantially faster than in the Base case, in line with that of [L_1]. As a result of the faster growth in resources and in **Y**, **K** also grows substantially faster (graph at the bottom-right of Figure 13). The policy tested, focusing on increasing investment only in **H** and **E**, seems therefore to be effective. In this case, we stimulate growth primarily through the reinforcing feedback loop R1, since **E** and **H** have a direct effect on **Y**. **E** and **H** also partially make the investment environment more favorable, so that we also obtain an increase in the strength of the R2 loop. Although not reported here, less significant results are obtained when increasing the amount of investment in **G** and infrastructure for this sub-group.

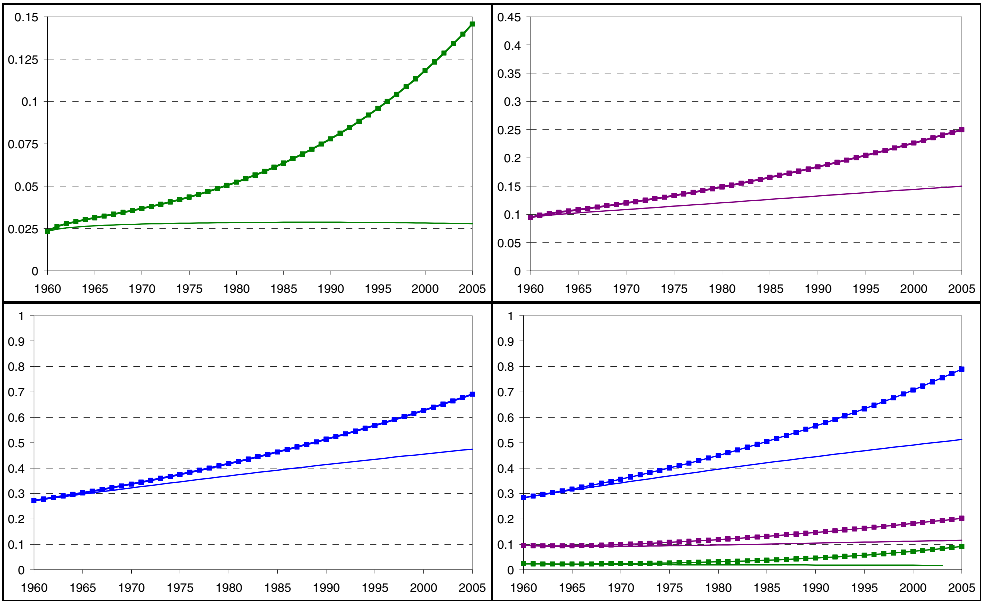

Figure 13: Results from the “Base” run (continuous lines) and “Policy” run (dotted lines). From the upper left corner, clockwise: output per unit of labor (Y) for $[L_0]$; Y for $[M_0]$; physical capital (K) for all $[-_0]$ sub-groups; and Y for $[H_0]$.

The $[M_0]$ sub-group starts from very difficult initial conditions relative to the $[M_1]$ group: Not only does it have a disadvantage re. most resources, but it also has an initially lower **Y**. In such a scenario, in order to obtain a trajectory that catches up on the amount of resources accumulated, we substantially increase the *m* parameters values for all resources (see Table 9). Such an increase must be sufficiently large to compensate also for the initially smaller **Y** of $[M_0]$. The changes introduced for **E** are proportionally less significant, as the $[M_0]$ is investing abundantly in education also in the Base run.

The graph in the upper-left corner of Figure 13 illustrates the results for **Y** for $[M_0]$ in the Base run (continuous line), and in the Policy run (dotted line). Also in this case, the changes introduced lead to a substantial acceleration in the growth of **Y**, sufficient to avoid an expansion of the relative gap in **Y** with $[M_1]$ throughout the period. **K** for $[M_0]$ also grows faster, as illustrated in the graph in the bottom-right corner of Figure 13. The policy tested is effective in avoiding a spread of the initial income gap between $[M_0]$ and $[M_1]$, although this requires a substantial stimulus to investment to ensure a build-up of all resources, compared to the more focused intervention tested for $[L_0]$. In this case, we robustly stimulate the action of both the loop R1 (through increases in investment in **E** and **H**), and the loop R2 (through increases in investment in all resources).

The $[H_0]$ sub-group also has an initial disadvantage relative to the $[H_1]$ sub-group in terms of **Y**, and regarding all resources. The gap is particularly evident in the case of the infrastructure, and less so for life expectancy (**H**), education (**E**), and governance (**G**). We therefore test a policy that includes a large increase in the values for the *m* parameters for the power generation capacity (**P**) and for the extension of the road (**R**) and telecommunication (**T**) networks, in the attempt at generating a catch up in the accumulation of such resources – despite the initially lower income in the case of [H_0]. The values for *m* adopted for **R** and **P** in particular, are larger than those historically observed in all groups. We also introduce a small increase in *m* for **E**, to avoid a spread in the gap for such resource.

Figure 13 illustrates the results of the Policy run vs. the Base run for **Y** of the [H_0] group (graph in the bottom-left corner). Also in this case, the policy results in an acceleration of growth for [H_0], so that the relative gap with [H_1] does not expand. The overall level of resources increases thanks to the increased *m* parameters, and so does **K**. In this case, we primarily stimulate growth through loop R2, as we primarily increase investment in those resources (**R**, **P**, and **T**) that do not have a direct effect on **Y**. Thus we create a better investment environment, which stimulates investment in **K**.

5. Conclusions

In this study we analyze differences in economic growth and development across groups of countries using a resource-based approach. Based on theory and empirical evidence, we identify a set of resources that are essential for production, and build a database for such resources covering the period 1960-2005. We develop a System Dynamics model providing an endogenous explanation of differences in growth and development based on the amount resources that a country may accumulate. We assume that some resources directly effect growth, while as others do so less directly, by creating a better investment environment and facilitating investment in physical capital.

Results from our Base run indicate that, over the period analyzed, fast growers performed better than slow growers for three main reasons. First, in some cases, fast growers had an initial advantage in terms of output, which allowed them to invest more in absolute terms and thus grow faster. Second, overall fast growers had initially a substantially larger amount of key resources, such as human capital, infrastructure and governance, providing a better investment environment, and thus facilitating investment in physical capital. Third, fast growers invested proportionally more, with respect to their output, in nearly all key resources throughout the period.

Results from our retrospective Policy runs highlight that, by investing proportionally more in the key resources, slow growers could have performed substantially better and could have kept-up with the initially more advantaged groups. In particular, our analysis indicates that increases in investment in human capital are particularly effective for low income countries; increases in investment in infrastructure are most effective for high income countries; and that slow growers in mid-income countries would have profited from larger investments across all resources. Such policies are not necessarily entirely feasible, as public policy can only partially affect investment in the key resources, but our results provide an indication on possible areas for successful intervention.

In this study, we focus on the mechanisms that drive growth and development, and we do not, therefore, explicitly consider the role of natural resources as possible determinant of growth. We think that this would be an important addition to our study, and that further work should be carried out in this direction. Similarly, we provide a representation of governance based only on the type of government a country has, which is certainly a limitation in this study. Recently, new databases on governance are being developed (WB 2008), and such data could be incorporated in this analysis to obtain a more representative proxy for such a resource. Finally, we observe important variations in the level of resources and in performances that characterize the various countries within each of the sub-groups analyzed. Such differences point to the fact that our policy recommendations do not fit equally well all the countries considered in this analysis, and that country specific models should be adopted to develop effective country specific policies. Nevertheless, we believe that our results provide an interesting, alternative perspective on growth and development issues.

References

Annen, K., 2003, "Social capital, inclusive networks, and economic performance", *Journal of Economic Behavior & Organization,* 50(4): 449-463.

Aschauer, D. A., 1989, "Public Investment and Productivity Growth in the Group of Seven", *Economic perspectives,* 13(5): 17.

Aschauer, D. A. and D. Holtz-Eakin, 1993, "Public Infrastructure Investment: A Bridge to Productivity Growth? Public Capital and Economic Growth ; New Federal Spending for Infrastructure: Should We Let This Genie Out of the Bottle?" *Economics Public Policy Brief Archive,* (4), Levy Economics Institute, The.

Barney, J., 1991, "Firm Resources and Sustained Competitive Advantage", *Journal of Management,* 17(1): 99-120.

Barro, R. J. and J.-W. Lee, 1993, "International Comparaison of Educational Attainment", *NBER Working Paper Series,* (4349), National Bureau of Economic Research, Cambridge, MA.

Barro, R. J. and J. W. Lee, 1993, "International Comparisons of Educational-Attainment", *Journal of Monetary Economics,* 32(3): 363-394.

Becker, G. S., 1975, *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, NBER.

Bloom, D. E., D. Canning, et al., 2001, "The Effect of Health on Economic Growth: Theory and Evidence", *NBER Working Paper Series,* (WP8587), National Bureau of Economic Research, Cambridge, MA.

Bosworth, B., S. M. Collins, et al., 1995, "Accounting for Differences in Economic Growth", *Discussion Papers Series,* (115), Brookings Institution, Cambridge, MA.

Calderón, C. and L. Servén, Eds. 2003, *The output cost of Latin America's infrastructure gap*, In: The Limits of Stabilization: Infrastructure, Public Deficits, and Growth in Latin America, Stanford University Press and the World Bank.

Calderón, C. and L. Servén, 2004, "The Effects of Infrastructure Development on Growth and Income Distribution", *World Bank Working Paper,* (WPS3400), World Bank, Washington D.C.

Canning, D., 1999, "The Contribution of Infrastructure to Aggregate Output", *World Bank Policy Research working Paper Series,* (2246), The World Bank, Washington D.C.

Cobb, C. W. and P. H. Douglas, 1928, "A Theory of Production", *The American Economic Review,* 18(1): 139-165.

Coleman, J. S., 1988, "Social Capital in the Creation of Human Capital", *The American Journal of Sociology,* 94(s1): s95-s120.

Costanza, R., R. d'Arge, et al., 1998, "The value of the world's ecosystem services and natural capital", *Ecological Economics,* 25(1): 3-15.

Cypher, J. M. and J. L. Dietz, 2004, *The Process of Economic Development,* London, Routledge.

Dey-Chowdhury, S., 2008, "Perpetual inventory method", *Economic & Labour Market Review,* 2(9): 48-52.

Easterly, W. and R. Levine, 2001, "It's Not factor Accumulation: Stylized Facts and Growth Models", *The World Bank Economic Review,* 15(2): 177-219.

EIA, 2004, International Energy Annual 2004, Energy Information Administration, July 2006

Forrester, J. W., 1994, "System Dynamics, Systems Thinking, and Soft OR", *System Dynamics Review,* 10(2/3): 245-256.

Hassink, R., 2007, "The strength of weak lock-ins: the renewal of the Westmunsterland textile industry", *Environment and Planning,* 39: 1147 ^ 1165.

HMC, 2000, The American Heritage Dictionary of the English Language Houghton Mifflin Company.

Howitt, P., 2005, Health, Human Capital and Economic Growth: A Schumpeterian Perspective, *Health and Economic Growth: Findings and Policy Implications*, G. Lopez-Casasnovas, B. Rivera and L. Currais, Cambridge, MA, MIT Press**:** 19-40.

IRF, 2006, "The IRF World Road Statistics 2006", International Road Federation, Geneva.

Kaufmann, D., A. Kraay, et al., 1999, "Governance Matters", *Policy Research Working Paper,* (2196), World Bank, Washington D.C.

Kaufmann, D., A. Kraay, et al., 2002, "Governance Matters II, Updated Indicators for 2000/01", *Policy Research Working Paper,* (2772), The World Bank, Washington D.C.

King, R. G. and R. Levine, 1994, "Capital Fundamentalism, Economic Development, and Economic Growth", *Policy Research Working Paper,* (1285), The World Bank, Washington D.C.

López-Casasnovas, G., B. Rivera, et al., 2005, Introduction: The Role Health Plays in Economic Growth, *Health and Economic Growth: Findings and Policy Implications*, G. López-Casasnovas, B. Rivera and L. Currais, Cambridge, MA, MIT Press.

Lucas, R. J., 1988, "On the mechanics of economic development", *Journal of Monetary Economics,* 22(1): 3-42.

Malthus, T. R., 1798, *An Essay On The Principle Of Population* London, J. Johnson.

Mankiw, N. G., E. S. Phelps, et al., 1995, "The growth of Nations", *Brookings paper on economic activity,* (1995/1), Brookings Institution, Washington D.C.

Mankiw, N. G., D. Romer, et al., 1992, "A Contribution to the Empirics of Economic Growth", *The Quarterly Journal of Economics,* 107(2): 407-437.

Marquetti, A. A., 2004, Extended Penn World Tables - Version 2.1, December 2008

Marshall, M. G. and K. Jaggers, 2006, Polity IV Project: Political Regime Characteristics, October 2006

Nehru, V. and A. Dhareshwar, 1993, "A New Database on Physical Capital Stock: Sources, Methodology and Results", *Revista de Analisis Economico,* 8(1): 37-59.

Penrose, E., 1959, *The Theory of the Growth of the Firm,* Oxford, Oxford University Press.

Peteraf, M. A., 1993, "The Cornerstones of Competitive Advantage: A Resource-Based View", *Strategic Management Journal,* 14(3): 179-191.

Ranis, G., Frances Stewart, Alejandro Ramirez, 2000, "Economic Growth and Human Development", *World Development,* 28(2): 197-219.

Richardson, G. P., 1991, System Dynamics: Simulation for Policy Analysis from a Feedback Perspective, *Qualitative Simulation Modeling and Analysis*, P. A. Fishwick and P. A. Luker, New York, Springer Verlag.

Romer, P., 1990, "Endogenous Technological Change", *The journal of political economy,* 98(5): s71-s102.

Senhadji, A., 1999, "Sources of Economic Growth: An Extensive Growth Accounting Exercise", *IMF Working Paper Series,* (WP/99/77), International Monetary Fund, Washington, D.C.

Smith, A., 1776, *An Inquiry into the Nature and Causes of the Wealth of the Nations*.

Solow, R. M., 1956, "A Contribution to the Theory of Economic-Growth", *Quarterly Journal of Economics,* 70(1): 65-94.

Sterman, J. D., 1984, "Appropriate summary statistics for evaluating the historical fit of system dynamics models", *Dynamica,* 10(2): 51-66.

Sterman, J. D., 2000, *Business Dynamics - System Thinking and Modeling in a Complex World*, McGraw-Hill Higher Education.

UN, 2003, "World Population Prospects: The 2002 Revision", United Nations Population Division, New York.

UN, 2007, UN Data, United Nations, June 2007

UPENN, 2007, Penn World tables 6.2, University of Pennsilvania, June 2007

Warren, K., 2002, *Competitive Strategy Dynamics,* Chichester, John Wiley & Sons Ltd.

WB, 1994, "World Development Report 1994 - Infrastructure for Development", The World Bank, Washington, DC.

WB, 1997, "World Development Report 1997 - The State in a Changing World", The World Bank, Washington D.C.

WB, 2005, "World Development Indicators 2005", World Bank, Washington D.C.

WB, 2005, "World Development Report 2005: A Better Investment Climate for Everyone", World Bank, Washington D.C.

WB, 2006, edstats, The World Bank, October 2006

WB, 2007, "World Development Indicators 2007", World Bank, Washington D.C.

WB, 2008, Governace & Anti-Corruption, The World Bank, December 2008

Wernerfelt, B., 1984, "A Resource-Based View of the Firm", *Strategic Management Journal,* 5(2): 171-180.