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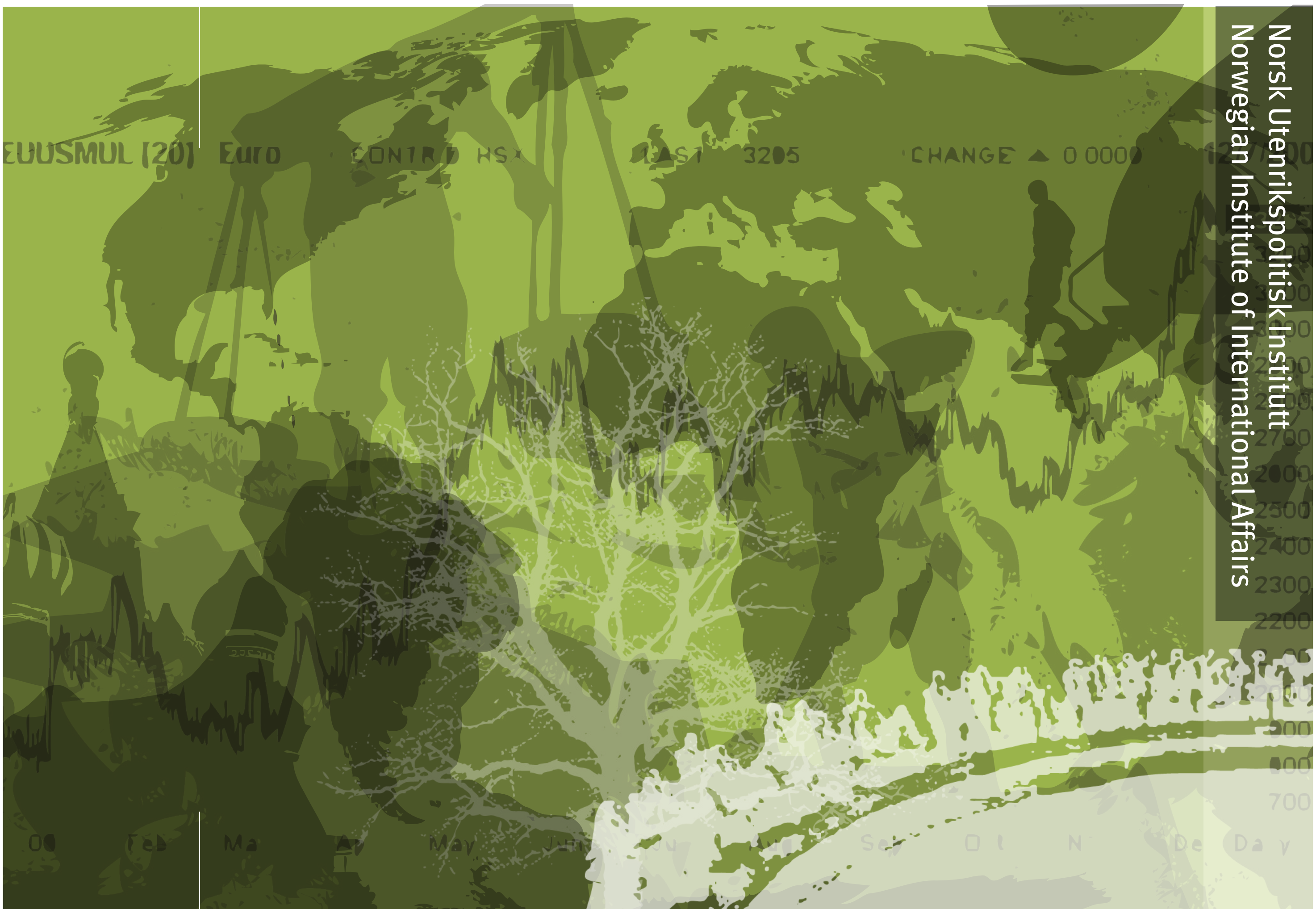

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Policy Strategies for Economic Development in Cuba: A Simulation Model Analysis

Fulvio Castellacci and Kanar Hamza
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Abstract
The economic reforms recently implemented in Cuba do not adequately deal with the structural issues that hamper the country's economic development. The paper presents a system dynamics model to investigate Cuba's development process, and a simulation analysis to compare different policy scenarios that may be realized in the future as economic reforms will continue. The results indicate that the most effective development policy would be to combine active public policies to enhance the R&D sector, on the one hand, and foster the emergence of an efficient private sector that will develop the capital infrastructure of the economy, on the other.

Keywords: Cuba; economic growth and development; policy strategies; system dynamics model; simulation analysis

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1. Introduction

The Cuban economy is at the crossroad. After the collapse of the Soviet Union, Cuba has been stagnating for more than two decades: its long-run development is hampered by an endemic lack of capital and infrastructures and a weak and inefficient supply-side (Marshall, 1998; Mesa-Lago, 1998). Cuban authorities have recently undertaken a process of reform that is intended to revive the economy – so-called “actualización” – but many argue that these economic reforms do not adequately deal with the structural issues that hamper the country’s development process (Torres et al., 2013).

What development policy model would make it possible for Cuba to achieve a higher and sustained growth path in the years ahead? The policy debate in Cuba has so far lacked a discussion about what long-run development strategy could enable to combine equity and growth objectives. Differently from many other developing countries, Cuban policy makers have often focused on the former type of objective and typically neglected the other (Deere and Meurs, 1992; Pastor and Zimbalist, 1995). At the same time, international scholarly research on Cuba’s economic development has also stagnated and failed to feed this policy debate.

The present paper intends to contribute to this research gap and policy debate by setting up a framework to discuss policy strategies and future scenarios for Cuba’s development in the long-run. The paper presents a system dynamics model to investigate the evolution of the Cuban economy in the future, and analyze how this will respond to different policy actions that may be implemented by national authorities as the reform process will continue.

This model is not only relevant for the policy debate in Cuba, but it may in principle be extended to study the experience of other developing countries. Its main rationale is that economic development is a complex process in which several factors co-evolve and interact with each other (Castellacci and Natera, 2013a). Any policy targeting a given part of the economy will turn out to have multiple effects on several other factors, through a web of direct and indirect feedback loops mechanisms. Ignoring this complex web of relationship limits our understanding of economic development policy. The system dynamics model presented in this paper conceptualizes economic development as a complex and holistic process in which several factors coevolve and shape each other's dynamics over time (Saeed and Prankprakma, 1997; Sterman, 2002; Rich, 2008).

In a nutshell, the model is composed by four main blocks interacting with each other: (1) production; (2) science and technology (S&T); (3) education and human capital; (4) population and health. These blocks represent four major engines of economic development that have been extensively investigated by the economic growth and development literature. The key novelty of our exercise is that, while most previous studies in this field have only focused on one of these dimensions at a time and neglected the others, our model considers them simultaneously and studies the dynamic interactions among them.

The main result of the simulation of this model for Cuba is that rapid and sustained economic growth in the long run could be achieved by combining active public policies to enhance the R&D sector and an efficient private sector that develops the capital infrastructure of the economy. The paper is organized as follows. Section 2 describes the background; section 3 presents the system dynamics model; section 4 shows the results of the model calibration for Cuba; section 5 builds up and compare different policy scenarios for the future; section 6 summarizes the main results and implications of the work.

2. The Cuban Economy at the Cross-road

Cuban authorities have recently started a process of economic reform intended to revive Cuba's economy, which has been stagnating for more than two decades of stagnation since the collapse of the Soviet Union. The reform process – so-called "actualización" – was the main theme of the 6th Congress of the Cuban Communist Party in April 2011. The underlying rationale of the reform process is that the survival of the socio-political system in Cuba depends on the sustainability of its economic system, and that the latter must therefore be restructured and made more efficient (Fernandez, 2013). Among other ongoing reforms, one objective is to gradually increase employment and value added shares in non-publicly owned activities, such as non-agricultural cooperatives and private sector enterprises (e.g. by allowing self-employed workers, "cuentapropistas", in the service sectors). Other declared objectives that are part of this reform process are also to update the management system of public enterprises, and to revise the economic planning system.

However, commentators and experts of the Cuban economy are currently questioning the speed and scope of the reform process, arguing that this is not adequately facing the urgent challenges that Cuba is faced with (Torres et al., 2013). Specifically, some major structural issues hamper long-run economic development in Cuba (Deere and Meurs, 1992; Pastor and Zimbalist, 1995; Mesa-Lago, 1998).

The first is the lack of competitiveness of the supply-side of the economy. The agricultural sector, which was once a primary source of income and export revenues, has progressively worsened its performance (Marshall, 1998). Similarly, some manufacturing industries have decreased their production and employment shares in the economy (with the notable exception of pharmaceuticals and biotechnology which represent more dynamic branches of industrial activity). Correspondingly, the service sectors have expanded rapidly, although much of this growth is accounted for by low-productivity activities such as social and personal services (Torres, 2013). More dynamic and innovative services (e.g. finance, TLCs, transport), which typically play a central role in developing countries' national innovation systems, have instead not increased their shares and productivity.

One of the factors explaining the low competitiveness and efficiency of the production sector of the Cuban economy is its weak rate of investments. Physical capital accumulation is a primary engine of economic growth for developing countries, since it enables to upgrade capital machineries used in production activities and the quality of infrastructures available to the population. But the process of capital accumulation is constrained in Cuba by the lack of financial resources available to the public sector, as well as the paucity of private investments undertaken by domestic firms and foreign MNEs (Castellacci and Natera, 2013b). Another factor explaining the low productivity level in the economy is the overall weak technological performance of its R&D sector. On the one hand, the Cuban economy has traditionally set technological innovation as an important policy objective in its agenda, and made some efforts to develop and support its national system of innovation (Nuñez and Montalvo, 2013). R&D expenditure is currently above the average of the Latin American region. On the other hand, however, R&D investments in Cuba are mostly accounted for by public research, while private R&D carried out by the business sector is quite limited. Correspondingly, there is scarce interaction between public science and research and the business sector, both domestic and international, which limits the dynamics of technological innovation and its potential for a more widespread diffusion throughout the economy (Nuñez and Montalvo, 2013).

The limited openness of the economy represents a further important obstacle to its long-run development. The US embargo and other institutional conditions forced Cuba to focus its trade activities with a restricted number of countries (e.g. Soviet Union in the past, and Venezuela more recently), leading to persistent trade imbalances, as well as fragility and uncertainty on its future prospects due to the strong dependence on external policy conditions and changes. Export activities have also been highly concentrated in a few industries, mostly related to natural resource-based and traditional activities, but with limited efforts to develop upstream linkages to the related domestic process-based industries. Two exceptions to this general pattern are biotechnology and professional services, which are more dynamic industries and potentially promising areas for export opportunities. Regarding inwards FDI, these are also substantially lower than other Latin American countries, and highly focused on a restricted set of countries. In general, the limited openness of the economy represents a major weakness for a small country like Cuba, which greatly hampers the process of technology imitation and international diffusion of advanced technologies that is so crucial for developing economies.

Finally, an important issue that is less frequently discussed refers to Cuba's population. According to recent projections, the country is expected to experience a sizeable decrease in its population during the next decades (UN, 2013). This will mostly be due to an ageing demographics and the progressive reduction of the fertility rate. As a consequence of this trend, the working age population will also experience a decrease in the long-run, limiting the pool of human resources that can be employed in productive activities (including the R&D sector). To counteract this trend, the economy will have to become in the future much more productive, efficient and innovative than it is at present.

The main problem with the current process of economic reform is that it fails to recognize the importance of these structural weaknesses of the Cuban economy, and that it lacks an analysis of what long-run development policy would make it possible to drive this back on a sustainable growth path. The current policy debate often points to Vietnam as a model to follow, but this discussion fails to recognize the huge differences between the two countries (Torres et al., 2013). When Vietnam speeded up its transition process – the "Doi Moi" undertaken with the 1986 Party Congress – the country had a much lower level of GDP per capita than Cuba has today, a younger and rising labor force and, above all, a much stronger political willingness to implement a rapid process of economic transformation and development. Thus, the emphasis on the Vietnam's model is largely misleading. What Cuba urgently needs is instead a thorough analysis and open debate about what long-run development model and what specific policy strategies would be appropriate for the country, making it possible to revive its economy while at the same time maintaining a commitment to equity and social objectives that it has had during the last few decades.

3. A System Dynamics Model

System dynamics (SD) is a methodology that studies the dynamic interactions and feedback effects among a set of variables that compose a system (Forrester 1961; Sterman, 2002). Variables are conceptualized as stocks, with inflows and outflows defining the value of each stock variable at a given time, and information flows that connect the various stock variables together. Mathematically, a SD model can be written as a set of ordinary nonlinear integral equations. Since it is not possible to obtain mathematically analytical solutions and dynamic equilibrium conditions for this type of complex systems, SD models make use of graphical representations (causal loop diagrams) to provide an intuitive visualization of the working of the model, and computer simulations to analyze its dynamic behavior and time trends.

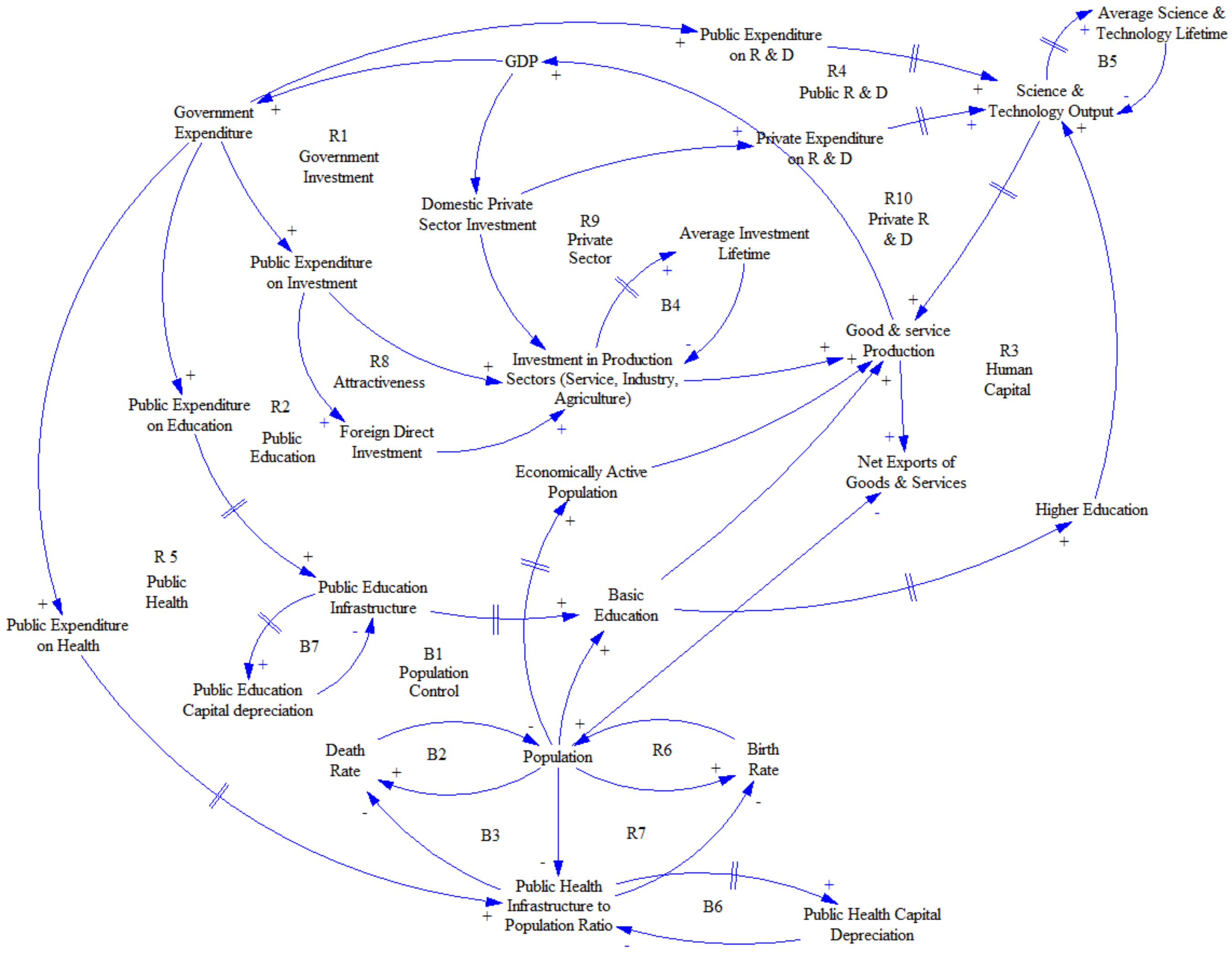
Within the social sciences, SD models have been extensively used in environmental, management and business studies. By contrast, the SD approach has had only limited applications within economics, in general, and growth and development economics, in particular (Saeed and Prankprakma, 1997; Rich, 2008). The reason for this is essentially that the economics discipline has traditionally devoted attention to the study of the equilibrium conditions that govern closed linear systems, and largely neglected disequilibrium behavior that characterizes complex non-linear systems.

However, economic development is a complex process in which several factors co-evolve and interact with each other. Any policy targeting a given part of the economy will turn out to have multiple effects on several other factors, through a web of direct and indirect feedback loops mechanisms. Ignoring this complex web of relationship limits our understanding of economic development policy. The motivation and rationale of the SD model presented in this paper is precisely to conceptualize economic development as a complex and holistic process in which several factors coevolve and shape each other's dynamics over time.

Our SD model has an intricate structure. It comprises around 80 variables that endogenously evolve over time, and nearly 40 parameters that represent (exogenous) structural characteristics of the economy. Both the mathematical representation of the model and its system dynamics implementation (*iThink* software, version 10.0.3) are available upon request as an online appendix. In this article, we only provide a descriptive presentation of the model, focusing on the main ideas, feedback loops and their implications for development policy.

The model aims at representing the evolution of the Cuban economy and how this will respond to different development policy strategies that may be implemented by national authorities in the future. Figure 1 presents the *causal loop diagram* that summarizes all main variables and relationships among them, indicating how the Cuban economic system evolves over time. The causal loop diagram highlights two different types of feedback loops: on the one hand, *reinforcing* loops (R) indicate the dynamics of two or more variables that sustain each other over time setting up a cumulative and self-reinforcing causation mechanism; on the other hand, *balancing* loops (B) point out a mechanism by which the growth of a variable is attenuated (hampered) by the growth of another variable, thus tending to report the system back to the initial equilibrium status. In this model, the dynamics of the economic system is governed by the set of reinforcing and balancing feedback loops among the main variables.

Figure 1: A system dynamics model: Overview of the main feedback loops



The model is composed by four main blocks interacting with each other: (1) production; (2) science and technology (S&T); (3) education and human capital; (4) population and health. These blocks represent four major engines of economic development that have been extensively investigated by the economic growth and development literature. The key novelty of our exercise is that, while most previous studies in this field have only focused on one of these dimensions at a time and neglected the others, our SD model considers them simultaneously and studies the dynamic interactions among them.

The heart of the model is the country's GDP. This is composed of two parts: private and public GDP. In Cuba, due to the legal constraints to private property, privately produced GDP is low (around 15%), whereas the public component of gross domestic product is very high (nearly 85%). One of the crucial policy debates in the country is the extent to which public ownership should gradually decrease in the future so as to give more opportunities to the development of the private sector of the economy. This is one of the key aspects that our simulation scenario analysis will analyze in the second part of the paper. Public GDP is allocated among four components (each referring to one of the four blocks of the model): public investments in infrastructure, public investments in science and technology, education and human capital investments, and public health services.

Production. The accumulation of physical capital is one of the central factors highlighted by mainstream economic growth theory (Solow, 1957; Azariadis and Drazen, 1990). In our SD model, there are three sources of physical capital investments: domestic firms' private investments, foreign MNEs' inward foreign direct investments (FDI) and national policy makers' public investments to develop the country's infrastructures. In Cuba, the lack of financial resources hampers the process of capital accumulation, and all of the three sources noted here are well below the average level in many other developing countries. Achieving a higher investment ratio is a crucial development policy priority for the future, which our simulation analysis will carefully scrutinize. Physical capital investments drive the growth of the economy through two distinct channels.

First, they increase labor productivity: a higher and better quality of capital infrastructure enables domestic companies to increase their productivity over time. Figure 1 points out two reinforcing feedback loops that drive the self-sustaining relationship between capital investment, on the one hand, and productivity and GDP growth, on the other (R1: Government investment; R9: private sector investment). We also assume that the growth of productivity fosters export dynamics, i.e. the country will increase its export sales of agricultural products, manufacturing goods and/or services as its sectoral productivity will grow over time. The process of physical capital accumulation is however hampered by capital depreciation, which lowers the quality and efficiency of capital machineries and infrastructures as time goes by (see balancing feedback loop B4).

Secondly, physical capital accumulation triggers a process of industrial transformations according to which workers tend to shift from traditional and low-skill jobs (e.g. in the primary sector) towards more technologically advanced and higher-productivity activities in secondary and tertiary branches. Specifically, our model assumes that there are three sectors in the economy – agriculture, manufacturing and services – and that workers decide their sector of occupation based on an *attractiveness* variable, which is a function of the total physical capital (infrastructures) that is invested in each of the three sectors. Hence, the basic idea is that as the economy develops, investments in manufacturing and service industries grow relatively faster than capital accumulation in the agriculture sector, and so workers would gradually shift from primary to secondary and tertiary branches. In figure 1, this mechanism is visualized by the reinforcing loops R8 (attractiveness), which is further fostered by loop R9 (private sector investment). Such a process of industrial transformation – often called *structural change* – is indeed an important feature of many countries' development process. In particular, Cuba is currently experiencing a rapid shift of labor towards the service sectors (Torres, 2013).

Science and technology (S&T). The creation and international diffusion of new technologies is the main engine of economic development pointed out by models of innovation and economic growth, both within new growth theory and in the evolutionary economics tradition (Nelson and Winter, 1982;

Romer, 1990; Castellacci and Natera, 2013a). In line with this literature, our SD model points out science and technology as key factors driving the dynamics of the economic system, but it also emphasizes the interactions that S&T variables have with the rest of the economic system. We assume that innovation is jointly determined by the interaction of two components: scientific activities carried out by public research organizations, and technological R&D investments undertaken by private business companies. Developing countries present a different balance between the two. Cuba is relatively strong in public S&T activities but still weak in terms of the R&D capability of its business sector. A crucial challenge ahead for the country is to address this unbalance and develop stronger links between public and private innovation activities in the future (Jover and Montalvo, 2013). Our model seeks to reproduce this feature of the economy.

Scientific activities are carried out by public research organizations (Universities and public research institutes) by using two main inputs: public resources allocated in each annual budget to R&D activities, and advanced human capital that is employed in this sector (e.g. PhD graduates that are employed in public S&T organizations). We assume that the larger the pool of advanced human capital that is publicly employed, the higher will be the productivity of scientific research. The overall scientific output produced by the country during each year (e.g. measured through the number of published scientific articles) is therefore a positive function of the amount of public resources invested in the sector as well as its productivity.

Technological R&D investments undertaken by private companies also use two types of inputs: financial resources that firms invest in R&D and skilled human capital (PhD graduates employed in the private sector). The latter factor enhances the productivity of applied research in the business sector. The overall technological output of the country at any given time t depends on three factors: the amount of R&D investments, the productivity of the private R&D sector, and the effect of scientific on technological output. This third factor represents the idea, well-known in the innovation literature, that science and technology are intertwined, and in particular that basic research constitutes an important platform upon which applied R&D activities unfold (Nelson, 1982).

As shown in figure 1, the effect of S&T relationships on the dynamics of the economic system is summarized by the two reinforcing feedback loops R4 and R5 (public and private R&D), which indicate that S&T activities will in turn have an impact on the productivity of the supply-side of the economy: innovation will spur companies' productivity, and this will in turn foster GDP dynamics through the reinforcing feedback loops R1 and R9 described above.

However, to make this cumulative growth process more realistic, we also introduce a lag between input and output of scientific and technological activities, reflecting the fact that R&D investments often take long time before having a visible and measurable impact in terms of scientific and technological output (see balancing loop B5). This slows down and partly counteracts the cumulative effect of innovation on productivity and GDP growth.

Education and human capital. This is another key engine of economic development investigated by a large number of contributions in growth theory (e.g. Verspagen, 1991; Benhabib and Spiegel, 1994). Public education has traditionally been an important policy objective for national authorities in Cuba during the last few decades, which have considered important to maintain active public support for developing the education level of the population, and achieved very good results *vis-à-vis* other developing economies (Brundenius, 2009). In our SD model, public expenditures on education affect economic growth in two ways. First, public education infrastructures and a good schooling system increase the basic education level of the working population (e.g. measured in terms of literacy rate, primary, secondary or tertiary ratios). This, we argue, will contribute to enhance the productivity of the supply-side of the economy, and hence further sustain GDP growth and publicly available resources in the future (see the reinforcing feedback loop R2 in figure 1). Secondly, a selected number of tertiary graduates will decide to enroll in PhD programmes (which may be financed either publicly or privately), and after obtaining their doctoral degree will work as researchers either in the public science system or in private R&D departments. Hence, greater public investments in education will also partly enhance the formation of advanced human capital, which will later contribute to the productivity of the S&T sector as noted above. Feedback loop R3 in figure 1 represents this second channel through which public education affects the country's growth via the dynamics of the S&T system.

Population and health. The dynamics of a country's population is another crucial factor to shape the nation's development path in the long-run. On the one hand, a growing population enhances economic growth by making available a large pool of human resources that can be used in productive business and S&T activities. On the other hand, however, a smaller population size means that a given level of GDP leads to a higher individual wealth on average (e.g. as measured by the country's GDP per capita). Models of population and economic development have extensively investigated these issues, e.g. by studying changes in fertility decisions along the demographic transition that many countries experience along their development process (Galor, and Weil, 2000). In Cuba, for instance, population projections indicate that the fertility rate will continue to decline in the next decades, so that the size of the population is also expected to decrease in the future. This is an important factor that will pose a further constrain to the country's economic development. Our model seeks to take this aspect into account too.

Our SD model provides a simplified view of the population and health sector of the economy. Public expenditures on health infrastructure is the fourth component of public GDP considered in the model. The health system is a policy priority in Cuba, so that public health investments typically account for a significant share of the Government's GDP. These expenditures tend to improve the country's health infrastructures by extending public health services as well as renovating depreciated health capital. These public efforts will have the effect of increasing the birth rate, decreasing mortality and hence increasing the size of the population that is able to work, thus indirectly fostering economic growth (reinforcing feedback loop R5). However, in line with models of the demographic transition, we also argue that as the country grows and become richer, parents will often choose to have less children, thus decreasing the average fertility rate in the economy (Galor, 2005). This second mechanism (balancing feedback loop B1) counteracts the first one and poses a constraint to the growth of the economy in the long run. As noted above, given current projections, this seems to be a highly relevant factor for future developments in Cuba.

4. Model Calibration and Results for Cuba

We have calibrated the model's parameters and the variables' initial values based on statistical data for Cuba for the year 2010 (data source: WDI, World Bank). The idea is to reproduce some of the main structural characteristics of the Cuban economy at the present stage, and then carry out a simulation analysis of the model in order to investigate how the country will evolve in the future in response to different policy strategies. Table 1 reports the initial values for some of the main variables considered in the model.

Table 1: Model calibration for the Cuban economy: initial values for the main variables based on statistical data for the year 2010 (source: WDI, World Bank).

Gross Domestic Product	
GDP (USD)	65000000000
Service Value Added (% of GDP)	74%
Industry Value Added (% of GDP)	21%
Agriculture Vale Added (% of GDP)	5%
Labor force	
Total labor force	5147849
Employment in agriculture	19%
Employment in industry	18%
Employment in services	63%
Government expenditures	
Total government expenditure (GE) (USD)	41600000000
Public education (% of GE)	18.3%
Public Health (% of GE)	14.5%
Public investments (GCF) (% of GE)	17%
Public R & D (% of GE)	0.95%
Other public expenditures	49.25%
Public investments (GCF)	
Service sector share	63%
Industry sector share	18%
Agriculture sector share	19%
Average investment lifetime	20 (years)
Private investments	
Service sector share	74%
Industry sector share	21%
Agriculture sector share	5%
Average investment lifetime	20 (years)
Science & technology (S&T)	
Scientific publications (articles)	222
Patents	59
Time lag between input and output	10 (years)
Population	
Total population (TP)	11281768
0 – 14 years old (% of TP)	18%
15 – 64 years old (% of TP)	70%
65 – above (% of TP)	12%
Death rate	0.7%
Birth rate	2%
Life expectancy (years)	79

Among the model's parameters, six of these are of particular interest because they represent policy instruments that can be set and controlled by national policy-makers. The model has six such *policy parameters*:

- Public expenditures on investments (share of total Government expenditures)
- Public expenditures on R&D (share of total Government expenditures)
- Public expenditures on education (share of total Government expenditures)
- Public expenditures on health (share of total Government expenditures)
- Private sector domestic investments (share of GDP)
- Inward foreign direct investments (share of GDP)

The first four parameters represent the components of the Government budget that we consider in the model. By changing the values of these parameters, we will be able to simulate a change in the allocation of public expenditures among these activities (e.g. policy strategies giving a greater focus on capital infrastructures, innovation, education or health). The other two parameters represent instead the two crucial components of private sector investments, carried out by domestic firms and foreign MNEs respectively. At present, both of these are very low in Cuba and play a secondary role on the country's growth trajectory. However, the current policy debate about the future of Cuba's development highlights private sector development and FDI as two crucial issues that Cuban policy makers must urgently deal with.
As noted in the previous section, the model has a large number of variables that evolve endogenously and interact with each other. Among these, we will focus on five key factors constituting relevant indicators of the performance of the economy in the long run. These six *outcome variables* are:

- GDP per capita
- Economically active working age population
- Innovative capability (in agriculture, manufacturing and services)
- Labor productivity (in agriculture, manufacturing and services)
- Employment share (in agriculture, manufacturing and services)
- Net export (in agriculture, manufacturing and services)

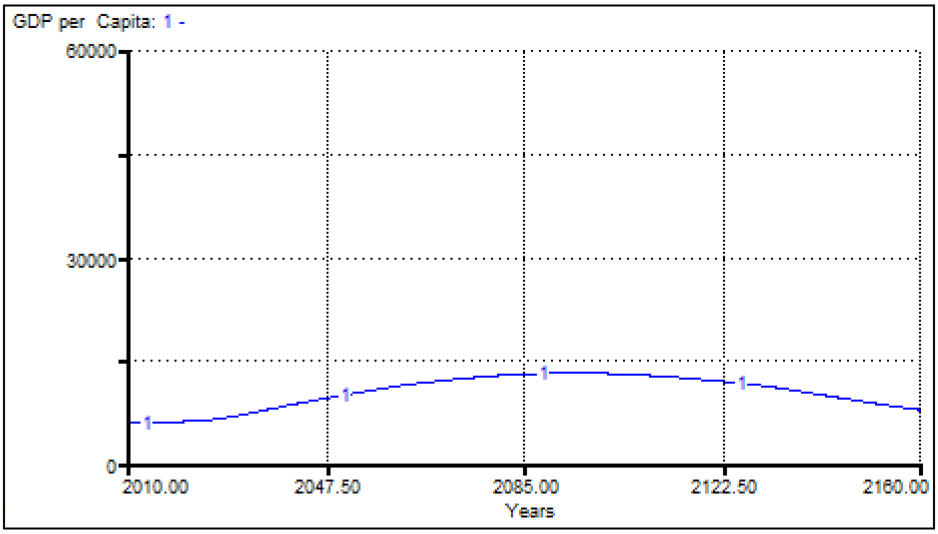
We now study the long-run behavior of the model by showing the time trends of these outcome variables for the baseline scenario, whereas the next section will illustrate the effects of some alternative policy scenarios. The baseline scenario considered here intends to reproduce in a stylized way some of the major features of the Cuban economy and its development policy strategy at present: (1) a relatively high share of total Government expenditures for education and health; (2) a relatively low share of public expenditures on physical capital accumulation and R&D investments; (3) very weak intensity of domestic investments by the private sector; (4) a very low share of inward FDI.

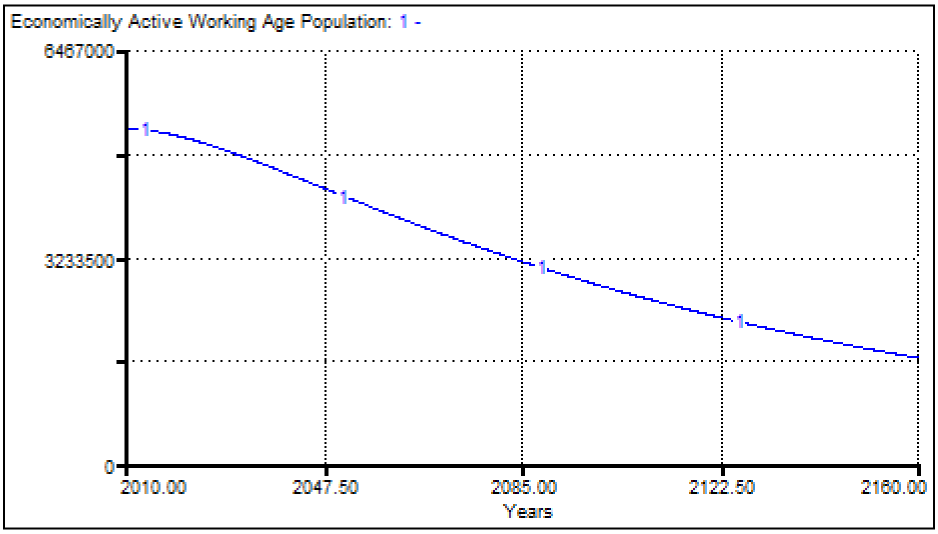
Figure 2 shows the time path of the outcome variables for a period of 150 years, i.e. starting in the year 2010 and ending in 2160. Obviously, for policy makers the relevant time span to assess the effects of policy actions is typically shorter, and so we will give more emphasis to the results of the simulations for the short- and medium-run. It is anyway interesting to look at the behavior of the model in the long-run as well.

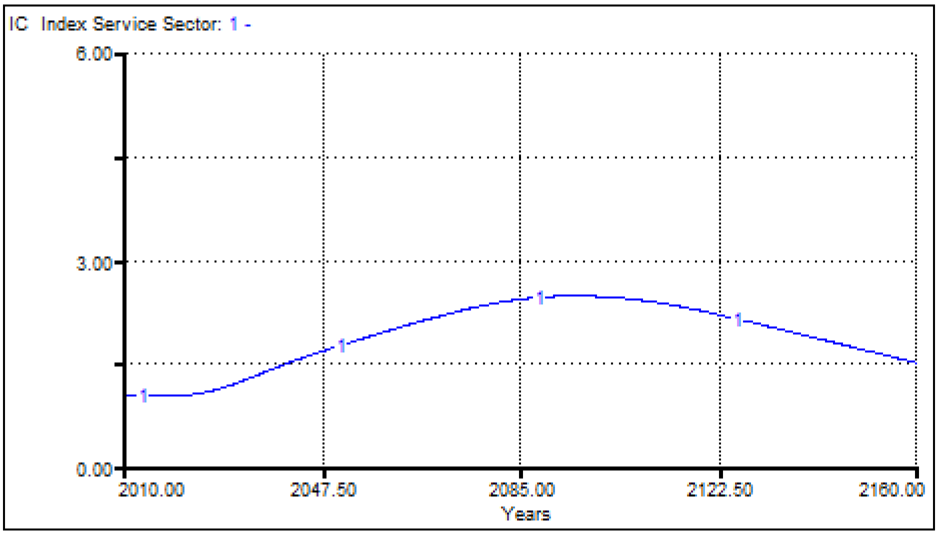
The first panel of figure 2 illustrates the simulated behavior of GDP per capita. Income per capita grows slowly following a logistic trend during the first 80 years of the simulation run, and it then gradually declines in the long run. The economy stagnates in the short-run, and it starts to pick up along a logistic path only in the medium-run (from year 2020 onwards). This growth can be explained as the outcome of the main reinforcing feedback loops among the model's variables described in the previous section. Specifically, physical capital accumulation (public and private investments) and infrastructure building spur productivity and GDP per capita growth, constituting a primary growth engine in this framework. S&T investments reinforce this path by increasing the innovative capability and labor productivity of the supply-side of the economy. Public education investments sustain the pool of human resources with basic education and advanced capabilities that represent a crucial input factor in production and S&T activities respectively. Finally, public health investments tend to improve health outcomes, such as life expectancy and mortality rates, counteracting the current downward trend of the fertility rate. In short, the Cuban economic system is driven in the long-run by the interaction of these reinforcing loop mechanisms, each of which is related to a different component of Government expenditures. The other panels of figure 2 corroborate this interpretation. We focus on the service sector, which assumes crucial importance in Cuba because of its large employment share and rapid growth in the last few years. Looking at the period 2010-2090, we observe a visible increase in the innovative capability, a corresponding increase in sectoral labor productivity, and a progressive improvement in the trade balance (the agricultural and manufacturing sectors, not reported in figure 2, follow a qualitatively similar trend).

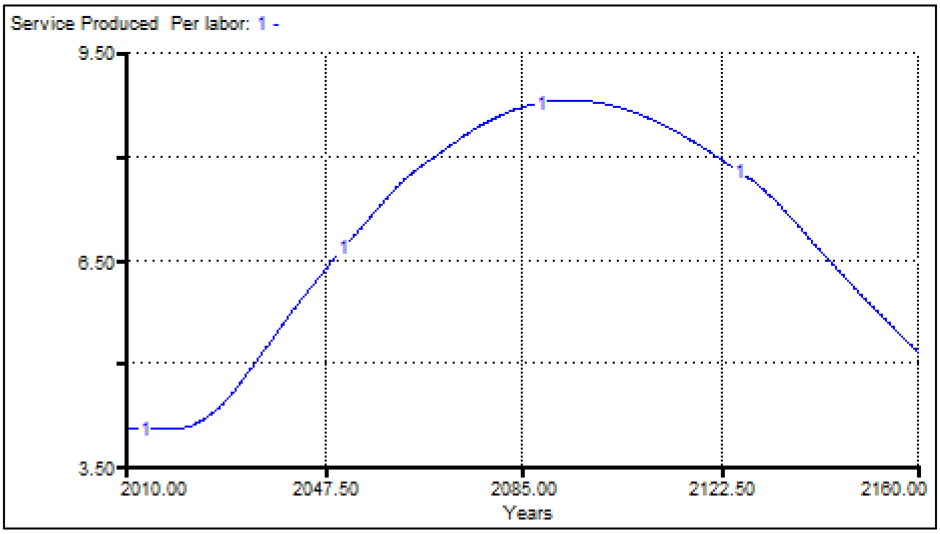
However, as shown by all of these graphs, the behavior of the model changes in the long-run (say, from year 2090 onwards). The reason for this is the downward trend of the population. This is illustrated in the second panel of figure 2, which shows the steady decline of the economically active working age population that Cuba is expected to experience in the long-run according to current demographic projections, mostly driven by a decrease in the fertility rate. Our model reproduces this pattern: in spite of the active public effort in the health sector, the size of the working population will gradually decline. In the short- and medium term, this will not have a major effect on the performance of the economy. But beyond a certain threshold (after year 2090), the sizeable contraction of the labor force will turn out to be an important hampering factor: the amount of human capital resources employed in productive activities and the number of skilled workers employed in the R&D sector will not be sufficient to achieve further productivity increases driving the growth of the economy in the long-run. As a consequence, the innovative capability, productivity, GDP and export performance of the economy will gradually decline, as long as population will continue its downward trend.

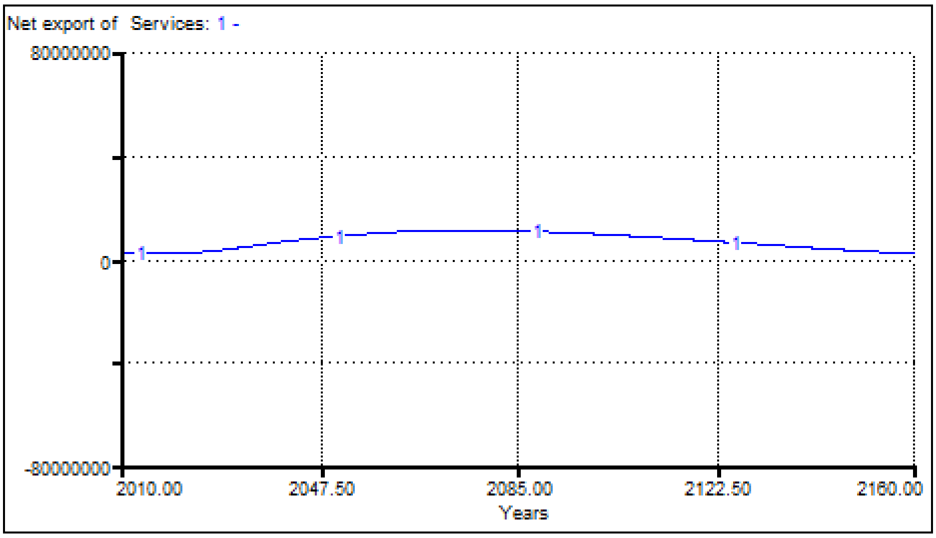
Figure 2: Simulation results I: baseline scenarios






IC Index Service Sector: 1 -
6.00
3.00
0.00
2010.00
2047.50
2085.00
2122.50
2160.00
Years


Service Produced Per labor: 1 -
9.50
6.50
3.50
2010.00
2047.50
2085.00
2122.50
2160.00
Years


Net export of Services: 1 -
80000000
0
-80000000
2010.00
2047.50
2085.00
2122.50
2160.00
Years

5. Comparing Policy Strategies and Future Scenarios

We now set five future scenarios based on different policy strategies that Cuban authorities may follow in the future to address the current challenges of the economy, and we compare each of them to the baseline scenario analyzed in the previous section. The objective of the comparison is to get insights about the effects of these strategies on the future performance of the Cuban economy, and hence about the new development model that Cuba may follow during the coming decades. Table 2 reports the calibration values that we have set in each of the six scenarios for the main policy parameters.

Cuba today (baseline scenario). This is the basic scenario that has been analyzed in the previous section, providing a stylized view of the Cuban economy today. The policy parameters describe an economy with a relatively low share of public expenditures on physical capital accumulation (17%), a low public R&D intensity (0.95%), a very weak intensity of domestic investments by the private sector, and a very low share of inward FDI (for simplicity, the last two parameters have been set to zero in the simulation analysis).

Privatization of the economy. This scenario is obtained by increasing the share of private domestic investments from 0 to 50%. This increase represents a substantial acceleration in the rate of privatization of the economy, according to which the non-State sector of the economy will gradually increase in the years ahead and public ownership will correspondingly decrease. In other words, this scenario characterizes a marked transition towards a mixed capitalist model where capital accumulation is driven by both public and private investments.

State-led capital accumulation. The only difference between this scenario and the baseline is that we hereby double the value of the parameter measuring public expenditures on investments (share of total Government expenditures), from 17 to 34%. This experiment represents a sharp change in the allocation of public expenditures, with a much stronger emphasis on capital accumulation and infrastructure building and, correspondingly, a lower amount of public resources allocated to other policy objectives (e.g. health, education, social policy, etc.).

FDI-driven growth. This scenario considers the possibility of a sharp increase in inward FDI, from the current very low level (among the lowest worldwide) up to 30% (which is the same level as the neighboring Dominican Republic has today). A marked increase in FDI would necessitate a mind shift of Cuban policy-makers and an active policy to efficiently attract private investments from foreign MNEs, many of which are already well established in the Caribbean area and Latin America at large. This policy would indeed be feasible and many commentators have recently pointed to FDI as a crucial channel that could bring new capital resources in the short-run, as well as boost the country's productivity growth in the longer term (Brundenius et al., 2013).

Innovation-based growth. This fifth experiment studies the effect of a sharp increase in public R&D investments, obtained by doubling the corresponding policy parameter from the current value (0.95%) up to a value of 2%. This 2% level would be comparable to the R&D intensity that characterizes many advanced countries, and would hence indicate scientific and technological investments as a central policy priority for Cuba's development model in the future (even higher than it has been the case so far). This policy too would be feasible: the increase of public R&D investments would be strong, but the total amount of Government resources devoted to this policy would be quite marginal as a total share of the public budget.

The Chinese model. Finally, we set up a scenario that combines together all of the policy changes described by the previous four scenarios. This is done by increasing simultaneously the values of the four parameters representing private investments, public investments, inward FDI and public R&D. We provocatively call this "the Chinese model", simply to indicate the adoption of an aggressive and multifaceted policy strategy that puts economic development at the centre of the policy stage and targets this by means of multiple strategies, combining public, private and foreign investments.

Table 2: Calibration values for six policy scenarios

Policy scenarios	Private investments (% of GDP)	Public investments (% of GE)	Inward FDI (% of GDP)	Public R&D (% of GDP)
1. **Cuba today** (no policy change; baseline scenario)	0%	17%	0%	0.095%
2. **Privatization of the economy** (increasing private sector investments)	50%	17%	0%	0.095%
3. **State-led capital accumulation** (increasing public sector investments)	0%	34%	0%	0.095%
4. **FDI-based growth** (increasing inward FDI)	0%	17%	30%	0.095%
5. **Innovation-based growth** (increasing public R&D)	0%	17%	0%	2%
6. **The Chinese growth model** (combining all policies 2 to 5)	50%	34%	30%	2%

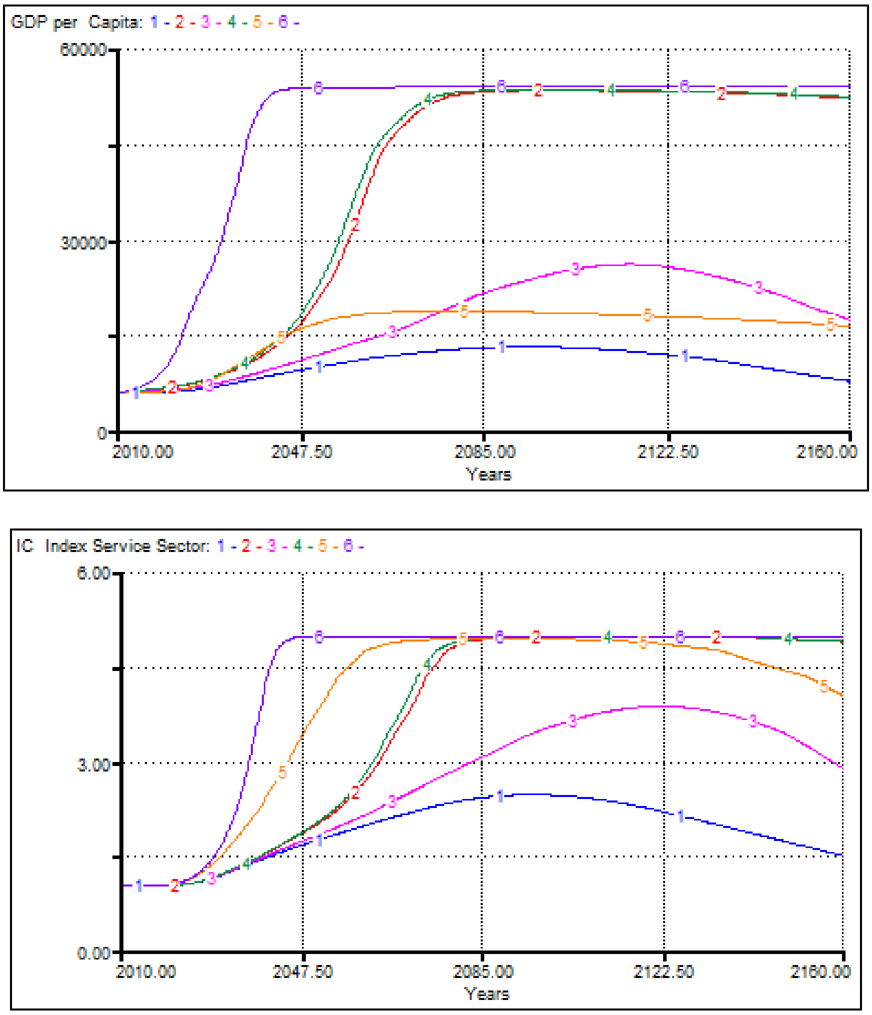
Figure 3 shows the time path of the main variables for these six policy scenarios. A comparison of scenarios 2 to 6 *vis-a-vis* the baseline scenario points out three main results. First, strategies 2 (*privatization of the economy*) and 4 (*FDI-driven growth*) make it possible to achieve a virtuous and sustained growth path that improves substantially the performance of the Cuban economy in the long-run. In these scenarios, GDP per capita grows rapidly and, differently from what observed in relation to the baseline scenario, it does not decline in the long-run as the size of the population contracts. A similar pattern is also followed by the innovative capability and sectoral productivity variables. Again, to save space, we only report here the graphs for service sector, that is the branch of the economy with the largest employment share and most dynamic pattern. Interestingly, these are the two scenarios where a visible process of industrial transformation (structural change) is at stake, entailing a shift of workers from the agricultural branch towards manufacturing industries and even more to the service sectors. In sum, the key point is that a greater degree of privatization in the Cuban economy (either through inward FDI of foreign MNEs or capital investments of private domestic companies) will pay off, and enable the achievement of a dynamic and sustained growth path for Cuba in the future.

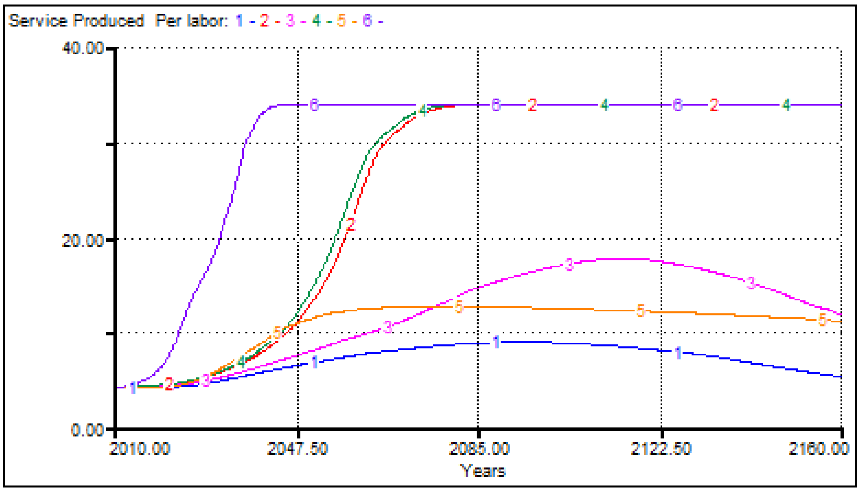
The second main result refers to policy scenarios 3 (*State-led capital accumulation*) and 5 (*innovation-based growth*). These strategies are different, but what they have in common is that they are both based on public resources, allocated to capital investments and public infrastructure building in the former case, and R&D expenditures in the latter. Policy strategy 3 leads to GDP per capita growth at a higher pace than it is the case in the baseline scenario, although this increased rate cannot be sustained in the long run, as it is gradually counteracted by the decreasing population dynamics (as noted above with respect to the baseline scenario). The bottom line here is that shifting public resources towards physical capital investments does not pay off: a stronger and more sustainable boost to the economy can be generated by means of private investments (either by domestic or foreign firms).

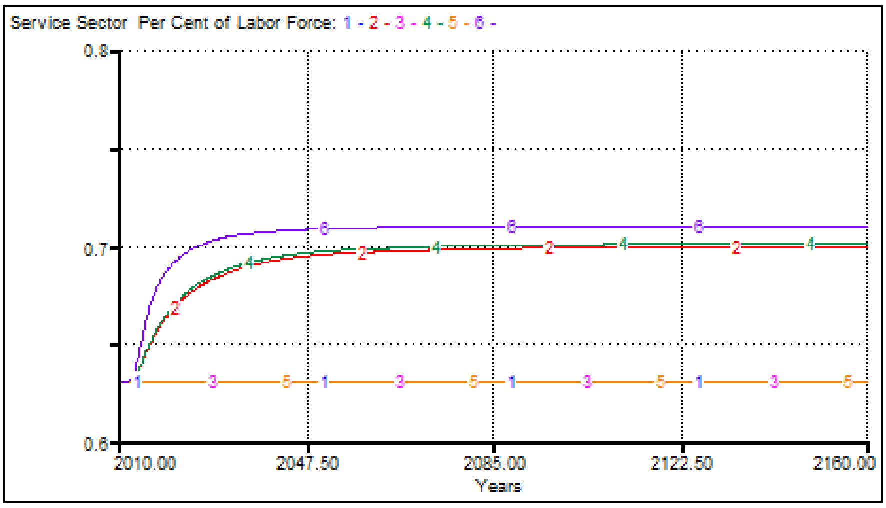
By contrast, the R&D-based policy strategy shows a relatively better long-run performance: the GDP per capita increases *vis-a-vis* the baseline situation, and it remains rather stable in the long-run. By enhancing the productivity of the supply side of the economy, scientific and technological innovations boost economic growth and export performance. And, as noted above, this policy scenario can be achieved by means of a relatively limited and feasible effort, i.e. only by increasing public R&D expenditures from 1 to 2% of GDP.

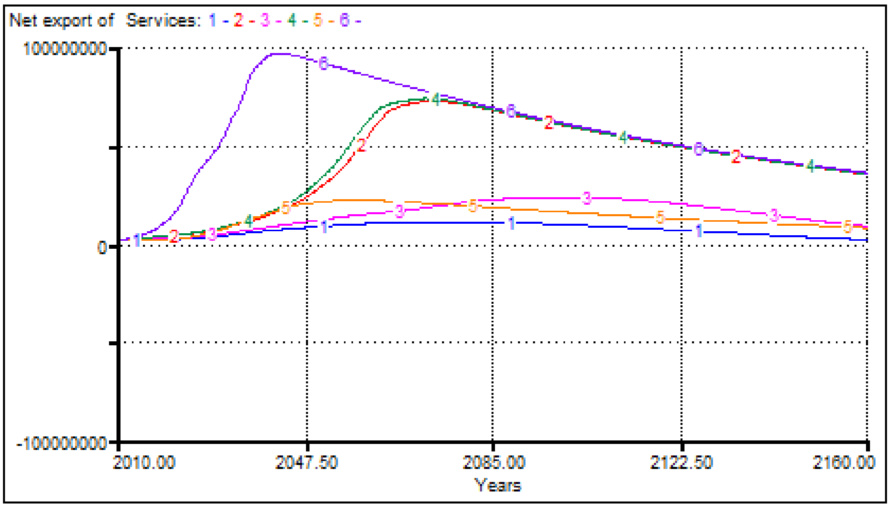
Finally, the third result relates to policy scenario 6 (*the Chinese model*), which combines all of the policy changes and parameter increases of the other experiments. This more aggressive policy strategy, combining public and private sources, does obviously outperform all others: the economy receives a strong boost already in the short-run (from year 2015 onwards), and reaches the maximum level of all outcome variables after only a four-decade period. This resembles the extraordinary catching up process of China and few other East Asian growth miracles, emphasizing that the combination active public policies and an efficient private sector is a crucial ingredient for rapid growth and catch up.

Figure 3: Simulation results II: a comparison of the six policy scenarios




Service Produced Per labor: 1 - 2 - 3 - 4 - 5 - 6 -
40.00
20.00
0.00
2010.00
2047.50
2085.00
2122.50
2160.00
Years


Service Sector Per Cent of Labor Force: 1 - 2 - 3 - 4 - 5 - 6 -
0.8
0.7
0.6
2010.00
2047.50
2085.00
2122.50
2160.00
Years


Net export of Services: 1 - 2 - 3 - 4 - 5 - 6 -
100000000
0
-100000000
2010.00
2047.50
2085.00
2122.50
2160.00
Years

7. Conclusions

The paper has presented a system dynamics model to investigate Cuba's economic development process, and a simulation analysis of this model to compare different policy strategies and scenarios that may be realized in the future as the reform of the Cuban economy will continue and deepen. The main motivation for setting up this framework is the important structural challenges that the Cuban economy is currently faced with, and the lack of a comprehensive development policy strategy to address these issues and to create the conditions for sustained growth in the long-run.

The simulation results point out three main results and policy implications. First, the current rate of physical capital accumulation and infrastructure building is not sufficient to generate sustained economic growth, and should be substantially increased. However, the public sector will not be able to achieve this alone. It lacks the financial resources to carry out large scale investments. Changing the Government's budget allocation in such a way to shift public resources towards physical capital investments, and reducing correspondingly investments in e.g. health or education, would not pay off. Our simulation analysis highlights that a stronger and more sustainable boost to the economy will only be generated by means of private investments carried out by profit-motivated business companies, either domestic SMEs or foreign MNEs, which typically have greater managerial capabilities and technological abilities than publicly-owned enterprises. Undertaking an active policy to attract inward FDI would represent a first and feasible step in this direction, bringing new financial resources that the economy needs in the short-run. Increasing the share of private companies in the economy would then be the second necessary step to sustain this policy strategy in the long-run.

Secondly, our simulation analysis points out the importance of scientific and technological innovations, which by enhancing the productivity of the supply side of the economy boost economic growth and export performance. R&D policy seems particularly important for two reasons: on the one hand, it is feasible, since it can be implemented by means of a relatively limited amount of public resources; on the other hand, its effects are pervasive, because R&D activities generate spillover effects that diffuse throughout the whole economy.

Finally, our exercise highlights that economic development is a complex and multidimensional process. The most effective development policy model would indeed be to combine together, to the extent possible, the various policy strategies that have been discussed in the simulation analysis. Specifically, the combination of active public policies to enhance the R&D sector and an efficient private sector that develops the capital infrastructure of the economy would represent the most effective platform to achieve rapid and sustained economic growth in the long run.

On the whole, these analytical results are intended to foster the policy debate about Cuba's long-run development model. This debate is largely missing and national authorities lack an analytical framework to set up a coherent long-run policy strategy. The frequently made reference to the Vietnamese model is misleading and drives attention away from the structural characteristics and systemic challenges currently faced by the Cuban economy. International scholarly research on Cuba's transition process is also scant and should in the future contribute more to inform and foster the policy debate in the country.

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