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## **Driving Forces of Economic Growth (ECG) as a Consolidating Initiative**

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### **Why focus on economic growth?**

Economic growth since industrialization is the “elephant in the room” that is the ultimate driving force behind most of the changes being studied in other IIASA programs (energy and other resources, pollution, climate change, land use, etc.), but since the demise of the TED program in the 1990s, it is not being talked about directly at IIASA in its globality and historical depth. Because economic growth entails what are usually taken to be enormous benefits to mankind and individual countries, all attempts to address its costs are often (and sometimes falsely) perceived as being unpleasant tradeoffs that are better postponed than met head on, a fact that has become conspicuously reinforced during the current economic crisis. Thus without addressing the drivers and dynamics of global economic growth, it is difficult to put the other pieces of the puzzle into perspective.

### **Origin and history of ECG**

Economic growth is a general phenomenon inseparable from global change. For many years, IIASA has treated economic growth from different perspectives.

In this context, it was not surprising that several IIASA's National Member Organizations put forward the idea of setting up systematic studies on economic growth at IIASA.

Based on a proposal by the Finnish, Norwegian and Swedish NMOs, in October 2005 IIASA organized a first workshop on economic growth, which suggested an overview of studies in this area.

The workshop gave a start to the involvement of new economists from the Nordic countries in the IIASA network. Since 2006 several projects on economic growth have been run under support of the Finnish Academy.

In January 2007, IIASA's DYN and POP Programs set up a joint initiative on Driving Forces of Economic Growth (ECG, [www.iiasa.ac.at/Research/ECG](http://www.iiasa.ac.at/Research/ECG)). At that point, a focus in IIASA's research on economic growth was identified – the *driving forces*.

IIASA researchers representing the DYN, FOR, POP and RAV Programs have linked seven research projects to ECG. Other ECG activities include

- 10 seminars
- two IIASA-Tokyotech Workshops on Hybrid Management of Technology in the 21st Century (September 2007 and September 2008)
- The First ECG Workshop on Applications of Dynamic Systems to Economic Growth with Environment (November 2008)

Today's workshop initiated by the Finnish, Swedish and Russian NMOs can help the ECG team identify further efforts in developing the ECG initiative.

## **Background: diverse views on the drivers of economic growth**

Planning further efforts should obviously be based on the existing background. Here, we briefly summarize IIASA's experiences in studying driving forces of economic growth.

### *Human capital*

The POP's Human Capital and Economy project views human capital as the key driver of economic growth. It is suggested, in particular, that patterns of influence of human capital on economic growth estimated for the past may be applied to the future (together with other information and assumptions) to make long-term economic growth projections ([www.iiasa.ac.at/Research/POP/humancapital.html](http://www.iiasa.ac.at/Research/POP/humancapital.html)). Recent research by POP concentrates also on the indirect effects of human capital on economic growth channeled through changes in institutions. In particular, POP is currently also concentrating on research concerning the effect of educational attainment on democratization processes.

### *R&D*

The DYN Program, in collaboration with the Tokyo Institute of Technology, has treated investment in R&D as the major driver of economic growth at a country level. Research includes theoretic and data-based analyses of the optimality of economic growth in Japan. Conceptual models for innovation race between technological leaders and technological followers have been developed. Research has been supported by Japan's Ministry of Education and Technology.

### *Useful work*

Robert Ayres, IIASA Scholar, suggests that useful work is a critical driving force for a country's economy. This idea is in agreement with ordinary intuition as well as economic history, but it has been neglected because of a widespread misunderstanding that the output elasticity of a factor of production should be equal to its cost share. Recent work by Kuemmel et al has shown this assumption to be false due to the presence of constraints on the relationship between the factors (i.e. not perfect substitutability). To test the idea, Kuemmel has introduced a new type of production function incorporating energy as a production factor. Robert Ayres has suggested that useful work is actually more appropriate. This approach has been supported theoretically by the DYN Program and tested using data for the USA and Japan (in a less comprehensive manner) for the UK and Austria. The results are very encouraging, insofar as they explain historical growth for these countries without any need for an exogenous driver.

### *Transport infrastructure*

A recent DYN-FOR research effort including an extended model-based analysis of the European data, states that the transport infrastructure acts as an important driving force of economic growth at a country level.

### *Evolutionary economics*

The evolutionary approach deriving from the work of Schumpeter and Nelson and Winter looks at economic growth as a process of creative destruction that is synergistically dependent on many factors such as human capital, competitive forces, R&D, infrastructure and institutions, resource exploitation and the environment, in a complex nonlinear way fundamentally analogous to other Darwinian processes.

## **Background: methodology**

Analysis of specific drivers of economic growth has been supported by developments in methodology. Here, we mention two IIASA-elaborated methodological approaches.

### *SEDIM model*

The POP Program has developed a Simple Economic Demographic Interaction Model (SEDIM) that can be used to produce forecasts of the relationship between demographic and educational change and economic growth (<http://www.iiasa.ac.at/Research/ECG/research/ws/index.html>) The SEDIM case study of economic growth in South Asia is close to completion. That study done in cooperation POP and ADP Programs shows the effects of investments in air pollution technology on health and GDP growth.

### *Control-theoretic methodology*

The DYN-elaborated mathematical theory of infinite-horizon optimal control suggests a general method for producing long-term economic growth trajectories. A series of successful applications, with the use of real econometric data, has created the basis for a new theory- and data-based system-analytic approach to modeling economic growth (<http://www.iiasa.ac.at/Research/ECG/research/as&kr/index.html>).

## **Future: methodological framework for inter-linking diverse approaches**

It is proposed that in the next stage of research ECG will develop a general methodological framework for inter-linking IIASA's diverse experiences in studying the drivers of economic growth. The desired methodological framework can incorporate the following ideas.

### *Cross-verification of models*

Any particular approach to modeling economic growth deals usually with an economic driver (or a set of drivers) and an economic output – an indicator (or a set of indicators) of the quality of economic growth; the latter indicator is often understood as the GDP growth rate. The driver is specific for every approach, whereas the output is, roughly, defined similarly for all of them. Therefore, models dealing with different drivers should produce, roughly, the same output.

This logic can be used to cross-verify alternative models. The fact that, roughly, the same output trajectory is produced based on different drivers will show that the underlying alternative models do mimic the same real dynamics (from different perspectives). An important specific conclusion will be that the alternative models capture the dynamics of the alternative drivers correctly.

From a system-analytic point of view, the proposed cross-verification technique will open up a new approach in systems analysis of economic growth and will multiply our knowledge on its driving forces.

### *Modeling proportional development of economic drivers*

Another methodological approach can focus on multi-factor economic growth models dealing with multiple economic drivers (factors). A point of departure will be the understanding that in the process of economic growth the economic factors develop proportionally – although the proportions can vary within certain limits and can change over time.

If one freezes a *proportionality scenario* — a trajectory for the factor-to-factor proportionality coefficients, the original multi-factor model is boiled down to a one-factor one; the latter can then be analyzed using relatively simple tools; in particular, the output trajectories can be produced using the control-theoretic methodology outlined above.

A next step will be the selection of the proportionality scenarios that give rise to the most appropriate output trajectories; the selection criteria can be motivated by a purpose of the analysis and can include: fit with data, maximization of a given utility index, technological constraints imposed by an adopted economic development paradigm, etc.

A challenging task will be to use the cross-verification technique (see above) to identify a “real” proportionality scenario. (In this task, one will deal with a multi-factor model that incorporates the factors employed in the cross-verified alternative one-factor models.)

### *Synergistic models of factor proportions*

In a generalization of the above approach, the driving forces of economic growth are not simply recipes that call for certain proportions of the ingredients, but components of a complex system in which the diverse factors interact in a highly nonlinear manner and thus *synergistically*. This might mean that a certain number of factors must be present at certain minimal levels (e.g., openness to trade, quality of governance, level of human capital, functionality of capital markets, size of markets) before economic growth responds in a jump-like way. Various approaches have been proposed in the literature to capture these highly nonlinear complementarities, such as NK rugged landscapes and percolation on networks. The standard growth accounting framework, which regards all factors as substitutes for each other, cannot capture these effects.

### *Extensions: incorporation of risk factors and heterogeneity*

It is expected that natural and human-made risks will be incorporated in the economic growth models, and associated risk analysis techniques will be developed.

Another task will be to extend the models by introducing heterogeneous agents pursuing diverse interests. The analysis of the multi-agent models will require the development of behavioral patterns and usage of game-theoretic methods.

### **Future: case studies**

In ECG, the development of a general methodological framework will be complemented by case studies, in which the proposed methods will be applied to specific regional problems. The ECG team, in collaboration with a research group from the Institute of Economic Growth, Delhi, has prepared a draft research plan for an Indian case study. It is expected that the list of the ECG case studies will be extended.