**EDUCATION**

**IN THE**

**WILLIAM IAM**

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## Introduction

Integrated assessment models (IAMs) are increasingly being used to inform the possible trajectories that human and ecological systems may follow in their quest for a sustainable future. However, a systematic and holistic approach is required to obtain solid knowledge that reflects the diversity of structures guiding the complex interactions between humans and the earth system. In spite of this is one of the main utilities of IAMs, authors such as Barnes et al. (2013) or van den Berg et al. (2019) point out the absence of the study of social dynamics and human behaviour in this type of model, which can hinder the correct representation of the feedbacks that occur between the different modules, which can distort reality. With all, this critique can be transformed into a challenge to help us refine the models and thus improve understanding of the key relationships between the physical world and socio-economic dynamics.

This challenge has been our starting point. Thus, our aim has been to develop a model that contains a structure rich in feedbacks and overcomes this limitation that is present in most global models, which tend to focus on specific sectors, leaving aside some of the main bi-directional interactions that occur between the different components of the Earth system.

Our model, WILLIAM is an energy-economy-environment IAM that is based on the use of the system dynamics tool (Sterman, 2000; Martín, 2003 and Aracil & Gordillo, 2007), with a global scale, which is grouped by region, and a long-range time scale. Interestingly, it is one of the few global models that addresses the issue of education. In this case, as one of the main components of the social module. The approach here exposed is based on the idea that society works to sustain the material conditions required to perpetuate itself. Educational institutions are designed to provide skills/abilities for population and correctly generate the commodities and services the society demand. In this structural thinking, economy requires skilled people from education.

## Why educational attainment level?

Traditionally, population size has been the most important source of information for projections of future population trends, often complemented by GDP per capita, which acted as an economic indicator. However, it is obvious that human populations are not homogeneous, and it is this heterogeneity that conditions future population growth. Thus, over time, the multidimensional population dynamics methods originated by the International Institute for Applied Systems Analysis began to reflect other variables that lead to stratifying society. In this sense, Lutz, Goujon & Doblhammer-Reiter (1998) discuss the criteria for choosing those dimensions that should be systematically addressed in all processes of demographic analysis. Finally, three guidelines state that (1) the variable must be of substantive interest in its own right, (2) it must be a source of empirically observable heterogeneity, and (3) it must be accessible in terms of data and methodology.

Many dimensions were considered, such as legal marital status, place of origin or ethnicity of individuals, but only three dimensions meet all these requirements and are considered ideal candidates for inclusion in standard demographic studies: age, gender and educational attainment level. Not surprisingly, gender and age are among them, while the incorporation of educational attainment may come as a surprise. This is because there are arguments that while the former are natural covariates, education is merely a social construct. However, educational status has a significant influence on a wide range of social, economic and health issues, and its consideration can significantly alter aggregate demographic projections (K.C. & Lentzner, 2010, Lutz & K.C., 2010 and Lutz & K.C., 2011).

As a consequence, new models have recently been developed that consider education as a relevant issue to be considered. This is the case of the *Functional Enviro-economic Linkages Integrated Nexus* model, better known as FeliX. This IAM is supported by modelling those indicators that represent eight of the seventeen Sustainable Development Goals (SDGs), which relate to sustainable food (SDG 2), health and well-being (SDG 3), quality education (SDG 4), clean energy (SDG 7), economic growth (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13) and the life of terrestrial ecosystems (SDG 15).

*Diagrama

Descripción generada automáticamenteFigure 1. Overview of the Fel*iX model

*Source: Moallemi, E.A., Eker, S., Gao, L., Hadjikakou, M., Liu, Q., Kwakkel, J., Reed, P.M., Obersteiner, M., Guo, Z. & Bryan, B.A. (2022).*

If we focus on the educational sub-module, which is included within the population module of the FeliX model, we can observe that, as Moallemi, Eker, Gao, Hadjikakou, Liu, Kwakkel, Reed, Obersteiner, Guo & Bryan (2022) argue, “the population size at different age cohorts feeds into the education module to compute the population of primary, secondary, and tertiary education graduates through the feedback loops among the enrollment rate, graduation rate, and persistence to eventually reach the last grade of each education level. The accumulation of the educated population in all age cohorts between 15 and 64, multiplied by a labor force participation fraction, computes the labor force input for the economy module” (p.804)

What is new in this model is that, as in our IAM, FeliX also computes an alternative measure, called the human development index, which is an indicator of health, education and income. We will see how it is constructed and how it is implemented in our model in section 4.

Interfaz de usuario gráfica, Aplicación, Word

Descripción generada automáticamenteFigure 2. Causal diagram of secondary education in FeliX

*Source:* *http://www.felixmodel.com/*

Another model that looks at education as one of the core issues to be studied is the International Futures (IFs) model, an integrated global computer simulation that attempts to understand multiple cross-cutting problem areas, including education, and explore possible actions that can help countries change course.

In the words of Irfan (2017), “IFs education model forecasts enrollment, financing and attainment of education in 186 countries. It covers formal education spanning elementary, lower secondary, upper secondary and tertiary. It forecasts intake, survival, graduation and transition rates for each of these levels separately for boys and girls” (p.4).

Diagrama

Descripción generada automáticamenteFigure 3. Overview of the IFs education submodule

*Source: Irfan (2017).*

Among the variables considered in this model, the level of educational attainment of the population represents a key issue, since, according to these dynamics, a higher level of educational attainment leads to an increase in economic productivity. Moreover, the level of educational attainment achieved by women significantly affects their fertility rates.

As with the population pyramids, the model contains a representation of educational attainment by five-year age cohorts and by gender. Thus, four categories of educational attainment are provided, namely: no education, completed primary education, completed secondary education and completed tertiary education. These are established separately for both men and women over 15 years of age and by five-year age cohorts. This ensures that the performance of the national education system is added to the educational attainment of the previously educated adult population.

## WILLIAM educational submodule

Before starting to explain the functioning of our educational sub-module, we need to specify some details of the numbering system used by UNESCO to identify the sequential levels of the different educational systems. This is the International Standard Classification of Education (ISCED-2011), which represents a statistical reference categorization that allows the distribution of educational programs and their corresponding certifications by levels of education and fields of study. Thus, most countries rely on the percentage of the population having completed a specific level of education to define their educational profiles. In this sense, data revealing the main trends in education in the different states are only available for the three levels of education that are linked to the aforementioned classification.

*Figure 4. Aggregate educational levels in relation to ISCED 2011.*

|  |  |  |
| --- | --- | --- |
| **Aggregate educational levels** | **Relevant qualification** | **Codes in ISCED-2011** |
| Below upper secondary education (LOW EDUCATION) | Early childhood education | ISCED 0 |
| Primary education | ISCED 1 |
| Lower secondary education | ISCED 2 |
| Upper secondary or post-secondary non-tertiary education (MEDIUM EDUCATION) | Upper secondary education | ISCED 3 |
| Post-secondary non-tertiary education | ISCED 4 |
| Tertiary education (HIGH EDUCATION) | Short-cycle tertiary education | ISCED 5 |
| Bachelor’s or equivalent level | ISCED 6 |
| Master’s or equivalent level | ISCED 7 |
| Doctoral or equivalent level | ISCED 8 |

*Source: Prepared by the authors based on information obtained from the UNESCO Institute for Statistics (2013).*

The use of this methodology is particularly useful when comparing different educational profiles between countries or regions. This has been demonstrated by the two previously studied integrated assessment models, and we have therefore decided to base ourselves on the categorization shown in *Figure 4*.

Having clarified this, let's move on to explain how our educational submodule works. Our education sub-module is linked, as can be seen in *Figure 5*, to the demographic module, in that it provides the school-age population, and to the economic module, from which it receives the distribution of the public budget earmarked for education. The allocation of public spending on education is a function of national income per capita, which represents the level of economic development of each region. This implies that, in general terms, the stock of human capital, i.e., the educational attainment of adults, is updated in the model as children reach adulthood and take their educational attainments with them.

Interfaz de usuario gráfica, Aplicación

Descripción generada automáticamenteFigure 5. WILLIAM educational submodule

*Source: Prepared by the authors.*

The way in which the function of educational attainment is posited allows us to see a fluid and progressive evolution, since we understand that economic expenditure on education is not the only variable that would affect the level of educational attainment. However, the cumulative average of public expenditure on education over the last 15 years allows to calculate, together with the parameters defined to find the level of educational attainment, the percentage of new labour force for each level of educational attainment. The cumulative average in per capita public expenditure on education is proposed here as a way of breaking down the unrealistic contrasts that would occur in the event of a sudden increase or decrease in public expenditure on education by governments. On the other hand, it is proposed that this average should include data from the previous 15 years, since this is the age that is usually used as a reference when calculating the general level of adult attainment in other models.

With regard to the *BETA 0* and *BETA 1* parameters, we should point out that they have been calculated for both high and medium levels of education (which later allows us to know the values for low levels of education) and, specifically, for the range of people between 25 and 34 years of age, as we consider that, in addition to finishing their studies, this is the age range where most people enter the labour market.

To this can be added a preceding flow of the gender parity index, which is a socio-economic index usually designed to calculate the relative access of men and women to education. In its simplest form, it is calculated as the ratio of the number of females to the number of males in a given stage of education. It should be noted here that this is a scenario parameter that is set exogenously by the model user, who needs to know that a value below one indicates differences in favour of boys, while a value close to one indicates that parity has been more or less achieved.

All this allows us to know what the percentages of the new labour force are for each level of educational attainment in that particular age group and according to sex. These percentages change, as the level of educational attainment increases or decreases, until they reach certain maximums or minimums. These limits are set by giving a certain margin to the maximum and minimum percentages observed through historical data.

The parity index is applied

Apply the maxima and minima, according to the data consulted (85,5)

The condition that the sum of the 3 percentages is 100 is applied

β0H + β1H x APE

β0M + β1M x APE

PercH - PercM

The next step is to know the increase in the labour force. Once we have the percentages previously calculated through the aforementioned parameters, i.e., the new labour force by each level of educational attainment, we have to apply them to the new labour force flows by region and gender. At this point, people leaving the 20-24 age range are counted, as this is the age at which people might be sufficiently educated to enter the labour market for the first time in their lives.

However, the labour force by educational level, comprising the working-age population, has as an inflow person above the previously defined age and as an outflow person of working age who die and those who reach retirement age. Likewise, its variation can be affected by migratory flows, which can be both positive and negative.

## Human Development Index

The Human Development Index was introduced in 1990 by the UNDP with the aim of emphasising the idea that people and their capabilities should be the guiding criterion for assessing the development of a given country, thus avoiding focusing solely on the rate of economic growth. This indicator also helps to question the different government policies adopted by different states, as it explores why countries with the same GDP per capita achieve different results in terms of human development. To this end, this measure summarises the average achievement in those dimensions considered key to human development: a long and healthy life, access to knowledge and a decent standard of living.

*Figure 6. Human Development Index.*

**Access to knowledge**

**Standard of living**

**Long and healthy life**

School life expectancy

Mean years of schooling

GDP per capita

Life expectancy at birth

Educational index

Life expectancy index

GDP Index

Human Development Index

*Source: Prepared by the authors based on information obtained by the United Nations Development Programme (2022).*

As shown in *Figure 6*, the health dimension is assessed by life expectancy at birth; the education dimension is measured by the mean years of schooling for adults aged 25 and over, as well as by the expected years of schooling for children of school-going age; and finally, the standard of living dimension is quantified with the help of gross national income per capita. Once the scores for all these variables are obtained, the geometric mean is used to aggregate them into a composite index.

The origin of these variables within WILLIAM is determined by different modules. Thus, GDP per capita comes from the economic module and is therefore endogenous. Life expectancy at birth, on the other hand, is a parameter that comes from the demography module, although it is now exogenous. Education, as can be seen in the previous section, is endogenous, although we must add two further observations.

When calculating the average years of schooling, data are taken from the working-age population, since it is assumed that part of the population reached schooling in earlier times, while school life expectancy considers current enrolments, which in the model are approximated by the percentages of the population that becomes part of the working-age population. In either case, the pre-determined years of duration of each educational programme, previously established by the ISCED-2011 categories, are taken as a reference.

In order to create the indices that estimate each dimension, minimum and maximum values have to be established, from which the components of the indicators are normalized, so that the former act as natural zeros and the latter as aspirational targets.

The setting of the natural zero for life expectancy at 20 years is based on historical evidence that no country has had a life expectancy lower than this in the entire 20th century. The maximum life expectancy is set at 85 years as this is considered a realistic target to which many countries aspire given the steady improvements in medical advances and living conditions.

On the other hand, societies can subsist without formal education, which justifies the minimum number of years of schooling expected to be 0, while the maximum is set at around 18 years, which is equivalent to obtaining a master's degree in most countries. With this in mind, the minimum mean years of schooling is set at 0 years, and the maximum at an average of 15 years, as this is what is assumed for 2025.

As far as the minimum value of gross national income per capita is concerned, it is set at 100 dollars, because of the considerable amount of subsistence production. In contrast, the maximum is set at $75,000, as only three economies exceed this income limit: Liechtenstein, Qatar y Singapore.

*Figure 7. Limits for the creation of dimensional indices*

|  |  |  |  |
| --- | --- | --- | --- |
| **Dimension** | **Indicator** | **Minimum** | **Maximum** |
| Health | Life expectancy (years) | 20 | 85 |
| Education | School life expectancy (years) | 0 | 18 |
| Mean years of schooling (years) | 0 | 15 |
| Standard of living | GDP per capita (2017 PPP$) | 100 | 75.000 |

*Source: Prepared by the authors based on information obtained by the United Nations Development Programme (2022).*

Thus, once these limits have been defined, the indices for each dimension are calculated as follows:

It should be noted here that, as far as the education dimension is concerned, this equation has to be applied individually for each of its indicators and then the arithmetic mean of the resulting indices has to be found. Given that many developing countries have a low level of schooling among adults but seem to be very keen to achieve universal schooling for children of school age, it is appropriate to use this formula which allows perfect substitutability between the expected years of schooling and the mean years of schooling.

Considering that the values set as minima in both education components are equal to 0, a simple way to calculate the education index is by applying the formula below:

Likewise, with regard to the living conditions dimension, it is important to point out that the natural logarithm must be used, both for the real values and for the maximum and minimum values:

However, having clarified that the Human Development Index is based on the aggregation of these three dimensions, it could be seen as the geometric mean of the three-dimensional index:

## Limitations and further work

As can be seen, our education module focuses on the number of people in the labour market according to their level of educational attainment. If we were to add to this the International Standard Classification of Education by areas and training (ISCED-2013), we could perhaps have a very complex idea of the different specializations that different States would demand.

This could help us to establish what skills are in demand in different countries' markets, so that states could formulate policies to promote those programmes and levels of education that are most in demand. This is something that we can perhaps already see in some Eastern European countries, where the levels of training achieved seem to reflect a structural dynamic of the system itself. Related to this, another option for improvement lies in the likelihood of disaggregating educational expenditure according to each l educational attainment level.

But certainly, this might mean overlooking many other benefits of education. It would be interesting, in the hypothetical case of creating a health module, to look for correlations between education and the different health statuses of the population. It could also have greater links with the demographic module, not only by taking life expectancy, as we shall see later, but could, for example, feed back into this same variable through its link with fertility or infant mortality rates, since, as Barro & Lee (2001) argue:

Human capital, particularly that attained through education, has been emphasized as a critical determinant of economic progress. A greater amount of educational attainment implies more skilled and productive workers, who in turn increase economy's output of goods and services. An abundance of well-educated human resources also helps to facilitate the absorption of advanced technologies from developed countries. In addition, the level and distribution of educational attainment has a strong impact on social outcomes, such as child mortality, fertility, education of children, and income distribution. (p. 541)

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