AWESOME

WATER-ECOSYSTEM-FOOD

DEMOGRAPHIC SCENARIOS REPORT

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Table of Contents

List of Acronyms

Abbreviations

e0	Life Expectancy
EIA	Energy Information Administration
EU	European Union
GDP	Gross Domestic Product
IIASA	Internation Institute for Applied Systems Analysis
ILO	International Labour Office
MIG	Net Migration
SSP	Shared Socioeconomic Pathways
TFP	Total Factor Productivity
TFR	Total Fertility Rate
UN	United Nations
WB	World Bank
WP	Work Package

List of Tables

List of Figures

EXECUTIVE SUMMARY

In this report we provide scenarios for population and economic drivers expected to impact the agricultural sector for countries in the Mediterranean and adjacent regions relevant for the AWESOME models (see Table 1) according to the Shared Socio-economic Pathways (SSP) guidelines for the horizon 2020-2100 as first WP2 deliverable D2.1 - Demographic Scenarios. Population scenarios are based on probabilistic scenarios using the Bayesian hierarchical population model by Raftery et al. [7], appropriately modified to fit within the SSP scenarios, while the economic drivers scenarios are provided in terms of the global macroeconomic MaGE model [3]. The full detailed scenarios are uploaded and available for use on the AWESOME repository. In this report, information concerning the methodology adopted for the scenario generation, the nature and format of the produced data as well as a small but representative sample of the produced projections are presented. In particular, Egypt and Greece at the country level, while the Mediterranean area at the regional level, in accordance with the spatial levels of AWESOME models.

1 INTRODUCTION

1.1 AIMS

The aim of this report is to provide socio-economic scenarios that are expected to impact the agricultural sector, including the analysis of population evolution and basic economic drivers for the time horizon 2020-2100 for various countries of the Mediterranean and adjacent regions which are relevant for AWESOME models. These scenarios will be used in conjunction with the other models employed in the AWESOME project. The aim of this report is to provide a brief documentation concerning the modeling methodology for the population and the economic drivers, the quantities reported and predicted, as well as the methodology employed for constructing the various scenarios. The full data and predictions are uploaded in the project's repository. For the sake of illustration in this report we present in some detail the results for Egypt that is the main country of interest for the project and for comparison reasons, we choose one more EU country in the Mediterranean region, Greece. We also present aggregate data for the whole Mediterranean region and relevant countries for the project's models.

Demographic projections play a key role in the modeling proposed in this project as they interact and provide input to all other models that will be developed and used in this and other WPs of the project. Economic modeling relies on demographics since for example labor force or savings cycle depend directly on the population's age structure, energy and food demand scenarios depend on population dynamics, etc. A pictorial representation of these inter-dependencies is shown on Figure 1.

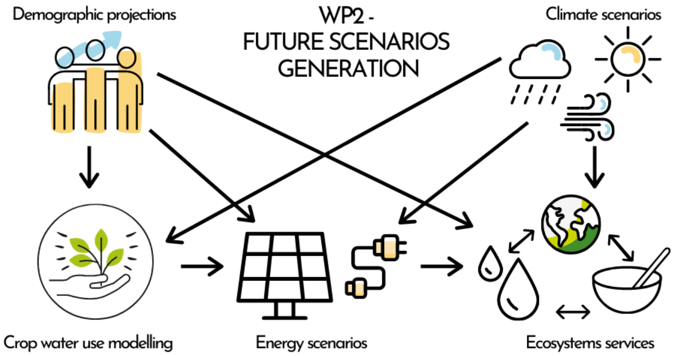

Figure 1 – Demographic projections task interaction with the other developed models in the AWESOME project

1.2 AREAS OF INTEREST

The study focus on the countries of the Mediterranean region and some adjacent countries like Sudan and Ethiopia which are considered as key factors to the economies of adjacent countries belonging to the Mediterranean core group. All countries included into this study are illustrated in Table 1 with their associated World Bank (WB) codes.

Table 1 – Countries of interest in the Mediterranean region or adjacent

Country	WB code	WB ISO3 code
Albania	ALB	008
Algeria	DZA	012
Croatia	HRV	191
Cyprus	CYP	196
Egypt	EGY	818
Ethiopia	ETH	231
France	FRA	250
Greece	GRC	300
Israel	ISR	376
Italy	ITA	380
Lebanon	LBN	422
Libya	LBY	434
Malta	MLT	475
Montenegro	MNG	496
Morocco	MAR	504
Spain	ESP	724
State of Palestine	PSE	275
Sudan	SDN	736
Syria	SYR	760
Tunisia	TUN	788
Turkey	TUR	792

1.3 DATA TO BE PROVIDED

The main goal of D2.1 - Demographic projections is to provide data regarding the population evolution and key economic indicators for all countries of interest described in Table 1 as long as for the Mediterranean region, under the Shared Socio-Economic Pathways (SSP) scenarios. These data are either collected from free online databases (like United Nations (UN) database[1] and others) or are created according to the modeling approaches discussed in the following sections. All data are uploaded on the AWESOME repository accessible to every member of the project's group. The provided data, will be available at two main scales:

- **country-level**: historical demographic data provided by United Nations (UN), International Institute for Applied Systems Analysis IIASA and other free online databases up to 2020 and related deterministic projections up to 2100 (concerning key demographic quantities like fertility,

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[1] `https://population.un.org/wpp/`

mortality, migration, population per sex and age groups, etc), probabilistic projections for population and related key demographic quantities up to 2100 (fertility, life expectancy, population per age group, sex, etc) and projections for basic economic drivers like gross domestic product (GDP), labour, capital, energy consumption, etc according to the SSP scenarios as provided by the global econometric model MaGE ([3]) which is discussed in detail in Section 3.

- **regional-level**: aggregated projections for the extended Mediterranean region about population dynamics and the related key demographic quantities and for the basic economic drivers provided by the global MaGE model projections according to all SSP guidelines.

Moreover, data regarding fuel emissions for the region of interest have been collected and uploaded to the project's repository in order to be used as input to the models concerning the following work packages of the AWESOME project.

2 PROBABILISTIC POPULATION PROJECTIONS

The methodology used for constructing population projections is presented in this section, definitions of the different future scenarios in this setting are also explicitly given, and a representative example of the output data for the cases of Egypt and Greece at country level and for the Mediterranean region is provided.

2.1 PROBABILISTIC MODELING METHODOLOGY

Population projections are provided according to the probabilistic approach proposed in [7] employing Bayesian modeling (hierachical models) in order to properly introduce uncertainty effects in the population projections. Based on the United Nations (UN) historical demographic data from all countries of the world, a probabilistic model for the mean population evolution is constructed under the hierarchical modeling approach, and then projections for the future years for each particular country or region is provided by simulating trajectories using the country- or region-specified probability distribution. The underlying model that is employed and enhanched with a probabilistic characterizations is the typical population projection model (deterministic) that UN use:

$$P_{c,t} = P_{c,t-1} + B_{c,t} - D_{c,t} + M_{c,t} \tag{1}$$

where $P_{c,t}$ denotes the population of country c at time t (corresponding either to a single year or a 5-year period), $B_{c,t}$ stands for the number of births (which depends on the total fertility rate), $D_{c,t}$ denotes the number of deaths (which depends on the life expectancy) and $M_{c,t}$ measures the net international migration. The probabilistic extension of this model will be used for the set of countries I which contains the indices of all countries mentioned in Table 1.

The under discussion probabilistic approach relies on model (1), however treats separately the components $B_{c,t}$ and $D_{c,t}$ according to the probabilistic modeling approach mentioned above, using estimates and projections for the net migration from the UN base (or other databases) and then combines these approaches in order to construct projections per country or regionally by simulating trajectories. First, a hierachical model is constructed for the *Total Fertility Rate (TFR)* which will provide projections for the fertility rates distribution at the country level and then the number of births distribution. Then, this information is used to build a hierachical model for the *Life Expectancy (e0)* at the country level, which is used to provide projections for the life expectancy distribution of females and males per country and the respective number of deaths distibution. Finally, available projections for *net migration (MIG)* per country (from UN or other data providers) are used as input to construct population projections according to model (1). The whole modeling task is illustrated in Figure (2).

As a result, the output of this approach is a sufficient number of population trajectories, which is used as the main database which for estimating/forecasting the probability distribution of the future population on country or regional-level. Below, we describe in detail the modeling approaches followed at each component (TFR, e0, MIG) of model (1).

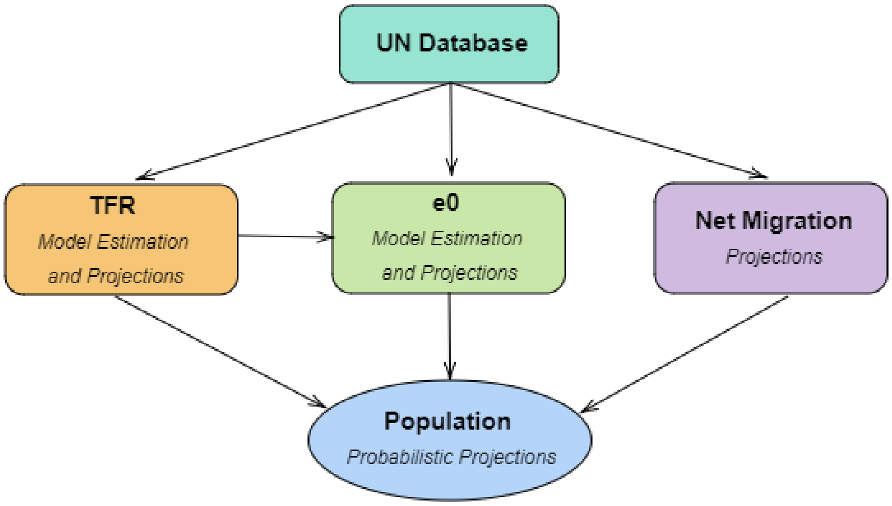

Figure 2 – The probabilistic population modeling procedure

2.1.1 Total Fertility Rate Modeling

The first and very basic component of the probabilistic population modeling task is the hierarchical model built on the total fertility rate. Total fertility rate is the average number of children a woman would bear if she survived through the end of the reproductive age span and is one of the key components in popoulation projections. The model that we discuss introduced in [1] and a related package called **bayesTFR** for the open source statistical language R[2] has been developed by [9].

The model is based on the assumption that the evolution of the TFR includes three phases, referred to as Phase I, II and III: (I) a *high-fertility pre-transition phase*, (II) the *fertility transition* in which the TFR decreases from high fertility levels towards or below replacement level fertility, and (III) a *low-fertility post-transition phase*, which includes recovery from below-replacement fertility toward replacement fertility and oscillations around replacement-level fertility. Phase-I is not modeled, however the time τ_c where the shift from the Phase-I to Phase-II for the country c occurs (in other words the start of the fertility transition) is of particular importance and described by the shift model

$$\tau_c = \begin{cases} \text{max}\{t \,:\, (f_c^M - f_{c,t}^L) < 0.5\}, & f_{c,t}^L > 5.5 \\ < \text{1950-55}, & \text{otherwise.} \end{cases} \qquad (2)$$

where f_c^M is the maximum observed TFR and $f_{c,t}^L$ the local maxima (note that time is considered as 5-year periods, e.g. 1950-55, 1955-1960, etc). The end of the fertility transition period and the start of Phase III is denoted by λ_c and is defined as

$$\lambda_c = \text{min}\{t \,:\, f_{c,t} > f_{c,t-1},\ f_{c,t+1} > f_{c,t} \text{ and } f_{c,s} < 2,\ \text{for } s = t-1, t, t+1\} \qquad (3)$$

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[2] https://www.r-project.org/

where $f_{c,t}$ denotes the TFR of country c and period t. If for some countries, Phase II has not been ended in the observed period then it is considered that $\lambda_c >$ 2005-10, i.e. after the observation window. The fertility transition model (Phase II) is the following

$$f_{c,t+1} = f_{c,t} - d_{c,t} + \epsilon^f_{c,t}, \;\; \tau_c \leq t < \lambda_c \tag{4}$$

where $f_{c,t}$ is the TFR of country c for the 5-year period t, $d_{c,t}$ is the decrement term modeling the sytematic decline during the fertility transition and $\epsilon^f_{c,t}$ is a random perturbation that models deviations from the systematic decline according to the probability distribution model

$$\epsilon^f_{c,t} \sim \begin{cases} N(m_t, s_t^2), & t = \tau_c \\ N(0, \sigma^2_{c,t}), & \tau_c < t < \lambda_c \end{cases} \tag{5}$$

where m_t, s_t are estimated by historical data close to time τ_c while $\sigma^2_{c,t}$ is estimated by data at later periods. The decrement term $d_{c,t}$ in TFR evolution model (4) is described as a function of the TFR level in the following way

$$d_{c,t} = d(\boldsymbol{\theta}_c, \tau_c, \lambda_c, f_{c,t}) = \begin{cases} g(\boldsymbol{\theta}_c, f_{c,t}), & f_{c,t} > 1 \\ 0, & \text{otherwise} \end{cases} \tag{6}$$

where $g(\cdot,\cdot)$ is a parametric decline function of the double-logistic type used by the UN models (see e.g. [11]). Then, a Bayesian hierarchical model is built and estimated on the parameters of the decline functions $\boldsymbol{\theta} = \{\boldsymbol{\theta}_c\}_{c\in I}$ for all countries included in the index set I extending the decline parametric model to a stochastic one. The parameters $\boldsymbol{\theta}$, on which the hierachical model is built on, are divided to country-specific and world-specific parameters providing a plausible setting for modeling each country's TFR in this Phase II with respect to the distribution of the mean tendency of all countries included in the study. Phase III concerns the time period $t \geq \lambda_c$ and the TFR evolution in this stage is described by the AR(1) model

$$f_{c,t+1} \sim N(\mu + \rho(f_{c,t} - \mu), s^2) \tag{7}$$

where location parameter μ is taken fixed to the value 2.1, the auto-regressive parameter satisfies the condition $|\rho| < 1$ (for stationarity of the process) and the standard deviation parameter s is obtained through maximum likelihood proceedure.

Having concluded successfully all the above estimation steps for all countries considered in the study (typically all countries of the world) the projection step for each country c is performed through the trajectories simulation model

$$f^{(i)}_{c,t+1} = f^{(i)}_{c,t} - d^{(i)}_{c,t} + \epsilon^{f,(i)}_{c,t} \tag{8}$$

where $d^{(i)}_{c,t}$ denotes the simulated decrement in TFR of country c, $\epsilon^{f,(i)}_{c,t}$ are randomly drawn from the distribution $N(0, \sigma^{(i)\,2}_{c,t})$ and i denotes the trajectory id. A sufficiently large number of trajectories are then simulated for each country (e.g., 100000) and for all time periods of interest in order to construct a base sample which will be used for simulating trajectories of the population.

2.1.2 Life Expectancy Modeling

The second key component for population probabilistic modeling approach is modeling mortality or, in our case, Life Expectancy (e0). The considered model for Life Expectancy will provide the distribution of the number of deaths and births per time period for both sexes and total population for all countries considered in the study. The discussed approach is presented in [8] and is accompanied by the related R-package **bayesLife**. The calibration method of the life expectancy evolution is similar to that described for TFR, following the general guidelines of UN but extending the framework by adding stochasticity to the model. In particular, the model that is used for the life expectancy projection is

$$\ell_{c,t+1} = \ell_{c,t} + g(\ell_{c,t}, \boldsymbol{\theta}_c) + \epsilon^{\ell}_{c,t+1} \tag{9}$$

where $g(\cdot,\cdot)$ is a growth function of the double-logistic type for the current level of life expectancy and $\epsilon^{\ell}_{c,t+1}$ denote random perturbations following a Gaussian law with zero location and dispersion term $\hat{\sigma}^2_{\ell,c,t-1}$ estimated by the historical data. A Bayesian hierarchical model is built on the parameters of the growth function allowing to calibrate both the mean life expectancy for all countries considered in the study through the world-level parameters and each country through the country-level parameters. However, since gaps between the life expectancy in different age groups between females and males appear, the described approach is first used to estimate the probabilistic model for the life expectancy of female population and at a second step is constructed the model for the male population. In particular, the gap $G_{c,t}$ between the life expectancy of both populations is modeled by fitting a model on appropriate covariates concerning the female population (e.g. life expectancy of females at the same age group, life expectancy at close time lags, etc). Therefore, the probabilistic life expectancy projections for the males are provided by parameterizing appropriately the shifts to the female population.

As a result, trajectories for the life expectancy for both sexes on a country c can be generated from the simulation model

$$\ell^{f,(i)}_{c,t+1} = \ell^{f,(i)}_{c,t} + g(\ell^{f,(i)}_{c,t}, \boldsymbol{\theta}^{(i)}_c) + \epsilon^{f,(i)}_{c,t+1}, \tag{10}$$

$$\ell^{m,(i)}_{c,t+1} = \ell^{f,(i)}_{c,t+1} + G^{(i)}_{c,t}(\ell^{f,(i)}_{c,t}, \boldsymbol{\beta}_c) + \epsilon^{m,(i)}_{c,t+1} \tag{11}$$

where $\ell^{f,(i)}_{c,s}, \ell^{m,(i)}_{c,s}$ denotes the life expectancy for females and males at time period s respectively, $\boldsymbol{\theta}^{(i)}_c, \boldsymbol{\beta}_c$ the respective parameters for growth functions and gap model, $\epsilon^{f,(i)}_{c,s}, \epsilon^{m,(i)}_{c,s}$ draws from the respective error terms and i denoting the id of the trajectory. Again, a sufficient number of such trajectoriesfor each country c is required in order to built an appropriate database allowing to induce the underlying probability distributions for life expectancy on both sexes.

2.1.3 Migration Modeling

Migration plays an important role in the evolution equation for the total population. Although the aforementioned approaches for TFR and e0 could be employed there are current limitations that do not allow us to apply the same approach for providing probabilistic projections for the migration too for all countries. Specificaly, lack of sufficient data regarding migration for most countries is the main problem since the fitting step of such a model to very poor datasets will not lead to stable results making the model unreliable. However, in the literature this approach has been discussed and applied in a small sample of countries with sufficient data for this cause (see e.g. [2]). Since, the countries that mostly interest this project have not yet developed a regular monitoring mechanism for migration, we will rely on the IIASA[3] estimates for the net migration based on the projection approaches discussed in [6] and which we will then introduce in the population equation (1) as a deterministic term. This approach consists of three scenario levels for each country, the *medium* one (*medium migration scenario*), which assumes constant in- and out-migration rates for the rest of the century at the average level that was observed for each country for the period 1960-2015; a *double migration* scenario (*high migration scenario*), which assumes twice this average level of in- and out-migration rates; and a *zero migration* scenario (*low migration scenario*), which assumes zero in- and outmigration. These three naive migration scenarios were designed by the Centre of Expertise on Population and Migration (CEPAM)[4] to essentially serve as benchmarks against which to understand the role of migration as a driver of future population trends with the perspective to improve the migration future projections with more sophisticated modeling approaches since more detailed migration monitoring mechanisms are developed.

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[3] `https://iiasa.ac.at/`

[4] `https://knowledge4policy.ec.europa.eu/projects-activities/cepam-centre-expertise-population-migration_en`

2.2 SCENARIOS DEFINITION

An important step in our approach is the definition of the various Sustainable Socio-economic Pathways scenarios (SSPs) in the probabilistic setting. This approach divides the possible states of the world in five scenarios (rapid development, medium development, stalled development, inequality and conventional development) according to the levels of specific demographic characteristics and specifically fertility, life expectancy (or mortality), migration and education. Since the population projection method we follow does not take into account the education levels we omit this factor for the time being. Each country's SSP scenario may differ depending its grouping as (a) high fertility country (HiFert), (b) low fertility country (LoFert) or (c) Rich-OECD country[5]. Specifications of the various SSPs with respect to the country groupings, as described in [5], are illustrated in Table 2.

Table 2 – Shared Socio-economic Pathways (SSP) definitions

	Country groupings	Fertility	Life expectancy	Migration
SSP1: rapid development	HiFert	Low	High	Medium
	LoFert	Low	High	Medium
	Rich-OECD	Medium	High	Medium
SSP2: medium	HiFert	Medium	Medium	Medium
	LoFert	Medium	Medium	Medium
	Rich-OECD	Medium	Medium	Medium
SSP3: stalled development	HiFert	High	Low	Low
	LoFert	High	Low	Low
	Rich-OECD	Low	Low	Low
SSP4: inequality	HiFert	High	Low	Medium
	LoFert	Low	Medium	Medium
	Rich-OECD	Low	Medium	Medium
SSP5: conventional development	HiFert	Low	High	High
	LoFert	Low	High	High
	Rich-OECD	High	High	High

Using the modeling approach presented in Sections 2.1.1 and 2.1.2, fertility and life expectancy for each country of interest are provided in terms of the samples of trajectories created under the underlying bayesian models. Therefore, the definition of the thresholds that separate low, medium and high scenario for each one of these quantities should be done according to the observed (from the simulated sample) variation. If the year 2100 is the time horizon we set, then the empirical distribution of the quantity of interest as obtained from the simulated trajectories can be used to define and quantify the various intensity levels corresponding to each scenario. In particular, if we need to determine three different intensity levels, high, low and medium, then the 33% and 66% quantiles of the sample's distribution at the terminal time 2100 will serve as the discrimination thresholds. According

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[5] `http://www.oecd.org/about/members-and-partners/`

to this rule, a trajectory is assigned to the high scenario if at terminal time 2100 the observation for the corresponding quantity lies on the top 66% of the empirical distribution. Similarly, for the other levels. One advantage of this methodology is that the corresponding levels for the scenarios are not preassigned but are determined endogenously by the history and dynamics of the data from the population model. Repeating the above procedure for all trajectories, we end up with three subsamples each corresponding to different possible realizations of the low, medium and high scenario. These subsamples can be used to provide statistical information, such as moments, variability, etc. within scenarios. A possible question to this procedure could be about the validity of the initial sample and its ability to represent all possible future states of the world. Since the bayesian model relies on the observed data from previous periods and takes into account possible relations of the country or region we study with other countries and regions of the world, then any reasonable scenario (with respect to the data that have been collected up to the time the projection task is executed) should be amenable to simulation. Then, using a sufficiently large number of simulated trajectories should guarantee that the results are reliable.

Let us describe the filtering rule that is incorporated for the classification of the initial sample of trajectories into different subgroups for each one of TFR and e0 simulated samples. In particular, from the induced distribution of the simulated TFR values for a country at a terminal time horizon T the various level scenarios are defined according to the rule:

- *low TFR scenario*: all trajectories with TFR value lower than the 33% quantile value at time $t = T$
- *medium TFR scenario*: all trajectories with TFR value larger than the 33% quantile value and lower than the 66% quantile value at time $t = T$
- *high TFR scenario*: all trajectories with TFR value larger than the 66% quantile value at time $t = T$

Similarly, from the distribution of the simulated e0 values for a country at time T the scenarios are defined according to the rule:

- *low e0 scenario*: all trajectories with e0 value lower than the 33% quantile value at time $t = T$
- *medium e0 scenario*: all trajectories with e0 value larger than the 33% quantile value and lower than the 66% quantile value at time $t = T$
- *high e0 scenario*: all trajectories with e0 value larger than the 66% quantile value at time $t = T$

Migration levels could be defined in the same manner if a probabilistic approach had been used, however in our case we use the deterministic projections for each SSP scenario as provided by Wittgenstein Center database[6]. In particular, net migration scenarios for each country are available in three

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[6] `http://www.wittgensteincentre.org/`

different levels (low, medium and high migration) where also other demographic quantities are available under the different SSPs assumptions.

In this manner, assigning each one of the countries of interest in the appropriate Country Grouping, country's specifications regarding fertility, life expectancy and migration for each one of the SSPs scenarios are set. Then, in order to construct a sufficient database for each SSP scenario, simulation of population trajectories for all countries of interest are drawn from population model (1) under each SSP's specifications defined by the aforementioned rules. For this task the R-package **bayesPop** is employed ([10]) for the construction of the population projection databases for all SSP scenarios. All data and relevant scenarios outputs have been uploaded to the AWESOME's project repository.

2.3 EGYPT, GREECE & MEDITERRANEAN REGION

In this section, we illustrate some snapshots of the results regarding population projections under the various SSP scenarios using the discussed probabilistic approach. At the country level, we have chosen to present two indicative examples and specifically Egypt and Greece (one HiFert country and one rich-OECD country) while at the regional level we illustrate the whole Mediterranean region as considered in this project.

2.3.1 The cases of Egypt and Greece

The produced results for Egypt and Greece are discussed in common in order to compare the population dynamics of two countries with different population structure. Therefore, first we examine the basic components of the population model, i.e. fertility rate, life expectancy and net migration, and at a second step some elements about total population projections under the various SSPs are illustrated. The three basic factors are presented for the time period 2020-2100 under the different levels (low, medium, high) which combinations of them are afterwards used to define the SSP scenarios according to the guidelines dicussed in Section 2.2. In order to more conveniently visualize the differences between the different scenario levels for each component, only the median trajectories and the 80% bounds are depicted for each case, i.e. the 50% quantile estimated for each year in the under consideration time period (2020-2100) of the simulated trajectories and the 10% and 90% quantiles.

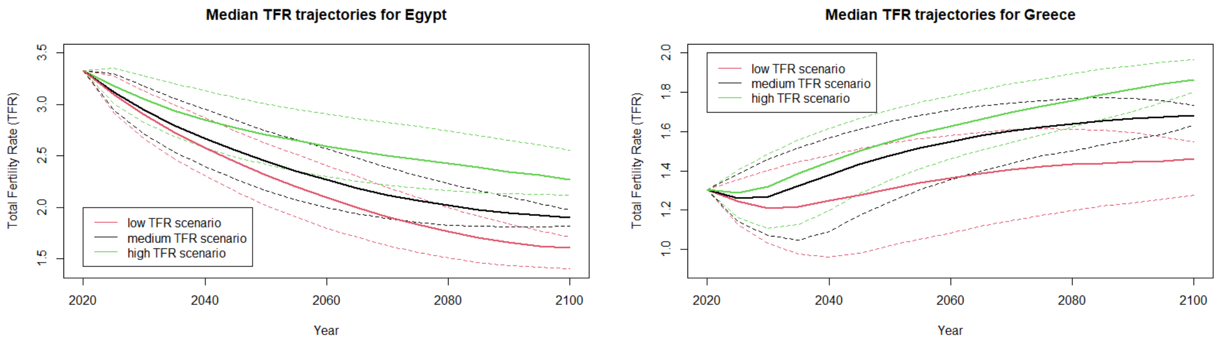


Figure 3 – Egypt (left) and Greece (right) median, 10% and 90% quantile TFR trajectories under low, medium and high scenarios

Figure 3 illustrates the different median and 80% uncertainty zones levels under consideration for the total fertility rate of both Egypt and Greece. Following the discussion about TFR modeling approach in Section 2.1, and taken into account that in the beginning of the period of interest Egypt is classified to Phase I (high fertility) and Greece to Phase II (fertility transition), it seems that Egypt will not conclude the fertility transition phase while Greece will also not exit Phase II in this time horizon. At the end of 2100, all three scenarios predict that Egypt will be classified to the fertility transition phase (Phase II). However, in the high scenario it seems that this transition will be done with much slower pace. Although both countries are classified to Phase II in under all scenarios, this happens under different circumstances since Egypt lowers its fertility while Greece increases its fertility in order to stabilize it and reach Phase III. This is a clear distinction of the population structures and dynamics between the two countries and is clearly depicted in this component of the population model under all scenarios.

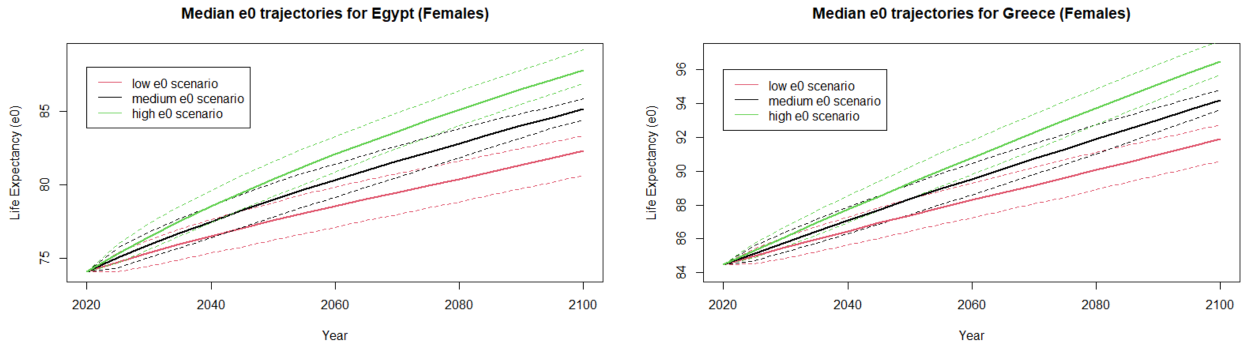


Figure 4 – Median, 10% and 90% quantile population trajectories of Egyptian females (left) and Greek females (right) for life expectancy at birth under low, medium and high scenarios

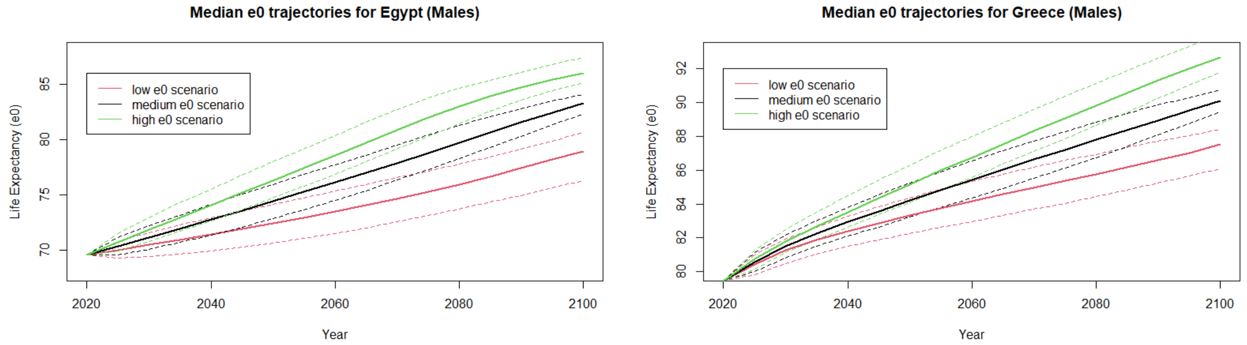


Figure 5 – Median, 10% and 90% quantile population trajectories of Egyptian males (left) and Greek males (right) for life expectancy at birth under low, medium and high scenarios

Figures 4 and 5 illustrate the different median levels of life expectancy at birth (e0) for both female and male population of Egypt and Greece. Different levels seem to be discriminated by a cap of maximum 4 years at the high variance year (2100) for both males and females for both countries. The distance between medium and high scenarios seems to be smaller than the distance between medium and low scenarios in the future for the males population of Egypt while in all other cases this is not observed (right column of Figure 5). One other artifact, indicating major difference in the life expectancy dynamics of these two countries is that in both female and male population there is a difference of about 8-10 years in life expectancy (Greece has higher life expectancy), which seems to stay unchanged to the whole time window.

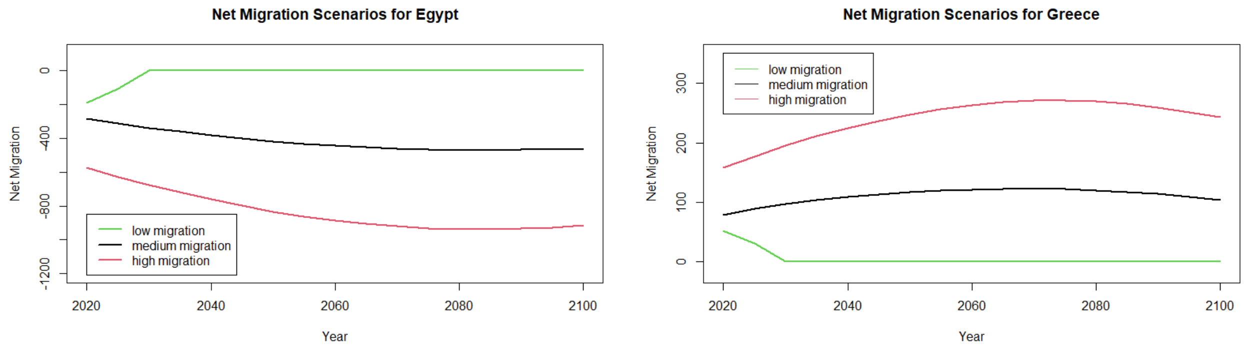


Figure 6 – Net migration projections for Egypt (left) and Greece (right) under low, medium and high level scenarios according to Wittgenstein Center database

Net migration levels are given in a deterministic manner by Wittgenstein Center database since the probabilistic approach cannot be implemented due to the lack of sufficient data for all countries in the Mediterranean region and the adjacent regions in order to provide reliable estimates from the bayesian model. Mean estimates regarding the future net migration about Egypt and Greece are provided in three levels. The low migration scenario refers to the zero migration case for both countries, while medium and high migration scenarios provide negative net values for Egypt indicating emigration and positive net values for Greece indicating immigration. Note that the medium and high level migration scenarios seem to provide more reasonable estimates than the low migration case (zero net migration). The latter as illustrated to Figure 6 provides a quite unrealistic shift to zero-level migration in about 10 years from now (which could be interpreted maybe by the occurence of specific events that could change the situation in Egypt and Greece) indicating reduction in emigration (Egypt) or immigration (Greece) while the other scenarios follow diverse trajectories.

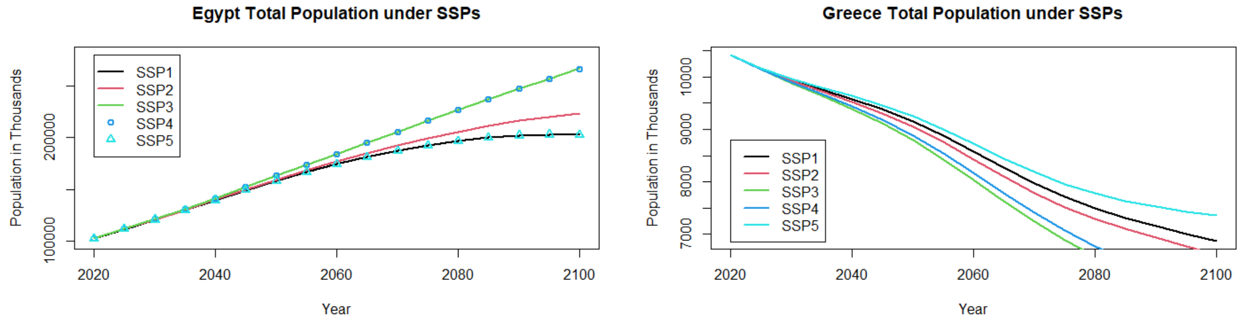


Figure 7 – Egypt (left) and Greece (right) median population under SSP scenarios

Probability distributions of the projected TFR and e0 affect directly the probability distribution of population of Egypt and Greece in any scenario (see Figure 7). However, it seems that there are not five much different scenarios for the population evolution of Egypt (as is the number of the different

SSPs) while for Greece this is not he case. In particular, three different median patterns are observed for the Egyptian population discriminating clearly SSP1, SSP2 and SSP3 but providing almost the same median estimates for the pairs SSP1-SSP5 and SSP3-SSP4 (the differences are only a few thousands in populations larger tha two hundred millions; see Table 3). The reason beside this could be the migration modeling approach since in the above pairs the only difference between the SSPs consists on the migration levels. Clearly, a more sophisticated approach regarding migration would possibly reveal more patterns for the population however for the time being and the available (and usable) models three levels for the population seems the most reasonable choice. On the other hand, although not much different there are five different scenarios for Greece. However, the scenarios pairs SSP1-SSP2 and SSP3-SSP4 do not differ that much but only a few thousands (see Table 3), but since the Greek population is much smaller in numbers comparing to the Egyptian one these differences are much more important.

Table 3 – Egyptian total population quantiles (in thousands) for each SSP scenario

Scenario	2020	2030	2040	2050	2060	2070	2080	2090	2100
	5% Quantile								
SSP1	102334	117569	131999	144316	152304	156499	157007	153966	147220
SSP2	102334	117701	132645	145854	155598	162390	166864	169061	168310
SSP3	102334	118217	134349	149522	162078	172482	181045	188154	193304
SSP4	102334	118227	134361	149614	162020	172607	181481	188479	193845
SSP5	102334	117555	132014	144244	152251	156318	157005	153820	147289
	50% Quantile								
SSP1	102334	120635	139582	158285	174200	187236	196645	201962	202675
SSP2	102334	120709	139977	159364	176712	192150	205442	216029	223283
SSP3	102334	121186	141563	162999	184058	205408	226531	247042	266534
SSP4	102334	121193	141552	163025	184104	205404	226526	247058	266383
SSP5	102334	120641	139590	158290	174173	187174	196606	201893	202618
	95% Quantile								
SSP1	102334	123751	147397	172887	198320	222920	244725	262025	273347
SSP2	102334	123843	147738	173728	200468	227801	254165	277874	296848
SSP3	102334	124259	149318	178044	209562	244229	283077	323859	367168
SSP4	102334	124214	149360	177963	209269	244345	282405	323692	367220
SSP5	102334	123766	147445	173039	198452	223164	245088	262347	273359

2.3.2 Aggregated Results: The Mediterranean Region

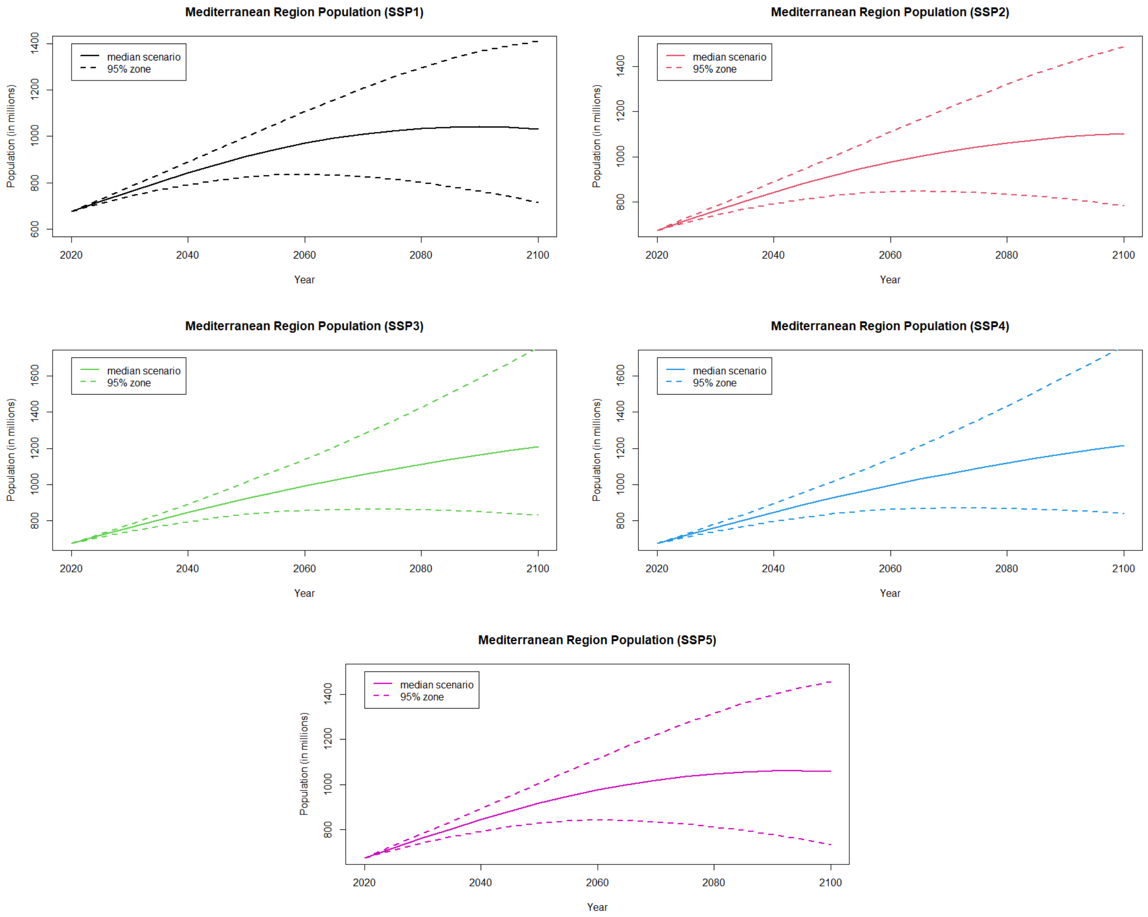
The aggregated projections of all countries considered as part of the Mediterranean region (according to Table 1) are presented under each SSP scenario. In order to derive these projections, separate modeling of the three major population components for each particular country is required while the aggregation is performed in terms of the population estimates. In Figure 8 the total population projections for the whole region up to 2100 are illustrated, with the solid lines representing the median estimate while the dashed lines represent the 95% confidence zone. The whole region consists

Table 4 – Greece total population quantiles (in thousands) for each SSP scenario

Scenario	2020	2030	2040	2050	2060	2070	2080	2090	2100
	5% Quantile								
SSP1	10423	9782	9186	8526	7752	6937	6226	5688	5232
SSP2	10423	9765	9133	8429	7611	6757	6025	5484	5012
SSP3	10423	9736	9036	8214	7257	6268	5394	4673	4010
SSP4	10423	9752	9086	8313	7405	6445	5597	4895	4254
SSP5	10423	9794	9231	8627	7918	7156	6520	6075	5710
	50% Quantile								
SSP1	10423	9938	9574	9152	8578	7974	7495	7152	6870
SSP2	10423	9919	9521	9053	8432	7790	7291	6934	6620
SSP3	10423	9881	9386	8791	8031	7240	6584	6059	5574
SSP4	10423	9898	9435	8884	8171	7416	6777	6276	5810
SSP5	10423	9960	9635	9252	8727	8184	7781	7527	7359
	95% Quantile								
SSP1	10423	10093	9892	9600	9174	8739	8416	8213	8076
SSP2	10423	10073	9839	9500	9024	8556	8206	7981	7800
SSP3	10423	10033	9729	9299	8726	8163	7699	7368	7048
SSP4	10423	10051	9777	9396	8867	8336	7905	7583	7295
SSP5	10423	10106	9925	9668	9289	8921	8670	8574	8575

of groups of countries with much different demographic characteristics, i.e. different fertility rates, life expectancies, migration levels, population age-structures, etc and therefore it is very interesting to study their aggregated results in order to ascertain how these different population dynamics are combined under the different SSP scenarios. For example, we discussed in the previous section the population projections of Egypt and Greece, which although being in the same neighbourhood, have quite different demographic characteristics. Taking into account so much different populations it is expected that these divergences will counter each other up to a level when cointegrating the population projections. This conviction can be better observed in Figure 9, where the median population projections under all SSP scenarios are illustrated in the same graph. In particular, up to year 2060 no great differences between all scenarios are observed, while some kind of diversification between all population evolution scenarios is first observed about the year 2080.

At the end year of the time horizon of interest (2100), four distinct cases are observed for the population evolution of Mediterranean region. In particular, SSP2 determines the mean (baseline) scenario SSP1 (rapid development) the lowest population levels case, SSP5 (conventional development) lies between the curves of SSP2 and SSP1, while SSP3-SSP4 represent the highest population levels which are extremely close as estimates. It is worth noting that the fertility rate considered for the HiFert countries significantly affects the population evolution. In particular, SSP3 and SSP4 high fertility levels are considered for HiFert countries leading to the highest population levels for the Mediterranean region as output. On the other hand, under SSP1 and SSP5 low fertility levels are considered for the HiFert countries leading to the lowest population levels for the region. The different population lev-


Mediterranean Region Population (SSP1)

Mediterranean Region Population (SSP2)

Mediterranean Region Population (SSP3)

Mediterranean Region Population (SSP4)

Mediterranean Region Population (SSP5)

Figure 8 – Mediterranean total population projections (median and 95% confidence intervals) under SSP scenarios

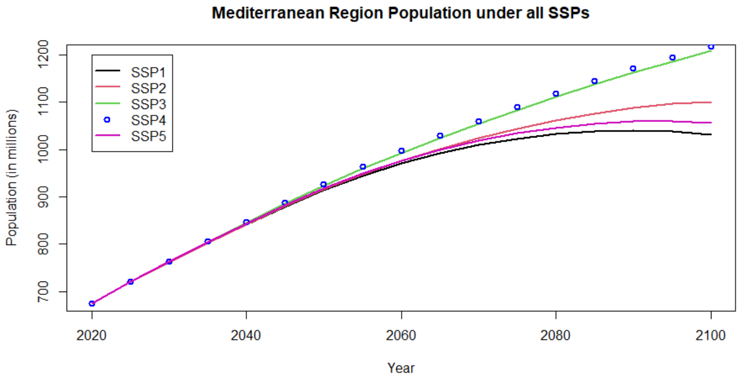

Mediterranean Region Population under all SSPs

Figure 9 – Mediterranean total population median projections under all SSP scenarios

els are better illustrated in Table 5 where the 5%, 50% and 95% population quantiles per decade are estimated.

Table 5 – Population quantiles (in thousands) for the Mediterranean region on each SSP scenario

Scenario	2020	2030	2040	2050	2060	2070	2080	2090	2100
	5% Quantile								
SSP1	675194	744840	799404	839101	856610	853175	834349	803626	759405
SSP2	675194	744662	799954	842596	866220	872485	868646	855450	832178
SSP3	675194	745678	803436	849945	879258	892756	897630	895158	885073
SSP4	675194	746079	805000	852844	883398	898742	904685	903425	894864
SSP5	675194	745386	801031	842304	862254	861470	846392	819152	779995
	50% Quantile								
SSP1	675194	761842	841517	913652	970213	1009344	1032735	1040830	1031442
SSP2	675194	761673	841824	915670	976311	1023563	1060570	1087505	1101288
SSP3	675194	762663	845180	923564	993023	1054510	1111284	1163132	1207994
SSP4	675194	763081	846624	926424	997539	1060013	1117606	1171175	1217242
SSP5	675194	762415	843451	917471	976319	1018686	1046206	1059047	1056258
	95% Quantile								
SSP1	675194	778129	881615	985606	1084697	1173990	1251274	1310759	1346658
SSP2	675194	778010	881155	985605	1087610	1184819	1275526	1356203	1418766
SSP3	675194	778979	885719	998567	1116360	1239235	1371143	1508102	1650473
SSP4	675194	779394	887150	1001063	1119914	1244631	1376443	1515570	1659156
SSP5	675194	778776	883734	989790	1091845	1186425	1269836	1337516	1383025

3 ECONOMIC DRIVERS PROJECTIONS

3.1 METHODOLOGY

Economics drivers scenarios are obtained using a global dynamic economic model (MaGE). The model was developed by J. Fouré, A. Bénassy-Quéré and L. Fontagné in CEPII ([3]) and is freely available from CEPII's website[7] in Stata[8] code.

MaGe assumes that the world consists of economies of individual countries with each country c characterized at time t by a three-factor CES production function with the capital and labour contributions modelled by the Cobb-Douglas form

$$Y_{c,t} = \left\{ \left(A_{c,t} K_{c,t}^{\alpha} L_{c,t}^{1-\alpha}\right)^{\frac{\sigma-1}{\sigma}} + \left(B_{c,t} E_{c,t}\right)^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}}, \quad 0 < \alpha < 1,\ 0 < \sigma < 1$$

where

- $Y_{c,t}$ is the GDP of country c at time t,
- $K_{c,t}$ is capital of country c at time t,
- $L_{c,t}$ is labour of country c at time t,
- $E_{c,t}$ is energy consumption of country c at time t

where t corresponds either to 1-year periods or 5-years periods.

The elasticities are assumed to be the same for all countries $\alpha = 0.31$, $\sigma = 0.136$ and constant in time, while the parameters $A_{c,t}$ (Total Factor Productivity or TFP) and $B_{c,t}$ (Energy Productivity) are assumed to be country specific and temporally varying. The model depends on population primarily through labour force and secondarily through the life cycle savings modelling which is introduced in the modelling of investment. In particular:

- *Population* enters the model through labour and uses the age groups in order to calculate the total $L_{c,t}$. Male population and female population are treated separately as they experience different participation rates in the labour market.
  - *Male populations*: Male participation rates by age group are taken from International Labor Organization (ILO), up to 2020. From 2021 to 2050, they are projected based on ILO's methodology, i.e. using the following equation for the participation rate

    $$\ell^{M}_{a,c,t} = \underline{\ell}_{a,c} + \frac{\overline{\ell}_{a,c} - \underline{\ell}_{a,c}}{1 + \exp(\alpha_{a,c} + \beta_{a,c} t)},$$

    where $\overline{\ell}_{a,c}, \underline{\ell}_{a,c}$ denote maximum and minimum participation rates per age group and $\alpha_{a,c}, \beta_{a,c}$ are constants (country specific).

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[7] http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=13

[8] https://www.stata.com/

  - *Female population*: Female participation rates by age group are projected from 2010 to 2050 based on an econometric relation between female participation rates and education. This choice allows us to account for the anticipated rise in female participation rates for a number of developing countries, in line with projected catch-up in terms of education. Education is captured through school attainment by age group, based on Barro and Lee (2010) database. It is projected based on a simple catching-up process, with the leader country (defined as the country displaying the highest share of educated people for each age group and each level of education) following a logistic scheme.

- *Capital stock* is accumulated through the process

$$K_{c,t} = (1-\delta)K_{c,t-1} + I_{c,t}$$

  where $I_{c,t}$ denotes the gross fixed capital investment, and $\delta = 0.06$ (depreciation rate).

- *Energy consumption* is estimated using a major assumption: **maximize** profit along their nested CES production function

$$\text{max}(Y_{c,t} - p_{E,c,t}E_{c,t} - p_{K,c,t}K_{c,t} - p_{L,c,t}L_{c,t})$$

$$\text{subject to}$$

$$Y_{c,t} = \left\{ (A_{c,t}K^{\alpha}_{c,t}L^{1-\alpha}_{c,t})^{\frac{\sigma-1}{\sigma}} + (B_{c,t}E_{c,t})^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}},$$

  where p_E, p_K, p_L denote the real prices of energy, capital and labour, respectively, relative to output. The solution of this programme yields

$$E_{c,t} = \frac{B^{\sigma-1}_{c,t}}{p^{\sigma}_{E,c,t}} Y_{c,t}. \tag{12}$$

  Substituting $E_{c,t}$ again in the production function we get a production function depending only on $K_{c,t}$ and $L_{c,t}$, of the form

$$Y_{c,t} = \left[1 - \left(\frac{B_{c,t}}{p_{E,c,t}} \right)^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}} A_{c,t}K^{\alpha}_{c,t}L^{1-\alpha}_{c,t} \tag{13}$$

  We use oil-price forecasts to 2035 provided by the Energy Information Administration (EIA) [4]. For 2035 to 2050, the price of energy is set to increase at a constant rate equal to its average growth rate over the 2030-2035 period. Past values of $B_{i,t}$ are obtained by (12) and past values of $A_{i,t}$ are obtained by (13).

- Population age structure re-enters the model in the savings ratios through an econometric relation

$$\left(\frac{S}{Y}\right)_{c,t} = \Phi\left(\left(\frac{S}{Y}\right)_{c,t-1}, y_{c,t}, g_{c,t-1}, d^{k}_{c,t-1} \right), \quad k = 1, \dots, K$$

where Φ is a quadratic regression in the savings ratio (S/Y), per capita GDP y,the rate of growth of per capita GDP, and demographic factors d with coefficients depending on the age population structure as

$$d_{c,t}^{k} = \sum_{j=1}^{J} j^{k} p_{j,c,t} - \frac{1}{J} \sum_{j=1}^{J} j^{k},$$

where $p_{j,c,t}$ is the proportion of cohort j, $j = 1, \ldots, J$, (0-4, 5-9, $\ldots$, 65-69 and 70+) in the population.

Then this is used in order to get $I_{c,t}$ through the Feldstein-Horioka relationship which is a linear regression model

$$\left(\frac{I}{Y}\right)_{c,t} = a_c + b_c \left(\frac{S}{Y}\right)_{c,t} + \epsilon_{c,t}$$

where $\epsilon_{c,t}$ denotes the error term.

The above models are econometric models which must first be estimated from past data and then used for prediction.

3.2 SCENARIOS DEFINITION

MaGE allows the user to run scenarios concerning the future state of the world which attempt to emulate at least partially the SSP1-5 scenarios and produce projections. In particular the model included in MaGE allows for the introduction of demographics (including education) and economics to allow for predictions concerning population growth and economic quantities such as growth, GDP, energy consumption and quantities such as $A_{c,t}$ or $B_{c,t}$.

Quoting from the MaGE description it does not allow for

> *urbanization, within-country inequality, international cooperation, environmental policy, energy technology change (towards renewable energy), land use, sector structure, international trade, agricultural productivity and consumption structure.*

Moreover, MaGE does not provide regional projections but only projections on a country level however aggregate projections for certain quantities (like GDP, Labor, etc,) are possible.

The demographic projections of MaGE rely on the UN predictions and the IIASA scenarios. As these are available from the methodology discussed in Section 2 we mainly utilize MaGE for the economic driver projections and, in particular, to report projections for economic quantities for the countries of interest such as

- GDP $Y_{c,t}$
- TFP $A_{c,t}$
- Energy productivity $B_{c,t}$
- Energy consumption $E_{c,t}$.

To avoid internal consistency issues with the model, UN and IIASA population scenarios are used within MaGE. Structure and philosophy of the MaGE model as well as computational restrictions does not allow MaGE to accomodate probabilistic scenario (or at least not in a computational feasible manner) hence for internal consistency issues UN and IIASA have been used to MaGE as by design. The results of the model concerning the above quantities will be further introduced into more detailed economic models from WP2 as input, such as energy and WATNEEDS models or CGE and RICE models from WP3. These more detailed models will employ the aggregated output from MaGE to further differentiate quantities concerning e.g., energy mix, required as input.

3.3 DATA OUTPUT DESCRIPTION

The output of the MaGE model yields detailed predictions for various quantities of interest related to population, education, as well as economic quantities. As MaGE uses the IIASA and the UN predictions as far as population is concerned we will report these separately (see also Section 2) and we will only use MaGE for predicting the various economic indicators. The relevant economic quantities that are provided at country and regional level and are uploaded to the AWESOME's repository for each SSP scenario are shown in Table 6. Note that beside Energy Productivity and TFP (non-aggregatable quantities), the remaining economic drivers are available also for the extended Mediterranean region described in Section 1.2.

Table 6 – Economic indicators projected by MaGE

Variable Name	Description	Unit
Capital	Capital stocks	Constant 2005 USD
Energy_Consumption	Energy consumption	Barrels
Energy_Productivity	Non-corrected energy productivity	Constant 2005 USD/barrel
Energy_Productivity_corr	Oil-corrected energy productivity	Constant 2005 USD/barrel
GDP	Total GDP	Constant 2005 USD
GDP_oil_corr	Oil-corrected total GDP	Constant 2005 USD
GDP_PPP_corr	PPP corrected total GDP	Constant 2005 USD
GDP_ira	Total GDP including real appreciation	Constant 2005 USD
GDP_per_capita	GDP per capita	Constant 2005 USD
GDP_per_capita_ira	GDP per capita including real appreciation	Constant 2005 USD
Investments	Investments amount	Constant 2005 USD
Savings	Savings amount	Constant 2005 USD
TFP	Non-corrected total factor productivity	
TFP_corrected	Oil-corrected total factor productivity	

3.4 EGYPT, GREECE & MEDITERRANEAN REGION

In this section we illustrate some of the economic drivers that MaGE produces projections under the SSP scenarios and as representative examples the cases of Egypt and Greece are presented at country-level and at regional-level the Mediterranean region as considered in this project.

3.4.1 The cases of Egypt and Greece

For illustration purposes we present here some snapshots of the results of economic projections for all SSP scenarions for the case of Egypt and Greece in the period 2020-2100. Presenting economic projections of two countries with different population dynamics (as already presented in Section 2.3) contributes in deeper understanding of the MaGE functionality and expected output in similar cases.

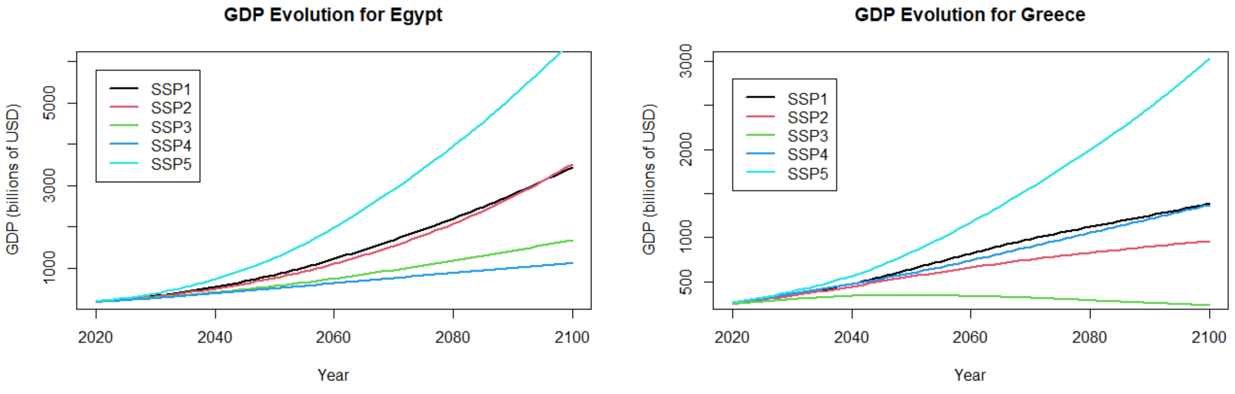

Figure 10 – GDP evolution for Egypt (left) and Greece (right) under the SSP scenarios

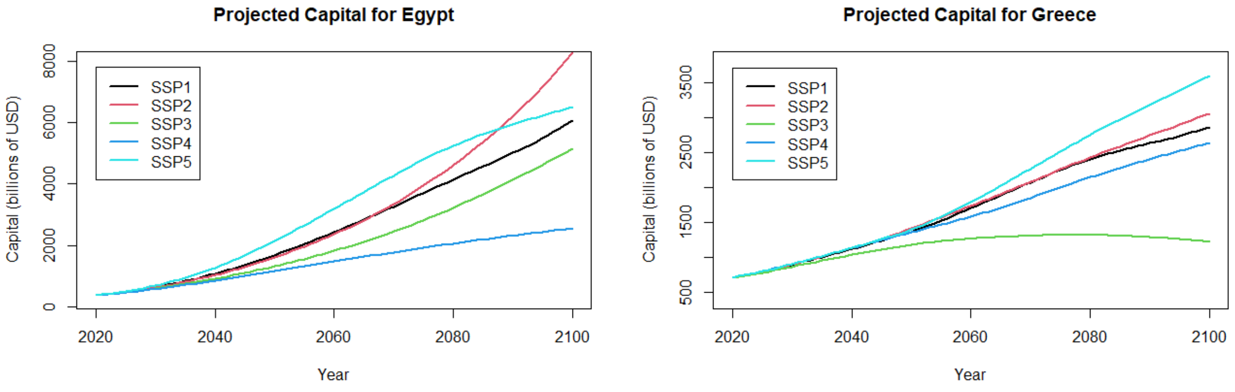

Figure 11 – Capital projections for Egypt (left) and Greece (right) under the SSP scenarios

First, in Figures 10 and 11 are illustrated the estimated GDP evolution and the capital projections for Egypt and Greece up to year 2100 under all SSP scenarios. Regarding GDP, Egypt presents three basic patterns with the medium one is represented by SSP1 and SSP2 scenarios, the lowest one by SSP3 and SSP4 scenarios and the highest one is represented by the SSP5 scenario. On the other hand, Greece presents also three patterns for GDP with the median case consisting of SSP1, SSP2 and SSP4 scenarios, SSP3 representing itself the lowest case and SSP5 representing the highest case. Capital projections for Egypt, indicate two main clusters with some diversification at the end of the time interval. In particular, SSP4 represents the lowest case while the other SSP scenarios seem to consist one cluster with SSP2 at the end of the horizon of interest becoming the highest scenario case. Capital projections for Greece are also clustered to two main trends with SSP3 representing the lowest trend in capital (in line with GDP projections), while the rest SSPs consist the higher trend group with SSP5 representing the highest trend (also in line with GDP projections). Therefore, deviant trajectories indicate the higher scenarios for Egypt and Greece respectively due to the different country groupings (HiFert and Rich-OECD).

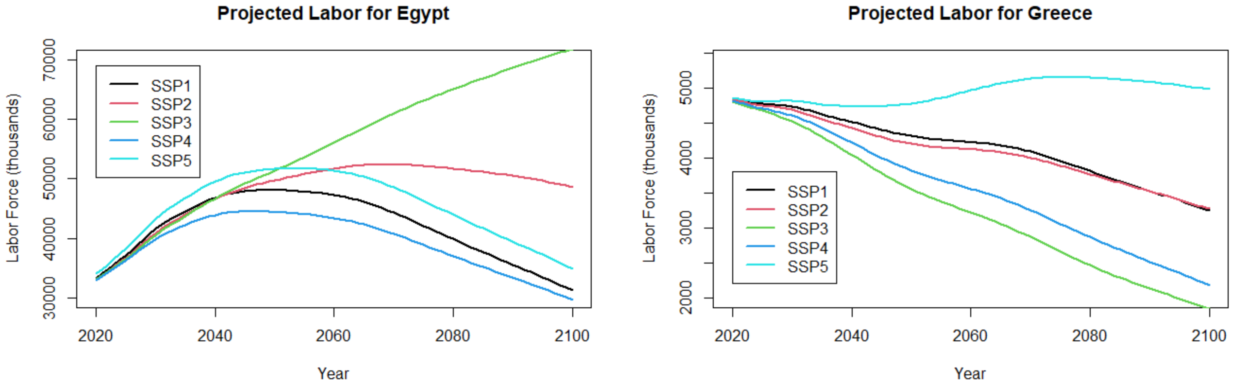

Figure 12 – Labor force projections for Egypt (left) and Greece (right) under the SSP scenarios

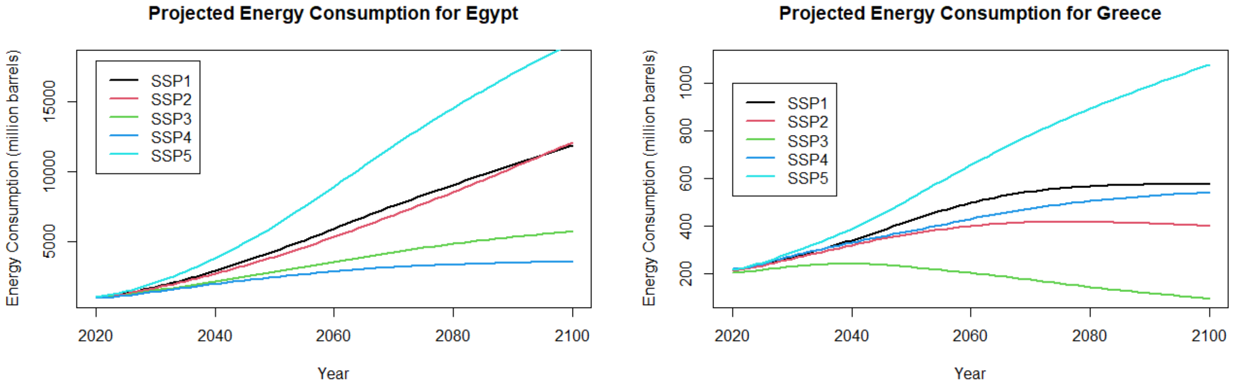

Figure 13 – Energy consumption projections for Egypt (left) and Greece (right) under the SSP scenarios

In Figure 12 Labor force projections are illustrated for the two countries which are directly affected by the population projections. Clearly, projected labor force in Greece seems to follow a declining trend under the majority of SSP scenarios with SSP3 representing the steepest decrease while SSP5 represents a stable trend (highest case). On the other hand, labor force in Egypt is rapidly increased under SSP3 while SSP5 is one of the scenarios leading to the lowest labor levels. In Figure 13, projected energy consumption is depicted for both countries under all the SSP scenarios. The shaped trends are absolutely in line with the trends observed for the GDP evolution of both countries, revealing the close connection between these two economic drivers.

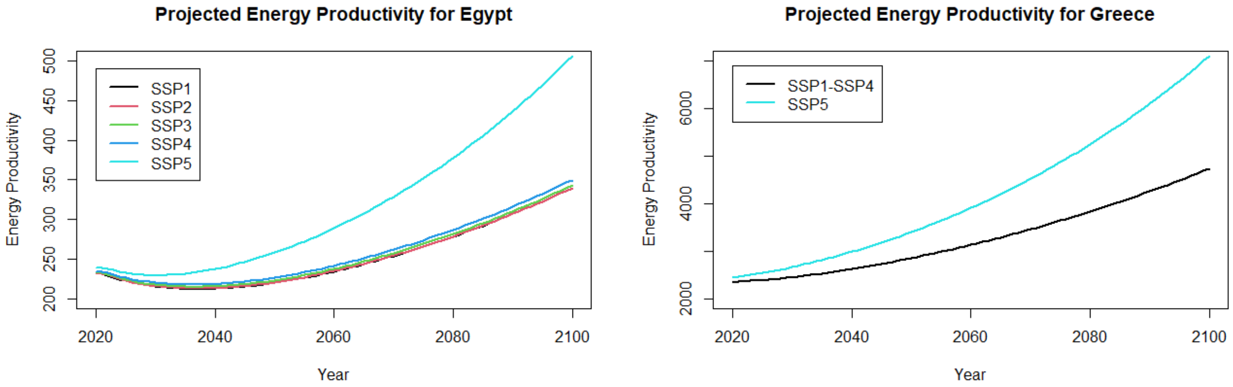

Figure 14 – Energy productivity projections for Egypt (left) and Greece (right) under the SSP scenarios

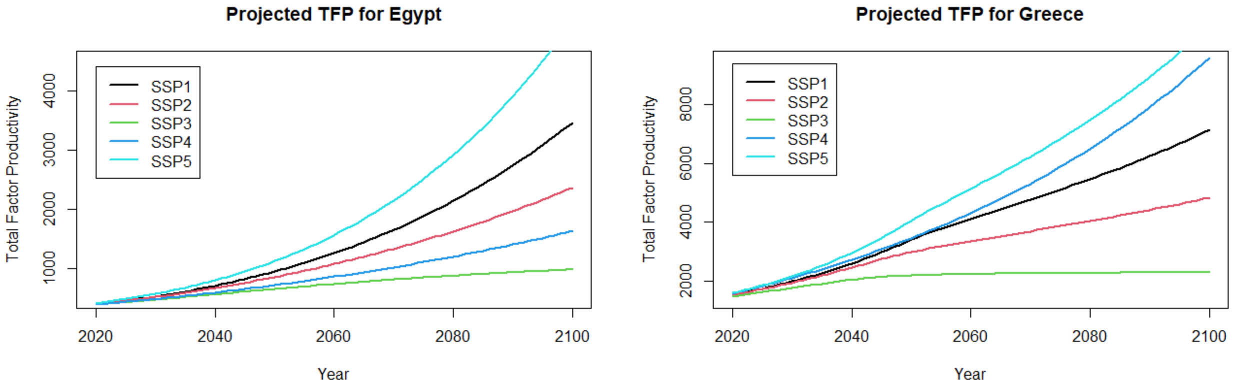

Figure 15 – Total Factor Productivity (TFP) projections for Egypt (left) and Greece (right) under the SSP scenarios

The projected Energy Productivity and Total Factor Productivity (TFP) are illustrated in Figures 14 and 15. Energy productivity presents two mainstreams in both countries with the upper trend being represented by SSP5 scenario while the rest SSPs comprise a very homogenous group with no major distinctions between the scenarios. For the case of Greece the difference are so small that cannot be observed in the plot. Regarding TFP, there are five distinct cases in both coutries with SSP3 and SSP5 scenarios indicating the lowest and highest trajectory respectively for both countries, while the rest SSPs determine the medium trends.

3.4.2 Aggregated Results: The Mediterranean Region

Aggregated results about GDP, Capital, energy consumption and labor force from all countries considered in the Mediterranean region are presented in this subsection under all socio-economic scenarios. In Figure 16 GDP evolution and capital projections according to each SSP are illustrated in the region. It is clear that in both cases, SSP5 corresponds to the high case scenario while SSP3 corresponds to the lowest case scenario. In connection to the results from the country-level results regarding Egypt and Greece, it seems that although the highest trend scenario is common between different country groupings (SSP5) the lowest trend is somewhat dominated from the Rich-OECD countries group. This is quite a reasonable finding since stalled development scenario (SSP3) assumes that the more advanced economies (Rich-OECD countries) would be stalled, causing a very low growth rate for both capital and GDP (even negative in some cases, e.g. Greece). Since, this country grouping dominates the controls the greatest part of the region's output in capital and GDP, it is reasonable to affect significantly its evolution.

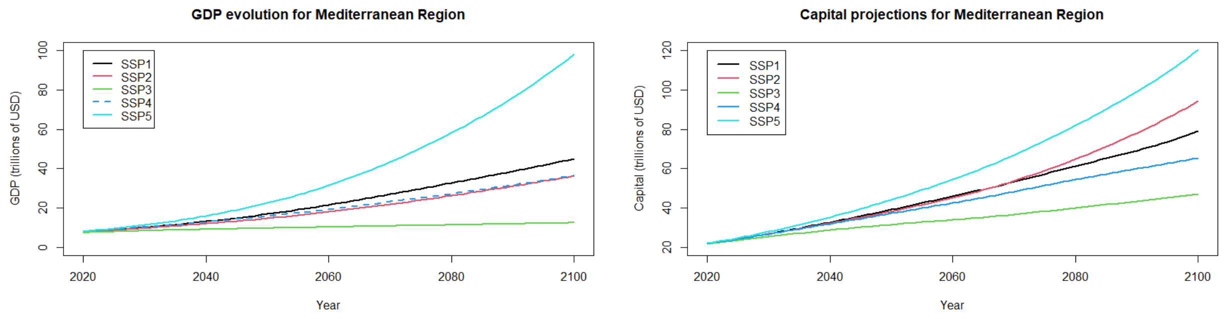

Figure 16 – GDP evolution (left) and capital projections (right) for the Mediterranean region under the SSP scenarios

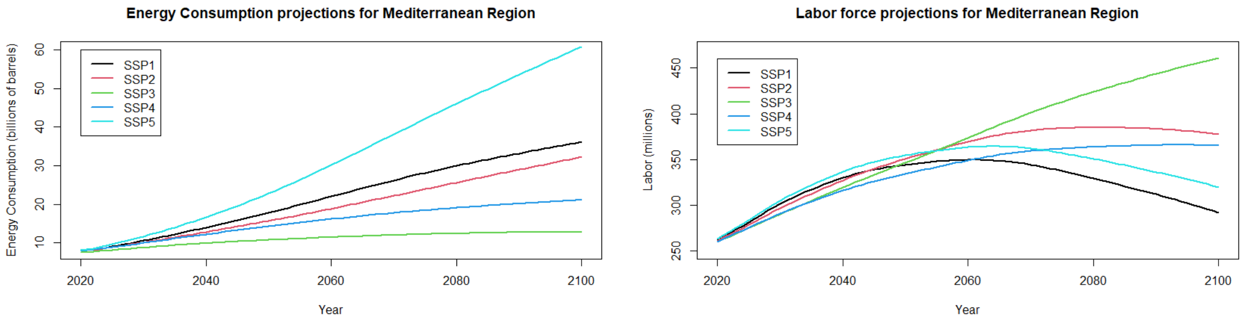

Figure 17 – Projected energy consumption (left) and labor force (right) for the Mediterranean region under the SSP scenarios

In Figure 17 the region's aggregated energy consumption and labor force projections are illustrated.

Energy consumption evolution under the different SSP scenarios is in complete accordance to the aggregated capital and GDP evolution. Moreover, aggregated labor force displays three major patterns where the highest outcome is produced by the SSP3 scenario which is dominated by the HiFert countries group. The lowest trend group consist of the SSP1 and SSP5 scenario with rapid development scenario (SSP1) leading to the lowest aggregated labor levels, while the median trend group consists of SSP2 and SSP4 indicating a stabilization of the labor force. The main conclusion regarding aggregated labor force evolution is similar to that of aggregated population projections, that is the HiFert group's fertility rate scenario significantly affects the labor force dynamics.

4 CONCLUSIONS

In this first WP2 report (Deliverable D2.1 - Demographic Scenarios), scenarios for population and economic drivers expected to impact the agricultural sector were provided for the time horizon 2020-2100 for various countries of the Mediterranean and adjacent regions which are relevant for AWESOME models.

The population scenarios provided are based on probabilistic scenarios using the Bayesian hierarchical population model of Raftery et al. [7], appropriately modified to fit within the SSP scenarios framework. This methodology allows for selecting the quantitative boundaries between different scenarios in an endogenous and not preassigned fashion purely relying on the dynamics of the system and the available information from historical data, thus (while computationally intensive) returning realistic scenarios as well as statistical information concerning their variability. This information will be valuable input to other models of this and other WPs for modeling energy demand, food demand, etc.

The economic drivers scenarios provided are obtained in terms of the global macroeconomic MaGE model [3]. This model produces projections for aggregate economic quantities such as GDP, energy consumption, labor force, etc. and generates scenarios compatible with the SSP framework for these quantities that are taken into account within the model.

The detailed results for all countries in the Mediterranean region as considered in this project are uploaded and available for use on the AWESOME repository. As representative examples in this report, we provide the results for the single country cases of Egypt and Greece, and aggregate results for the Mediterranean and adjacent regions of interest in this project. It was observed that different scenarios produce qualitatively as well as quantitatively different realizations for the demographics as well as for key socio-economic indicators, with certain economic quantities being more scenario sensitive than others (for example Labor or GDP is more sensitive to scenarios than energy productivity). Moreover, another interesting finding is that the fertility level scenario in HiFert group of countries dominates the total population evolution in the region of Mediterranean area.

References

[1] Alkema, L., Raftery, A. E., Gerland, P., Clark, S. J., Pelletier, F., Buettner, T., & Heilig, G. K. (2011). Probabilistic projections of the total fertility rate for all countries. *Demography*, 48(3), 815-839.

[2] Azose, J. J., & Raftery, A. E. (2015). Bayesian probabilistic projection of international migration. *Demography*, 52(5), 1627-1650.

[3] Fouré, J., Bénassy-Quéré, A., & Fontagné, L. (2013). Modelling the world economy at the 2050 horizon. *Economics of Transition*, 21(4), 617-654.

[4] International Energy Agency, World Energy Outlook 2011, *IEA Publications*, Paris, 2011.

[5] Lutz, W., Butz, W. P., & Samir, K. E. (Eds.). (2014). World population and human capital in the twenty-first century. *Oxford University Press*.

[6] Lutz, W., Goujon, A., Kc, S., Stonawski, M., & Stilianakis, N. (2018). Demographic and human capital scenarios for the 21st century: 2018 assessment for 201 countries. *Publications Office of the European Union*.

[7] Raftery, A. E., Li, N., Sevciková, H., Gerland, P., & Heilig, G. K. (2012). Bayesian probabilistic population projections for all countries. *Proceedings of the National Academy of Sciences*, 109(35), 13915-13921.

[8] Raftery, A. E., Chunn, J. L., Gerland, P., & Sevciková, H. (2013). Bayesian probabilistic projections of life expectancy for all countries. *Demography*, 50(3), 777-801.

[9] Sevciková, H., Alkema, L., & Raftery, A. E. (2011). bayesTFR: An R package for probabilistic projections of the total fertility rate. *Journal of Statistical Software*, 43(1), 1.

[10] Sevciková, H., & Raftery, A. E. (2016). bayesPop: probabilistic population projections. *Journal of Statistical Software*, 75.

[11] United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects. The 2004 Revision, Vol. III, Chapter VI. Methodology of the United Nations population estimates and projections; 2006. p. 100-104. `http://www.un.org/esa/population/publications/WPP2004/WPP2004_Volume3.htm`