SSP Long Run Scenarios for European NUTS2 Regions

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Abstract

In this paper we illustrate the development of a modeling framework aimed at producing detailed quantiative estimates for economic variables, consistent with Shared Socio-economic Pathways, and their assumptions about national income and population. Our model not only provides infomation on industrial production levels, employment, consumption patterns, trade flows and other macroeconomic variables, but disaggregates them further at the sub-national level, for European NUTS2 regions. Estimates are produced by an especially designed dynamic general equilibrium model (G-RDEM), augmented with a regional down-scaling module. The latter takes into account the different sectoral composition of the regional economies, their endowments of primary resources, as well as the possible existence of structural and agglomeration externalities. After illustrating the methodology, the paper provides a brief overview of SSP-consistent economic development scenarios produced for the European regions.

Keywords:

Shared Socio-economic Pathways, Regional Economic Growth, Dynamic General Equilibrium Models, Computable General Equilibrium Models, Long-run Economic Scenarios, Structural Change, Economic Growth.

JEL Codes:

C68, C82, C88, D58, E17, F43, O11, O40.

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1 Introduction

Starting from the 5th Assessment Report (Pachauri et al., 2014), the Intergovernmental Panel of Climate Change (IPCC) has promoted the constructions of two separate groups of scenarios for the analysis of climate change impacts and policies: Representative Concentration Paths (RCP), which are based on physical GHGs concentration targets (Van Vuuren et al., 2014), and Shared Socio-economic Pathways (SSP), which specifically defines assumptions of development in terms of GDP, demographic structure, education and urbanization rates (Riahi et al., 2017). SSP scenarios are increasingly being adopted not only in the context of climate change, but in a variety of other research fields, requiring an extended time perspective, for instance in contrasting economic growth and availability of natural resources, like water (Roson and Damania, 2017), or assessing the future risk of hunger (Hasegawa et al., 2015), land-use patterns (Popp et al., 2017), civil conflicts (Hegre et al., 2016).

The SSPs are based on five narratives describing broad socioeconomic trends that are intended to span the range of plausible futures. They include: a world of sustainability-focused growth and equality (SSP1); a "middle of the road" world where trends broadly follow their historical patterns (SSP2); a fragmented world of "resurgent nationalism" (SSP3); a world of ever-increasing inequality (SSP4); and a world of rapid and unconstrained growth in economic output and energy use (SSP5). The various scenarios are differentiated with respect to two main dimensions: "socio-economic challenges" (adaptation) and "environmental challenges" (mitigation).

To translate these qualitative storylines into quantitative information, to be possibly used in subsequent numerical analyses, some numerical models are employed under assumptions broadly consistent with the narratives. For instance, Dellink et al. (2017) describe how the OECD ENV-Growth model was used to derive (per capita) GDP projections on a country basis. The methodology is based on a convergence process and places emphasis on some key drivers of economic growth in the long run: population, total factor productivity, physical capital, employment and human capital, and energy and fossil fuel resources (specifically oil and gas).

A data repository is maintained at IIASA[1], containing baseline information, for each SSP and country, about: population structure, urbanization rates, and GDP (three estimates generated by different models). Furthermore, an effort was undertaken to feed a set of Integrated Assessment Models[2] with these data, to get additional information about energy, land use, and greenhouse gas emissions (Riahi et al., 2017). The quantitative translation of the qualitative narratives, however, is still insufficient in terms of scale for many policy and impact assessment applications. For instance, estimates about the structural composition of an economy would be needed, in addition to just the average per capita GDP, when assessing the potential future pressure on natural resources. Also,

[1]http://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about#v2

[2]Specifically: AIM, IMAGE, MESSAGE-GLOBIOM, REMIND, WITCH and GCAM.

when analyses are undertaken at sub-national level, nation-wide macroeconomic forecasts may be of little help to shape a scenario for the regional economies.

Two main strategies are being employed when more spatial (and possibly sectoral) detail is required. One strategy focuses on the qualitative side and essentially aims at constructing SSP-consistent regional narratives, through a systematic process of involvement of experts, policy makers and stakeholders (Absar and Preston, 2015; Nilsson et al., 2017). Of course, this methodology is not designed to generate quantitative estimates, although it could be viewed as a preliminary step in this direction. The second strategy is based on forcing results from a detailed macro model, which is often a Computable General Equilibrium one (Fujimori et al., 2017). For instance, GDP levels are imposed from the outside and the model is allowed to endogenously compute parameters, like productivity factors, that will bring about the given GDP target. In this respect, CGE or similar models are employed as "multipliers of scenario variables", since they identify a hypothetical market equilibrium and thus can specify production volumes, trade flows and many other macroeconomic variables.

However, this second approach suffers from two main deficiencies. The first one is that CGE and similar models were not conceived and designed for economic analysis in the medium and long run. Rather, they were intended for short-term policy assessment, like simulating the effects of a fiscal reform, or the implementation of a trade agreement. This explains why most parameters are usually "calibrated" to a relatively recent Social Accounting Matrix (or Input Output Table), such that the observed structure of an economic system is taken as a benchmark, from which counterfactual experiments are conducted. But, of course, when the economy is analyzed at a longer time horizon, the current economic structure, as estimated from some past national accounts, is no more a valid reference.

To overcome this disadvantage, a special type of CGE model, named G-RDEM, has been developed. The G-RDEM model, which is briefly described in Section 2, was specifically designed for the generation of long run scenarios of economic development. It is intended to capture processes of structural adjustment like the changing composition of consumption at higher income levels, the impact of demographic structure on savings rates, and other effects.

Even with these special features, however, the employment of a macroeconomic model like G-RDEM is constrained by the fact that its parameters are estimated on the basis of official national economic accounts. As such, its typical spatial scale is national, and the temporal scale is yearly. If a finer resolution is needed, the macroeconomic model should be used in conjunction with a downscaling module or interfaced with an external model.

This paper describes and discusses how most output variables from G-RDEM can be regionally disaggregated for the European NUTS2 regions (Nomenclature of Territorial Units for Statistics by Eurostat, layer 2). Some economic information for these European regions is available from Eurostat[3], and it is combined with national data in the model. Our methodology is aimed at capturing pos-

[3] http://ec.europa.eu/eurostat/web/regions-and-cities

sible divergencies between regional and national economic growth paths, which could be due to differences in the sectoral composition, as well as to specific peculiarities of the regional economies, like agglomeration externalities.

The paper is organized as follows. The next section briefly describes the G-RDEM model and its peculiar characteristics. Section 3 illustrates the regional downscaling module, which is based on a specification of the regional production structure and an econometric estimation of the regional productivity bias. The spatially disaggregated G-RDEM provides a very large amount of data, so that a detailed illustration of all scenario variables would not be feasible here,[4] and likely not even useful. However, we do provide in Section 4 a brief overview on some salient characterisics of the scenarios, to highlight the additional information obtained from the model, at the sub-national level. A final section concludes.

2 G-RDEM: a dynamic general equilibrium model for the definition of long-run economic scenarios

G-RDEM is a computable general equilibrium model, designed for the construction of internally consistent and sufficiently detailed scenarios of long-run economic development (Britz and Roson, 2018). The model is a recursive dynamic extension of the GTAP standard comparative static model, with the inclusion of five distinguishing feautures, meant to capture some key adjustment processes in the long run.

The structure of the GTAP model is fully described in Hertel and Tsigas (1997), although some minor changes have been introduced recently (Itakura and Hertel, 2001; Corong et al., 2017). Most basic assumptions in the model are canonical for a general equilibrium setting: industries are modeled through representative, cost-minimizing firms with constant returns to scale and zero profits; households maximize utility under a budget constraint; revenues are obtained by selling services of primary factors; all macroeconomic identities hold, etc.

Some other assumptions are less common, in particular:

- Utility of the representative household is implicitly defined as a Constant Differences in Elasticity (CDE) function (Hanoch, 1975). This function allows for (rather limited) differences in income elasticities among consumed goods and services.

- Aggregate savings are a constant share of national income. Savings are virtually collected by a global bank and redistributed as physical investments, without the need to match national savings to investments, therefore to have the trade balance in equilibrium.

[4] More detailed information is available on request.

- Trade and transport margins in international commerce are handled similarly, by means of virtual global transport and trade agents.

Although a dynamic variant of the GTAP model does exist (Ianchovichina and Walmsley, 2012), the simplest way of making the model dynamic is by framing it as a chain of temporal general equilibria. This can be simply done by making the (exogenous) capital stock at time t dependent on (endogenous) investments at time *t-1*. When there is no intertemporal optimization, this approach is often termed "recursive dynamics". In general, that extension alone will not generate a realistic path of economic growth.[5] This is why the usual methodology for the calibration of this kind of models entails the generation of a "baseline" path, obtained by imposing GDP levels at each period (obtained, e.g., by a macroeconometric model or by a given scenario), while making endogenous some productivity parameter. Counterfactual simulations are then obtained by setting the resulting productivity parameter back to exogenous, while over-imposing shocks, possibly time-dependent, to other parameters. This means that the model dynamics is partly endogenous (capital accumulation) and partly exogenous (productivity growth).

G-RDEM introduces five additional features into the recursive system:

1. The GTAP CDE utility function is replaced by an AIDADS demand system. The AIDADS is An Implicit, Directly Additive Demand System (Rimmer and Powell, 1992). It can be understood as a generalization of a Linear Expenditure System, where marginal budget shares are not fixed, but are a combination of two vectors, depicting the budget structure at very low and very high utility (income) levels. The reason for replacing CDE with AIDADS is that the latter can account for more effects driven by differences in income elasticity, which is important when variations in per-capita income are large, as it is typically the case in the long run.

2. Total factor productivity is allowed not to vary uniformly among industries and sectors. Indeed, differential productivity growth is one key factor of structural change in the economic systems, and probably the most important one (Swiecki, 2017). In G-RDEM, a function of the GDP growth rate is used, expressing the variation of productivity in Agriculture and Manufacturing relative to the one in the Services. The latter is endogenously computed during the generation of the baseline dynamic path, to get consistency with the imposed trajectory of growth.

3. The national, aggregate saving rate (marginal propensity to save out of the national income) can change over time, mainly as a consequence of variations in the demographic structure. The saving rate is expressed as a function of: (a) Population composition by age group; (b) per capita GDP growth; (c) Foreign savings (trade balance) relative to national income.

[5] There are several reasons for this. One reason, for example, is the assumption of exactly one year lag for the transformation of investments in fresh new capital, which may not hold in the real world.

Parameters for this relationship have been estimated through a cross-section econometric regression.

4. Interest payments on cumulated past foreign debt are considered in the model. To this end, an equation is introduced, which computes the debt stock.[6] The given interest payments on the stock of foreign debt enter the equation defining the regional income, in addition to the factor and tax income. They are positive for a country which was in the past a lender and negative for past debtors.

5. Parameters of the production function, applied to the representative firm in each regional industry, are calibrated on the observed cost structures of the base year SAM, but in G-RDEM they are allowed to vary. This is because, as the economy grows, the average industrial cost structure may vary even if the production technologies for individual goods stay the same. The relevance of the composition effect is a purely empirical question, which is addressed in the model by checking for the existence of a relationship between cost shares and an index of per-capita income[7]. It is found that, out of the 65 input-output coefficients with a cost share of at least 1%, more than 40 turn out to have a highly significant relation with per capita income. The estimates have therefore been introduced in G-RDEM as functions, updating input-output coefficients (parameters of the industrial production functions), from one time period to the next.

3 Introducing sub-national economic systems into the G-RDEM model

The estimation of structural parameters in a Computable General Equilibrium model is usually obtained through a calibration process based on a Social Accounting Matrix (SAM). A SAM, which provides a detailed picture of income flows among sectors of an economy (consistent with national accounts) is very expensive to produce, and for this reason it is not generally constructed at the regional level. However, some regional economic data are available, such as employment levels, value added, industrial output volumes. These data are collected and published in Europe by Eurostat.

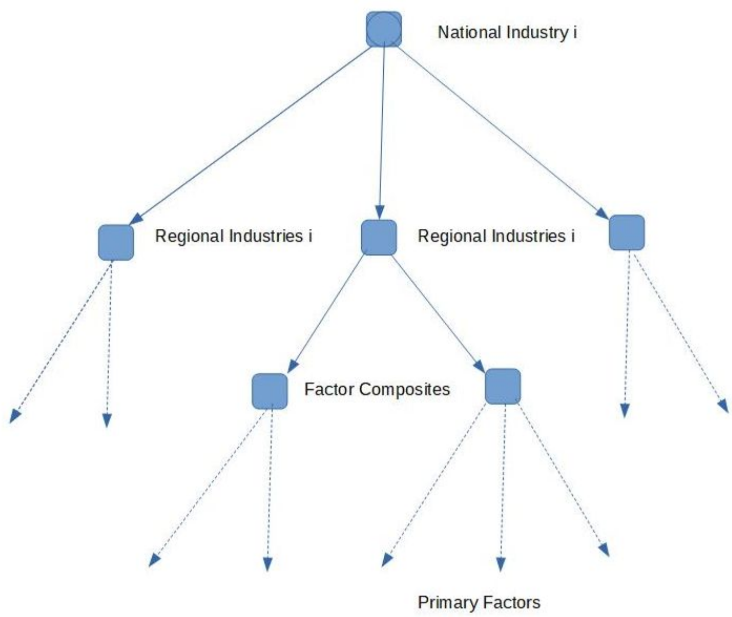
Therefore, to get regional detail in the G-RDEM model, we devise a strategy to exploit the available information without transforming the model into a full-fledged multi-regional CGE.[8] The strategy involves a disaggregation of its supply side, keeping single national components for the final demand, such as household consumption, investments, public expenditure and foreign trade. As it is usual in most CGE models, the production function of each representative

[6] This is usually assumed to be zero in the starting year.

[7] Economies are not closed in our system. Therefore, the index was built though trade weighted aggregation of per-capita incomes.

[8] Actually, the model is a multi-regional one in the sense that regions are countries or aggregations of countries, but not in the sense of explicitly considering sub-national economies.

Figure 1: CES Tree structure in the industrial production function



industrial firm is modeled as a series of nested CES[9] functions. As graphically depicted in Figure 1, we add an additional layer of substitution between regional variants inside the production function of the national composite output of each industry. By doing this, we apply at the regional level the so-called "Armington assumption", which postulates that goods produced in different countries, even when belonging to the same product category, are imperfect substitutes in international trade.[10]

The cost structures, or shares of employed production factors, can be different for the same industry in the various regions. More importantly, endowents of primary resources (labor, capital, land, natural resources) vary, according to regional economic data. Differences in resources drive relative prices and define a sort of comparative advantage at the regional level.

The general equilibrium system expresses a demand for the national goods and services. This demand is allocated down to the regional industries on the basis of their relative competitiveness. Since regional income can be defined as the sum of value added of all regional industries, the model generates income differentials: regions with a higher incidence of fast-growing industries will grow

[9]Constant Elasticity of Substitution: relative factor shares depend on relative factor prices, on the basis of a constant elasticity parameter, assigned to each nest.

[10]For instance, in the standard GTAP model, there are two CES nests in the demand: domestic products are imperfect substitutes with imports, while imports are a composite aggregate of goods of different foreign origin.

more, and vice versa.

Some early tests with this model specification have revealed that the mechanism is insufficient to fully capture the regional income dynamics, though.[11] Indeed, there could be other factors explaining income differentials among regions: agglomeration externalities, external economies (or dis-economies) of scale, inter-industrial knowledge and productivity spill-overs, etc. To account for these additional factors, we follow a modeling strategy akin to the one we used for sectoral productivity growth: we introduced an endogenous total factor productivity shifter at the regional level.

Parameters for the functional relationship defining values for the regional tfp shifters have been estimated econometrically. More precisely, we used a multiple linear regression, based on an unbalanced panel, to explain the ratio between regional and national income per capita. To increase the number of observations, we used data at the finer geographical scale NUTS3 for the years 2000-2016, as available from Eurostat, in total around 24.000 observations. The explanatory variables are Gross Value Added (GVA) shares for sectoral aggregates, their squares, their ratio to the national average share, regional population and its square, as well as the difference between the regional and national population growth rate. An AIC based model selection process (backward and forward) was used to filter out insignificant variables.

[11]When comparing regions in different countries, we noticed that regions belonging to the same nation tend to "move together", as a consequence of the common drivers of national demand.

Table 1: Regression results

VARIABLE DESCRIPTION	VARIABLE NAME	COEFFICIENT	STD. ERROR
Difference between the regional and national population growth rate and regional population density	Population	0.006	(0.00)**
	Density	0.066	(0.00)***
	Density_sqr	-0.001	(0.00)***
GVA share of agriculture	Agric	-1.316	(0.07)***
GVA share of extraction, electricity, gas and water production and distribution	Extr_El_Gas_Water	0.160	(0.06)**
GVA share of manufacture	Manuf	-1.958	(0.10)***
	Manuf_sqr	3.583	(0.14)***
	Manuf_rel	0.031	(0.01)***
GVA share of Information and communication	Commun.	2.030	(0.48)***
	Commun_sqr	12.471	(1.72)***
	Commun_rel	-0.108	(0.02)***
GVA share of construction	Constr	-5.173	(0.27)***
	Constr_sqr	30.442	(1.39)***
	Constr_rel	-0.181	(0.01)***
GVA share of public administration and defence, social security, education	Pub.Services	-2.727	(0.18)***
	Pub.Services_sqr	4.231	(0.31)***
	Pub.Services_rel	-0.252	(0.02)***
GVA share of financial, insurance, professional, scientific, technical and administrative activities	Prof.Services	-4.792	(0.19)***
	Prof.Services_sqr	17.198	(0.42)***
	Prof.Services_rel	0.381	(0.01)***
GVA share of wholesale and retail trade, accommodation and food services	Trade	0.363	(0.09)***
	Trade_rel	-0.096	(0.02)***
Intercept	Constant	2.018	(0.05)***

Estimates are presented in Table 1. As expected, population growth and density are associated with relatively higher income per capita, although the relationship should be interpreted in terms of correlation, rather than causation. Scenario data provide estimates of population only at the country level. To get regional population, we employ forecasts produced by Eurostat for the year 2050 which, however, do not refer to any SSP scenario and are therefore used here only as regional split factors, applied to the national totals. However, regional population forecasts discount hypotheses of internal migration, which is also driven by income differentials. The inclusion of a productivity shifter based on parameters of Table 1, therefore, ensures some degree of consistency between income and population estimates, by considering the existing correlation.

Interpreting the role of the sectoral composition of the regional economy is somewhat more difficult, because industry shares appear as regressors not only in levels, but also as squares and relative to the corresponding national aggegate. For a better reading of the estimates, we simulated the impact on relative income of a marginal increase in any of the shares, compensated by a reduction in the other ones, to ensures that all shares keep adding up to unity. Results are shown in Table 2, differentiated by country.

We can notice that regions having higher shares of value added in the Communication as well as in Financial, Insurance, Professional, Scientific, Technical and Administrative Services (which are more diffused in urbanized areas) are generally richer. A positive role is also played by Construction, but in this case we are inclined to interpret our findings in terms of reverse causation: dynamic regions attract investments, which stimulates growth in this industry.[12] On the other hand, lagging regions are typically associated with higher shares of Agriculture, Extraction, Public Services and Trade.

Our results appear to be broadly consistent with the literature. For instance, Melitz (2005) revisits the case for infant industry protection when the industry is competitive and experiences dynamic learning effects that are external to firms (as it could be the case for Communication and Technical Services). Inter-sectoral spill-overs and externalities have been studied, among others, by Gemmell et al. (2000), Naito and Ohdoi (2008), Antonelli and Gehringer (2015). Agglomeration (density) externalities are at the core of the "new economic geography" and theories of regional economic growth (Morrison Paul and Siegel, 1999; De Groot et al., 2009; Mariotti et al., 2010; Marrocu et al., 2013).

Parameter values of Table 2 are used in the model to identify a function, which drives a regional parameter of total factor productivity, on the basis of the (endogenous) industrial shares and population projections. The introduction of such a shifter makes the regional paths of economic growth more differentiated.

[12] As explained for the case of population, correlation matters, not causation, in this conext.

Table 2: Simulated impact on regional income of a change in sectoral share

Country	Agric.	EEGW	Manuf.	Comm.	Constr.	Pub.Ser	Prof.Ser	Trade
Austria	-4.45	-2.95	-0.99	8.53	20.71	-2.80	18.39	-3.17
Belgium	-4.60	-3.11	-1.17	9.17	20.11	-2.72	16.34	-3.41
Bulgaria	-5.06	-3.50	-1.56	9.48	20.19	-3.85	14.80	-3.81
Cyprus	-5.12	-3.60	-1.44	8.09	20.45	-3.07	14.18	-3.81
Czech R.	-4.71	-3.19	-1.18	9.69	20.36	-3.31	18.22	-3.55
Germany	-4.15	-2.66	-0.66	9.90	19.26	-2.40	19.59	-3.10
Denmark	-4.35	-2.85	-0.92	9.71	19.34	-2.30	16.95	-3.17
Greece	-4.65	-3.11	-1.17	9.71	20.90	-3.26	19.86	-3.36
Estonia	-3.69	-2.17	-0.19	9.48	18.43	-1.66	19.06	-2.37
Spain	-4.79	-3.28	-1.34	9.10	21.15	-2.95	19.03	-3.51
Finland	-4.51	-3.00	-1.04	9.82	20.72	-2.57	24.19	-3.41
France	-4.54	-3.03	-1.09	9.82	20.47	-2.55	19.05	-3.40
Croatia	-4.81	-3.26	-1.33	9.33	20.29	-3.29	15.58	-3.56
Hungary	-4.21	-2.66	-0.68	10.28	18.89	-2.56	18.56	-3.03
Ireland	-4.73	-3.23	-1.22	11.05	11.21	-3.12	14.54	-3.66
Italy	-4.43	-2.92	-0.98	9.34	20.18	-2.70	17.48	-3.22
Lithuania	-4.20	-2.67	-0.70	8.54	21.08	-2.87	24.58	-2.76
Luxemb.	-7.09	-5.61	-3.47	7.86	17.41	-5.73	11.73	-5.95
Latvia	-4.32	-2.79	-0.85	9.58	20.61	-2.81	19.79	-2.94
Malta	-4.85	-3.35	-1.41	10.03	18.96	-2.75	15.20	-3.61
Netherl.	-4.73	-3.23	-1.29	9.45	19.56	-2.82	15.19	-3.54
Norway	-4.03	-2.48	-0.51	9.38	20.43	-2.25	20.61	-3.06
Poland	-5.00	-3.47	-1.51	8.18	21.51	-3.60	18.32	-3.66
Portugal	-4.55	-3.04	-1.10	8.82	19.98	-2.65	15.89	-3.26
Romania	-4.65	-3.07	-1.02	9.24	21.12	-3.34	22.08	-3.85
Sweden	-4.57	-3.07	-1.12	9.98	20.18	-2.69	19.39	-3.44
Slovenia	-4.53	-3.02	-1.04	9.16	20.31	-2.86	17.66	-3.32
Slovakia	-5.20	-3.67	-1.70	8.76	21.48	-3.79	18.55	-3.94
U.King.	-5.00	-3.51	-1.55	9.80	19.80	-3.14	14.95	-3.89

4 Scenarios overview

5 Conclusion

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