DOCUMENTATION of the SEER WORKFORCE MODEL version 3c [WorkforceModel_SEERdata_v03c.mdl]

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INTRODUCTION

This document contains the model documentation of the SEER Work Force Model, more precisely of the model version 'WorkforceModel_SEERdata_v03c.mdl'.

The model documented here is a so-called multi-scale data-rich System Dynamics simulation model. The four scales hierarchically connected in the model are: the EU scale, the EU country scale (NUTS0), the NUTS1 regional scale, and the NUTS2 regional scale. The model loads and uses large data sets and calculates multi-dimensional variables. Three dimensions are combined in many of the model variables: NUTS2 regions (229), NACE sectors (either 11 or 16 sectors, or 63 subsectors), and ISCO job types (31). For variables that combine these three dimensions, either 78089, or 113584, or even 447237 different combinations are calculated. The model is a System Dynamics model: it consists of stock-flow structures and contains feedback loops. It was built and can be simulated with Vensim, a System Dynamics software.

The model was developed with Vensim DSS 8.2.1 double precision x64. Further development of the model requires Vensim DSS since many subscripts (vectors) and complex subscript ranges (to build the multi-scale hierarchies) are used.

Many abbreviations are used in the model. For instance, *WF* refers to *Work Force*, *yr* refers to *year*, *fr* refers to *fraction*, and *rel to* or *r* or *r2* stands for *relative to*.

OVERVIEW of the MODEL

The model consists of 12 building block (BB) modules. Each of the building blocks groups variables that are closely linked and that – together – perform one or more specific functions (see Figure 1). The modules group building blocks that cannot really be separated.

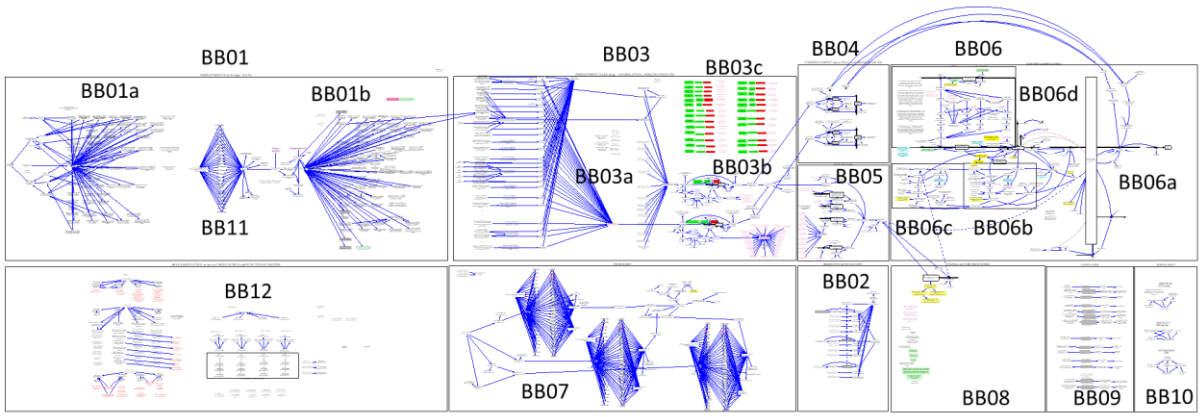

Figure 1: overview of the SEER Work Force model

BB01 and BB02 import, merge and display data. B03 identifies data patterns and extrapolates these data patterns during simulation and adds policy effects for specific sectors. BB04 calculates job losses. BB05 calculates the jobs needed and provides what-if scenario capabilities. BB06 is the core

Work Force module with employed and unemployed Workforce, hiring and firing, same-sectoring/resectoring/relocation and reskilling. BB07 infers unemployment data. BB08, BB09 and BB10 show outputs on different scales and for different purposes. BB11 allows for aggregating variables. And BB12 is a WIP module to set up the model in terms of functional job classes and skill levels.

SUBSCRIPTS, VECTORS, MATRICES, MULTI-SCALE MODELLING:

This model makes extensive use of vector notation and matrix calculation. In Vensim, vectors are called subscripts. Multiple subscripts can be combined, and, by doing so, form matrices. Multiple subscripts added to a variable make it multi-dimensional. Subscripts are noted between square brackets in variables and equations: variable X[NUTS2, NACE] = Y[NUTS2, NACE] + Z[NUTS2, NACE]. In this equation these variables have the same dimensions, namely of the dimension of the NUTS2 vector times the dimension of the NACE vector.

These subscripts consist of a constant number of Subscript Elements, separated by commas. A (combined) subscript element of a variable is a variable. Subscripts and combinations of subscripts make models denser and speed up development. In this model, following subscripts are used for:

- sectors:
  - The **NACE** subscript consists of 11 elements:
    - A Agri Forestry Fishing,
    - BCDE Industry except construction,
    - F Construction,
    - GHI Trade Vehicle Repair Logistics Accommodation Food,
    - J Information and Communication,
    - K Financial and Insurance Activities,
    - L Real Estate Activities,
    - MN ProfScienceTechnical and AdminSupport,
    - OPQ PubAdmin Defence Education Health Social Work,
    - RSTU Recreational Household and Other Services,
    - NRP NACE
  - The **NACE1digit** subscript consists of 16 elements:
    naceA, naceB, naceC, naceD, naceE, naceF, naceG, naceH, naceI, naceJ, naceK, naceL, naceM, naceN, naceOPQ, naceRSTU
  - The **NACEdetails** subscript consists of 63 elements (but more can be added):
    B, B05, B06, B07, B08, B09, C, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C33, D, D35, E, E36, E37, E38, E39, F, F41, F42, F43, G, G45, G451, G452, G453, G454, G455, G47, G473, H, H49, H50, H51, H52, H53, I, I55, I56, J, J62, J63, L, M, M71, M72, M74, N, N77, N78, N81, N82, S95
- scales:
  - The **NUTS0** subscript and the **NUTS0codes** subscript consists of 26 elements:
    - AT Osterreich, BE Belgique, BG Bulgaria, CY Kypros, CZ Cesko, DE Deutschland, DK Danmark, EE Eesti, ES Espana, FI Suomi, FR France, HR Hrvatska, HU Magyarorszag, IE Eire, IT Italia, LT Lietuva, LU Luxembourg, LV Latvija, MT Malta, NL Nederland, PL Polska, PT Portugal, RO Romania, SE Sverige, SI Slovenija, SK Slovensko
    - AT, BE, BG, CY, CZ, DE, DK, EE, ES, FI, FR, HR, HU, IE, IT, LT, LU, LV, MT, NL, PL, PT, RO, SE, SI, SK

    - The **NUTS1** subscript and the **NUTS1codes** subscript consist of 88 elements:
        - AT1 Ostosterreich, AT2 Sudosterreich, AT3 Westosterreich, BE1 RegiondeBruxellesCapitale, BE2 VlaamsGewest, BE3 Regionwallonne, BG3 SevernaiYugoiztochnaBulgaria, BG4 YugozapadnaiYuzhnatsentralnaBulgaria, CY0 Kypros, CZ0 Cesko, DE1 BadenWurttemberg, DE2 Bayern, *etc*.
        - AT1, AT2, AT3, BE1, BE2, BE3, BG3, BG4, CY0, CZ0, DE1, DE2, *etc*.
    - The **NUTS2** subscript consists of 229 elements:
        - AT11, AT12, AT13, AT21, AT22, AT31, AT32, AT33, AT34, BE10, BE21, BE22, BE23, BE24, BE25, BE31, BE32, BE33, BE34, BE35, BG31, BG32, BG33, BG34, BG41, BG42, CY00, CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08, DE11, DE12, DE13, DE14, DE21, DE22, DE23, DE24, DE25, DE26, DE27, *etc*.
- jobs :
    - The ISCO subscript consists of 31 elements:
        - OC11 Chief executives senior officials and legislators,
        - OC1z Middle Managers,
        - OC21 Science and engineering professionals,
        - OC26 Legal social and cultural professionals,
        - OC31 Science and engineering associate professionals,
        - OC4 Clerical support workers,
        - OC6 Agri forestry fishery workers,
        - OC74 Electrical and electronic trades workers,
        - OC7z Craft and related trades workers REST,
        - OC82 Assemblers,
        - OC83 Drivers and mobile plant operators,
        - OC92 Agricultural forestry and fishery labourers,
        - OC24 Business and administration professionals,
        - OC25 ICT professionals,
        - OC32 Health associate professionals,
        - OC33 Business and administration associate professionals,
        - OC5z Service and sales workers,
        - OC71 Building and related trades workers excluding electricians,
        - OC72 Metal machinery and related trades workers,
        - OC9z Helpers labourers assistants rest,
        - OC02 Non commissioned armed forces officers,
        - OC22 Health professionals,
        - OC23 Teaching professionals,
        - OC34 Legal social cultural and related associate professionals,
        - OC35 Information and communication technicians,
        - OC81 Stationary plant and machine operators,
        - OC93 Labourers in mining construction manufacturing and transport,
        - OC53 Personal care workers,
        - OC03 Armed forces occupations other ranks,
        - OC01 Commissioned armed forces officers,
        - NRP ISCO
- educational levels
    - The **ISCED** subscript consists of 3 elements: ED02, ED34, ED58

- The **ISCEDdetails** subscript consists of 9 elements: ED0, ED1, ED2, ED3, ED4, ED5, ED6, ED7, ED8

Subscripts can easily be extended by adding subscript elements (see Vensim manuals) – although not during simulation. Alternative subscripts are defined here to load and work with data with different dimensions. Subscript mapping allows to convert one subscript to another, for instance, **NUTS1codes -> NUTS1** makes that variables with a NUTS1codes subscript (on the left hand side of the equation) can use NUTS1 subscripts (on the right hand side of the equation).

Subscript ranges are also used to perform operation only on a subset of the subscript vector. For instance, only on jobs of a particular skill level. Skill Level ranges are used to group the ISCO jobs into groups of the same skill level:

- sl4 == skilllevel4 == {OC11 Chief executives senior officials and legislators, OC24 Business and administration professionals, OC26 Legal social and cultural professionals, OC25 ICT professionals, OC21 Science and engineering professionals, OC22 Health professionals, OC01 Commissioned armed forces officers}
- sl3 == skilllevel3 == {OC1z Middle Managers, OC33 Business and administration associate professionals, OC34 Legal social cultural and related associate professionals, OC31 Science and engineering associate professionals, OC35 Information and communication technicians, OC23 Teaching professionals, OC32 Health associate professionals, OC02 Non-commissioned armed forces officers}
- sl2 == skilllevel2 == {OC4 Clerical support workers, OC5z Service and sales workers, OC71 Building and related trades workers excluding electricians, OC72 Metal machinery and related trades workers, OC74 Electrical and electronic trades workers, OC7z Craft and related trades workers REST, OC81 Stationary plant and machine operators, OC82 Assemblers, OC83 Drivers and mobile plant operators, OC53 Personal care workers, OC6 Agri forestry fishery workers, OC03 Armed forces occupations other ranks}
- sl1 == skilllevel1 == {OC9z Helpers labourers assistants rest, OC93 Labourers in mining construction manufacturing and transport, OC92 Agricultural forestry and fishery labourers, NRP ISCO}

Making multi-scale models in Vensim requires defining *subscript ranges* and mapping subscript elements and subscript ranges such that one or more lower-scale elements correspond to a particular higher-scale element: (AT11, AT12, AT13) -> AT1

Variable behaviour can be assessed for all elements of a subscript, only for a range, or just for an element.

DATA VARIABLES:

The model is a data-rich model. Several large data sets are loaded and used. They are loaded in the model by means of following data variables:

EmploymentDATA:
- Subscripts: [NUTS2,NACE]
- Loaded via file: nace_nuts_rimer.vdfx
- Source: EUROSTAT database lfst_r_lfe2en2
- Contents: Employment by sex, age, economic activity, and NUTS2 regions (NACE Rev. 2) in 1000 persons
- https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfe2en2/default/table?lang=en

Persons employed

- Subscripts: [NUTS2, NACEdetails]
- Source: EUROSTAT database sbs_r_nuts06_r2
- Contents: SBS data by NUTS 2 regions and NACE Rev. 2 (from 2008 onwards)
- https://ec.europa.eu/eurostat/databrowser/view/sbs_r_nuts06_r2/default/table?lang=en

unemploymentinthousands

- Subscripts: [NUTS1codes, ISCED]
- Loaded via file: unemployment.vdfx
- Source: lfst_r_lfu3pers
- Contents: Unemployment by sex, age, educational attainment level and NUTS2 regions (in 1000 persons)
- https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfu3pers/default/table?lang=en

ratioNI:

- Subscripts: [NACE, ISCO]
- Loaded via the cin file ratio_nace_isco.cin
- The rationNI is the data from the EUROSTAT data request by Systemiq.

The MODEL IN (MORE) DETAIL

BB01 – DATA IMPORT and DATA-BASED ASSESSMENT

The first building block (BB01 – see Figures 1 and 2) imports employment data into the model and splits it out across NACE sectors and NACE subsectors. That is, employment data from different data sets ("*EmploymentDATA*" and "*Persons Employed*") are corrected and merged, and subsequently split out into many data variables that can be looked at separately without having to use the Vensim subscript control.

In more detail:

- Two data sets are loaded ("*EmploymentDATA*" and "*Persons Employed*"), which both contain workforce data across NACE sectors and, in case of *Persons employed*, NACE subsectors. Both datasets contain gaps: these gaps are first filled with zeros for lacking data[1]. The raw data variables are coloured dark purple.
- These two datasets differ in terms of their granularity: the *Persons employed* dataset has subscripts [NUTS2, NACEdetails] with 63 subscript elements[2] for the NACEdetails subscript whereas the *EmploymentDATA* dataset has [NUTS2, NACE] subscripts with 11 subscript elements[3] for the NACE subscript. The latter subscript (NACE) is used across the model, and the more detailed subscript (NACEdetails) is used to fill gaps and include relevant subsectors.

[1] Vensim assigns very large negative numbers to data gaps, which could mess up calculationsa

[2] NACEdetails := B, B05, B06, B07, B08, B09, C, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C33, D, D35, E, E36, E37, E38, E39, F, F41, F42, F43, G, G45, G451, G452, G453, G454, G455, G47, G473, H, H49, H50, H51, H52, H53, I, I55, I56, J, J62, J63, L, M, M71, M72, M74, N, N77, N78, N81, N82, S95

[3] NACE := A Agri Forestry Fishing, BCDE Industry except construction, F Construction, GHI Trade Vehicle Repair Logistics Accommodation Food, J Information and Communication, K Financial and Insurance Activities, L Real Estate Activities, MN ProfScienceTechnical and AdminSupport, OPQ PubAdmin Defence Education Health Social Work, RSTU Recreational Household and Other Services, NRP NACE. With NRP NACE containing workforce not assigned to one of the other 10 categories.

Working with the fully detailed NACEdetails subscript would slow down the model substantially.

- However, our data analysis showed that the *EmploymentDATA* data for the combined GHI and MN NACE sectors underreports the numbers of persons working in these sectors. Hence, the more detailed *Persons employed* dataset is used to calculate the gap (in variables '*Persons employed NACE GHI notin EmploymentData NUTS2*' and '*Persons employed NACE MN notin EmploymentData NUTS2*'), which is then added to the data based on the NACE subscript[4]. This corrected dataset is subsequently extended with the ISCO job dimension in the '*EmploymentDATAc NUTS2 NACE ISCO*' variable[5] by multiplying the corrected '*EmploymentDATA NUTS2 NACEc*' with a Constant Initial Numbers file '*ratioNI*' which contains the fraction of persons working in jobs captured by the ISCO subscript in each of the NACE sectors.

The "*Persons Employed*" data (with the NACEdetails subscript) contains lots of data about employment in sectors and subsectors. The data is very useful to investigate the size and dynamics of NACE sectors for all EU countries. Since the model contains employment data on different scales, one could explore the data on multiple scales. Although it is possible to access and explore all this data via the subscripted variables, by using the subscript control, adding separate variables for sectors and subsectors eases the exploration. This is what most variables in BB01 do. The cluster of variables on the right (BB01a) shows data on the country scale (NUTS0) for many NACE sectors and subsectors. For instance, the equation of the variable '*Persons employed in NACE B Mining and quarrying NUTS0*' simply equals *Persons employed NUTS0c[NUTS0,B]*. In other words, it captures the '*Persons employed*' data for all NUTS0 entities (countries). In other words, this cluster is useful to investigate the size and dynamics of NACE sectors for all EU countries. Additional aggregator variables are added, like the variable 'JOBS in FOSSIL and CAR INDUSTRY' to enable exploration of persons employed in the different sectors that contribute to the Fossil and Car Industries.

The cluster of variables on the right (BB01b) shows regional scale data (NUTS2). This cluster is useful to investigate the size and dynamics of NACE (sub)sectors for all 229 NUTS2 regions represented in the current model or a subset thereof.

BB11 – MULTISCALE AGGREGATION

Building block BB11 aggregates the NUTS2 data from BB01b to the NUTS1 scale. Employment data on the NUTS1 scale is available too: it could possibly be used to identify data gaps. See Figures 1 and 10.

BB02 – DATA-SUBSCRIPT TRANSFORMATION

BB02 (see Figure 1 and 3) further transforms the data from these two data sets such that all 1-digit NACE categories are correctly captured in the variable "*Employment NACE1digit NUTS2*" – for NUTS2 and NACE 1-digit[6]. That is, grouped NACE categories BCDE, GHI and MN are split out in NACE categories B, C, D, E, G, H, I, M and N. The more detailed data set ('Persons employed' with the NACEdetails subscript) is used to calculate the fractions of each of these NACE categories in the grouped categories. These fractions are multiplied by the grouped categories to obtain [NUTS2, NACE1digit] data.

[4] For instance: Persons employed NACE GHI notin EmploymentData NUTS2 = MAX(0, (Persons employed NUTS2c[NUTS2,G] + Persons employed NUTS2c[NUTS2,H] + Persons employed NUTS2c[NUTS2,I]) - EmploymentDATA NUTS2 NACE[NUTS2, GHI Trade Vehicle Repair Logistics Accommodation Food])

[5] EmploymentDATAc NUTS2 NACE ISCO [NUTS2, NACE, ISCO] = EmploymentDATA NUTS2 NACEc[NUTS2,NACE] * ratioNI[NACE,ISCO]

[6] naceA, naceB, naceC, naceD, naceE, naceF, naceG, naceH, naceI, naceJ, naceK, naceL, naceM, naceN, naceOPQ, naceRSTU

BB03 – ADDING DATA PATTERNS and POLICY EFFECTS

BB03 is displayed in Figures 1 and 4. BB03a takes the [NUTS2, NACE] data from BB02 and [NUTS2, NACE1digit] data from BB11 and bundles them into two variables, on the one hand the '*data Employment NUTS2 specialNACE*' variable which groups all NACE subsectors that might be of interest for SEER and on the other hand the '*Employment NACE1d NUTS2 RESTsectors*' variable which groups the rest of the NACE sectors. These two variables are the inputs to (two identical) structures that perform two functions in view of simulating the data as well as the dynamics *after* the model switches from data to simulation (i.e., after the end of the data series). Two separate structures are used because all special subsectors are bundled in a separate vector (namely the subscript named '*NACEspecials4joblosses*'). These structures in BB03b:

- Allow one to introduce policy effects between a chosen start time (with background colour fluorescent green) and a chosen end time (with background colour red), by means of a relative goal value: a 'fr goal rel2startyr B07' of 1.25 with a 'startyr pol B07' of 2030 and an 'endyr pol B07' of 2040 will result in a 25% linear increase between 2030 and 2040.
- Identify the type of behaviour of each of the (sub)sectors bundled in these two multi-dimensional variables and force the identified type of behaviour upon these variables after the final data points, but not during the time a policy effect is being introduced (see previous bullet).

The policies can be set for the NACE (sub)sectors of interest by means of the variables with green background colour, red background colour and light pink font colour in BB03c: the policy start time, policy end time, and the total policy effect can be set for each NACE (sub)sector of interest. Note that, due to the formulation of the model[7], these exogenous evolutions result in linear dynamics from start time to end time. These dynamics are exogenous.

In addition, the maximum fractional change per year can be set (e.g., *max frCH normal growth B07*). The latter may be needed to limit unreasonable growth or decline derived from the data. That is, if a (sub)sector in a NUTS2 region grew excessively between 2008 until 2021, then an excessive average growth rate is calculated and used successively, unless a "*max frCH normal growth*" value limits this growth. Currently, the values are limited to 10% growth per year – which is a lot: 10% growth per year leads to doubling after just 7 years.

BB04 – JOB LOSSES and CULUMATIVE JOB LOSSES

BB04 (see Figures 1 and 5) takes the resulting data plus their simulated dynamics from the two BB03 output variables (i.e., from '*Employment NUTS2 EXTRAPfrDATA RESTnaceX*' and '*Employment NUTS2 EXTRAPfrDATA SPECIALnaceX*') and calculates the resulting job losses (by means of the variables '*jobs lost variety specialNACE*' and '*jobs lost RESTsectors*'), but also jobs created, cumulative job losses, cumulative jobs created, and net cumulative job losses. The latter calculates the net job losses corrected for by jobs created for those that lost their jobs. Job losses are calculated explicitly here, because these jobs are explicitly lost in BB06 outflow variable '*net decrease WF NUTS2 NACE ISCO'.* In the model, job losses in a particular sector at a particular point in time are calculated simply as the

[7] E.g., net increase extrapolated value restNACE [NUTS2,NACE1digit] =
IF THEN ELSE((Time >= startyr pol restNACE[NUTS2,NACE1digit] :AND: Time < endyr pol restNACE[NUTS2,NACE1digit]),
ZIDZ(fr goal rel2startyr restNACE[NUTS2,NACE1digit] * ini b4goal restNACE[NUTS2,NACE1digit] - extrap value restNACE[NUTS2,NACE1digit],(**endyr pol restNACE[NUTS2,NACE1digit] - Time**)),
AVGfrCHmaxd restNACE[NUTS2,NACE1digit] * extrap value restNACE[NUTS2,NACE1digit])

difference between the jobs in that sector in the previous time step and the current jobs in that sector and, as long as this value is positive[8].

BB05 – EU-NUTS2-NACE-ISCO WHAT-IF SCENARIO GENERATION

BB05 (see Figures 1 and 6) is a building block to simulate alternative scenarios starting from the simulated patterns generated in BB03. BB05 allows for changing the relative growth of the European workforce (via '*rel change whatifNEEDED WF GENERALacrossEU*'), for changing the relative growth of the workforce in different NUTS2 regions (via '*rel change NEEDED WF NUTS2r*'), for changing the relative growth of the workforce in different NACE sectors (via, for instance, '*rel change NEEDED WF A*'), for changing the relative growth of the workforce required in different ISCO job categories (via '*rel change NEEDED WF ISCOr*'), and combinations thereof. Minimal changes to these structures allow for simulating dynamic patterns over time. BB05 is applied across all 1-digit NACE sectors – not for specific subsectors.

These growth factors can be set independently, but ultimately, their joint multiplicative effect matters[9].

This is why the variable '*Employment NUTS2 EXTRAPfrDATA SPECIALnaceX*' – that groups all SEER specific subsectors – is first converted into the '*Employment NUTS2 EXTRAPfrDATA SPECIALnaceX inNACE1digit*' variable which is subsequently merged with the '*Employment NUTS2 EXTRAPfrDATA RESTnaceX*' variable. The resulting variable – which sums the SEER specific sector values and the rest sector values for each of the sectors – is the input to BB05.

The output variable of BB05 is the variable 'NEEDED WF N2NI rel to', which simulates the data until the end of the data series after which it takes the simulated patterns corrected by the policy effects[10], which are subsequently (possibly) changed by what-if scenario effects of BB05[11]. This output is one of the main inputs in the core building block of the model, BB06.

BB06 – EMPLOYED and UNEMPLOYED WORK FORCE, HIRING and FIRING

Building block BB06 (see Figures 1 and 7) is the core building block of the model: it consists of the core Work Force (WF) structure (BB06a). Background colours are used in this building block (and subsequently discussed building blocks): Fluorescent yellow is used to draw attention to interesting KPI variables and light blue is used to draw attention to interesting policy variables.

The core Work Force structure (BB06a) accounts for the workforce ('*ACTUAL WF NUTS2 NACE ISCO*') as well as for firing (via outflow variable '*net decrease WF NUTS2 NACE ISCO*') and hiring (via inflow variable '*net hiring WF NUTS2 NACE ISCO*'). The main hiring mechanism is endogenous to this building block (BB06a). That is, BB06a contains the mechanism through which unemployed workers [NUTS2,NACE,ISCO] are hired in case of work force shortage ('*shortage WF N2NI*') for a type of ISCO job in a particular NACE sector in each NUTS2 region compared to the work force needed there

[8] jobs lost RESTsectors[NUTS2,NACE1digit] = MAX(0, (jobs TminTS NUTS2 RESTsectors[NUTS2,NACE1digit] - jobs NUTS2 EXTRAPfrDATA RESTsectors[NUTS2,NACE1digit])/TIME STEP)
With: jobs TminTS NUTS2 RESTsectors[NUTS2,NACE1digit] = DELAY FIXED(jobs NUTS2 EXTRAPfrDATA RESTsectors[NUTS2,NACE1digit], TIME STEP, jobs NUTS2 EXTRAPfrDATA RESTsectors[NUTS2,NACE1digit])

[9] whatif NEEDED WF N2NIr[NUTS2,NACE,ISCO] = rel exp D4L NUTS2 EXTRAPfrDATA NACEhigherlevel[NUTS2,NACE] * whatifNEEDED WF GENERALacrossEU r2lastdata * NEEDED WF NUTS2xyz r2lastdata[NUTS2] * NEEDED WF NACEuvw r2lastdata[NACE] * NEEDED WF ISCOabc r2lastdata[ISCO]

[10] lastDATA value N2Nic[NUTS2,NACE,ISCO] = SAMPLE IF TRUE(Time <= EndOfData, ACTUAL WF NUTS2 NACE ISCO [NUTS2, NACE, ISCO], ACTUAL WF NUTS2 NACE ISCO[NUTS2,NACE,ISCO])

[11] NEEDED WF N2NI rel to[NUTS2,NACE,ISCO] = whatif NEEDED WF N2NIr[NUTS2,NACE,ISCO] * lastDATA value N2NIc [NUTS2,NACE,ISCO] + additional jobs due to targeted industrial policy[NUTS2,NACE,ISCO] * SWITCH no0 industrial1 policy

calculated in BB05 (variable 'NEEDED WF N2NI rel to'). This is referred to here as "same sectoring". One of two main firing mechanisms is also endogenous to this building block. That is, the surplus workforce relative to the work force needed ('*NEEDED WF N2NI rel to*') is calculated here (variable '*surplus WF N2NI*'): surplus work force (for a particular type of ISCO job for a particular NACE sector for each NUTS2 region compared to the work force needed there) divided by an average '*time to fire*' are laid off. In addition to this balancing mechanism, work force laid off in SEER specific (sub)sectors are also directly laid off here. A separate stock variable ('*unemplWF avail4 JOBS*') keeps stack of the unemployed workforce for each ISCO job for each NACE sector for each NUTS2 region that is available for hiring. The firing outflow of the Work Force stock is an inflow into this Unemployed Work Force stock and the hiring inflow into the Work Force stock is an outflow out of this Unemployed Work Force stock.

Not everyone available for an ISCO job in a NACE sector in a NUTS2 region that is available for hiring is per definition and directly hired: only a particular fraction of the possible matches (determined by the '*fr of matches same sectoring*' parameter) is made (in variable '*L supply hired by localN2NI L demand*'). Moreover, the resulting value is divided by the '*time to hire'*. If the time to hire is set to two years, then only half of the effective matches results in hires in any one year. In the base version of the model, the value of the value of the '*time to hire*' parameter is set to '*Time Step*'. Given that the time step in the base model equals a quarter of a year, gaps in the workforce are practically filled immediately (compared to the time step of the model). A '*time to hire*' of, say, one year, would smooth hiring – as is the case on the firing side of the model with a '*time to fire*' equal to 1 year.

BB06 contains – apart from 'same sectoring' – three additional hiring routes, referred here to as 'resectoring' (BB06b), 'relocation' aka 'bringing people to jobs' (BB06c), and 'reskilling' (BB06d). Currently, these hiring processes are set up in the model in a sequential manner: unemployed workers who are not hired through same sectoring, may be hired through resectoring (in the same ISCO job and the same NUTS2 region but in another NACE sector). Those who are not hired – neither through same sectoring nor through resectoring – may be hired in other NUTS2 regions (but in the same ISCO job and NACE sector), referred to here as 'relocation' or as 'bringing people to jobs'. Those who are not hired through same sectoring, resectoring, and relocation, may still find a job after reskilling.

Resectoring (BB06b) and relocation (BB06c) are operationalized in the current version of the model by means of a Vensim function/mechanism called "ALLOCATE BY PRIORITY". In short, it allocates all those (unemployed workers) that are available for *and willing* to resector or relocate to vacant jobs in other NACE sectors (in case of resectoring) or NUTS2 regions (in case of relocation). See the Vensim manual for a detailed explanation of this Vensim specific function/mechanism. There is room for improvement by connecting the allocate by priority function to specific criteria such as salaries or distance to the region of origin.

Not all unemployed workers are assumed to be willing to resector or relocate. The parameter '*fr WFavail4jobs RWA4resectoring*' determines the fraction of the unemployed workforce not hired through same sectoring that is willing to resector. The parameter '*fr WFavail4jobs RWA2b brought2job*' determines the fraction of the unemployed workforce that is not hired through same sectoring and resectoring that is willing to relocate. These fractions now apply across all NUTS2 regions, NACE sectors and ISCO jobs, but they can easily be made region-specific, sector-specific and/or job-specific by adding subscripts to these parameters.

Note that, in the current version of the model, priorities among sectors (in case of resectoring) and priorities among regions (in case of relocation) are not linked to a specific criterion (such as salaries

or distance to the region of origin). These could be set in '*priority NACE wVacancies*' or in '*priority NUTS2 destination*', respectively.

Reskilling (BB06d) is set up differently than resectoring and relocation to account for the time it takes (in the model) to reskill and the multi-dimensional nature of reskilling (changing ISCO jobs and NACE sectors within each of the NUTS2 regions). First, long term unemployment is calculated ('*smoothed WF avail4 JOBS*') by means of third order exponential smoothing (see SMOOTH3 in the Vensim manual), starting from the '*unemplWF avail4 JOBS*' variable and using a '*smoothing time unemployed2reskilling*' parameter of 2 years in the current model version. Subsequently, the minimum is taken from either that smoothed value or the stock of unemployed. In other words, the smoothed value is used in combination with the current value, to calculate minimum structural unemployment. From the resulting value, only a fraction (set by the '*fr smoothed unemplWF RWA2reskill pYR*' parameter) is really moving from the unemployed workforce stock (in stock variable '*unemplWF avail4 JOBS*') to the '*umemplWF being reskilled fromISCOx*' stock. After a '*minimal time in reskilling*' during which they are still identified by their previous NACE-ISCO identity, those who proceeded to reskilling are reassigned to a new ISCO job in a new NACE sector. Reskilling in this model does not assume that anyone with any background can be reskilled into any job for any sector: in the current version of the model, reskilling happens within each of 4 skill levels. Skill level 1 group jobs that require minimal years of schooling or years of specialization/experience, whereas skill level 4 groups jobs with maximum years of schooling or maximum years of specialization/experience. So, after a '*minimal time in reskilling*', within each skill level and NUTS2 region, unemployed from all NACE sectors are first reassigned to new ISCO jobs (belonging to that skill level) with most open vacancies), after which they are allocated to the NACE sectors with most of the specific ISCO vacancies. That is, they are assumed to choose a profession with many vacancies, after which they are attracted to sectors in proportion to the vacancies in those sectors for the job chosen. After that, people complete their job and sector specific reskilling in the stock variable '*umemplWF being reskilled intoISCOy*', after which they flow via the flow variable '*reskilled unemployed*' back into the '*unemplWF avail4 JOBS*' stock. From there, they can be hired via same sectoring, resectoring, and relocation. The parameter '*time in reskilling 4ISCOy*' determines the total time people are in reskilling. It needs to be bigger than the 'minimal time in reskilling' parameter since the latter is part of the '*time in reskilling 4ISCOy*'. Note that, in the current version of the model, reskilling reduces the number of unemployed people that are available for hiring: while being reskilled, people are not available for hiring.

Note also that the number of vacancies is currently used as priority criterion: other criteria that reflect the attractiveness of jobs and sectors could be built in. The disadvantage of the number of vacancies is that larger sectors take priority over smaller sectors. The priorities of jobs and sectors can be set manually as well, which allows for setting reskilling policies. Note, finally, that the initial value and data series before simulation of the variable '*unemplWF avail4 JOBS*' could either be set as constant value ('*assumed fr unempl pN2NI*' times the '*ACTUAL WF NUTS2 NACE ISCO*') as during the workshops and presentations in January 2023 (by setting the 'SWITCH cteIni0 dataIni1' to 0), or as a time series derived from time series data on the NUTS1 scale in terms of the ISCED classification (ED02, ED34, ED58). The latter data is derived in BB07.

BB07 – INFERENCE of DYNAMIC UNEMPLOYMENT DATA for BB06

BB07 (see Figures 1 and 8) infers dynamic unemployment data for variable "*unemplWF avail4 JOBS*" from [NUTS1,ISCED] unemployment data. This was not available in January 2023 yet, which is why a switch is added to BB06 to use constant values as in January 2023 or to use the time series derived in BB07.

The difficulty with multiscale simulation models is that not all data is available at the scale it is needed for. If data is available at a lower scale and required at a higher scale, then one can simply aggregate the data. If data is available on a higher scale and needed on a lower scale, then one needs to infer values for the lower level scale from the data on the higher level scale. In our case, the '*unemploymentinthousands*' data is available for NUTS1codes and 3 ISCED categories (ED02, ED34, ED58), while we need unemployment data on the NUTS2 scale for all NACE sectors and ISCO jobs.

Since unemployment data is available on the NUTS1 scale for ISCED categories, we transform the employment data ('*ACTUAL WF NUTS2 NACE ISCO*') to 4 Skill Levels (which relate to ISCED levels) and aggregate the data to the NUTS1 scale. This data is combined with the unemployment data ('*unemployment DATAc for NUTS1codes ISCED*') to calculate unemployment rates for different skill levels (e.g., '*fr unemployed of totalWF NUTS1 acrossNACE sl4*' for Skill Level 4). Assuming that the unemployment rates for all jobs in skill levels are the same, we can transform the ISCED data to ISCO data. Assuming that the unemployment rates at the NUTS2 scale are the same as the unemployment rates at the corresponding NUTS1 scale, unemployment rates are subsequently pushed to the NUTS2 scale. Finally, NACE sectors need to be brought in to create data of the correct dimensionality. Finally, unemployment rates of the correct dimensionality ([NUTS2, NACE, ISCO]) are calculated in '*unemployed of totalWF NUTS2 NACE ISCOc*'. A correction factor is calculated ('unempl Data on sssNNI') to ensure that the data transformation preserves the order of magnitude of the data.

Note that this entire module can be replaced with data or calculated data of the right dimensions. Calculating the data outside of Vensim is the preferred option.

BB08, BB09, BB10 – POLICY OUTPUTS, RESCALED MODEL OUTPUTS, OUTPUTS WITH SPECIAL FOCUS

Modules BB08, BB09, B10 display outputs (see Figures 1 and 9). BB08 shows one of many possible outputs that could be used to inform policy making, in this case, industrial policy. This stock-flow structure calculates the additional jobs targeted industrial policy could create[12].

Module BB09 rescales NUTS2 outputs to NUTS0 country scale outputs.

Module BB10 displays outputs for a selection of NUTS2 regions.

BB12 – A FUTURE EXTENSION OR ALTERNATIVE SETUP

Module BB12 (see Figures 1 and 11) contains variables and functions to reclassify the [NACE,ISCO] data in 3 functional groups [managerial jobs, technical jobs, sector specific jobs] and 4 different skill levels. The current [NACE,ISCO] setup of the model may be overly constraining job changes: only within sectors and for specific jobs. Recasting jobs in 3 functional groups and 4 skill levels may be a better representation of the real differences between jobs.

MODEL MANIPULATION

Model manipulation happens with the policy settings BB03 (policy effects), with the scenario settings in BB05 (What If), and with the Work Force policy settings in BB06.

[12] job creation through industrial policy[NUTS2,NACE,ISCO] = EndOfData0 to sim1 * SWITCH no0 industrial1 policy * remaining L supply after NUTS2andEU hiring[NUTS2,NACE,ISCO] / job creation time

APPENDICES

BUILDING BLOCKS – IN DETAIL

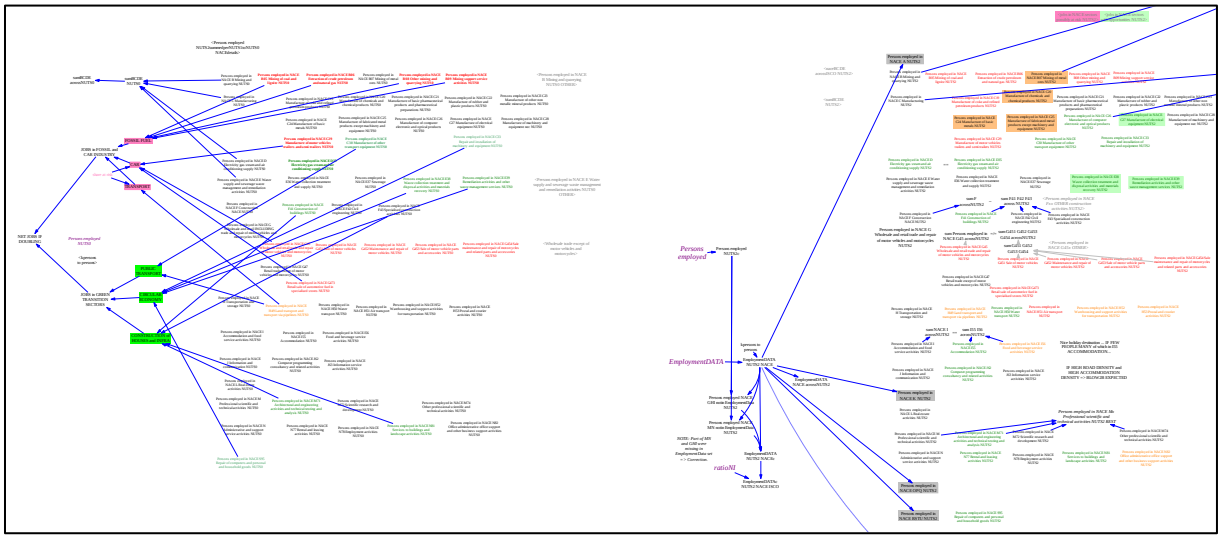

Figure 2: Module / Building Block 1

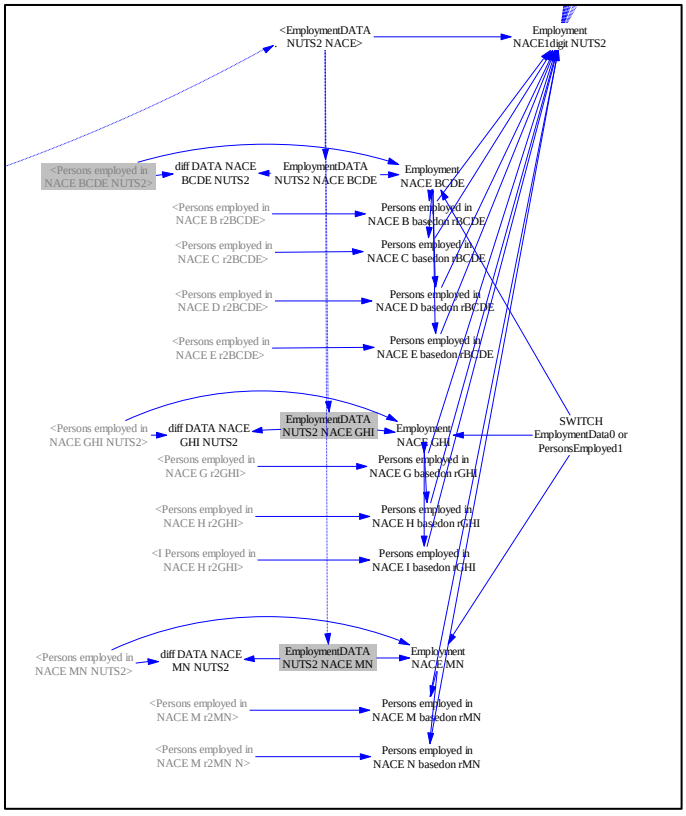

Figure 3: Module / Building Block 2

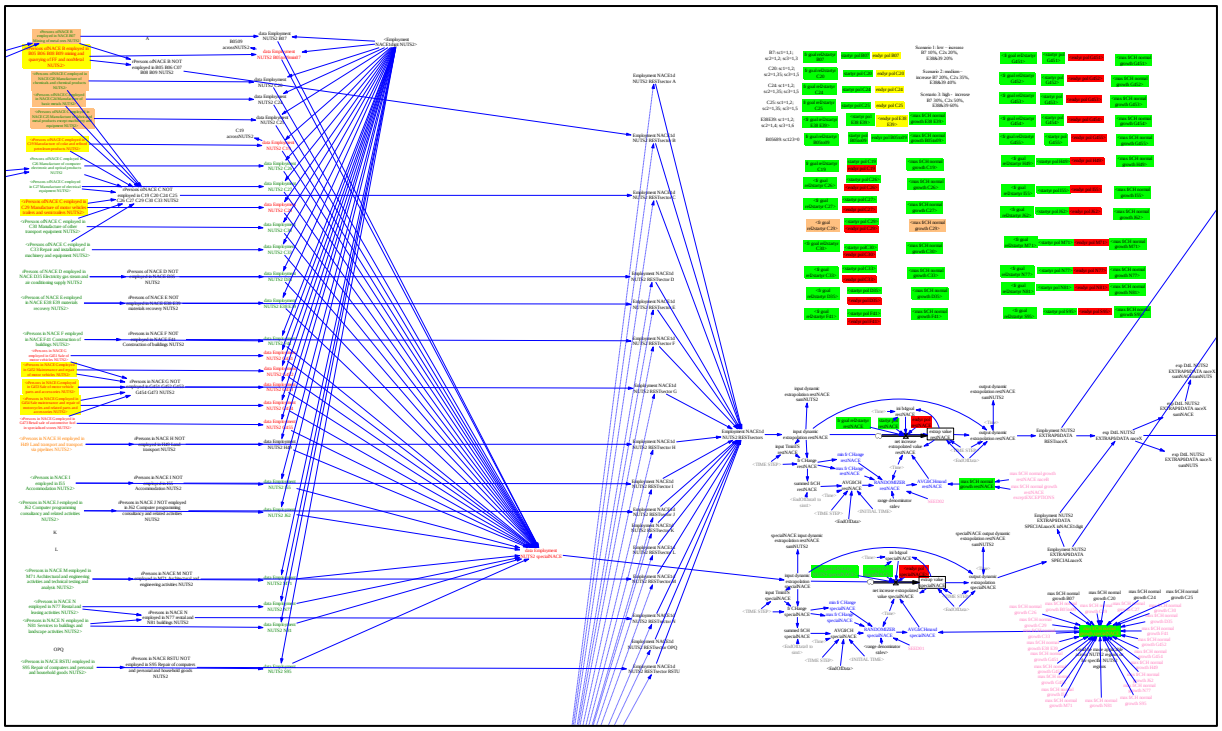

Figure 4: Module / Building Block 3

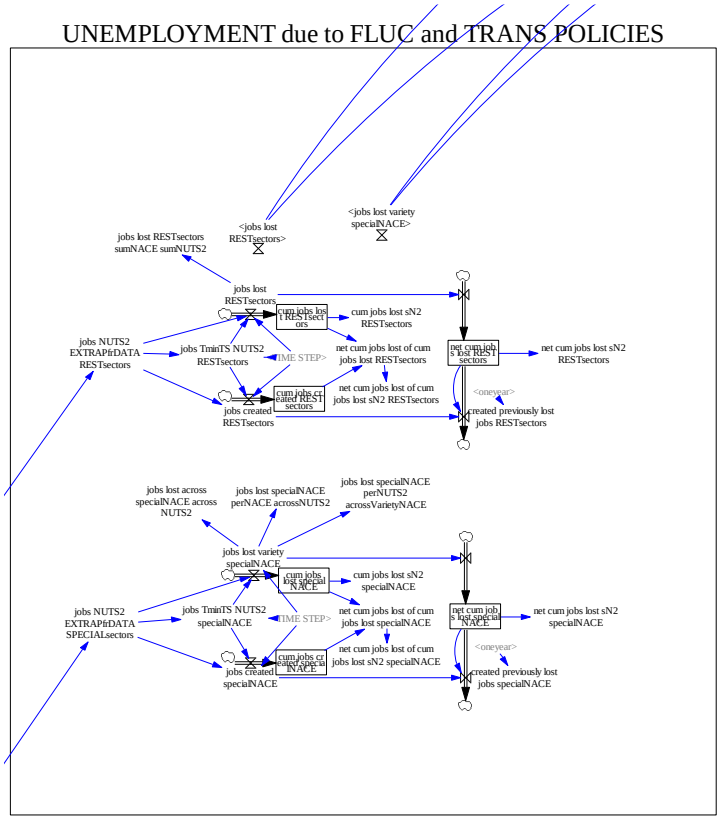

Figure 5: Module / Building Block 4

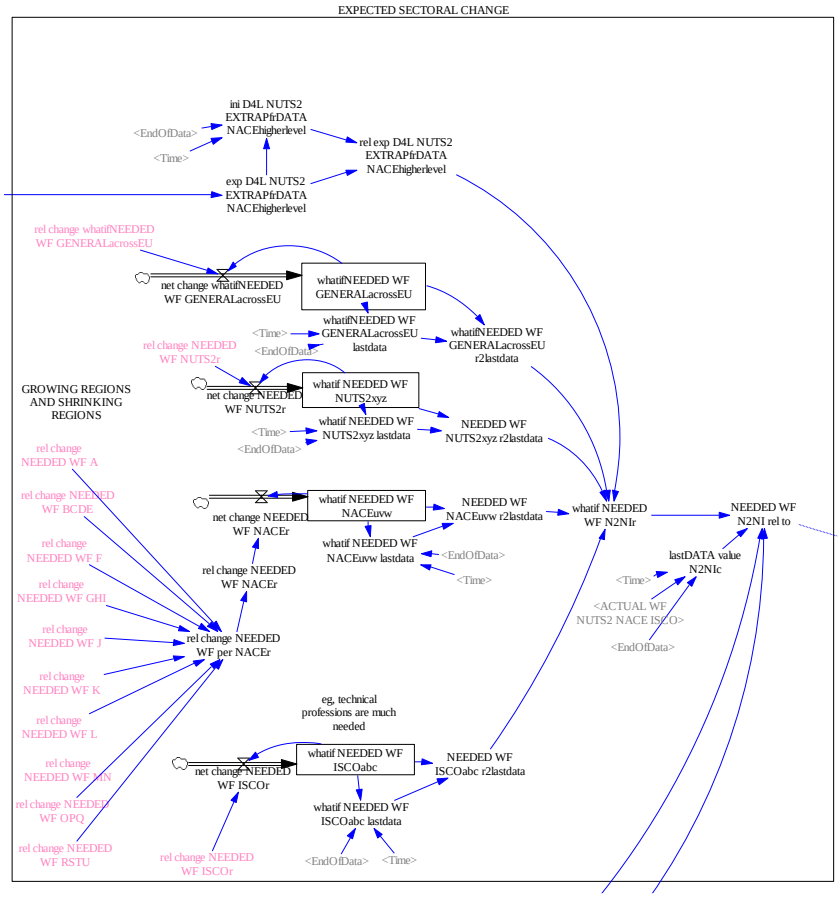

Figure 6: Module / Building Block 5

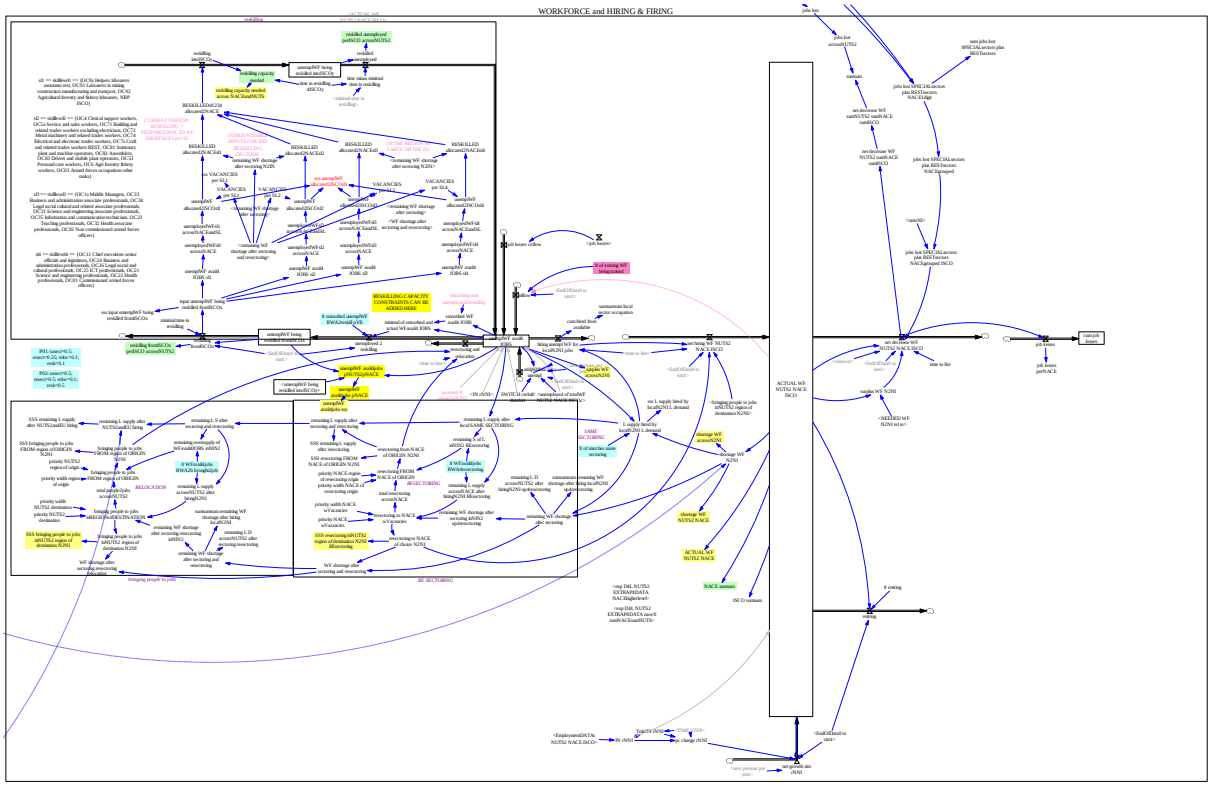

Figure 7: Module / Building Block 6

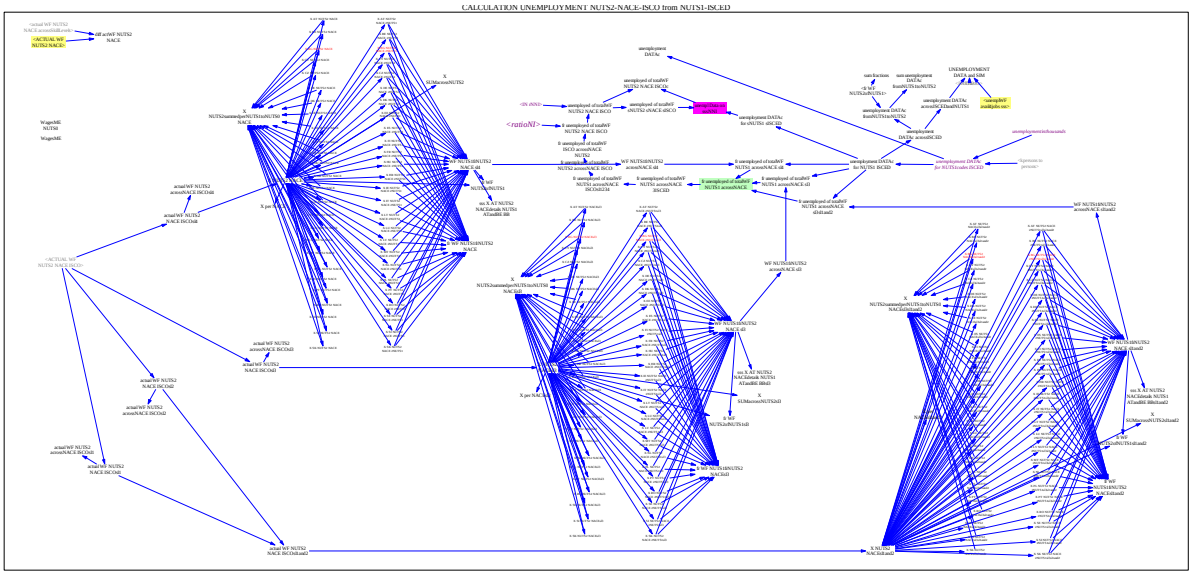

Figure 8: Building Block 7

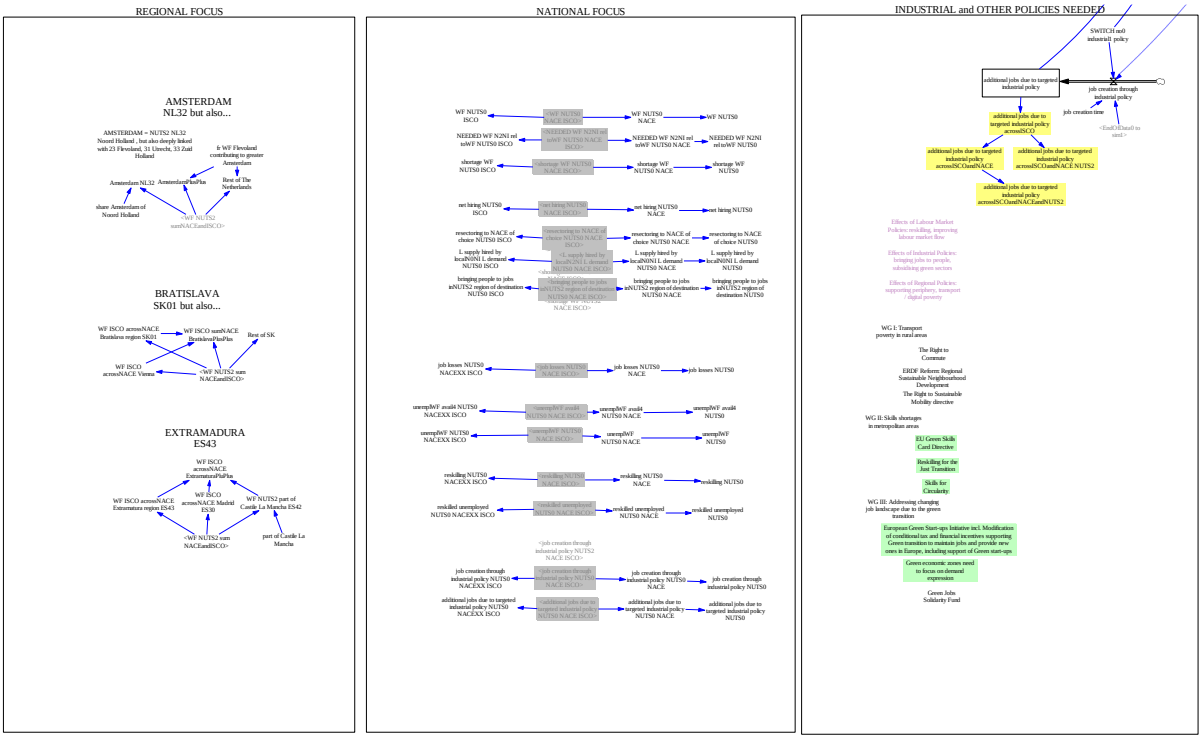

Figure 9: Building Blocks 8 9 10 (right to left)

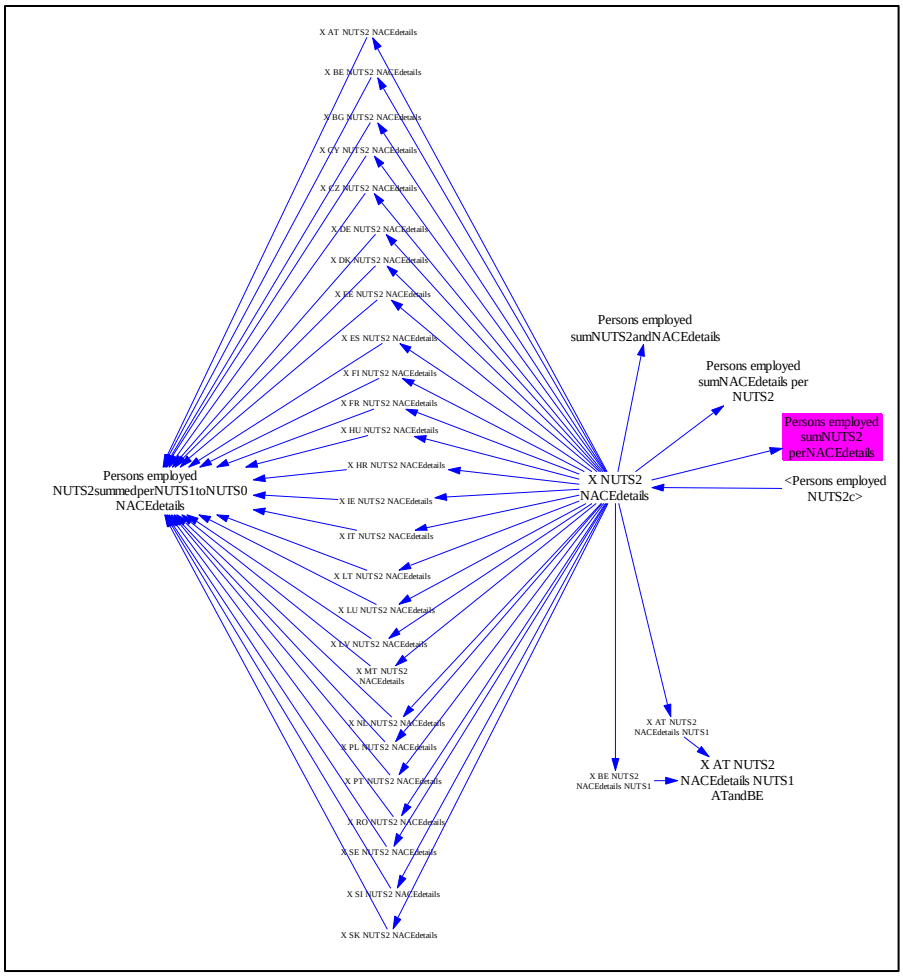

Figure 10: Module / Building Block 11

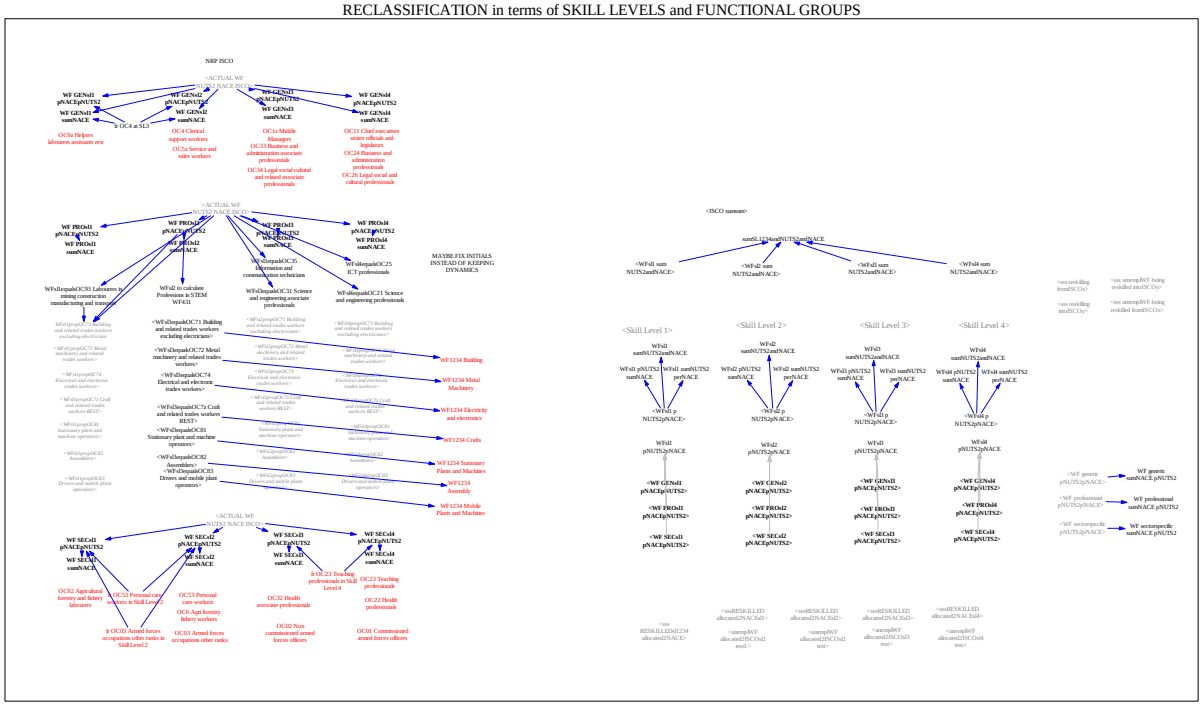

Figure 11: Module / Building Block 12

NUTS2 DATA VARIABLES for DETAILED ASSESSMENTS

Persons employed in NACE A NUTS2

Persons employed in NACE B Mining and quarrying NUTS2

Persons employed in NACE B05 Mining of coal and lignite NUTS2

Persons employed in NACE B06 Extraction of crude petroleum and natural gas NUTS2

Persons employed in NACE B07 Mining of metal ores NUTS2

Persons employed in NACE B08 Other mining and quarrying NUTS2

Persons employed in NACE B09 Mining support service activities NUTS2

Persons employed in NACE C Manufacturing NUTS2

Persons employed in NACE C19 Manufacture of coke and refined petroleum products NUTS2

Persons employed in NACE C20 Manufacture of chemicals and chemical products NUTS2

Persons employed in NACE C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations NUTS2

Persons employed in NACE C22 Manufacture of rubber and plastic products NUTS2

Persons employed in NACE C23 Manufacture of other non metallic mineral products NUTS2

Persons employed in NACE C24 Manufacture of basic metals NUTS2

Persons employed in NACE C25 Manufacture of fabricated metal products except machinery and equipment NUTS2

Persons employed in NACE C26 Manufacture of computer electronic and optical products NUTS2

Persons employed in NACE C27 Manufacture of electrical equipment NUTS2

Persons employed in NACE C28 Manufacture of machinery and equipment nec NUTS2

Persons employed in NACE C29 Manufacture of motor vehicles trailers and semi trailers NUTS2

Persons employed in NACE C30 Manufacture of other transport equipment NUTS2

Persons employed in NACE C33 Repair and installation of machinery and equipment NUTS2

Persons employed in NACE D Electricity gas steam and air conditioning supply NUTS2 ==

Persons employed in NACE D35 Electricity gas steam and air conditioning supply NUTS2

Persons employed in NACE E Water supply and sewerage waste management and remediation activities NUTS2

Persons employed in NACE E36 Water collection treatment and supply NUTS2

Persons employed in NACE E37 Sewerage NUTS2

Persons employed in NACE E38 Waste collection treatment and disposal activities and materials recovery NUTS2

Persons employed in NACE E39 Remediation activities and other waste management services NUTS2

Persons employed in NACE F Construction NACE NUTS2

Persons employed in NACE F41 Construction of buildings NUTS2

Persons employed in NACE F42 Civil engineering NUTS2

Persons employed in NACE F43 Specialised construction activities NUTS2

Persons employed in NACE Fxx OTHER construction activities NUTS2 <<~REST>>

Persons employed in NACE G Wholesale and retail trade and repair of motor vehicles and motorcycles NUTS2

Persons employed in NACE G45 Wholesale and retail trade and repair of motor vehicles and motorcycles NUTS2

Persons employed in NACE G451 Sale of motor vehicles NUTS2

Persons employed in NACE G452 Maintenance and repair of motor vehicles NUTS2

Persons employed in NACE G453 Sale of motor vehicle parts and accessories NUTS2

Persons employed in NACE G454 Sale maintenance and repair of motorcycles and related parts and accessories NUTS2

Persons employed in NACE G45x OTHER <<~REST>>

Persons employed in NACE G47 Retail trade except of motor vehicles and motorcycles NUTS2

Persons employed in NACE G473 Retail sale of automotive fuel in specialised stores NUTS2

Persons employed in NACE H Transportation and storage NUTS2

Persons employed in NACE H49 Land transport and transport via pipelines NUTS2

Persons employed in NACE H50 Water transport NUTS2

Persons employed in NACE H51 Air transport NUTS2

Persons employed in NACE H52 Warehousing and support activities for transportation NUTS2

Persons employed in NACE H53 Postal and courier activities NUTS2

Persons employed in NACE I Accommodation and food service activities NUTS2 ==

Persons employed in NACE I55 Accommodation NUTS2

Persons employed in NACE I56 Food and beverage service activities NUTS2

Persons employed in NACE J Information and communication NUTS2

Persons employed in NACE J62 Computer programming consultancy and related activities NUTS2

Persons employed in NACE J63 Information service activities NUTS2

Persons employed in NACE K NUTS2

Persons employed in NACE L Real estate activities NUTS2

Persons employed in NACE M Professional scientific and technical activities NUTS2

Persons employed in NACE M71 Architectural and engineering activities and technical testing and analysis NUTS2

Persons employed in NACE M72 Scientific research and development NUTS2

Persons employed in NACE M74 Other professional scientific and technical activities NUTS2

Persons employed in NACE Mx Professional scientific and technical activities NUTS2 REST

Persons employed in NACE N Administrative and support service activities NUTS2

Persons employed in NACE N77 Rental and leasing activities NUTS2

Persons employed in NACE N78 Employment activities NUTS2

Persons employed in NACE N81 Services to buildings and landscape activities NUTS2

Persons employed in NACE N82 Office administrative office support and other business support activities NUTS2

Persons employed in NACE OPQ NUTS2

Persons employed in NACE RSTU NUTS2

Persons employed in NACE S95 Repair of computers and personal and household goods NUTS2

SIMULATION SETTINGS

UNCERTAINTIES

Evolutions of sectors in NUTS2 regions

SEED01 = 1234 -> Random Normal Function for *specialNACE*

SEED02 = 1234 -> Random Normal Function for *restNACE*

max frCH normal growth restNACE naceB

max frCH normal growth restNACE exceptEXCEPTIONS

POLICY LEVERS

P00 – No specific policy settings:

fr of matches same sectoring	0,5
fr WFavail4jobs RWA4resectoring	0,25
fr WFavail4jobs RWA2b brought2job	0,1
fr smoothed unemplWF RWA2reskill pYR	0,05

LOCAL SAME SECTORING and RESECTORING P01

fr of matches same sectoring	1
fr WFavail4jobs RWA4resectoring	1
fr WFavail4jobs RWA2b brought2job	0,1
fr smoothed unemplWF RWA2reskill pYR	0,1

BRINGING PEOPLE TO JOBS P02

fr of matches same sectoring	0,5
fr WFavail4jobs RWA4resectoring	0,25
fr WFavail4jobs RWA2b brought2job	1
fr smoothed unemplWF RWA2reskill pYR	0

RESKILLING P03

fr of matches same sectoring 0,5

fr WFavail4jobs RWA4resectoring 0,25

fr WFavail4jobs RWA2b brought2job 0

fr smoothed unemplWF RWA2reskill pYR 0,25

COMBINING NACE AND ISCO

The sum of all jobs across each NACE category sums to 1:

NACE category "A Agri Forestry Fishing"	fraction ISCO
ratioNI[A Agri Forestry Fishing, NRP ISCO]=0.0004692359475542645	0,000469236
ratioNI[A Agri Forestry Fishing, OC01 Commissioned armed forces officers]=5.608528944736889e-06	5,61E-06
ratioNI[A Agri Forestry Fishing, OC02 Non Commissioned armed forces officers]=0.0	0
ratioNI[A Agri Forestry Fishing, OC03 Armed forces occupations other ranks]=0.0	0
ratioNI[A Agri Forestry Fishing, OC11 Chief executives senior officials and legislators]=0.003542782641325515	0,003542783
ratioNI[A Agri Forestry Fishing, OC1z Middle Managers]=0.023745193420290408	0,023745193
ratioNI[A Agri Forestry Fishing, OC21 Science and engineering professionals]=0.013006474619961579	0,013006475
ratioNI[A Agri Forestry Fishing, OC22 Health professionals]=0.000667112826645413	0,000667113
ratioNI[A Agri Forestry Fishing, OC23 Teaching professionals]=0.000466113151012189	0,000466113
ratioNI[A Agri Forestry Fishing, OC24 Business and administration professionals]=0.003623459430015536	0,003623459
ratioNI[A Agri Forestry Fishing, OC25 ICT professionals]=0.0004991345450172503	0,000499135
ratioNI[A Agri Forestry Fishing, OC26 Legal social and cultural professionals]=0.001295206986933842	0,001295207
ratioNI[A Agri Forestry Fishing, OC31 Science and engineering associate professionals]=0.02437939071509422	0,024379391
ratioNI[A Agri Forestry Fishing, OC32 Health associate professionals]=0.0013480009140696852	0,001348001
ratioNI[A Agri Forestry Fishing, OC33 Business and administration associate professionals]=0.01176214352927637	0,011762144
ratioNI[A Agri Forestry Fishing, OC34 Legal social cultural and related associate professionals]=0.002305333577191685	0,002305334
ratioNI[A Agri Forestry Fishing, OC35 Information and communication technicians]=0.0003038575140019869	0,000303858
ratioNI[A Agri Forestry Fishing, OC4 Clerical support workers]=0.022195714381918114	0,022195714
ratioNI[A Agri Forestry Fishing, OC53 Personal care workers]=0.0004329706174858357	0,000432971
ratioNI[A Agri Forestry Fishing, OC5z Service and sales workers]=0.021067472692935834	0,021067473
ratioNI[A Agri Forestry Fishing, OC6 Agri forestry fishery workers]=0.6102915499379178	0,61029155
ratioNI[A Agri Forestry Fishing, OC71 Building and related trades workers excluding electricians]=0.004173000375543169	0,004173
ratioNI[A Agri Forestry Fishing, OC72 Metal machinery and related trades workers]=0.01319653151427067	0,013196532
ratioNI[A Agri Forestry Fishing, OC74 Electrical and electronic trades workers]=0.0013053740497262262	0,001305374
ratioNI[A Agri Forestry Fishing, OC7z Craft and related trades workers REST]=0.00637165436742995	0,006371654
ratioNI[A Agri Forestry Fishing, OC81 Stationary plant and machine operators]=0.004953812229529608	0,004953812
ratioNI[A Agri Forestry Fishing, OC82 Assemblers]=0.0001965735185630716	0,000196587
ratioNI[A Agri Forestry Fishing, OC83 Drivers and mobile plant operators]=0.05861924538098679	0,058619245
ratioNI[A Agri Forestry Fishing, OC92 Agricultural forestry and fishery labourers]=0.1571918476992244	0,157191848
ratioNI[A Agri Forestry Fishing, OC93 Labourers in mining construction manufacturing and transport]=0.0076064100065719505	0,00760641
ratioNI[A Agri Forestry Fishing, OC9z Helpers labourers assistants REST]=0.004978781047268462	0,004978781
SUM	1

Operator & Developer Guide - SEER Work Force Model v03

by dr. Erik Pruyt, Center for Policy Exploration, Analysis and Simulation (PEAS Center)

WHAT, WHY, HOW

- WHAT?
  - This is a minimalistic "Operator and Developer Guide", written for those who want to use the SEER WORKFORCE Model as well as for those who want to further develop it.
- WHY?
  - The SEER Work Force Model was developed for the SEER project and could be used in continuations of the SEER project, but it could also be used for other projects that require an EU workforce module.
- HOW?
  - This guide is as minimalistic as possible. It is not a full modelling and simulation manual. To the contrary, only aspects that cannot be found elsewhere are explained.
  - The model was developed with Vensim DSS 8.2.1 double precision x64. Further development of the model requires Vensim DSS since many subscripts (vectors) and complex subscript ranges (to build the multi-scale hierarchies) are used.
  - For other/additional/general information regarding modelling and simulation beyond the information provided here, readers/users/developers are referred to Vensim Help (in the program itself and available online), more specifically to:
    - the Vensim "User Guide" (called "Introduction and Tutorial") for a brief overview of Vensim and step-by-step examples of small Vensim models, as well as the "Modeling Guide" for some Methodology and more examples,
      - the "Reference Guide" for a detailed description of the Vensim language and the modelling development environment, as well as the "DSS Supplement" for Software Developers which deals with advanced topics for software developers using Vensim,
      - free online *Small Models for Big Issues* e-book (Pruyt, 2013) to learn basic System Dynamics modelling. Multi-scale data-rich System Dynamics modelling is not explained in Pruyt (2013) which is why somewhat more details are discussed here.

MODEL, MODEL FORMATS, MODEL VERSIONS, OPEN MODEL

- The ***WORKFORCE_v03_PEAS4SEER*** model is a multi-scale data-rich System Dynamics model.
  - For a System Dynamics model, it is relatively poor in terms of its feedback loops. If the SEER project continues, or the model is further developed for other purposes, additional feedback loops need to be added, including the loop connecting NACE sectors and Work Force in these sectors (which is included in this model), but also the loops that connect needs and desires by the population, assets that satisfy these needs and desires, household spending power, and consumption and investments in assets.
  - The model is multi-scale for the EU (the EU countries scale and two regional scales within these countries are included), but it does not include the Rest of the World (yet).
  - The model is data-rich, but it could and should become even richer in terms of data. The current version uses rich data about existing ISCO jobs in NACE (sub)sectors in

NUTS2 regions and EU countries, as well as rich data about unemployed persons given their ISCED educational level in NUTS1 regions. Salaries data is available too but has not been used in the model yet. Data on schooling and retirements should be added.

- The four scales hierarchically connected in the model are: the EU scale, the EU country scale (NUTS0), the NUTS1 regional scale, and the NUTS2 regional scale. The model loads and uses large data sets and calculates multi-dimensional variables. Three dimensions are combined in many of the model variables: NUTS2 regions (229), NACE sectors (either 11 or 16 sectors, or 63 subsectors), and ISCO job types (31). For variables that combine these three dimensions, either 78089, or 113584, or even 447237 different combinations are calculated. The model is a System Dynamics model: it consists of stock-flow structures and contains feedback loops. It was built and can be simulated with Vensim DSS and READER.

- The model exists in two different formats:
  - The ***WORKFORCE_v03_PEAS4SEER.mdl*** model in mdl format is a fully open access version that is available only to the PEAS Center and to Systemiq. Since it is highly multi-dimensional, for which subscripts are used, it only works with Vensim DSS and (probably with) Vensim PRO. Vensim DSS is recommended – even needed for simulating the model under deep uncertainty with python code, for instance with the EASLE or EMA Workbench. Please do not share the mdl version without prior consent.
  - The ***WORKFORCE_v03_PEAS4SEER.vmf*** model in vmf format is available to all possible users. It is essentially the same file, but it is saved as a binary format model (*.vmf*) that can be read by the free Vensim Model Reader. It can be used, but it cannot be changed.
- This is the ***third version*** of this model:
  - The first version of the WORKFORCE model was a simple data-rich model developed for the SEER workshop in Brussels on 1 December 2022.
  - The second version of the WORKFORCE model was a more refined version developed for the board meeting on 12 January 2023, and used for meetings in January 2023. In the second version, a simplified constant unemployment rate was assumed to apply to all jobs in all sectors in all NUTS2 regions.
  - The third version of the WORKFORCE model – the one discussed here – is an extension of the second version. The third version of the model is extended with calculations to approximate unemployment across regions, sectors, and jobs starting from data on unemployed persons and their ISCED educational level on the NUTS1 scale. Moreover, the third version was extended – for demonstration purposes – with some NACE subsectors that might be impacted positively by the Critical Raw Materials directive.
  - Many other model structures have been developed for the SEER project. They have not been integrated in the model (yet). They are documented in a separate document.
- Figure 1 provides an overview of the third version of the Workforce model. It consists of 12 modules or building blocks described in more detail in the Model Documentation. In short: The SEER WORKFORCE Model (version 03) consists of data building blocks BB01 and BB02, a data pattern generation-NACE effects building block BB03 which extrapolates data patterns and adds specific NACE-sector effects, a what-if scenario building block BB05 which enables adding scenario for Europe/regions/sectors/jobs, a workforce and workforce policies building block BB06 (which is the core model) which contains four workforce policies (same sectoring and re-sectoring, relocation and reskilling ('bringing people to jobs')), an unemployment data building block BB07, an industrial policy building block BB08 ('bringing jobs to people'), a national KPIs building block BB09 and a local KPIs building block BB10, and, finally, two potentially useful building blocks that are not used in the current version of the model.

- The model is an ***open model***, to uncover and explore instead of covering up. That is, it is not protected against wrong use or uninformed use. The model is still under development and can be further developed for multiple purposes. This is why only few protective functions have been used. Protective functions used include: MAX(0,X) functions to keep values above a floor (0), MIN(1,Y) functions to keep values below a ceiling (1), ZIDZ(V,W) functions to protect against division by zero, and IF THEN ELSE(data var XYZ = :NA:, 0, data var XYZ) functions to fill data gaps with values equal to zero. Moreover, for exploratory modelling (i.e., one of the intended uses), the model should remain as open as possible. There is a fine line between protective modelling such that a model can be used by anyone and exploratory modelling such that the model can be used to explore new horizons (but also impossible ones). The judgement of an experienced exploratory System Dynamics modeller is therefore still needed for use of the current model. Finally, some switches have been added to activate alternative structures or assumptions and activate policies, but the model has not been set up such that all policies can be automatically without manual intervention. See the section on "how to operate the model".
- Many abbreviations are used in the model – too many to cover all of them here. For instance, *WF* refers to *Work Force*, *yr* refers to *year*, pYR to per Year, *fr* to *fraction*, and *rel to* or *r* or *r2* stands for *relative to*. Abbreviations should be clear to modellers when looked at in combination with the equations and functions in the variables.

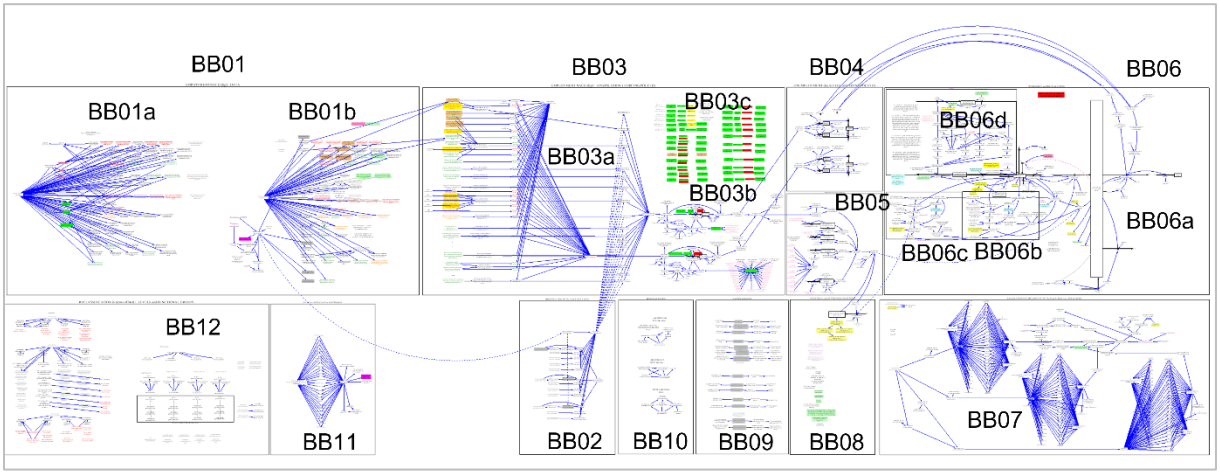

Figure 1: The SEER WORKFORCE Model (v03), with data building blocks BB01 and BB02, the data pattern generation-NACE effects building block BB03, the what-if scenario building block BB05, the core workforce and workforce policies building block BB06, the industrial policy building block BB08, national KPIs building block BB09 and local KPIs building block BB10

HOW TO OPERATE THE MODEL

- The simulation settings of the mdl version of the model can be changed in **Model > Settings…**
  - Initial time, Final time, Data time
    - The model has been set up for simulation on an annual basis. Any other time scale (e.g., months or quarters) needs to be transformed to years.
    - The INITIAL TIME of the model is the year 2008. This is also the first year of data (for NACE rev. 2). Although later start years could be chosen, the results will be worse since behaviour patterns are derived from the data series.
    - The end of the data series is (for most data) the year 2021. A parameter in the model, ***EndOfData***, captures the year after which model behaviour is

simulated instead of based on the data. If data beyond 2021 is added, then this parameter needs to be adjusted.
        - The FINAL TIME of the model is any time beyond the year 2008, for instance the year 2040, and preferably beyond the value of the ***EndOfData*** parameter.
        - After adding another data point for all data variables in 2023, the 2008-2021 data period can be extended from 2008-2021 to 2008-2022 by changing the value of the EndOfData parameter to 2022.
    - Time step and Integration type:
        - The Time Step of the model is 0.25 year (or smaller). Note: that does not mean the model simulations can be interpreted as 4 quarters per year. The smaller time step of the model is needed to simulate the annual behaviour. Seasonality and other temporal effects within a year have not been added.
        - The integration type used is Euler, both for speed of simulation and for dealing with discrete data functions used in the model. New applications required testing of the time step integration type combination, by halving the time step and checking the convergence of the model behaviour, until the behaviour is similar enough with the previous time step.
    - Saving list:
        - Currently, no *saving list* (see Vensim manuals) is defined and used. Consequently, all variables are saved at every time step. This results in simulation run files of about 3GB. Save lists can be used to only save variables and/or KPIs of interest.
        - Another trick to reduce the output file size is to save data once a year instead of four times per year.
- Simulation:
    - To simulate the model, press the “Sim setup” button -> Change the simulation run name in the “Simulation results file name” -> Change scenario/policy/simulation-specific parameters/lookups that light up in blue (or other colour for coloured constants) when pressing the “Sim setup” button to -> press the “Simulate” button.
    - Before pressing the simulation button, one needs to select the right settings, including the right settings for switches, the right parameter values for policy effects,
    - Switches and settings
        - “SWITCH EmploymentData0 or PersonsEmployed1” determines which data source is used for Work Force data during the data period (until 2021) for “Employment NACE BCDE”, “Employment NACE GHI”, and “Employment NACE MN”, and through these, workforce data for sectors B, C, D, E, G, H, I, M and N. The standard value equals 1, which means the “Persons Employed” data set is used. The alternative value 0 means that the Employment data is used. There are differences between the data sets due to incompleteness. See for example Figure 2 for the effects for all NUTS2 regions in the Netherlands.
        - “SWITCH cteIni0 dataIni1” relates to the use of unemployment data. This switch enables one to use model version 2 (when the SWITCH is set to 0) in which unemployment was assumed to be 6.5% of the Work Force for every job in any sector and for all NUTS2 regions. If the SWITCH is set to 1, proxy data derived in BB07 from [NUTS1, ISCED] data is used instead. The standard setting of this SWITCH == 1.

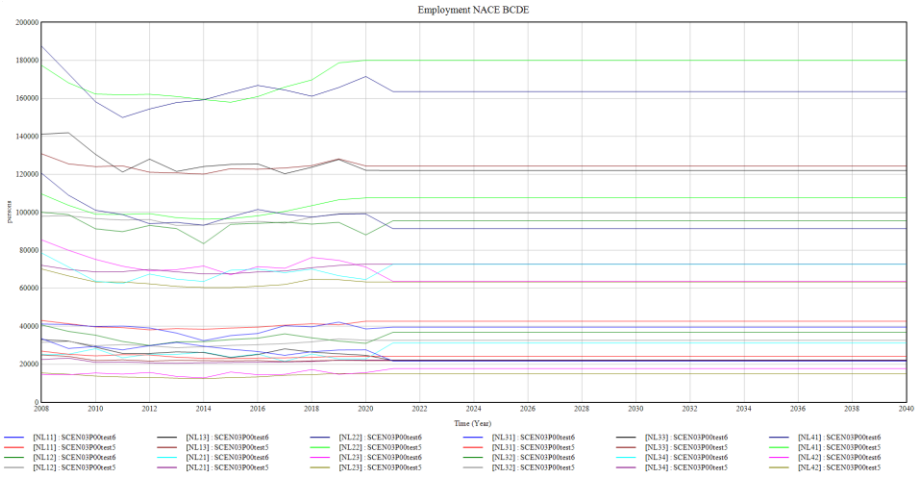

Figure 2: differences in employment data for NACE sectors BCDE for all Dutch NUTS2 regions due to different data settings ("SWITCH EmploymentData0 or PersonsEmployed1") parameter

- "SWITCH no0 industrial1 policy" – if set to 1 – enables one to use the model to identify (expected) unemployed workforce [NUTS2, NACE, ISCO] for industrial policy instead of workforce policies (same sectoring, re-sectoring, relocation of labour, reskilling).

- Effects of regional-sectoral [NUTS2, NACE] dynamics in BB03 on Demand for Labour (D4L) and via D4L on needed workforce (BB05 & BB06), and on jobs lost (BB04 & BB06):
  - Policy effects on employment in specific NACE subsectors can be set in BB03:
    - Subsectors currently available in the data set include NACE (sub)sectors B, B05, B06, B07, B08, B09, C, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C33, D, D35, E, E36, E37, E38, E39, F, F41, F42, F43, G, G45, G451, G452, G453, G454, G455, G47, G473, H, H49, H50, H51, H52, H53, I, I55, I56, J, J62, J63, L, M, M71, M72, M74, N, N77, N78, N81, N82, S95.
    - Not all subsectors in the data set are currently included in the selection of NACE subsectors for which policy effects can be specified (that differ from the rest of the NACE1d category they belong to). Only the subscripts contained in the subscript range ***NACEspecials4joblosses*** are dealt with separately. Currently, the NACEspecials4joblosses subscript range includes subsectors B05, C19, C26, C27, C29, C30, C33, D35, E38, F41, G451, G452, G453, G454, G455, H49, I55, J62, M71, N81, S95, B07, C20, C24, C25.
    - If no policy effects (for a particular subsector in subscript range ***NACEspecials4joblosses***) need to be simulated, then either make sure that the start date "startyr pol Cxx" is larger than the simulation FINAL TIME or that the "endyr pol Cxx" is smaller than the policy start date "startyr pol Cxx" or even the simulation INITIAL TIME (for instance, 0). It is not enough to set the effect – "fr goal rel2startyr Cxx" – to 1: setting the effect to 1 basically means that the behaviour will be forced back to its value at the end of the data series / start of the simulation.
    - The NACE policy/scenario effects are relative to the value at the start year of the forcing period (e.g., "startyr pol F41"). A value of the "goal

value" (e.g., "fr goal rel2startyr F41") equal to 1.2 (i.e., 120%) causes the workforce needed in subsector F41 at the end of the forcing period (e.g., "endyr pol F41") to be 120% of its value at the start of the forcing period (i.e., at "startyr pol F41"). Entirely closing a sector in 10 years, thus requires a value 0 (e.g., "fr goal rel2startyr B05to09"= 0) and an "endyr pol" that is 10 years later than the corresponding "startyr pol".

- So far, not all potentially interesting subsectors have been added to the ***NACEspecials4joblosses*** subscript range and corresponding structures in BB03. The reason is that, once added there, their settings need to be handled separately. Other subsectors can be added by:
    - adding the corresponding *NACE subsector code* to the ***NACEspecials4joblosses*** subscript range (to do that, open any variable in the Equation editor, subsequently *Search Model* for ***NACEspecials4joblosses***, and add the *NACE subsector code* to the ***NACEspecials4joblosses*** subscript range list),
    - connecting the corresponding data variable from building block BB01 (e.g., '*data Employment NUTS2* *NACE subsector code*') to the *data Employment NUTS2 specialNACE* variable by adding two variables ("rPersons ofNACE C employed in NACE *NACE subsector* NUTS2" and "data Employment NUTS2 *NACE subsector*") and adding the latter to the '*data Employment NUTS2* *NACE subsector code*' variable by adding another subscript function,
    - excluding it from the corresponding NACE1d REST variable ('*Employment NACE1d NUTS2 RESTsector* *NACE1d code*') by subtracting it from the "rPersons of NACE XX NOT employed in XXij NUTS2" variable or, if this variable does not exist yet, by creating a variable that keeps track of the subsectors not dealt with separately and linking the latter to the corresponding "Employment NACE1d NUTS2 RESTsector *NACE 1-digit*" variable,
    - adding a corresponding "max frCH normal growth *subsector*" parameter and value to the "max frCH normal growth specialNACE" variable (see below).

- The dynamic patterns generated outside of the NACE policy effect forcing period can be influenced in two ways:
    - The Random Normal function and its two parameters ("range denominator stdev" (equal to 4) and "SEED01" and "SEED02" could be changed, for instance, by changing the Random Normal into Random Uniform functions, or by changing the value of the SEED (to call another pseudo random series).
    - Large growth rates lead in dynamic models like the current model to excessive exponential growth. During the 2008-2021 data period, the growth of some sectors in some regions was large, either due to real growth or due to administrative changes. The "max frCH normal growth *subsector code*" parameters limit the annual growth rate generated with the random function based on the data.

- In BB05, **what-if scenarios** can be imposed on top of the dynamic patterns and NACE policy effects, more precisely what-if effects:
  - For all jobs, sectors, and regions **across Europe** (e.g., to simulate economic effects across the whole of Europe), by changing the "rel change whatifNEEDED WF GENERALacrossEU" parameter. The way it has been implemented in the current version (i.e., as a percentage change to a stock variable that keeps track of the relative change compared to the end of the data period) implies that a parameter value of 0.1 results in 10% continuous exponential growth, and -0.1 results in a 10% continuous annual decline. This constant rate of change could easily be changed into cyclic or variable rates of change.
  - Across all jobs and sectors but for **specific NUTS2 regions** (e.g., to simulate growth in some (types of) regions and decline in other (types of) regions), by changing the "rel change NEEDED WF NUTS2r" parameter for [NUTS2] subscript elements. The way it has been implemented in the current version (i.e., as a percentage change to a stock variable that keeps track of the relative change compared to the end of the data period) implies that a parameter value of 0.1 results in 10% continuous exponential growth, and -0.1 results in a 10% continuous annual decline. The constant rate of change implementation could easily be changed into cyclic or variable rates of change.
  - Across all jobs and NUTS2 regions but for **specific sectors** (e.g., to simulate growth in some sectors and decline in other sectors), by changing the "rel change NEEDED WF A", "rel change NEEDED WF BCDE", *et cetera* parameters. The way it has been implemented in the current version (i.e., as a percentage change to a stock variable that keeps track of the relative change compared to the end of the data period) implies that a parameter value of 0.1 results in 10% continuous exponential growth, and -0.1 results in a 10% continuous annual decline. The constant rate of change implementation used in the current version of the model could easily be changed into cyclic or variable rates of change.
  - Finally, across all regions and sectors, but for **specific jobs** (e.g., to simulate growth in demand for particular types of job specializations), by changing the "rel change NEEDED WF ISCOr" parameter for [ISCO] subscript elements. The way it has been implemented in the current version (i.e., as a percentage change to a stock variable that keeps track of the relative change compared to the end of the data period) implies that a parameter value of 0.1 results in 10% continuous exponential growth, and -0.1 results in a 10% continuous annual decline. The constant rate of change implementation used in the current model version could easily be changed into cyclic or variable rates of change.
- Workforce Policies?
  - Four workforce policies or personal preferences of unemployed individuals to find a job have been implemented in this model, to some extent in a sequential way. That is, there is an order in which job seekers are looking for a job and are accepting a job. First, a fraction of the unemployed workforce might look for and accept the same type of job in the same sector in the same region (referred to here as "same-sectoring"). Second, a fraction of those who did not find a job through same-sectoring, might look for the same type of job in the same region but in another sector (referred to here as "re-sectoring"). Third,

a fraction of those who did not find a job through same sectoring and re-sectoring, might look for the same type of job in the same sector but in another region (referred to here as “relocation”). Finally, a fraction of the unemployed population might consider reskilling. Although the order between same-sectoring, re-sectoring and relocation could be changed, it requires a bit of modelling. But even without modelling, different scenarios/policies can be simulated.

- The parameter “fr of matches same sectoring” sets the fraction out of all possible matches due to same-sectoring. The parameter “fr WFavail4jobs RWA4resectoring” sets the fraction of possible matches (after same-sectoring) due to re-sectoring. The parameter “fr WFavail4jobs RWA2b brought2job” sets the fraction of possible matches (after same-sectoring and re-sectoring) due to relocation.
- The “fr smoothed unemplWF RWA2reskill pYR” sets the fraction of unemployed that leave the stock of unemployed available for the labour market because they decide to spend time on reskilling. Related to reskilling, there are some other parameters that matter: the “minimal time in reskilling” and total “time in reskilling 4ISCOy” (which always needs to be larger than the “minimal time in reskilling”), the “smoothing time unemployed2reskilling” which is used to limit reskilling to long(er) term unemployed.
- Following policies were defined to illustrate the different policies/preferences:
    - P00 (base case) may be specified by “fr of matches same sectoring” = 0.5; a “fr WFavail4jobs RWA4resectoring” = 0,25; a “fr WFavail4jobs RWA2b brought2job” = 0,1; and a “fr smoothed unemplWF RWA2reskill pYR” = 0,05.
    - P01 (improved ‘local same-sectoring and re-sectoring’) may be specified by “fr of matches same sectoring” = 1; a “fr WFavail4jobs RWA4resectoring” = 1; a “fr WFavail4jobs RWA2b brought2job” = 0,1; and a “fr smoothed unemplWF RWA2reskill pYR” = 0,1.
    - P02 (bringing people to jobs by relocation) may be specified by “fr of matches same sectoring” = 0,5; a “fr WFavail4jobs RWA4resectoring” = 0,25; a “fr WFavail4jobs RWA2b brought2job” = 1; a “fr smoothed unemplWF RWA2reskill pYR” = 0.
    - P03 (bringing people to jobs by reskilling) may be specified by a “fr of matches same sectoring” = 0,5; a “fr WFavail4jobs RWA4resectoring” = 0,25; a “fr WFavail4jobs RWA2b brought2job” = 0; a “fr smoothed unemplWF RWA2reskill pYR” = 0,25.
- Both re-sectoring and for relocation are implemented with a double ‘allocate by priority’ structure (see Vensim manuals). This implies that it is possible for the re-sectoring process to vary the priority of the NACE sector of origin that employers want to hire from (“priority NACE region of resectoring origin”) and NACE sectors of destination worksers might want to re-sector to (“priority NACE wVacancies”), and for the relocation process to vary the priority of regions of origin that employers want to hire from (“priority NUTS2 region of origin”) and regions of destination workers might want to relocate to (“priority NUTS2 destination”).

- Although almost all parameters in the model could be considered uncertain to some degree, and may therefore be included in deep uncertainty simulations, there are also

some uncertainties that are typical model uncertainties. They are in the model due to specific formulations and may influence the outcomes. They include:
    - "smoothing time unemployed2reskilling", set to 2 years, which determines how many years are averaged in the calculation of long term unemployment.
    - "priority width NACE of resectoring origin", currently set to 1, "priority width NACE wVacancies", currently set to 1, "priority width region of origin", currently set to 1, and "priority width NUTS2 destination", currently set to 1. For priority width parameters, see the Vensim manual on Allocate by Priority.
    - The priority structures in the reskilling building block could also be considered to be model uncertainties. Currently, reskilling is split out over skill levels. Within each skill level, priority is given (across all NACE sectors and per skill level) to jobs with a larger shortage. After that first proportional assignment, people are assigned to sectors, proportional to sectors with more vacancies.
  - The model also contains some simplifications that could currently be dealt with as uncertainties, but that really require data and proper model structures. They include:
    - The fraction of the workforce retiring at any point in time ("fr retiring").
    - The new workforce entering the labour market at any point in time (modelled currently by means of a "fr of existing WF being trained" multiplied by the actual workforce).
- Visualisation, exploration, Analysis:
  - In the Control Panel, one or more previously simulated runs can be selected for visualization/analysis, time axes can be set, etc.
  - In the Subscript Panel, one can select the subscript elements of interest that will be shown in graphs and tables for the variables that will be investigated.
  - The Graph button can be used to visualize simulation runs selected in the control panel for the subscripts selected in the subscript panel. Curves can be deselected in the graphs. Tables can be shown for selected variables by pressing the Table button.
  - Particularly useful for preliminary exploration are the data variables in Module BB01 (both on the country BUTS0 scale and on the regional NUTS2 scale).

DATA AND HOW TO UPDATE THE DATA

Data is currently loaded into the model by means of following data variables:

- EmploymentDATA:
  - Subscripts: [NUTS2,NACE]
  - Loaded via file: nace_nuts_rimer.vdfx
  - Source: EUROSTAT database lfst_r_lfe2en2
  - Contents: Employment by sex, age, economic activity, and NUTS2 regions (NACE Rev. 2) in 1000 persons
  - https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfe2en2/default/table?lang=en
- Persons employed
  - Subscripts: [NUTS2, NACEdetails]
  - Source: EUROSTAT database sbs_r_nuts06_r2
  - Contents: SBS data by NUTS 2 regions and NACE Rev. 2 (from 2008 onwards)
  - https://ec.europa.eu/eurostat/databrowser/view/sbs_r_nuts06_r2/default/table?lang=en
- unemploymentinthousands
  - Subscripts: [NUTS1codes, ISCED]

    - Loaded via file: unemployment.vdfx
    - Source: lfst_r_lfu3pers
    - Contents: Unemployment by sex, age, educational attainment level and NUTS2 regions (in 1000 persons)
    - https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfu3pers/default/table?lang=en
- ratioNI:
    - Subscripts: [NACE, ISCO]
    - Loaded via the cin file ratio_nace_isco.cin
    - The rationNI is the data from the EUROSTAT data request by Systemiq.

Three data sets are loaded with vdfx files (used for time series data), and one data set is loaded with a cin file (used for **C**onstant **In**itials).

- Working with vdfx files:
    - Updating and cleaning data
        - See Jupyter Notebook files. The result is a *.dat file.
    - Requirement for "dat files":
        - Same names as variable names and same subscript names and dimensions
        - Add a control variable that fills data gaps (in Vensim, missing data can be tested for by means of ":NA:" which takes an incredibly small number) and corrects for units, for example:
            - EmploymentDATA NUTS2 NACE = IF THEN ELSE(EmploymentDATA[NUTS2,NACE] = :NA:, 0, EmploymentDATA[NUTS2,NACE] * kpersons to persons)
    - How to turn *.dat files into *.vdf/vdfx files:
        - Import the *.dat file as follows in Vensim: Model > Import dataset… which should result in a message "Imported without errors" and a vdf or vdfx file.
        - Press the "Simulation Control" button, open de "Advanced" tab, change the comma-separated data sources (add new ones, delete old ones), click on Set.
        - In case newer data is added, say the year 2022 is added, then the "End of data0" parameter needs to be changed to "2022". Data will then drive the model until 2022, and from 2023 on, the model will be simulated.
- Working with *.cin files:
    - Updating, cleaning, creating cin files
        - See Jupyter Notebook files
    - Including cin files in simulation models
        - Include a model variable with the right subscripts and with the same name as the Constant Initial in the cin file, and give it some value, any (see "ratioNI").
        - Load the cin file in **Simulation Control > Load Changes from…**

SHORT TERM MODEL IMPROVEMENTS and LONGER TERM EXTENSIONS

- The aim of the SEER project was to investigate the effects of EGD and System Change Compass (SCC) transitions on the labour market and the labour market on EGD and SCC transitions. Given that the SEER project time was halved, only half of the modelling work was done, more specifically the effects of transitions on the labour market (workforce and unemployed workforce). The workforce model really is a core model building block (BB06) with auxiliary building blocks. It is also the starting point for closing the loop between NACE production and

NACE employment as visualized in Figure 3. Many of the remaining aspects to be modelled are already modelled in a data poor fashion.

- Three aspects to address soon in the current model are:
    - Unemployment data was added in January 2023, right before the DG GROW presentation. Model structures were added after the workshop. A correction structure was added to correct an unresolved problem in that structure, more precisely in "fr unemployed of totalWF NUTS2 NACE ISCO", meant to expand the dimensionality of the data from [NUTS2, ISCO] to [NUTS2, NACE, ISCO]. One of the first steps to take, is to investigate why the original formulation without the correction factor does not work properly.
    - Salaries data is available in the DAT file. It has not been included in this version of the model yet. It could be added as a criterion for re-sectoring, relocation, reskilling.
    - The current model contains the preliminary structures to set up a model based on a more generic classification of jobs in 3 functional groups and 4 skill levels – as conceptualized in September 2022. The advantage is a better assessment of the flexibility and substitutability in the labour market.

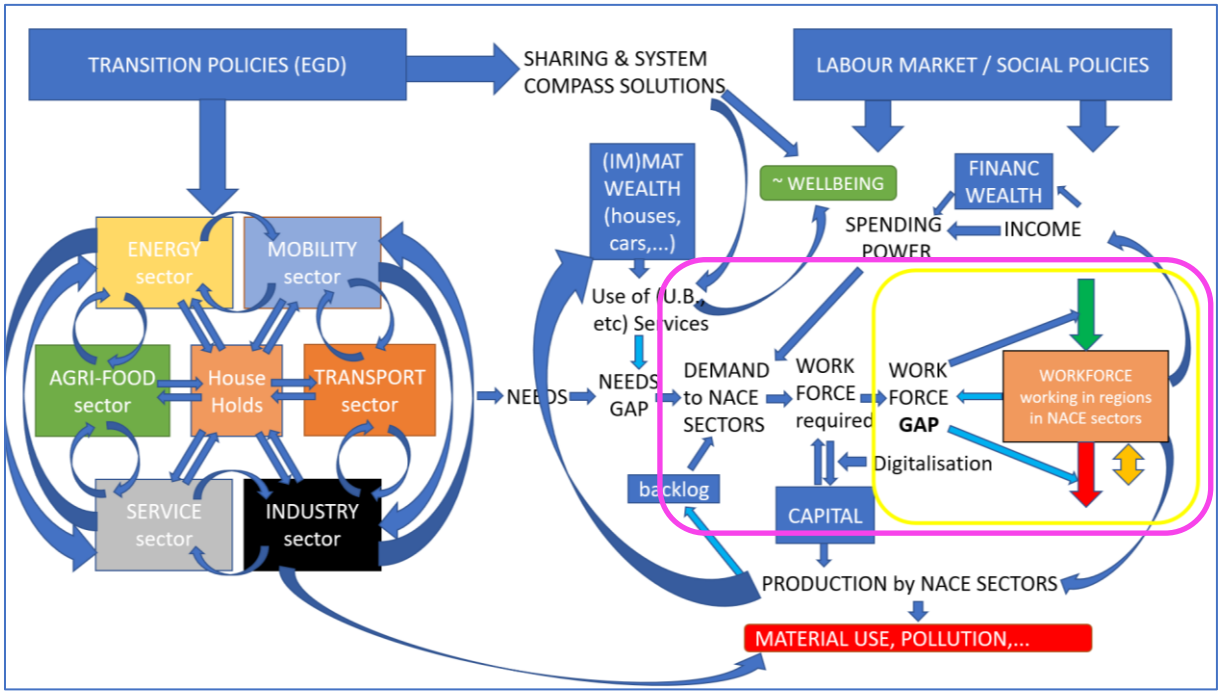

Figure 3: The core workforce building block (in yellow) in the current workforce model (in pink) in the planned final model