DELIVERABLE

D5.3 PoliRural Model (ed.3)

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Revision History

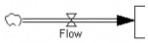
Revision	Date	Author	Organization	Description
0.1	22/01/2021	Mª Eugenia García de Garayo Patricia San Segundo Andrés Montero	TRAGSA	Several modifications and adds were introduced following TRAGSA comments.

Table of Contents

List of Tables

List of Figures

Glossary

Term	Definition
Causal Loop Diagram (CLD)	Map of a system with all its constituent components and their interactions.
dmnl	Abbreviation for dimensionless, normally applied to ratios (%…)
Flow	The rate of change in a stock and is represented by an arrow.  The cloud represents 'out of the system', meaning that is not relevant for the model where it comes from or where it goes.
Module	Part of a model containing stocks flows and variables referring to a particular subject. The division in modules is just a question of easing the understanding of the model.
Scenario	Values given to a set of variables to represent possible future behaviours.
Stock	The term for any entity that accumulate or depletes over time and is represented by a rectangle or box. 
Stock and Flow diagram	Translation of a CLD in quantitative terms using stocks, flows, variables and mathematical formulas to defines relations.
XMILE	OASIS XML Interchange Language (XMILE) for System Dynamics

Executive Summary

This Deliverable is a detailed explanation of the edition 3 of the System Dynamics Model (SDM). The introduction highlights the major improvements from previous editions, and the corrections included after the review by the Commission.

Chapter 2 explains the model, starting with the main feedback loops, then signalling main improvements from previous editions. Special mention is the effort in the different mechanisms to introduce data, explained in 2.2.3. Finally, a description of the eight modules that make up the model is written in 2.3.

Next steps are explained in chapter 3, including work with pilots (customization and final calibration); scenario building; and relation with WP3.

Some reflections about the work done and the challenges ahead can be found in the conclusions (3.2).

Annex I contains all the modules' structure and equations.

1 Introduction

This deliverable explains in detail the third edition of the System Dynamic Model (SDM). The new version contains major modifications from previous versions, and it is indeed a working model, ready to be adjusted by pilot data to fit into their trends and so test policy evaluation and action.

The origin of SDM ed. 3 is ed. 1 and 2 modified after review by the Commission. The review has caused an unavoidable delay, agreed with the project management, but has also allowed to correct some conceptual deviations and address course of action. In this sense, deepening in subjects such as natural capital, social capital or social innovation, and considering in a more detailed approach other economic sectors than agriculture, are some of the corrections introduced, giving a larger perspective of the European rural areas.

As it is written in the Grant Agreement, PoliRural Model ed. 3 contains *individual modules updated with secondary data and primary data obtained in (T4.5)*. Actually, ed.3 introduces inputs coming from pilots mainly coming from WP4 (D4.1, D4.2 and D4.4), but D4.5 was not ready at the time of building the model, so that inputs coming from there could not be used. Nevertheless, once D4.5 is finished, a revision of policies and variables will be done, to test the model.

Many inputs came through project meetings and one-to-one conversations with pilots. Of special relevance was the meeting held on December 15th, 2020 with pilots, for it served to refine relations and dynamics.

Following the nomenclature introduced in D5.2, ed. 3 represents the last version of the High-Level Model. The model contains eight modules with multiple crossed interrelations, as it is explained below.

But above all, this new version is a working model. Equations have been introduced and the model has been tested to ensure a smooth and robust behaviour. This way the model is ready to meet the requirements for MS4: *Base model incorporates evaluation results and is ready for adaptation by different pilots; computerised model ready for testing and validation; base model includes at least five different modules.*

2 Description of PoliRural Model 3

PoliRural ed. 3 is an evolution of ed. 1 and 2. In the first place the main feedback loops intervening in the general dynamics are explained (2.1). Then, the improvements in relation to previous edition (2.2) are detailed, including new relations and feedbacks, transformation into a working model and data entry.

Finally, chapter 2.3 is a description of the eight modules included in the model: Agriculture, Education, Population, Quality of Life, Natural Capital, Employment, Rural Attractiveness and Rural Retention Capacity. In each of the modules the main relations and feedbacks are explained, as well as a relation of the main assumptions considered.

2.1 Main feedback loops

Although many variables of the different modules are related to each other, there are three main negative or goal seeking loops: Endogenous Development, Housing Accessibility and Natural Capital. They are described below.

Be aware that the terms used in the loops are more conceptual and generic that the ones used in the model, where the translation must be specified.

2.1.1 Endogenous Growth

Employment is considered the main force driving rural attractiveness. If there is employment available, new population is attracted to the rural area. However, proportion of newcomers is a brake to the social capital and so the social innovation strength weakens. This implies a decay in endogenous development, driving to less employment, and so diminishing rural attractiveness.

Equilibrium point is reached when Endogenous Development is absorbing the local workforce and even a small differential, covered by newcomers, without damaging the social capital that triggers social innovation, and so new initiatives providing goods and services.

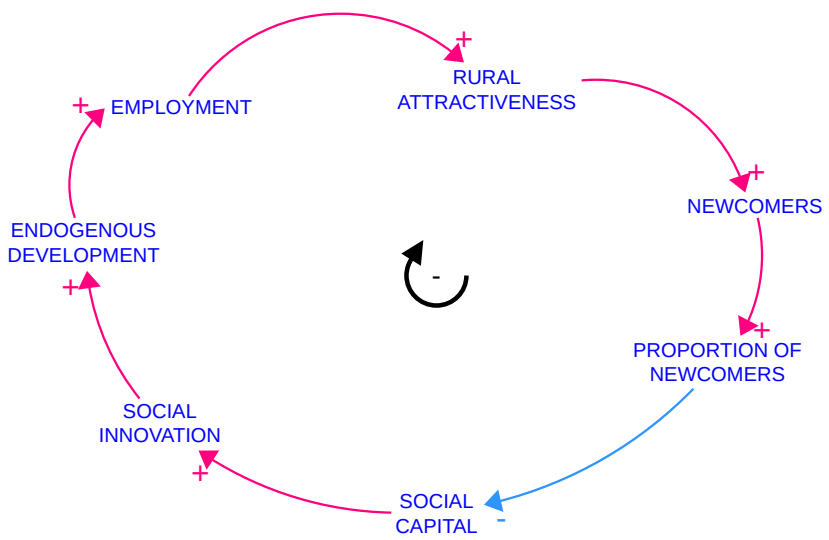


Figure 1 Endogenous Growth negative loop

2.1.2 Housing accessibility

Housing accessibility is an important variable to decide moving to a rural area. As before, a negative loop can be established linking Rural Attractiveness and Housing Accessibility. At a certain point, due to scarcity or increasing prizes, housing is not accessible to the population and no more population is attracted, until new housing opportunities arise, as drawn below.

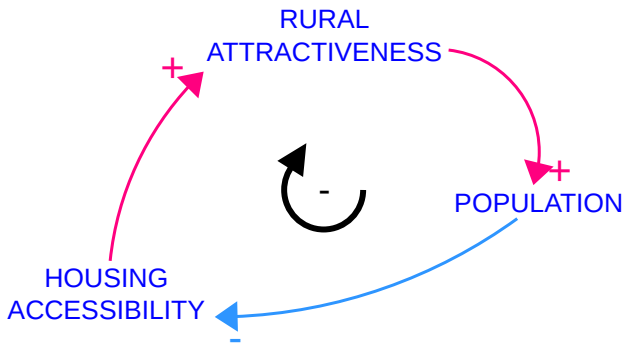


Figure 2 Housing Accessibility negative loop

This loop, as well as the previous one, are also useful for commuters. In this case Housing Accessibility will be measured by comparing prizes and available stock between rural areas and urban conurbations. In the loop showed in 2.1.1, commuters tend to be less implicated in local social life, so that the integration time (the time to become a member of the community, and thus leaving the status of newcomer) may be longer if commuters represent a large amount of the total newcomers.

2.1.3 Natural Capital

Natural Capital may be a source of attraction for tourism. However, an excess of tourism may be damaging at a long-term natural capital and so erode both, natural capital as such and a source of development for the region.

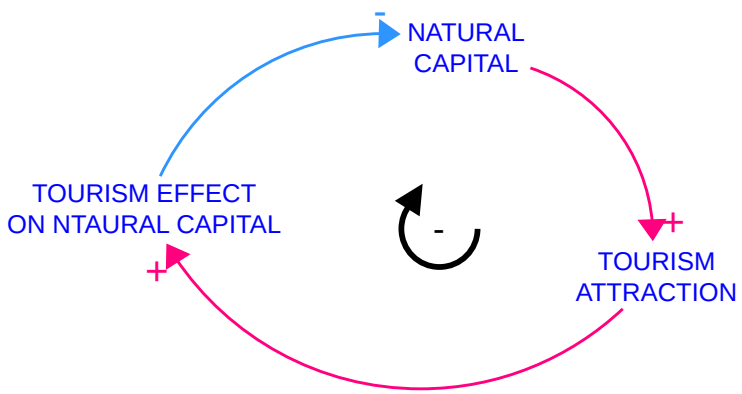


Figure 3 Natural Capital negative loop

2.2 Improvements on edition 3

Edition 3 presents major improvements from previous editions 1 and 2. These are based in new inputs coming from pilot, via task 4.5 but also through regular pilot meetings or more specific ones. In this sense it was especially useful the Pilot Foresight Meeting held on December 15th, 2020. Some one-to-one meetings with pilots were also clarifying.

Nevertheless, the most important improvement of the new version is converting the maps of previous version in an operative working simulation model. The challenges faced in this sense are explained in point 2.2.2.

Last improvement to be mentioned refers to the mechanisms to enter data. Point 2.2.3 describes the solutions to enter quantitative and qualitative data into the model.

2.2.1 New feedbacks and relations

In view of the new elements provided by the pilot areas a number of changes were introduced in the model. Find below the main ones.

- **Newcomers**
  Introduced as a stock, fed by newcomers' arrival and emptied by newcomers' integration, after an *integration time* that can be regulated.
  Newcomers affects shared knowledge, now turned into a stock to better reflect accumulation process.

- **Natural Capital module**
  This module was merely drawn in edition 1 and 2 and has now been developed properly. Three main inputs modify *Natural Capital Net Variation*: the effect of tourism, the effect of agriculture (through diversification and CAP Eco-Schemes), and an objective of natural land extension that can be fixed for year 2030.
  Natural capital is expressed in *ha equivalent*. This unit allows us to add real natural extension to relative extensions linked to other uses, such as agriculture.

- **Tourism jobs**
  The new developments made in tourism attraction has allowed the model to introduce tourism jobs, defined by the number of visitors and the ratio *visitors per tourism workplace*.

- **Agriculture module**
  Besides operative improvements on the module, the major change relates to the introduction of a stock considering *local income per farm*, modified by the technical obsolescence time. This allows variables such as AKIS strength and climate change impact to be introduced in the model, acting as modifiers of the technical obsolescence time.
  Attending the structure of the agriculture sector, the approach has moved from *agriculture land* concept (expressed in ha) to *number of farms*. This change will allow pilots to regulate variables concerning retirement, profitability, abandonment, etc.

- **Biodiversity**
  To attend biodiversity matters a variable called *effect of agriculture on Natural Capital* has been introduced. The variable is affected by *CAP Eco-Schemes* and *Agriculture diversification and multifunctionality*, and it affects the natural capital net variation over time.

- **Energy**
  New means of energy production can be introduced in the model through the *creation of primary jobs*.

2.2.2 Transformation into a working model

Up to now the models were basically maps, with some equations in the main loops, but not mathematically closed. Edition 3 has suffered major refinements to make it work smoothly and robustly. The changes affect not only formulas relating variables, but also the structure has gone through more or less complex modifications, to allow it to be run. This implies more complex structures, that should not affect the user interface (to be defined in WP3).

Main operative changes are described below.

- Variables becoming stocks, to better reflect accumulation in time and control input and output sources.
- Variables take relative values, either comparing with previous values (in time) or with totals.
- New structures to allow long term goals to be introduced.
- New variables to allow the model to be calibrated with pilots' data.
- Definition of units to give consistency to the model.

Find in Annex I a complete relation of the equations used in the model.

2.2.3 Data entry

Edition 3 is the High-Level model, from which pilots must be able to test policies and goals. But previous to the test the model has to be calibrated to fit with real local data. To allow pilots this twofold task, some mechanisms to introduce data have been added. They concern to both, quantitative and qualitative data, as explained below.

2.2.3.1 Quantitative data

Quantitative data may respond to initial values for variables and stocks (initial population, jobs, etc.); constant data over time (ratios) or long-term goals. The first and second ones are more of a calibration matter and scenario design. The last one defines policies and capacity of action.

It is important to signal that any of the variables can change from one category to another in the customization process, if the pilot feels it better reflects local dynamics. To do this, a structure adjustment will be needed.

- **Initial data**
  Initial real values for stocks and variables reflect the starting point of the simulation. Some examples are *population by age*; *initial fraction of students* (Vocational Training students, University students); *initial jobs by sectors*; *percentage of population covered by broadband infrastructure*, etc.
  Since they are considered as functioning data, they will normally be introduced by the modelling team into the customized model. Pilots will have to supply data to be filled in. In some cases, data will be asked in a ten-year series (2010 – 2020).

- **Constant data over time**
  These are data that will keep constant for the whole simulation. They represent typically rates and ratios.
  Examples of this type of data are *birth rate*, *life expectancy*, *mean jobs per farm*, *mean related jobs on agri-food industry per farm*, etc.
  Since rates and ratios are elaborated rather than raw data, pilots may have different formats, or they may have to elaborate from local raw data themselves. In any case the modelling team will introduce the data provided by the pilots.

- **Forecasts and objectives**
  In order to build scenarios data reflecting possible trends have been introduced, referring forecasted values for the end of the simulation period, or for any other period within the simulation.
  Some examples of forecasts to be introduced in the model refer to BASELINE, COVID19 (*life expectancy drop for the period 2020 – 2022*; *additional commuting attraction from 2021*) and CLIMATE CHANGE scenarios (*technical obsolescence for agriculture techniques at the end of the period*).
  Objectives follow the same rule, but they respond not to general trends but rather to policy options (where to allocate funding). Objective variables are usually paired with a *time to achieve objective* variable.
  Examples of objectives can be found in Quality of Life (mobility infrastructures objective; population covered by broadband objective; institutional support to entrepreneurship initiatives); Natural Capital or Education modules.
  In both cases, forecasts and objectives, values will be introduced by the pilots, with the possibility to change values and test results.

2.2.3.2 Qualitative data

In the previous point quantitative variables were considered. They are real, expected or achievable data, but they always may be expressed in numbers (representing relative or absolute values). Qualitative data do not present the same structure for they cannot be identified with a single *real* value.

To tackle this kind of data, a twofold solution has been put in place. The first one deals with weights, and it has been applied in decision contexts, where different factors affect the final choice. The second one reproduces evolution in relation with other variable or over time in a graphical form, and it is an approach for testing different behaviours.

- **Weights**
  As mentioned above, weights are used in the context of different components affecting decision context. They are present in Rural Attractiveness and Rural Retention modules, and they express the importance for different collectives of variables such as housing accessibility, natural capital, medical care and others in the decision to move or stay in rural areas.
  Weights are expressed in relative terms and their sum will give 1 as a result (100%). In some cases, the result will give a value a bit over 1, indicating that the factor is acting as attraction beyond its own nominal value (e.g., *employment* may function as an attractor of an area in a way which is beyond the job shortage in a certain time).
  Weights will be introduced by pilots and they are considered constant throughout the simulation.

- **Graph**
  There are two kind of graph representing qualitative variables in the model. The first one refers to the relation between two (or more) variables. The input of the graph is a variable or a combination of variables and the output is a value between 0 and 5, where 5 is the best result it can be found (e.g., the km needed to qualify *University Accessibility* as 5 will vary from one area to the other).
  Some of the most used graph are saved and can be used as templates. In the image below template behaviour are shown.

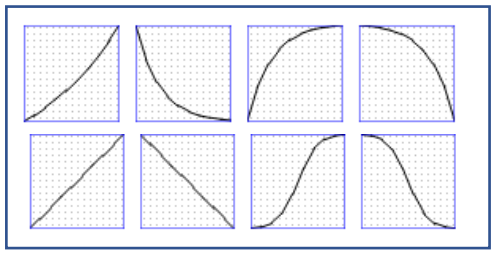


Figure 4 Behaviour Templates

The second one refers to behaviours over time, and they reflect usually previewed or desired evolutions of variables affecting policies and their effects.
In both cases the user will be able to define the boundaries and draw the graph.

2.3 Description of modules

The following is a description of the eight operative modules that make up the model: POPULATION, EDUCATION, QUALITY OF LIFE, AGRICULTURE, NATURAL CAPITAL, EMPLOYMENT, RURAL ATTRACTIVENESS and RURAL RETENTION CAPACITY.

The complete image and equations of the modules can be found in Annex I.

2.3.1 POPULATION

The base of the module is the aging chain described in D5.1, shown in the image below. As explained in that deliverable, the key driver of the population module lays in the net migration flows (total flow coming in or out the rural areas). The regulation of this flows will be defined in RURAL ATTRACTIVENESS and RURAL RETENTION CAPACITY, taking values from all the rest of modules.

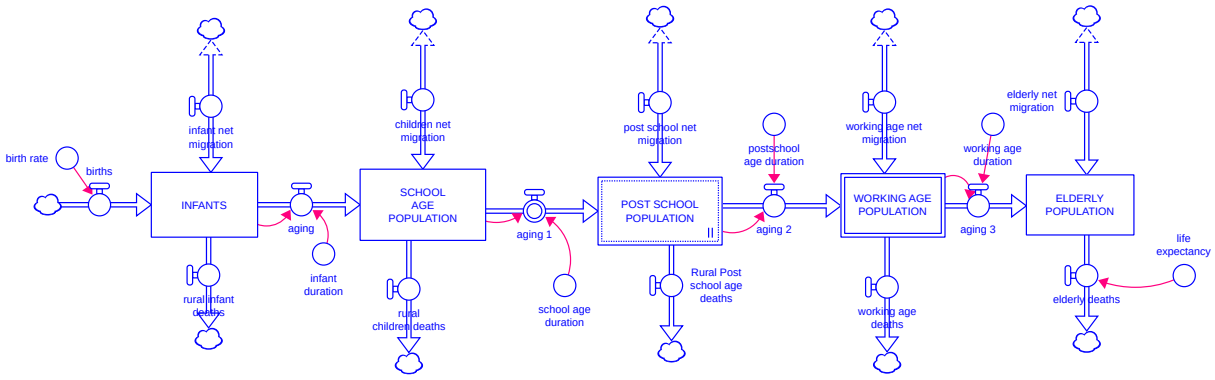


Figure 5 Rural Population Aging Chain

To the base chain, a new stock structure was added for NEWCOMERS. This is due to the effect of the proportion of newcomers in aspects concerning quality of life and employment, as explained in the respective modules. The stock is fed by the same flows as the main chain and is emptied by the variable *integration time* than can be modified.

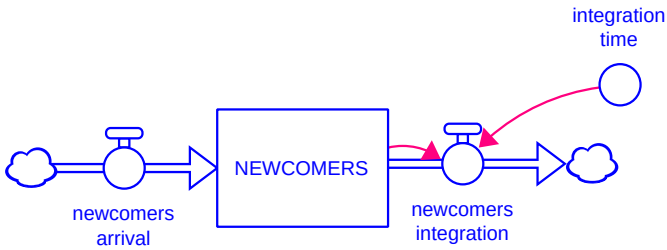


Figure 6 Newcomers stock structure

2.3.2 EDUCATION

Starting point for Education is people leaving the stock SCHOOL AGE POPULATION and entering in POST SCHOOL POPULATION. The flow is diverted in UNSKILLED WORKERS, VT STUDENTS and UNIVERSITY STUDENTS. Each of the stocks follows an aging chain considering time to finish studies and time to work (as VT professional, graduated professional or unskilled worker).

Initial proportion of the three are given by local data, and the long-term objective can be fixed in the *education campaign*, together with the duration of the campaign.

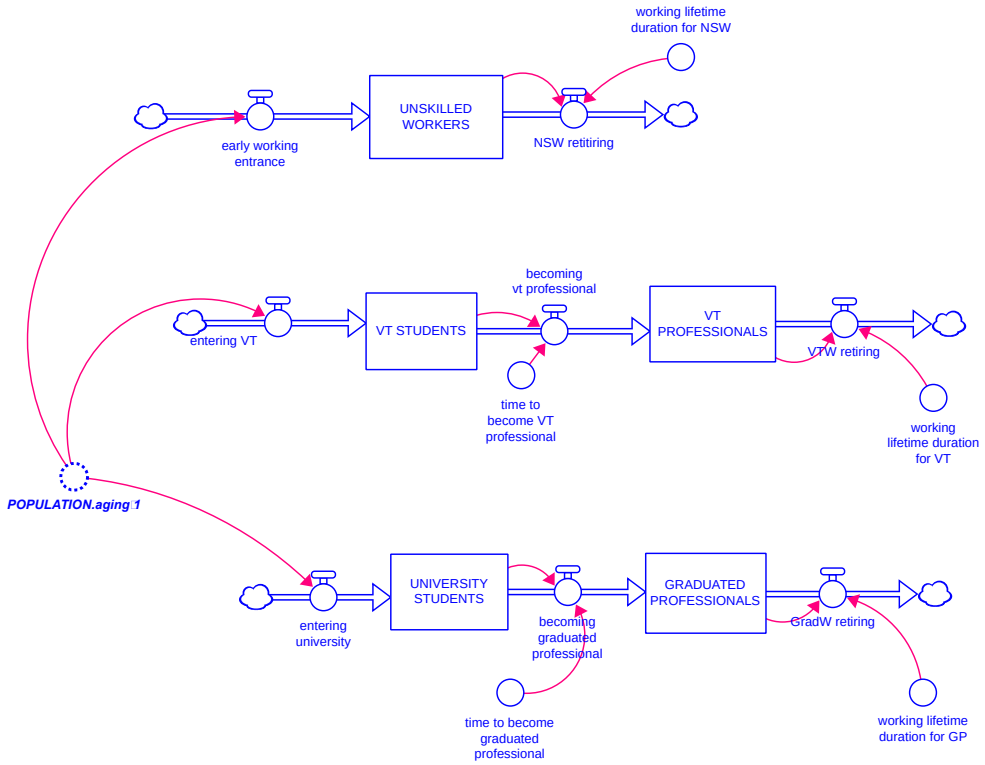


Figure 7 Education basic structure

2.3.3 QUALITY OF LIFE

This module has suffered many changes with respect to previous versions, deepening in the concepts and dynamics linked with the rest of the model. The module has three basic components, with multiple interrelations. These are: infrastructures, social capital and entrepreneurship.

Entrepreneurship is considered in this module, rather than in Employment, for its connections with *social capital* and *social innovation* variables. The idea is that a dynamic economic atmosphere is part of quality-of-life definition.

2.3.3.1 Infrastructures

Infrastructures are divided into mobility infrastructure and broadband infrastructure. The first one is responsible for the accessibility to basic services (health, education, regional connections and community activity), and it is measured in km of infrastructure, representing not the literal value but a relative value explaining infrastructure needs (roads, railroads, etc.).

The second one will impact in the attraction and retention capacity and will stir entrepreneurship. It is measured in percentage of the population covered by broadband.

Both of them are structured as simple stocks, with an inflow indicating construction of infrastructures and a depletion time regulating the outflow. Users may indicate initial values as well as an objective and a period to achieve it.

Base infrastructure structure is shown in the image below.

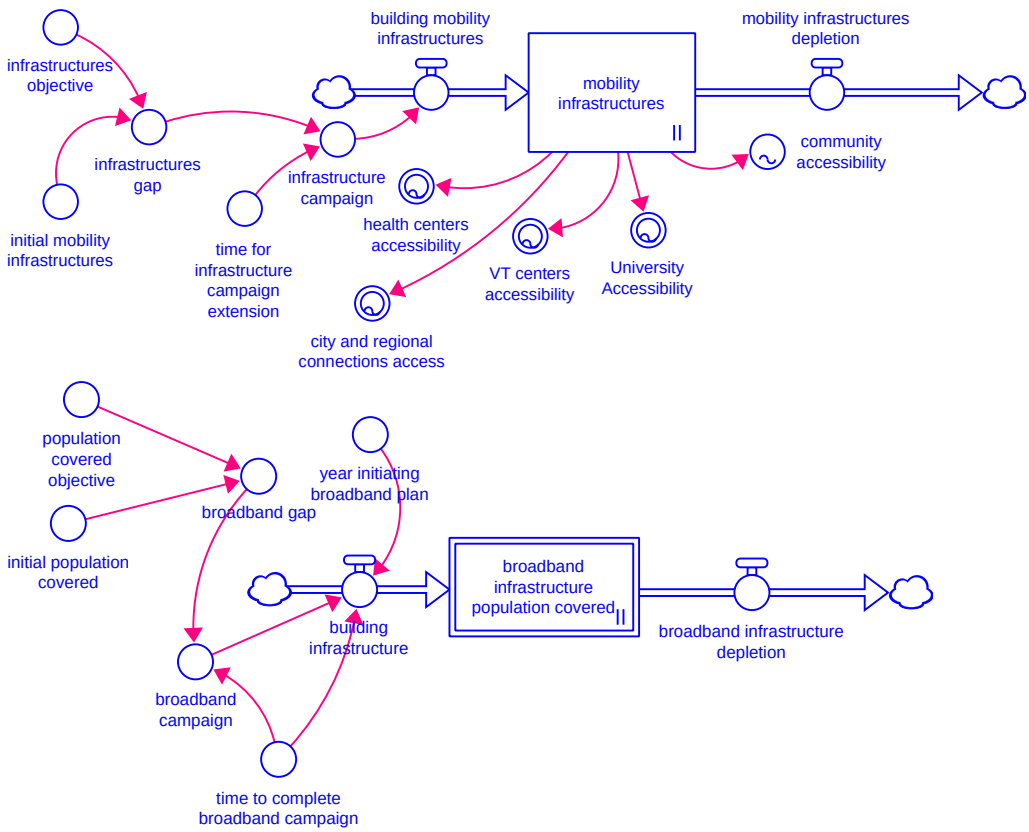


Figure 8 Infrastructures in Quality of Life module

2.3.3.2 Social Capital

Social capital structure is built from the stock of *shared knowledge*. This is a dimensionless stock fed by the building of shared knowledge and emptied by the loss. Building shared knowledge depends on the intensity of *community activity and networks* and a *time to build effective shared knowledge*, function of the proportion of newcomers in the area. Shared knowledge is then a ratio indicating the strength of the community, but the data has to be looked in terms of behaviour, that is the trend over time, rather than a concrete value in a given time.

Shared knowledge defines the *social capital* and *cultural appeal* of the area.

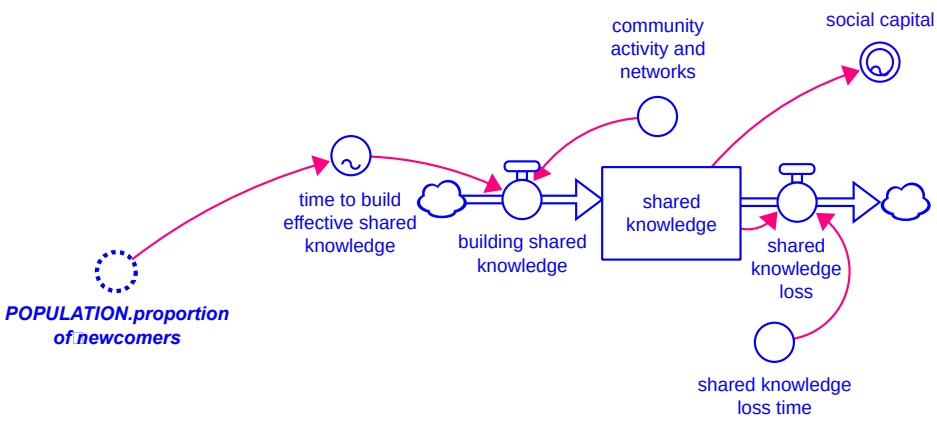


Figure 9 Social Capital structure in Quality of Life module

2.3.3.3 Entrepreneurship

Entrepreneurship is measured by the number of new initiatives local inhabitants have, and it is structured upon the base of two stocks: POTENTIAL INITIATIVES and IMPLEMENTED INITIATIVES.

The number of potential initiatives is defined as a function of *social innovation* (a variable depending on social capital and workforce specialization) and *broadband coverage*, and it is expressed as a fraction of the total *Working Age Population*.

Potential initiatives can become implemented ones once they have been planned. *Institutional support* can stir the number of potential initiatives thriving.

Once they have been implemented, the initiatives give place to new jobs, defining a *mean of jobs per initiative* for each sector (primary, industrial and services), and a *time to implement the initiatives*. Agriculture it is not included in this structure, for the sector is treated separately as a module.

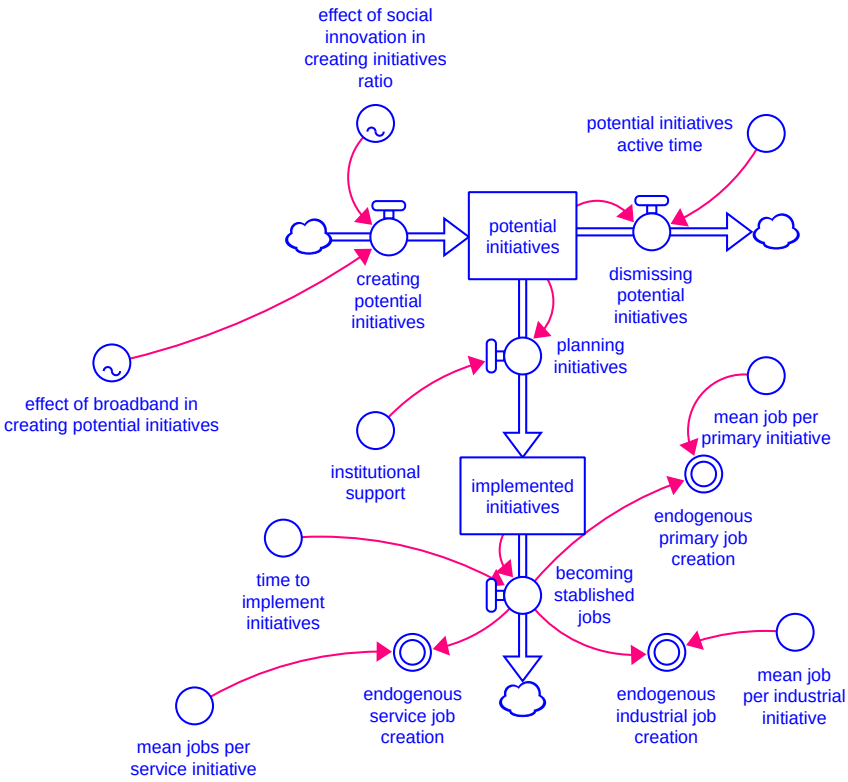


Figure 10 Entrepreneurship structure in Quality of Life module

2.3.4 AGRICULTURE

Agriculture module has been largely modified from previous versions, to better fit to the local realities, as defined in European bibliography and also expressed by pilots. The main change refers to the units (explained in 2.3.4.1). The second change refers to the addition of the stock *mean local income per farm*, to reflect agriculture profitability, and the consequences on the farming attraction fraction and abandonment ratio (2.3.4.2). Finally, CAP reform figures have been introduced: AKIS, Eco-Schemes and Farm to Fork Strategy (2.3.4.3).

2.3.4.1 Farm stock structure

Farm has been considered more appropriate than agricultural land, not only because it better reproduces the structure of property and work in the sector, but also because it allows concepts as *farmer retirement*, *average farm area* or *income per farm* to be introduced, referring to the unit of work 'farm'.

Thus, the first structure is a stock for the number of farms, with an inflow and an outflow. The inflow, increasing the number of farms, comes from new entrants, via a *farming attraction factor*, which at its turn is affected by *land access* and *agriculture profitability*. The more agriculture profitability the more likely new entrants will access new farms, considering there is land availability and access to land has been eased.

The outflow refers to abandonment and retirement. The first one is direct function of the profitability of the farming business. Retirement considers a mean working period for farmers work, after which a substitution process may or not occur. The retirements not covered will decrease the number of farms.

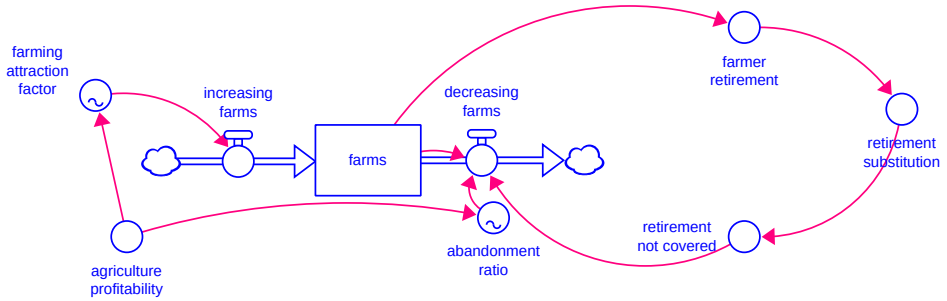


Figure 11 Number of Farms stock structure

2.3.4.2 Farm business profitability

Profitability is defined considering a *technical obsolescence time*, this is the time in which the agricultural practices will no longer be profitable. Technical obsolescence time is considered to vary in the period modelled, especially due to the climate change effects. Obsolescence can be covered (totally or partially) by the local ecosystem, as explained below. Diversification of the farm activity is considered to improve income per farm.

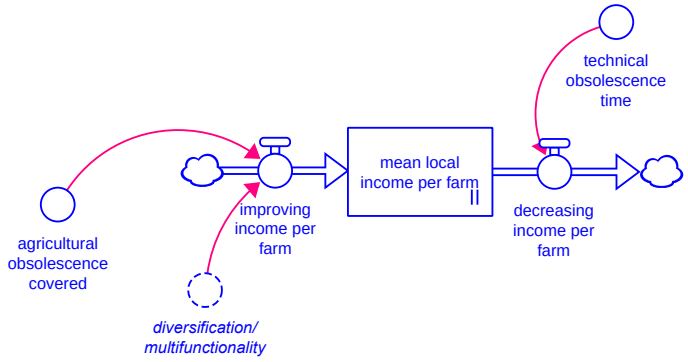


Figure 12 Income per farm structure

From the number of farms, a set of variables are defined: agricultural land (considering an *average farm area*), agriculture jobs (considering *jobs per farm*) and *related agricultural jobs in services* and *industry*.

Variable jobs per farm can be modified by diversification: the more diversified a farm is, the more capacity to give jobs.

2.3.4.3 CAP reform figures

CAP reform has a central role in the agriculture module, specified in the following figures (defined in the CAP reform): Agriculture Knowledge Innovation System (AKIS), Eco-Schemes, and Farm to Fork strategy.

The variable to valuate **AKIS** is *AKIS strength*, a qualitative measure going from 0 to 5 and varying in time. AKIS strength is responsible for the access to newcomers into the farming business, the number jobs created by the agriculture in services and industry, and the agricultural technical obsolescence covered. Thus, AKIS reflects the strength of the economic ecosystem around agriculture and may affect many of the variables in the module.

Eco-Schemes are an important part of the CAP reform, for they will represent an important part of the payments to farms. Eco-Schemes take the form of annual commitments defined by member states and voluntary for farmers to join. Eco-Schemes affects in the model *CAP payment*, and so profitability of the farm, and also *Natural Capital*.

Farm to fork strategy of the EU is a key in the new CAP reform. The objective of the strategy is to strengthen local food chains and make them sustainable in the long term. Farm to fork strategy has been translated in the model considering the effect it may have in industry and service jobs.

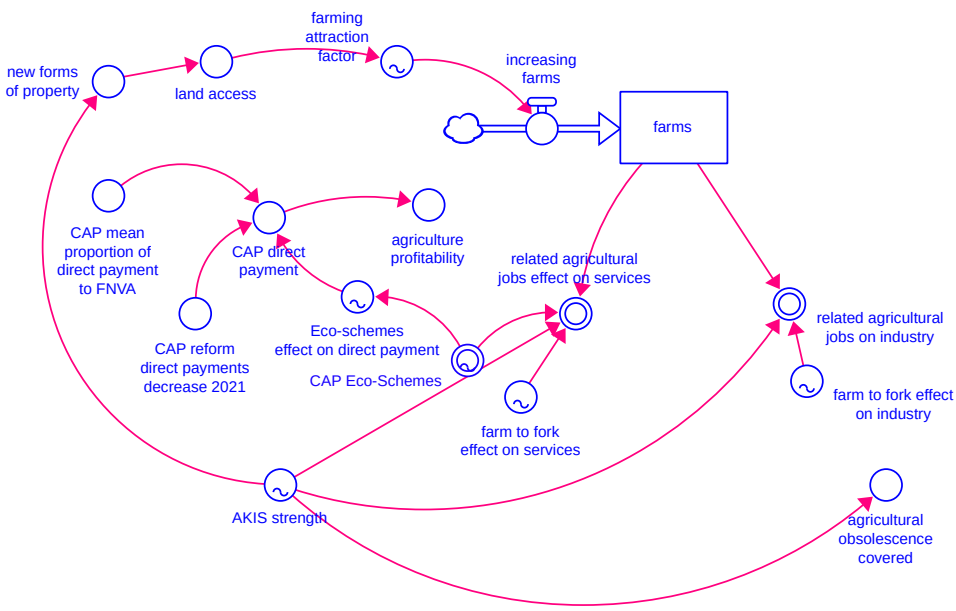


Figure 13 CAP reform variables: AKIS, Eco-Schemes and Farm to Fork

2.3.5 NATURAL CAPITAL

The centre of the Natural Capital module is the stock Natural Capital and is measured in equivalent hectares[1]. The stock can be increased by a long-term objective on natural land, and by the effect of tourism and agriculture.

The effect of agriculture on the stock of Natural Capital will depend on the efficacity of the Eco-Schemes, and also on the diversification of the farm business. Tourism will affect the natural capital following a function of the proportion of visitors with relation to the local population.

As mentioned in 2.1.3, Natural Capital is also acting as a tourism attractor, and the natural capital perception affects rural attraction and retention ratios.

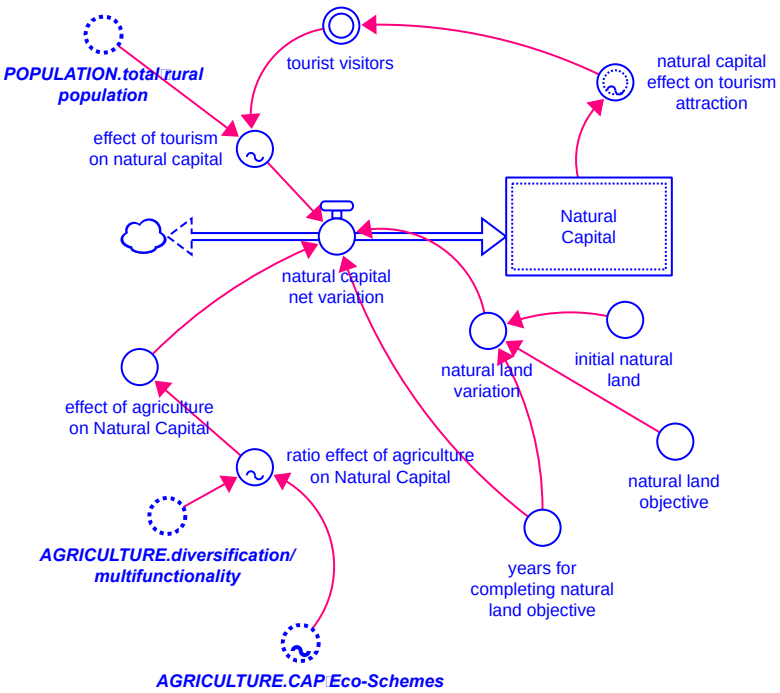


Figure 14 Natural Capital stock structure

2.3.6 EMPLOYMENT

Employment module is made up of four stocks containing primary sector (excluding agriculture), industrial, services and population services jobs. The first three ones share a common structure. They have an inflow of creation of jobs and an outflow of destruction of jobs.

Creation is always a variable coming from Entrepreneurship (2.3.3.3), and the destruction ratio is regulated through a destruction time. See below the example for industrial jobs, but the structure repeats for primary and services jobs.

[1] Equivalent hectares are obtained by adding to the natural land, some of the rest of land uses affected by a factor. In the case of PoliRural ed.3 the coefficient applies to agricultural land.

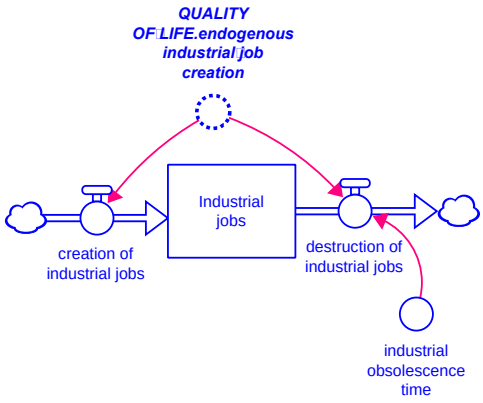


Figure 15 Stock structure for job sectors

Population services follow a different rule, for it is defined as a function of the population living in the area.

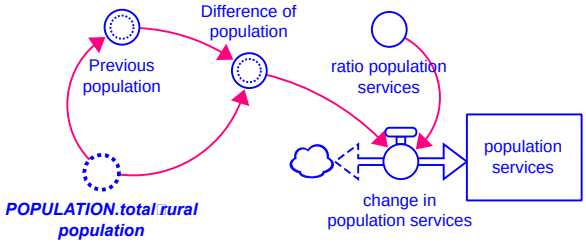


Figure 16 Population Services stock structure

Remote workers have also been included in the module. These are not defined as a stock but with a potential figure for 2030, fixed by the users and taking into account that *broadband coverage* allows the potential to be deployed.

Agriculture jobs coming from Agriculture module are added to calculate total employment.

From total employment two main indicators are found: employment gap (comparing with *total workforce*) and economic diversification (that is the weight of the different sectors in total employment and the behaviour over time).

2.3.7 RURAL ATTRACTIVENESS

Rural attractiveness is generated mainly by employment gap, except in the cohort of elderly population. From the employment generator conditions and weights modulate the final result. Weights are different for each population cohort as seen in next table. In the case of elderly, there is a maximum population moving, and the value is again modulated by the factors and weights considered.

	YOUNG POPULATION	WORKING AGE POPULATION	ELDERLY POPULATION
Housing accessibility	weight	weight	weight
Natural capital	weight	weight	weight
Cutural appeal		weight	weight
Medical and care services			weight
TOTAL	0 - 50%	0 - 52%	0 - 100%
	0 - 102% of employment gap (>0)		0 - 100% of the maximum elderly population moving

Table 1 Factors and weights for Rural Attractiveness

Both the factors and the weights can be modified by the users.

There is a different entry created for Commuters. These are considered a stock (*potential commuters*), with an outflow when they move to the rural. The outflow is a function of housing accessibility and city and regional connections access, as shown in the image below.

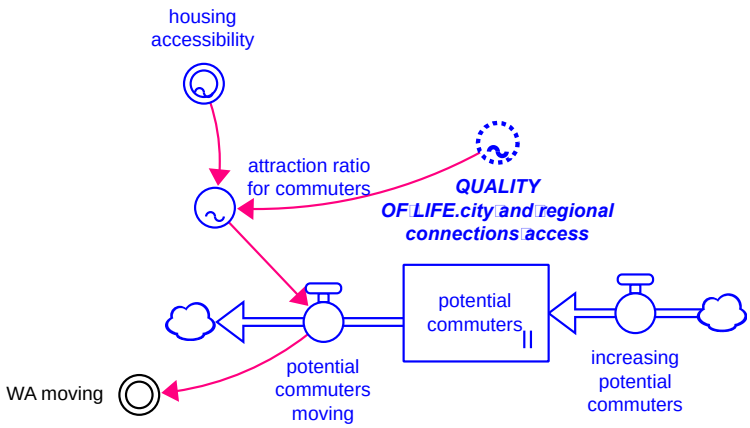


Figure 17 Structure for Commuters in Rural Attractiveness

2.3.8 RURAL RETENTION CAPACITY

This module follows the same structure as previous Rural Attractiveness, but with slight differences. Factors are different from attraction, as in real world the factors considered to move do not coincide with the ones considered to stay. Factors and weights are shown in next table.

Employment is considered as a factor for young people to stay, and normally will have a considerable weight in the decision process. In the case of working age people, the effect of employment is multiplying up to two times the leaving ratio (the translation is that lack of employment may even double the will to leave a rural area).

In the case of elderly population, factors considered to stay are social capital and medical care. Instead of depending on employment, there is a maximum elderly population leaving per year, then modified by the factors and weights fixed.

As in the case of Rural Attractiveness, factors and weights can be modified by the users.

	YOUNG POPULATION	WORKING AGE POPULATION	ELDERLY POPULATION
Higher education accessibility	weight		
Housing accessibility	weight		
Employment	weight	multiplier	
Broadband coverage	weight	weight	
Social capital	weight	weight	weight
City and regional connections		weight	
Medical and care services			weight
TOTAL	0 - 100% retention	0 - 100% retention	0 - 100% retention

Table 2 Factors and weights for Rural retention capacity

3 Next Steps and Conclusions

PoliRural edition 3 is an important milestone in the project. It has many improvements and refinements with respect to edition 1 and 2, and it is yet a working model. But there is still a lot of work pending to achieve the objectives of the System Dynamic Model in the context of the project, as explained in 3.1.

Finally, some conclusions of the work and perspectives are written in 3.2 Conclusions.

3.1 Next Steps

Once a complete working version of the model has been achieved, adaptation works and refinements can be considered. Main tasks involved in this phase are adaptation to pilot's data and context (3.1.1); choice of relevant variables for scenario building (3.1.2); final calibration and use by the pilots (3.1.3).

In parallel, tasks related with WP3, started in M13, follow their course and will have a key role to achieve full potential as a tool to help policy definition in rural areas (3.1.4).

3.1.1 Pilot's customization

The model worked out so far is the High-Level Model explained in D5.2. It responds to the conclusions and requirements found in bibliography and expressed by pilots. Present edition is ready to be adapted to pilots by introducing their real data and refining the dynamics to better fit their local situation.

One of the main challenges the modelling exercise faces is the fully understanding by the pilots of the potential and usefulness in the design of policy options. Without this understanding, no customization or calibration is possible, and furthermore, no usefulness in the foresight exercise would be draw from it.

To avoid this, an interface of the High-Level Model has been built in parallel with the works of D5.3, to allow pilots to test a working model and explore the potential of the tool. This test model, based on PoliRural ed.3, will be available and in use during the Fourth General Meeting to be held 20th and 21st of January 2021. The test will include scenario building and policy analysis, and it will be run over data reproducing a general rural area.

During the months previous to September 2021, a one-to-one work with each of the pilots will be made, to have 12 pilot models ready to be run and extract conclusions to help in the foresight analysis.

3.1.2 Scenario Building

Besides the work with pilots, it is also necessary to define scenarios. In terms of modelling, this is to pick up relevant variables that are going to better reflect different scenarios. In this sense, the starting point will be the 'Deep Dives' exercise that CKA is going to present in the next weeks.

Deep Dives exercise is going to deal with the following subjects: COVID19, CAP Reform, EU Green Deal and Biodiversity Strategy. The definition and sharing with pilots will help to adapt the model and choose relevant variables to define scenarios that are of interest for them.

However, it has to be said that one of the main features of SDM software is the possibility to modify variables and see the result in outputs. This can be done in a very straight way, so the main job here is to define criteria and variables to modify, and pilots will be able to build their own scenarios.

The workshop that took place on January 21st, during the 4th Project Meeting, illustrated the way to build scenarios and policy options and the possibilities the model offered in this sense. To facilitate this task a list of variables that can be modified will be introduced in a tutorial that is foreseen, to explain how to use SDM.

3.1.3 Final Calibration

After the first round with pilots and scenarios definition completed, the model will have a final calibration to be ready to use by pilots. They will be accompanied by modellers to perform all the capacities SDM can offer, and to help them draw conclusions and action.

3.1.4 Relation with WP3

Works to introduce SDM in the Innovation Hub started with deliverable D3.3. At the moment works focus on D3.5, the initial prototype of the System Dynamics tool. It is important to signal that ed.3 is already the operative version with which the design of the prototype is done. To allow this, an XMILE version of the model has been created.

Next steps in the development of the SD tool are key to ensure usability and usefulness by rural areas.

3.2 Conclusions

As mentioned above, this deliverable represents a major advance in the modelling process. Delays caused by the review have been unavoidable, but they have also allowed the model to be focused on the points that are really important for rural areas across Europe.

The model is now ready to adapt to pilot users, as the first step for a more generic adoption. However, challenges still lay ahead, main ones being interaction with users and usability of the final solution. Works in WP5 and WP3 should allow us to overcome them.

Annex I Model Structure and Equations

The model has been designed with Stella Architect v2.0. Find in this annex the complete structure of the model, including maps and equations of the eight operative modules.

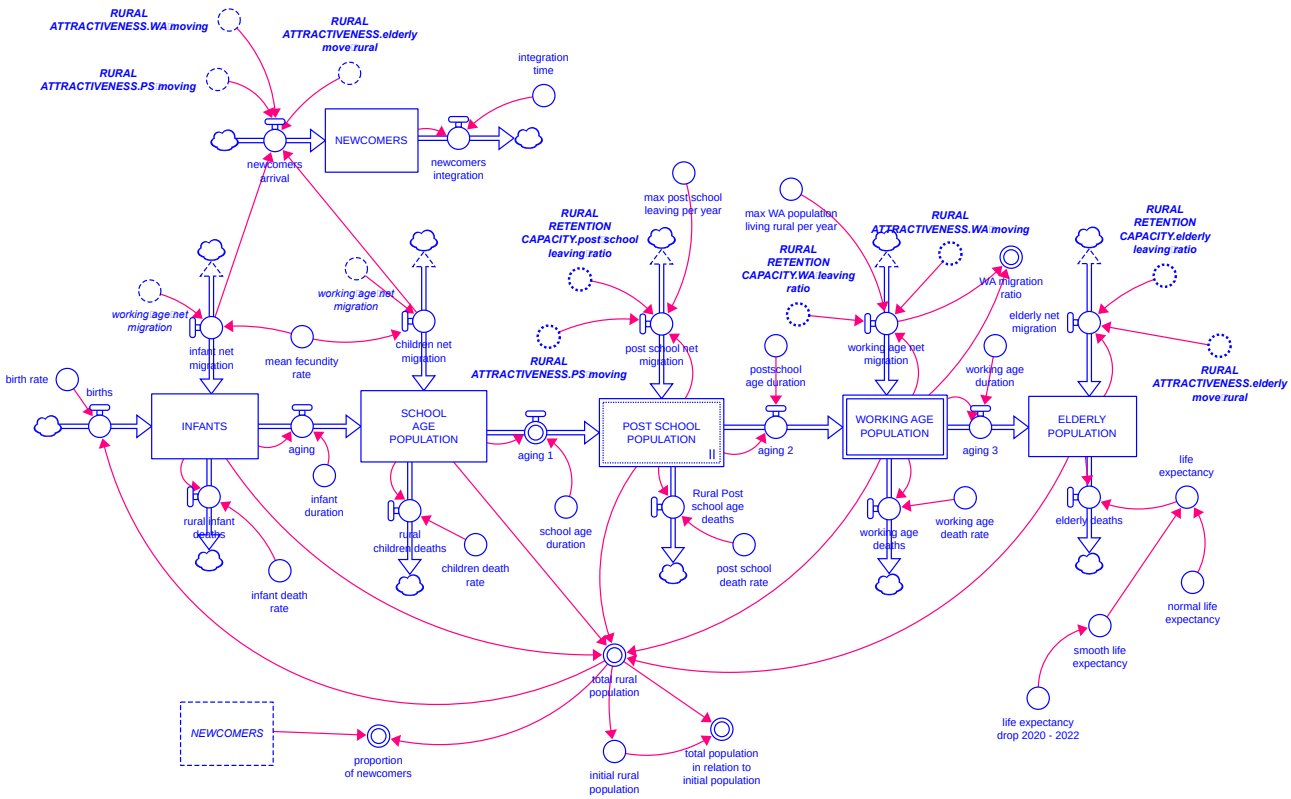


Figure 18 Population Module

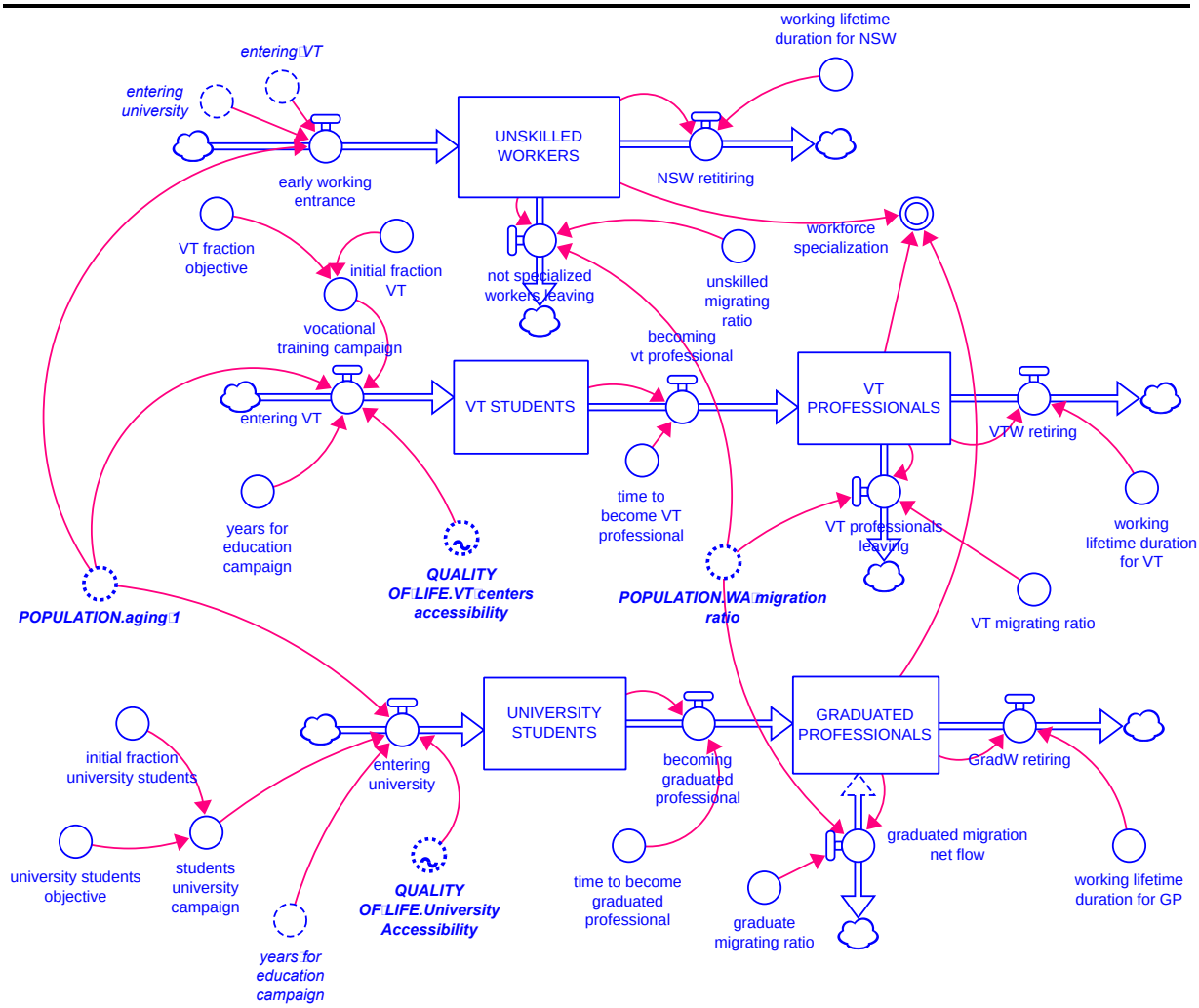


Figure 19 Education Module

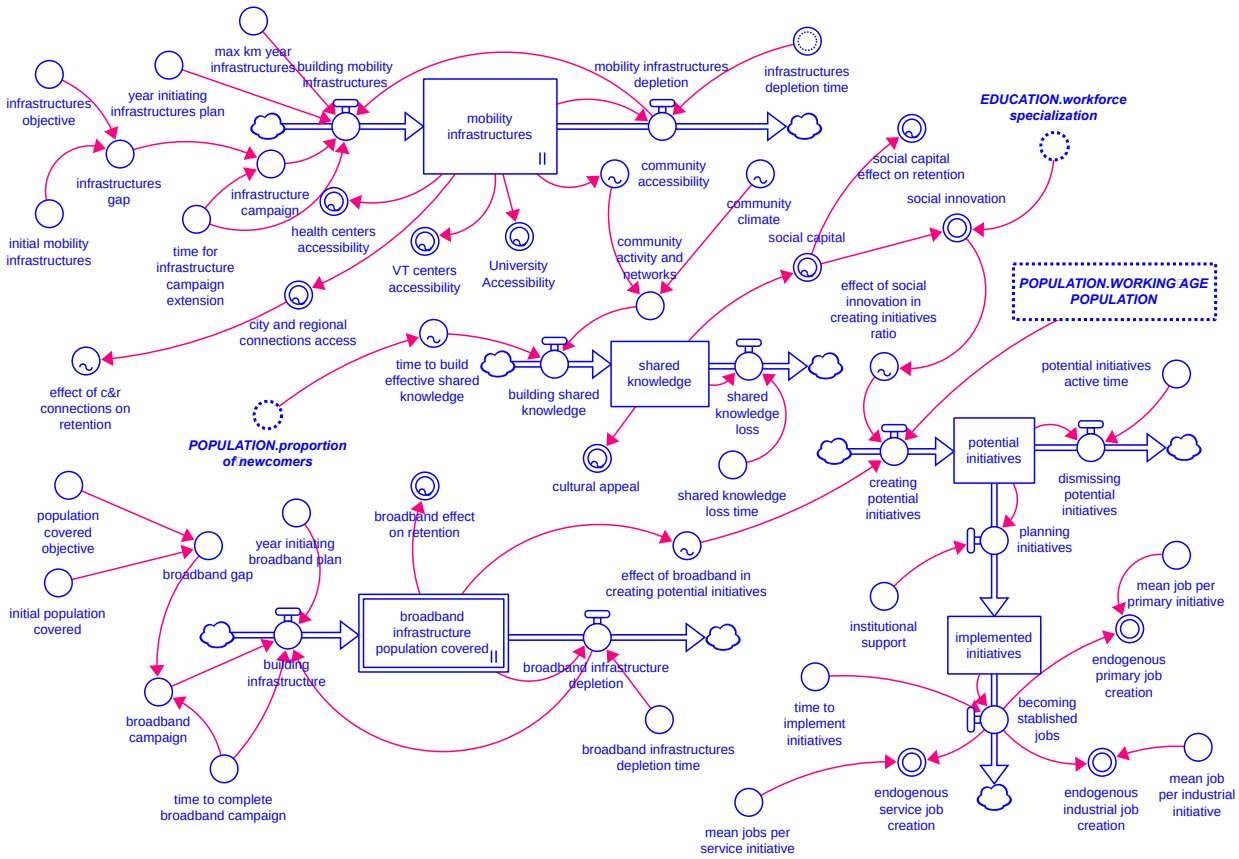


Figure 20 Quality of Life Module

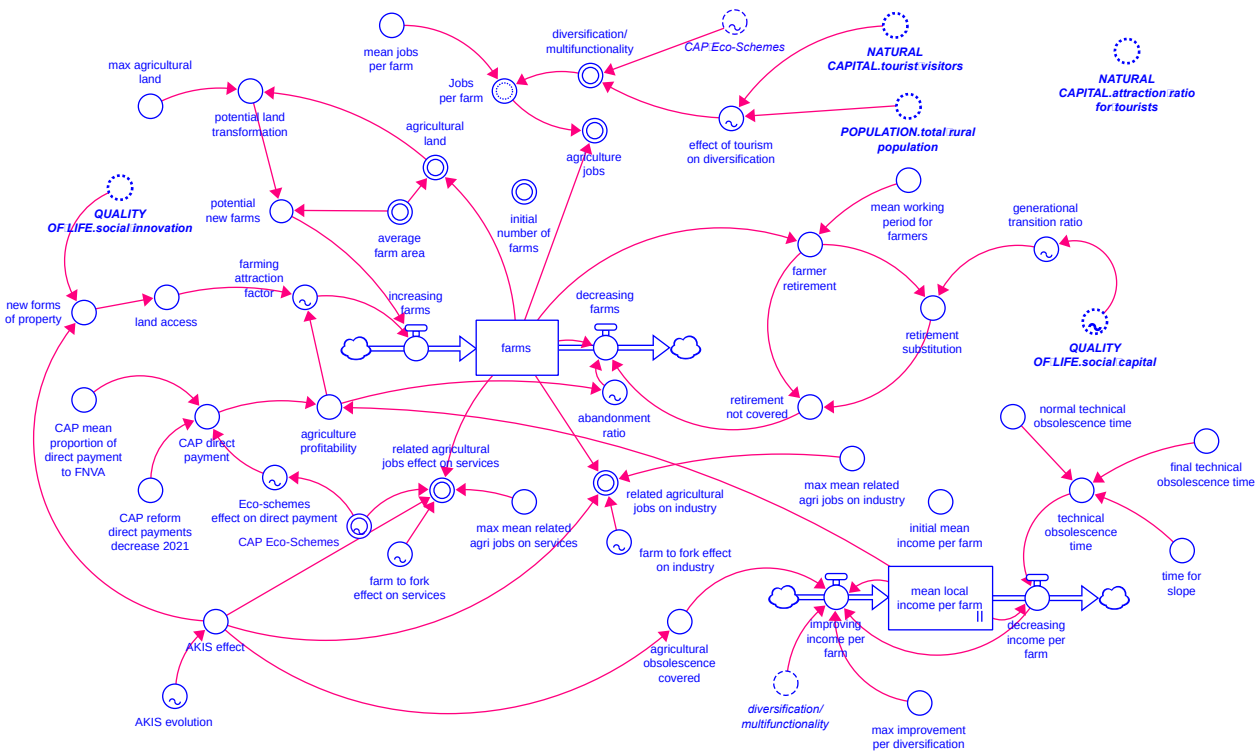


Figure 21 Agriculture module

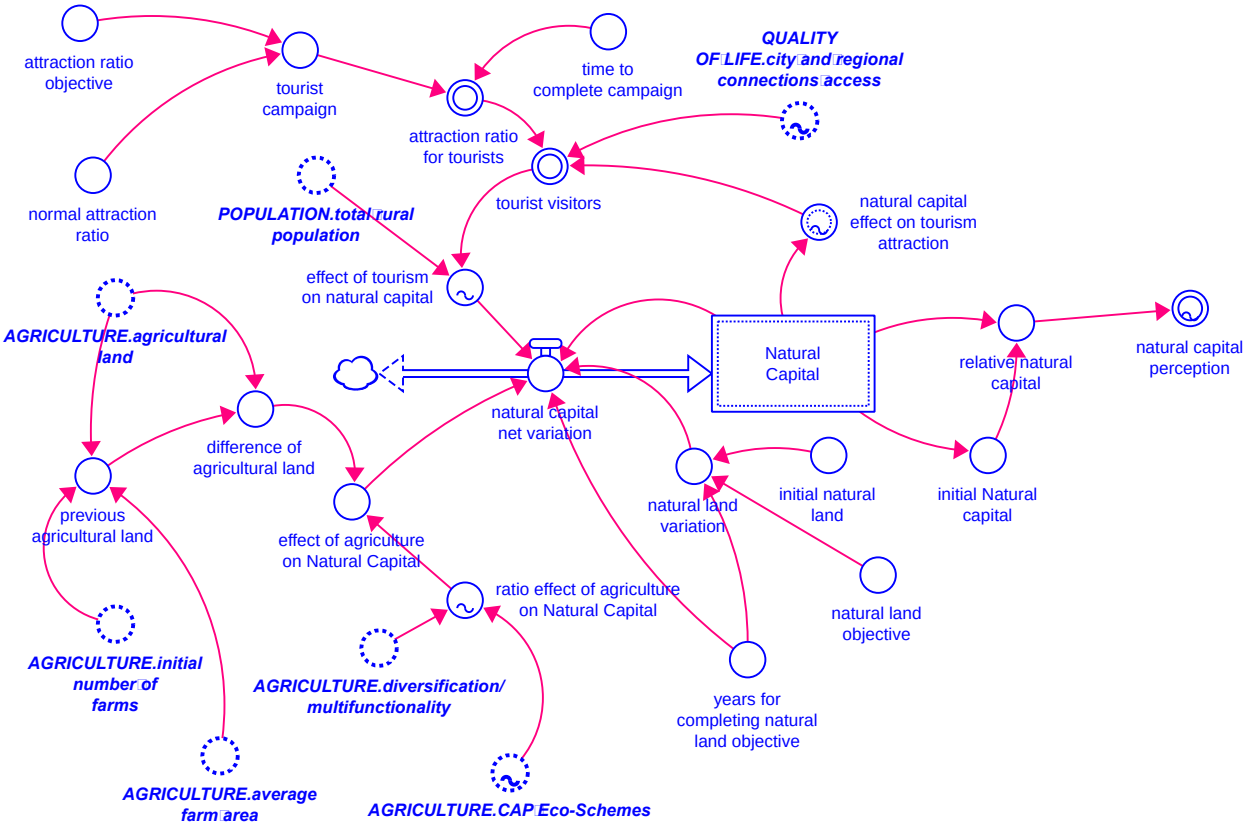


Figure 22 Natural Capital module

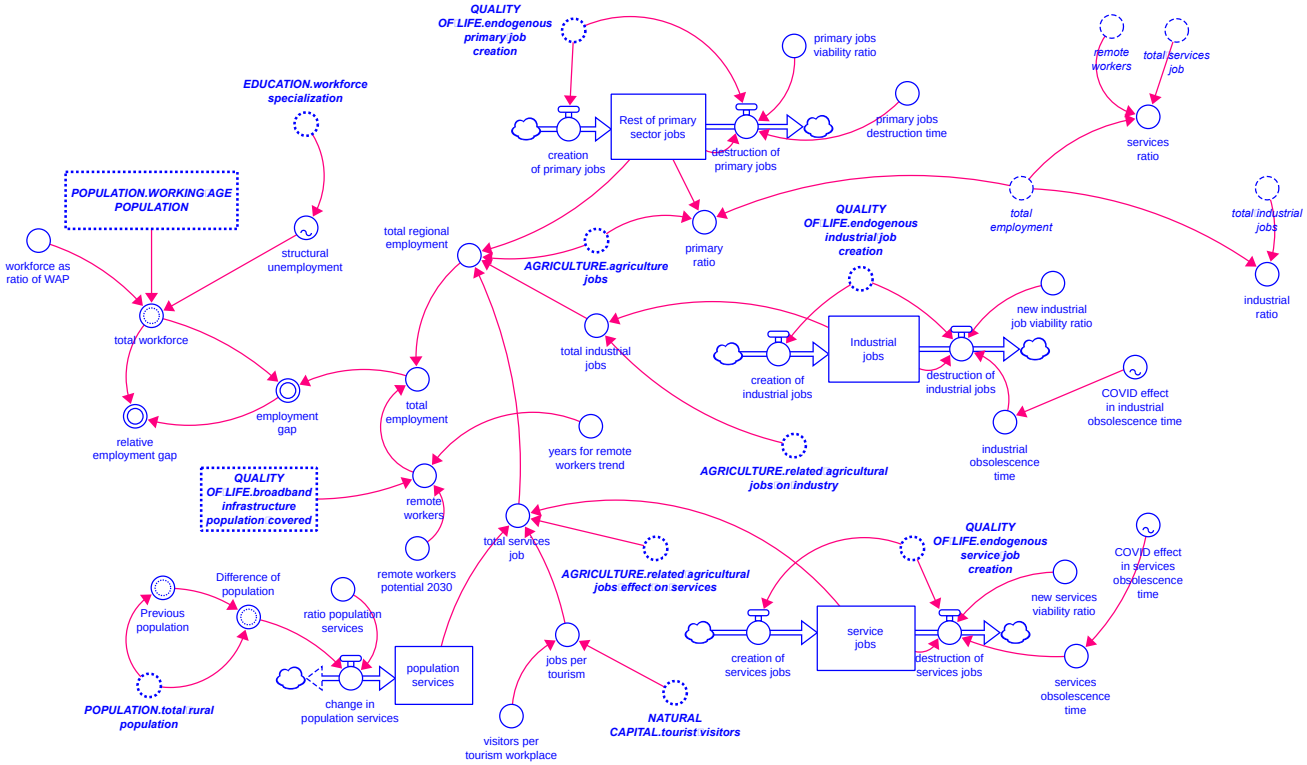


Figure 23 Employment module

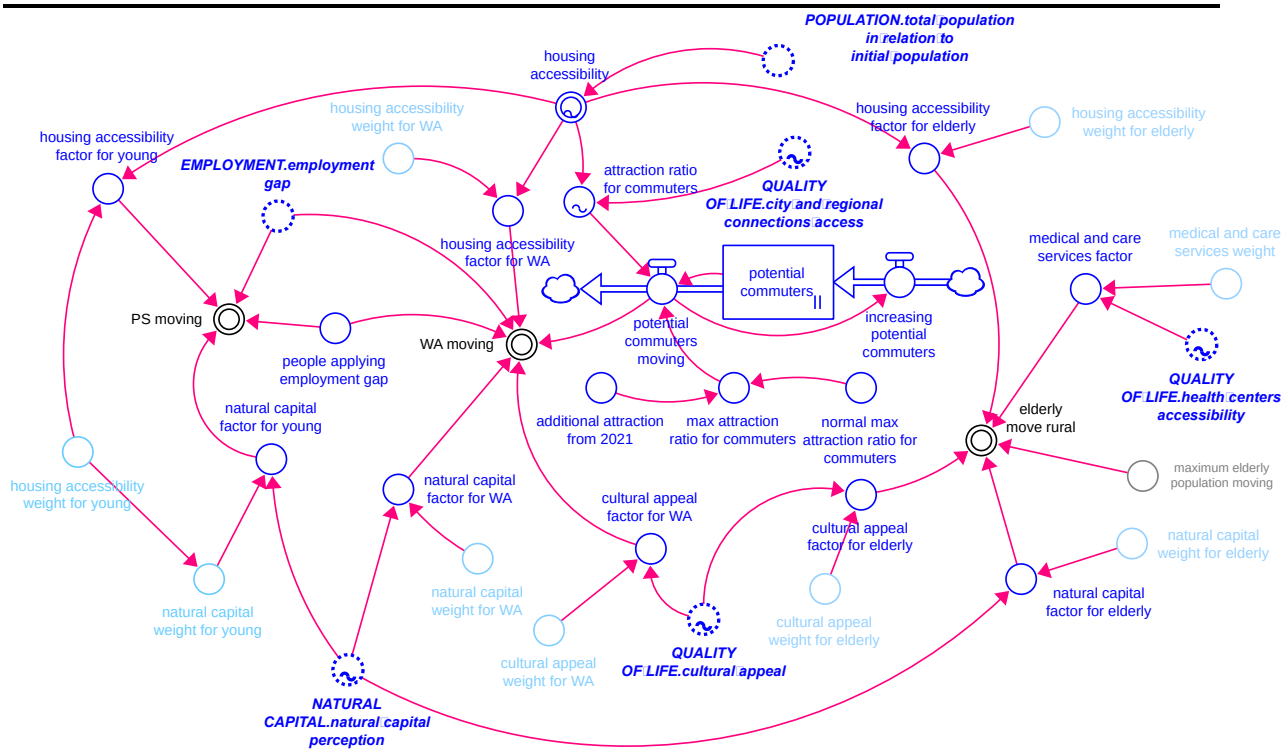


Figure 24 Rural Attractiveness module

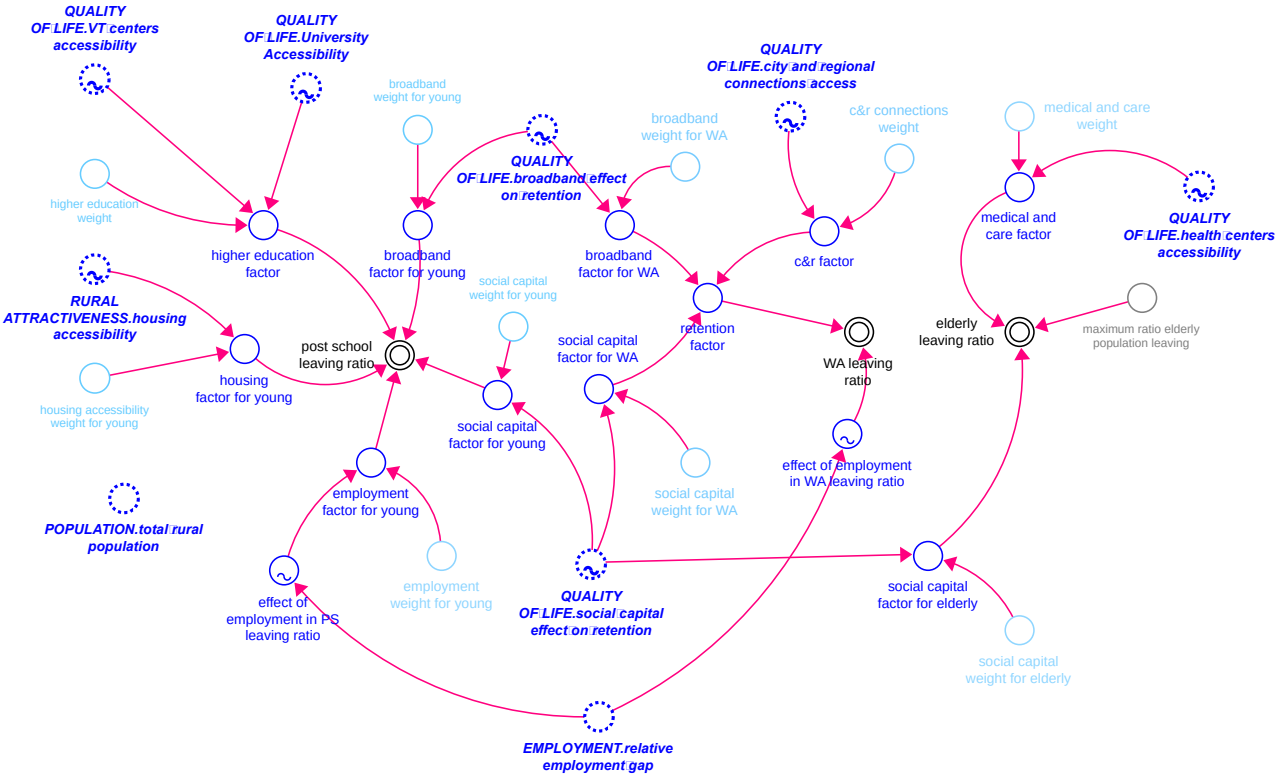


Figure 25 Rural Retention Capacity module

	Equation	Properties	Units
Top-Level Model:			
AGRICULTURE:			
farms(t)	farms(t - dt) + (increasing_farms - decreasing_farms) * dt	INIT farms = initial_number_of_farms	farm
mean_local_income_per_farm(t)	mean_local_income_per_farm(t - dt) + (improving_income_per_farm - decreasing_income_per_farm) * dt	INIT mean_local_income_per_farm = initial_mean_income_per_farm	€/farm
decreasing_farms	(farms*abandonment_ratio)+retirement_not_covered		farm/year
decreasing_income_per_farm	mean_local_income_per_farm/technical_obsolescence_time		€/farm/Years
improving_income_per_farm	(decreasing_income_per_farm*agricultural_obsolescence_covered) + ("diversification/_multifunctionality"*mean_local_income_per_farm*max_improvement_per_diversification)		€/farm/Years
increasing_farms	potential_new_farms*farming_attraction_factor		farm/year
abandonment_ratio	GRAPH(agriculture_profitability) Points: (0, 0,993307149076), (11250, 0,924141819979), (22500, 0,500), (33750, 0,0758581800212), (45000, 0,00669285092428)		dmnl/year
agricultural_land	farms*average_farm_area		ha
agricultural_obsolescence_covered	MAX (0,6; AKIS_effect)		dmnl
agriculture_jobs	farms*Jobs_per_farm		job
agriculture_profitability	mean_local_income_per_farm*(1+CAP_direct_payment)		€/farm
AKIS_effect	AKIS_evolution*0,22		dmnl
AKIS_evolution	GRAPH(TIME) Points: (2021,00, 3,000), (2022,00, 3,000), (2023,00, 3,000), (2024,00, 3,000), (2025,00, 3,000), (2026,00, 3,000), (2027,00, 3,000), (2028,00, 3,000), (2029,00, 3,000), (2030,00, 3,000), (2031,00, 3,000), (2032,00, 3,000), (2033,00, 3,000), (2034,00, 3,000), (2035,00, 3,000), (2036,00, 3,000), (2037,00, 3,000), (2038,00, 3,000), (2039,00, 3,000), (2040,00, 3,000)		dmnl
average_farm_area	23		ha/farm
CAP_direct_payment	CAP_mean_proportion_of_direct_payment_to_FNVA-STEP(CAP_reform_direct_payments_decrease_2021; 2021)+ STEP ("Eco-schemes_effect_on_direct_payment"; 2021)		dmnl
"CAP_Eco-Schemes"	GRAPH(TIME) Points: (2021,00, 2,000), (2021,95, 2,000), (2022,90, 2,000), (2023,85, 2,000), (2024,80, 2,000), (2025,75, 2,000), (2026,70, 2,000), (2027,65, 2,000), (2028,60, 2,000), (2029,55, 2,000), (2030,50, 2,000), (2031,45, 2,000), (2032,40, 2,000), (2033,35, 2,000), (2034,30, 2,000), (2035,25, 2,000), (2036,20, 2,000), (2037,15, 2,000), (2038,10, 2,000), (2039,05, 2,000), (2040,00, 2,000)		dmnl

CAP_mean_proportion_of_direct_payment_to_FNVA	0,3		dmnl
CAP_reform_direct_payments_decrease_2021	0,05		dmnl
"diversification/_multifunctionality"	(effect_of_tourism_on_diversification+"CAP_Eco-Schemes")/2		dmnl
"Eco-schemes_effect_on_direct_payment"	GRAPH("CAP_Eco-Schemes") Points: (0,000, 0), (0,500, 0,003060351228), (1,000, 0,00644256240429), (1,500, 0,0101804838351), (2,000, 0,0143115258945), (2,500, 0,0188770334399), (3,000, 0,0239226996053), (3,500, 0,0294990231137), (4,000, 0,0356618136849), (4,500, 0,0424727505984), (5,000, 0,05)		dmnl
effect_of_tourism_on_diversification	GRAPH(NATURAL_CAPITAL.tourist_visitors/POPULATION.total_rural_population) Points: (0,00, 2,473), (1,11111111111, 4,069), (2,22222222222, 4,628), (3,33333333333, 4,734), (4,44444444444, 5,000), (5,55555555556, 5,000), (6,66666666667, 4,654), (7,77777777778, 1,277), (8,88888888889, 0,505), (10,00, 0,000)		dmnl
farm_to_fork_effect_on_industry	GRAPH(TIME) Points: (2021,00, 2,000), (2021,95, 2,000), (2022,90, 2,000), (2023,85, 2,000), (2024,80, 2,000), (2025,75, 2,000), (2026,70, 2,000), (2027,65, 2,000), (2028,60, 2,000), (2029,55, 2,000), (2030,50, 2,000), (2031,45, 2,000), (2032,40, 2,000), (2033,35, 2,000), (2034,30, 2,000), (2035,25, 2,000), (2036,20, 2,000), (2037,15, 2,000), (2038,10, 2,000), (2039,05, 2,000), (2040,00, 2,000)		dmnl
farm_to_fork_effect_on_services	GRAPH(TIME) Points: (2021,00, 2,000), (2022,00, 2,000), (2023,00, 2,000), (2024,00, 2,000), (2025,00, 2,000), (2026,00, 2,000), (2027,00, 2,000), (2028,00, 2,000), (2029,00, 2,000), (2030,00, 2,000), (2031,00, 2,000), (2032,00, 2,000), (2033,00, 2,000), (2034,00, 2,000), (2035,00, 2,000), (2036,00, 2,000), (2037,00, 2,000), (2038,00, 2,000), (2039,00, 2,000), (2040,00, 2,000)		dmnl
farmer_retirement	farms/mean_working_period_for_farmers		farm/year
farming_attraction_factor	GRAPH(land_access*agriculture_profitability) Points: (0, 0,000), (10000, 0,0139810175321), (20000, 0,0336236144274), (30000, 0,0612204336079), (40000, 0,0999925182228), (50000, 0,154465265084), (60000, 0,230996619537), (70000, 0,338519161579), (80000, 0,489582697952), (90000, 0,701819049401), (100000, 1,000)		dmnl/year
final_technical_obsolescence_time	7		year
generational_transition_ratio	GRAPH(QUALITY_OF_LIFE.social_capital) Points: (0,000, 0,000746028833837), (0,500, 0,00314121328483), (1,000, 0,0131253183371), (1,500, 0,0531511363981), (2,000, 0,191545348561), (2,500, 0,500), (3,000, 0,808454651439), (3,500, 0,946848863602), (4,000, 0,986874681663), (4,500, 0,996858786715), (5,000, 0,999253971166)		dmnl
initial_mean_income_per_farm	35000		€/farm
initial_number_of_farms	506		farm

Jobs_per_farm	mean_jobs_per_farm*MAX(1; "diversification/_multifunctionality"/4)		job/farm
land_access	MIN(0,6; new_forms_of_property)		dmnl
max_agricultural_land	50000		ha
max_improvement_per_diversification	0,015		dmnl/year
max_mean_related_agri_jobs_on_industry	5		farm/job
max_mean_related_agri_jobs_on_services	10		farm/job
mean_jobs_per_farm	1,5		job/farm
mean_working_period_for_farmers	45		year
new_forms_of_property	QUALITY_OF_LIFE.social_innovation*AKIS_effect/5		dmnl
normal_technical_obsolescence_time	7		year
potential_land_transformation	max_agricultural_land-agricultural_land		ha
potential_new_farms	potential_land_transformation/average_farm_area		farm
related_agricultural_jobs_effect_on_services	(farms/max_mean_related_agri_jobs_on_services)*MAX(1; STEP(("CAP_Eco-Schemes"+farm_to_fork_effect_on_services)/8; 2021)) * AKIS_effect		job
related_agricultural_jobs_on_industry	(farms/max_mean_related_agri_jobs_on_industry)*MAX(1; STEP (farm_to_fork_effect_on_industry/4; 2021))* AKIS_effect		job
retirement_not_covered	farmer_retirement-retirement_substitution		farm/year
retirement_substitution	farmer_retirement*generational_transition_ratio		farm/year
technical_obsolescence_time	normal_technical_obsolescence_time+ RAMP(((final_technical_obsolescence_time-normal_technical_obsolescence_time)/time_for_slope); 2021)		year
time_for_slope	19		year
EDUCATION:			
GRADUATED_PROFESSIONALS(t)	GRADUATED_PROFESSIONALS(t - dt) + (becoming_graduated_professional - graduated_migration_net_flow - GradW_retiring) * dt	INIT GRADUATED_PROFESSIONALS = 21700*0,05	person
UNIVERSITY_STUDENTS(t)	UNIVERSITY_STUDENTS(t - dt) + (entering_university - becoming_graduated_professional) * dt	INIT UNIVERSITY_STUDENTS = 2410*0,05	person
UNSKILLED_WORKERS(t)	UNSKILLED_WORKERS(t - dt) + (early_working_entrance - NSW_retitiring - not_specialized_workers_leaving) * dt	INIT UNSKILLED_	person

		WORKERS = 2410*0,8	
VT_PROFESSIONALS(t)	VT_PROFESSIONALS(t - dt) + (becoming_vt_professional - VTW_retiring - VT_professionals_leaving) * dt	INIT VT_PROFESSIONALS = 21700*0,15	person
VT_STUDENTS(t)	VT_STUDENTS(t - dt) + (entering_VT - becoming_vt_professional) * dt	INIT VT_STUDENTS = 2410*0,15	person
becoming_graduated_professional	UNIVERSITY_STUDENTS/time_to_become_graduated_professional		person/ year
becoming_vt_professional	VT_STUDENTS/time_to_become_VT_professional		person/ year
early_working_entrance	POPULATION.aging_1-entering_VT-entering_university		person/ year
entering_university	POPULATION.aging_1* (QUALITY_OF_LIFE.University_Accessibility/5)* DELAY1(students_university_campaign; years_for_education_campaign)		person/ year
entering_VT	POPULATION.aging_1* (QUALITY_OF_LIFE.VT_centers_accessibility/5)* DELAY1(vocational_training_campaign; years_for_education_campaign)		person/ year
graduated_migration_net_flow	POPULATION.WA_migration_ratio*GRADUATED_PROFESSIONALS*graduate_migrating_ratio	OUTFLOW PRIORITY: 1	person/ year
GradW_retiring	GRADUATED_PROFESSIONALS/working_lifetime_duration_for_GP	OUTFLOW PRIORITY: 2	person/ year
not_specialized_workers_leaving	POPULATION.WA_migration_ratio*unskilled_migrating_ratio*UNSKILLED_WORKERS	OUTFLOW PRIORITY: 2	person/ year
NSW_retitiring	UNSKILLED_WORKERS/working_lifetime_duration_for_NSW	OUTFLOW PRIORITY: 1	person/ year
VT_professionals_leaving	POPULATION.WA_migration_ratio*VT_PROFESSIONALS*VT_migrating_ratio	OUTFLOW PRIORITY: 2	person/ year
VTW_retiring	VT_PROFESSIONALS/working_lifetime_duration_for_VT	OUTFLOW PRIORITY: 1	person/ year
graduate_migrating_ratio	0,6		dmnl
initial_fraction_university_students	0,05		dmnl
initial_fraction_VT	0,15		dmnl
students_university_campaign	initial_fraction_university_students+ STEP (university_students_objective-initial_fraction_university_students; 2021)		dmnl
time_to_become_graduated_professional	5		year
time_to_become_VT_professional	3		year

university_students_objective	0,05		dmnl
unskilled_migrating_ratio	0,1		dmnl
vocational_training_campaign	initial_fraction_VT+ STEP(VT_fraction_objective-initial_fraction_VT; 2021)		dmnl
VT_fraction_objective	0,15		dmnl
VT_migrating_ratio	0,3		dmnl
workforce_specialization	(VT_PROFESSIONALS+GRADUATED_PROFESSIONALS)/(VT_PROFESSIONALS+GRADUATED_PROFESSIONALS+UNSKILLED_WORKERS)		dmnl
working_lifetime_duration_for_GP	40		year
working_lifetime_duration_for_NSW	45		year
working_lifetime_duration_for_VT	42		year
years_for_education_campaign	2031-2021		year
EMPLOYMENT:			
Industrial_jobs(t)	Industrial_jobs(t - dt) + (creation_of_industrial_jobs - destruction_of_industrial_jobs) * dt	INIT Industrial_jobs = 3192+250	job
population_services(t)	population_services(t - dt) + (change_in_population_services) * dt	INIT population_services = 38700*0,04	job
Rest_of_primary_sector_jobs(t)	Rest_of_primary_sector_jobs(t - dt) + (creation_of_primary_jobs - destruction_of_primary_jobs) * dt	INIT Rest_of_primary_sector_jobs = 437	job
service_jobs(t)	service_jobs(t - dt) + (creation_of_services_jobs - destruction_of_services_jobs) * dt	INIT service_jobs = 7203	job
change_in_population_services	Difference_of_population*ratio_population_services		job/Years
creation_of_industrial_jobs	QUALITY_OF_LIFE.endogenous_industrial_job_creation		job/Years
creation_of_primary_jobs	QUALITY_OF_LIFE.endogenous_primary_job_creation		job/Years
creation_of_services_jobs	QUALITY_OF_LIFE.endogenous_service_job_creation		job/Years
destruction_of_industrial_jobs	(Industrial_jobs/industrial_obsolescence_time)+ (QUALITY_OF_LIFE.endogenous_industrial_job_creation*(1-new_industrial_job_viability_ratio))		job/Years

destruction_of_primary_jobs	(QUALITY_OF_LIFE.endogenous_primary_job_creation*(1-primary_jobs_viability_ratio))+(Rest_of_primary_sector_jobs/primary_jobs_destruction_time)		job/Years
destruction_of_services_jobs	(service_jobs/services_obsolescence_time)+ STEP((QUALITY_OF_LIFE.endogenous_service_job_creation*(1-new_services_viability_ratio)); 2015)		job/Years
COVID_effect_in_industrial_obsolescence_time	GRAPH(TIME) Points: (2021,00, 0,00), (2021,95, 0,00), (2022,90, 0,00), (2023,85, 0,00), (2024,80, 0,00), (2025,75, 0,00), (2026,70, 0,00), (2027,65, 0,00), (2028,60, 0,00), (2029,55, 0,00), (2030,50, 0,00), (2031,45, 0,00), (2032,40, 0,00), (2033,35, 0,00), (2034,30, 0,00), (2035,25, 0,00), (2036,20, 0,00), (2037,15, 0,00), (2038,10, 0,00), (2039,05, 0,00), (2040,00, 0,00)		year
COVID_effect_in_services_obsolescence_time	GRAPH(TIME) Points: (2021,00, 0,00), (2021,95, 0,00), (2022,90, 0,00), (2023,85, 0,00), (2024,80, 0,00), (2025,75, 0,00), (2026,70, 0,00), (2027,65, 0,00), (2028,60, 0,00), (2029,55, 0,00), (2030,50, 0,00), (2031,45, 0,00), (2032,40, 0,00), (2033,35, 0,00), (2034,30, 0,00), (2035,25, 0,00), (2036,20, 0,00), (2037,15, 0,00), (2038,10, 0,00), (2039,05, 0,00), (2040,00, 0,00)		year
Difference_of_population	POPULATION.total_rural_population-Previous_population		person
employment_gap	total_employment- total_workforce		job
industrial_obsolescence_time	20- STEP (COVID_effect_in_industrial_obsolescence_time; 2021)		year
industrial_ratio	total_industrial_jobs/total_employment		dmnl
jobs_per_tourism	NATURAL_CAPITAL.tourist_visitors/visitors_per_tourism_workplace		job
new_industrial_job_viability_ratio	0,6		dmnl
new_services_viability_ratio	0,6		dmnl
Previous_population	PREVIOUS(POPULATION.total_rural_population; 38700)		person
primary_jobs_destruction_time	10		year
primary_jobs_viability_ratio	0,4		dmnl
primary_ratio	(AGRICULTURE.agriculture_jobs+Rest_of_primary_sector_jobs)/total_employment		dmnl
ratio_population_services	0,04		job/person/year
relative_employment_gap	employment_gap/total_workforce		dmnl
remote_workers	DELAY1(STEP (remote_workers_potential_2030; 2021); years_for_remote_workers_trend)* QUALITY_OF_LIFE.broadband_infrastructure_population_covered/100		job
remote_workers_potential_2030	785		job

services_obsolescence_time	15- STEP (COVID_effect_in_services_obsolescence_time; 2021)		year
services_ratio	(total_services_job+remote_workers)/total_employment		dmnl
structural_unemployment	GRAPH(EDUCATION.workforce_specialization) Points: (0,000, 0,0799224590134), (0,100, 0,0797078641254), (0,200, 0,0789101785383), (0,300, 0,0760774799945), (0,400, 0,0674504380872), (0,500, 0,05), (0,600, 0,0325495619128), (0,700, 0,0239225200055), (0,800, 0,0210898214617), (0,900, 0,0202921358746), (1,000, 0,0200775409866)		job/person
total_employment	total_regional_employment+remote_workers		job
total_industrial_jobs	AGRICULTURE.related_agricultural_jobs_on_industry+Industrial_jobs		job
total_regional_employment	AGRICULTURE.agriculture_jobs+ total_industrial_jobs+ total_services_job+ Rest_of_primary_sector_jobs		job
total_services_job	population_services+AGRICULTURE.related_agricultural_jobs_effect_on_services+service_jobs +jobs_per_tourism		job
total_workforce	POPULATION.WORKING_AGE_POPULATION* (workforce_as_ratio_of_WAP-structural_unemployment)		job
visitors_per_tourism_workplace	200		person/job/year
workforce_as_ratio_of_WAP	0,7		job/person
years_for_remote_workers_trend	7		year
NATURAL_CAPITAL:			
Natural_Capital(t)	Natural_Capital(t - dt) + (natural_capital_net_variation) * dt	INIT Natural_Capital = initial_natural_land-1160	ha
natural_capital_net_variation	DELAY1(natural_land_variation; years_for_completing_natural_land_objective)+ (Natural_Capital*effect_of_tourism_on_natural_capital)+ effect_of_agriculture_on_Natural_Capital		ha/year
attraction_ratio_for_tourists	DELAY1(tourist_campaign; time_to_complete_campaign)		dmnl
attraction_ratio_objective	0,05		dmnl
difference_of_agricultural_land	AGRICULTURE.agricultural_land-previous_agricultural_land		ha
effect_of_agriculture_on_Natural_Capital	IF difference_of_agricultural_land<0 THEN ABS (difference_of_agricultural_land)* ratio_effect_of_agriculture_on_Natural_Capital ELSE difference_of_agricultural_land* ratio_effect_of_agriculture_on_Natural_Capital		ha/year
effect_of_tourism_on_natural_capital	GRAPH(tourist_visitors/POPULATION.total_rural_population) Points: (0,000, 0,0000), (0,214285714286, 0,0058), (0,428571428571, 0,0101), (0,642857142857, 0,0138), (0,857142857143, 0,0119), (1,07142857143, -0,0052),		dmnl/year

	(1,28571428571, -0,0186), (1,500, -0,0394), (1,71428571429, -0,0511), (1,92857142857, -0,0601928552048), (2,14285714286, -0,0738073544218), (2,35714285714, -0,0838173695694), (2,57142857143, -0,0904980622933), (2,78571428571, -0,0946186541998), (3,000, -0,0970239541399)		
initial_Natural_capital	INIT(Natural_Capital)		ha
initial_natural_land	400000		ha
natural_capital_effect_on_tourism_attraction	GRAPH(Natural_Capital) Points: (200000, 3346,42546214), (260000, 8993,10498105), (320000, 23712,9365888), (380000, 59601,4610111), (440000, 134470,710685), (500000, 250000), (560000, 365529,289315), (620000, 440398,538989), (680000, 476287,063411), (740000, 491006,895019), (800000, 496653,574538)		person/year
natural_capital_perception	GRAPH(relative_natural_capital) Points: (0,000, 0,000531042606491), (0,500, 0,00330862021279), (1,000, 0,0205543756117), (1,500, 0,125434810767), (2,000, 0,691191365862), (2,500, 2,500), (3,000, 4,30880863414), (3,500, 4,87456518923), (4,000, 4,97944562439), (4,500, 4,99669137979), (5,000, 4,99946895739)		dmnl
natural_land_objective	550000		ha
natural_land_variation	STEP((natural_land_objective-initial_natural_land)/years_for_completing_natural_land_objective; 2021)		ha/year
normal_attraction_ratio	0,05		dmnl
previous_agricultural_land	PREVIOUS(AGRICULTURE.agricultural_land; AGRICULTURE.initial_number_of_farms*AGRICULTURE.average_farm_area)		ha
ratio_effect_of_agriculture_on_Natural_Capital	GRAPH(AGRICULTURE."CAP_Eco-Schemes"+AGRICULTURE."diversification/_multifunctionality") Points: (0,00, -0,19732285963), (1,00, -0,192805516015), (2,00, -0,181029650729), (3,00, -0,152318831191), (4,00, -0,092423431452), (5,00, 0,0000), (6,00, 0,092423431452), (7,00, 0,152318831191), (8,00, 0,181029650729), (9,00, 0,192805516015), (10,00, 0,19732285963)		dmnl/year
relative_natural_capital	Natural_Capital/initial_Natural_capital		dmnl
time_to_complete_campaign	8		year
tourist_campaign	normal_attraction_ratio+ STEP (attraction_ratio_objective-normal_attraction_ratio; 2021)		dmnl
tourist_visitors	DELAY1((attraction_ratio_for_tourists*(QUALITY_OF_LIFE.city_and_regional_connections_access/5))*natural_capital_effect_on_tourism_attraction; 3)		person/year
years_for_completing_natural_land_objective	10		year
POPULATION:			

ELDERLY_POPULATION(t)	ELDERLY_POPULATION(t - dt) + (aging_3 + elderly_net_migration - elderly_deaths) * dt	INIT ELDERLY_POPULATION = 8508	person
INFANTS(t)	INFANTS(t - dt) + (births + infant_net_migration - aging - rural_infant_deaths) * dt	INIT INFANTS = 6161*0,33	person
NEWCOMERS(t)	NEWCOMERS(t - dt) + (newcomers_arrival - newcomers_integration) * dt	INIT NEWCOMERS = 4000	person
POST_SCHOOL_POPULATION(t)	POST_SCHOOL_POPULATION(t - dt) + (post_school_net_migration + aging_1 - aging_2 - Rural_Post_school_age_deaths) * dt	INIT POST_SCHOOL_POPULATION = 24069*0,1	person
SCHOOL_AGE_POPULATION(t)	SCHOOL_AGE_POPULATION(t - dt) + (children_net_migration + aging - aging_1 - rural_children_deaths) * dt	INIT SCHOOL_AGE_POPULATION = 6161*0,67	person
WORKING_AGE_POPULATION(t)	WORKING_AGE_POPULATION(t - dt) + (working_age_net_migration + aging_2 - aging_3 - working_age_deaths) * dt	INIT WORKING_AGE_POPULATION = 24069*0,9	person
aging	INFANTS/infant_duration	OUTFLOW PRIORITY: 2	person/ year
aging_1	SCHOOL_AGE_POPULATION/school_age_duration	OUTFLOW PRIORITY: 2	person/ year
aging_2	POST_SCHOOL_POPULATION/postschool_age_duration	OUTFLOW PRIORITY: 1	person/ year
aging_3	WORKING_AGE_POPULATION/working_age_duration	OUTFLOW PRIORITY: 2	person/ year
births	total_rural_population*birth_rate		person/ year
children_net_migration	working_age_net_migration*mean_fecundity_rate*2/3		person/ year
elderly_deaths	ELDERLY_POPULATION/ DELAY1(life_expectancy; 1)		person/ year
elderly_net_migration	RURAL_ATTRACTIVENESS.elderly_move_rural-(ELDERLY_POPULATION*RURAL_RETENTION_CAPACITY.elderly_leaving_ratio)		person/ year
infant_net_migration	working_age_net_migration*mean_fecundity_rate/3		person/ year
newcomers_arrival	MIN(0; infant_net_migration)+ MIN(0; children_net_migration)+ RURAL_ATTRACTIVENESS.PS_moving+ RURAL_ATTRACTIVENESS.WA_moving+ RURAL_ATTRACTIVENESS.elderly_move_rural		person/ year
newcomers_integration	NEWCOMERS/integration_time		person/ year
post_school_net_migration	RURAL_ATTRACTIVENESS.PS_moving-(POST_SCHOOL_POPULATION*max_post_school_leaving_per_year* RURAL_RETENTION_CAPACITY.post_school_leaving_ratio)		person/ year

rural_children_deaths	SCHOOL_AGE_POPULATION*children_death_rate	OUTFLOW PRIORITY: 3	person/year
rural_infant_deaths	INFANTS*infant_death_rate	OUTFLOW PRIORITY: 3	person/year
Rural_Post_school_age_deaths	POST_SCHOOL_POPULATION*post_school_death_rate	OUTFLOW PRIORITY: 3	person/year
working_age_deaths	WORKING_AGE_POPULATION*working_age_death_rate	OUTFLOW PRIORITY: 3	person/year
working_age_net_migration	RURAL_ATTRACTIVENESS.WA_moving-(WORKING_AGE_POPULATION*RURAL_RETENTION_CAPACITY.WA_leaving_ratio*max_WA_population_living_rural_per_year)		person/year
birth_rate	0,009		dmnl/year
children_death_rate	0,0000091		dmnl/year
infant_death_rate	0,0017		dmnl/year
infant_duration	5		year
initial_rural_population	INIT (total_rural_population)		person
integration_time	7		year
life_expectancy	(normal_life_expectancy- STEP (smooth_life_expectancy; 2020)+ STEP(smooth_life_expectancy; 2022))- 65		year
"life_expectancy_drop_2020_-_2022"	0		year
max_post_school_leaving_per_year	0,02		dmnl/year
max_WA_population_living_rural_per_year	0,07		dmnl/year
mean_fecundity_rate	1,4		dmnl
normal_life_expectancy	82		year
post_school_death_rate	0,00002475		dmnl/year
postschool_age_duration	5		year
proportion_of_newcomers	NEWCOMERS/total_rural_population		dmnl
school_age_duration	10		year
smooth_life_expectancy	SMTH3("life_expectancy_drop_2020_-_2022"; 5)		year
total_population_in_relation_to_initial_population	total_rural_population/initial_rural_population		dmnl

total_rural_population	INFANTS+ SCHOOL_AGE_POPULATION+ WORKING_AGE_POPULATION+ ELDERLY_POPULATION+ POST_SCHOOL_POPULATION		person
WA_migration_ratio	IF working_age_net_migration<0 THEN ABS(working_age_net_migration/WORKING_AGE_POPULATION) ELSE 0		dmnl/year
working_age_death_rate	0,001755		dmnl/year
working_age_duration	40		year
QUALITY_OF_LIFE:			
broadband_infrastructure_population_covered(t)	broadband_infrastructure_population_covered(t - dt) + (building_infrastructure - broadband_infrastructure_depletion) * dt	INIT broadband_infrastructure_population_covered = initial_population_covered	dmnl
implemented_initiatives(t)	implemented_initiatives(t - dt) + (planning_initiatives - becoming_stablished_jobs) * dt	INIT implemented_initiatives = 353*0,2	initiative
mobility_infrastructures(t)	mobility_infrastructures(t - dt) + (building_mobility_infrastructures - mobility_infrastructures_depletion) * dt	INIT mobility_infrastructures = initial_mobility_infrastructures	km
potential_initiatives(t)	potential_initiatives(t - dt) + (creating_potential_initiatives - planning_initiatives - dismissing_potential_initiatives) * dt	INIT potential_initiatives = 353	initiative
shared_knowledge(t)	shared_knowledge(t - dt) + (building_shared_knowledge - shared_knowledge_loss) * dt	INIT shared_knowledge = 5	dmnl
becoming_stablished_jobs	implemented_initiatives/time_to_implement_initiatives		initiative/year
broadband_infrastructure_depletion	broadband_infrastructure_population_covered/broadband_infrastructures_depletion_time		dmnl/year
building_infrastructure	broadband_infrastructure_depletion+ STEP (broadband_campaign; year_initiating_broadband_plan)- STEP(broadband_campaign; year_initiating_broadband_plan+time_to_complete_broadband_campaign)		dmnl/year
building_mobility_infrastructures	MIN (max_km_year_infrastructures; mobility_infrastructures_depletion+ STEP(infrastructure_campaign; year_initiating_infrastructures_plan)- STEP(infrastructure_campaign; year_initiating_infrastructures_plan+time_for_infrastructure_campaign_extension))		km/Years
building_shared_knowledge	community_activity_and_networks/time_to_build_effective_shared_knowledge		dmnl/year
creating_potential_initiatives	effect_of_social_innovation_in_creating_initiatives_ratio*effect_of_broadband_in_creating_potential_initiatives*POPULATION.WORKING_AGE_POPULATION		initiative/year

dismissing_potential_initiatives	potential_initiatives/potential_initiatives_active_time	OUTFLOW PRIORITY: 2	initiative/year
mobility_infrastructures_depletion	mobility_infrastructures/infrastructures_depletion_time		km/Years
planning_initiatives	potential_initiatives*institutional_support	OUTFLOW PRIORITY: 1	initiative/year
shared_knowledge_loss	shared_knowledge/shared_knowledge_loss_time		dmnl/year
broadband_campaign	broadband_gap/time_to_complete_broadband_campaign		dmnl/year
broadband_effect_on_retention	GRAPH(broadband_infrastructure_population_covered) Points: (63,00, 0,8300), (65,00, 0,9700), (70,40, 0,9837), (74,10, 0,9873), (77,80, 0,993546776182), (81,50, 0,997173519462), (85,20, 0,998777254131), (88,90, 0,999486420645), (92,60, 0,999800011885), (96,30, 0,999938680963), (100,00, 1,0000)		dmnl
broadband_gap	population_covered_objective-initial_population_covered		dmnl
broadband_infrastructures_depletion_time	10		year
city_and_regional_connections_access	GRAPH(mobility_infrastructures) Points: (0, 0,000), (2000, 1,67915455835), (4000, 2,80472551921), (6000, 3,5592182975), (8000, 4,06496993138), (10000, 4,40398538989), (12000, 4,63123424764), (14000, 4,78356371243), (16000, 4,88567320628), (18000, 4,9541192469), (20000, 5,000)		dmnl
community_accessibility	GRAPH(mobility_infrastructures) Points: (0, 0,000), (2000, 0,229619398287), (4000, 0,411695209995), (6000, 0,556071519037), (8000, 0,670554153589), (10000, 0,761332714843), (12000, 0,833315223069), (14000, 0,890393473912), (16000, 0,935653451643), (18000, 0,971542175526), (20000, 1,000)		dmnl
community_activity_and_networks	community_accessibility*community_climate		dmnl
community_climate	GRAPH(TIME) Points: (2010,00, 3,000), (2011,50, 3,000), (2013,00, 3,000), (2014,50, 3,000), (2016,00, 3,000), (2017,50, 3,000), (2019,00, 3,000), (2020,50, 3,000), (2022,00, 3,000), (2023,50, 3,000), (2025,00, 3,000), (2026,50, 3,000), (2028,00, 3,000), (2029,50, 3,000), (2031,00, 3,000), (2032,50, 3,000), (2034,00, 3,000), (2035,50, 3,000), (2037,00, 3,000), (2038,50, 3,000), (2040,00, 3,000)		dmnl
cultural_appeal	GRAPH(shared_knowledge) Points: (0,00, 0,000), (4,00, 1,67915455835), (8,00, 2,80472551921), (12,00, 3,5592182975), (16,00, 4,06496993138), (20,00, 4,40398538989), (24,00, 4,63123424764), (28,00, 4,78356371243), (32,00, 4,88567320628), (36,00, 4,9541192469), (40,00, 5,000)		dmnl
effect_of_broadband_in_creating_potential_initiatives	GRAPH(broadband_infrastructure_population_covered) Points: (0,0, 0,00669285092428), (10,0, 0,0179862099621), (20,0, 0,0474258731776), (30,0, 0,119202922022), (40,0, 0,26894142137), (50,0, 0,500), (60,0, 0,73105857863), (70,0, 0,880797077978), (80,0, 0,952574126822), (90,0, 0,982013790038), (100,0, 0,993307149076)		dmnl
effect_of_c&r_connections_on_retention	GRAPH(city_and_regional_connections_access) Points: (4,000, 0,7000), (4,140, 0,7100), (4,230, 0,9100), (4,600, 0,9658), (4,800, 0,9819), (5,000, 1,0000)		dmnl

effect_of_social_innovation_in_creating_initiatives_ratio	GRAPH(social_innovation) Points: (0,000, 0), (0,500, 0,0100749273501), (1,000, 0,0168283531152), (1,500, 0,021355309785), (2,000, 0,0243898195883), (2,500, 0,0264239123393), (3,000, 0,0277874054859), (3,500, 0,0287013822746), (4,000, 0,0293140392377), (4,500, 0,0297247154814), (5,000, 0,03)		initiative/person/year
endogenous_industrial_job_creation	becoming_stablished_jobs*0,2*mean_job_per_industrial_initiative		job/year
endogenous_primary_job_creation	becoming_stablished_jobs*0,1*mean_job_per_primary_initiative		job/year
endogenous_service_job_creation	becoming_stablished_jobs*0,7*mean_jobs_per_service_initiative		job/year
health_centers_accessibility	GRAPH(mobility_infrastructures) Points: (0, 0,000), (2000, 0,147718181852), (4000, 0,332894099942), (6000, 0,565026124654), (8000, 0,856021181965), (10000, 1,22080550453), (12000, 1,67809025436), (14000, 2,25133128886), (16000, 2,96993230005), (18000, 3,87075304072), (20000, 5,000)		dmnl
infrastructure_campaign	infrastructures_gap/time_for_infrastructure_campaign_extension		km/year
infrastructures_depletion_time	30		year
infrastructures_gap	infrastructures_objective-initial_mobility_infrastructures		km
infrastructures_objective	9000		km
initial_mobility_infrastructures	9000		km
initial_population_covered	65		dmnl
institutional_support	0,2		dmnl/year
max_km_year_infrastructures	500		km/year
mean_job_per_industrial_initiative	10		job/initiative
mean_job_per_primary_initiative	5		job/initiative
mean_jobs_per_service_initiative	5		job/initiative
population_covered_objective	65		dmnl
potential_initiatives_active_time	2		year
shared_knowledge_loss_time	3		year
social_capital	GRAPH(shared_knowledge) Points: (0,00, 1,000), (1,00, 1,26666666667), (2,00, 1,53333333333), (3,00, 1,800), (4,00, 2,06666666667), (5,00, 2,33333333333), (6,00, 2,600), (7,00, 2,86666666667), (8,00, 3,13333333333), (9,00, 3,400), (10,00,		dmnl

	3,66666666667), (11,00, 3,93333333333), (12,00, 4,200), (13,00, 4,46666666667), (14,00, 4,73333333333), (15,00, 5,000)		
social_capital_effect_on_retention	GRAPH(social_capital) Points: (0,000, 0,5000), (0,500, 0,667915455835), (1,000, 0,780472551921), (1,500, 0,85592182975), (2,000, 0,906496993138), (2,500, 0,940398538989), (3,000, 0,963123424764), (3,500, 0,978356371243), (4,000, 0,988567320628), (4,500, 0,99541192469), (5,000, 1,0000)		dmnl
social_innovation	social_capital*EDUCATION.workforce_specialization		dmnl
time_for_infrastructure_campaign_extension	10		year
time_to_build_effective_shared_knowledge	GRAPH(POPULATION.proportion_of_newcomers) Points: (0,0000, 1,0267714037), (0,0400, 1,07194483985), (0,0800, 1,18970349271), (0,1200, 1,47681168809), (0,1600, 2,07576568548), (0,2000, 3,000), (0,2400, 3,92423431452), (0,2800, 4,52318831191), (0,3200, 4,81029650729), (0,3600, 4,92805516015), (0,4000, 4,9732285963)		year
time_to_complete_broadband_campaign	10		year
time_to_implement_initiatives	1		year
University_Accessibility	GRAPH(mobility_infrastructures) Points: (0, 0,000), (2000, 1,86230131944), (4000, 3,0379416854), (6000, 3,78010422143), (8000, 4,24861929274), (10000, 4,54438519493), (12000, 4,73109737188), (14000, 4,8489657156), (16000, 4,92337407332), (18000, 4,97034685263), (20000, 5,000)		dmnl
VT_centers_accessibility	GRAPH(mobility_infrastructures) Points: (0, 0,000), (2000, 1,93372405103), (4000, 3,12550371254), (6000, 3,86001325169), (8000, 4,31270117761), (10000, 4,59169872269), (12000, 4,76364859303), (14000, 4,86962356819), (16000, 4,93493734445), (18000, 4,97519108702), (20000, 5,000)		dmnl
year_initiating_broadband_plan	2021		year
year_initiating_infrastructures_plan	2021		year
RURAL_ATTRACTIVENESS:			
potential_commuters(t)	potential_commuters(t - dt) + (increasing_potential_commuters - potential_commuters_moving) * dt	INIT potential_commuters = 10000	person
increasing_potential_commuters	SMTH3(potential_commuters_moving; 3)		person/year
potential_commuters_moving	SMTH1(potential_commuters*attraction_ratio_for_commuters* max_attraction_ratio_for_commuters; 3)		person/year
additional_attraction_from_2021	0		dmnl/year
attraction_ratio_for_commuters	GRAPH(housing_accessibility+QUALITY_OF_LIFE.city_and_regional_connections_access) Points: (0,00, 0,000), (1,11111111111, 0,00702648084747), (2,22222222222, 0,018675727878), (3,33333333333, 0,0379890881967), (4,44444444444, 0,0700088304014), (5,55555555556, 0,123094563487),		dmnl

	(6,66666666667, 0,211105736068), (7,77777777778, 0,35702001565), (8,88888888889, 0,598932222491), (10,00, 1,000)		
cultural_appeal_factor_for_elderly	cultural_appeal_weight_for_elderly*QUALITY_OF_LIFE.cultural_appeal/5		dmnl
cultural_appeal_factor_for_WA	cultural_appeal_weight_for_WA*0,52*QUALITY_OF_LIFE.cultural_appeal/5		dmnl
cultural_appeal_weight_for_elderly	0,1		dmnl
cultural_appeal_weight_for_WA	0,15		dmnl
elderly_move_rural	maximum_elderly_population_moving* (natural_capital_factor_for_elderly+ cultural_appeal_factor_for_elderly+ housing_accessibility_factor_for_elderly+ medical_and_care_services_factor)		person/ year
housing_accessibility	GRAPH(POPULATION.total_population_in_relation_to_initial_population) Points: (0,7000, 4,99893072664), (0,788888888889, 4,99301633912), (0,877777777778, 4,954684716), (0,966666666667, 4,71784921323), (1,05555555556, 3,5943758176), (1,14444444444, 1,4056241824), (1,23333333333, 0,282150786772), (1,32222222222, 0,0453152840046), (1,41111111111, 0,00698366088015), (1,5000, 0,00106927335882)		dmnl
housing_accessibility_factor_for_elderly	housing_accessibility_weight_for_elderly*housing_accessibility/5		dmnl
housing_accessibility_factor_for_WA	housing_accessibility_weight_for_WA*housing_accessibility*0,52/5		dmnl
housing_accessibility_factor_for_young	housing_accessibility_weight_for_young*0,5*housing_accessibility/5		dmnl
housing_accessibility_weight_for_elderly	0,25		dmnl
housing_accessibility_weight_for_WA	0,7		dmnl
housing_accessibility_weight_for_young	0,65		dmnl
max_attraction_ratio_for_commuters	normal_max_attraction_ratio_for_commuters+ STEP(additional_attraction_from_2021; 2021)		dmnl/year
maximum_elderly_population_moving	500		person/ year
medical_and_care_services_factor	QUALITY_OF_LIFE.health_centers_accessibility*medical_and_care_services_weight/5		dmnl
medical_and_care_services_weight	0,55		dmnl
natural_capital_factor_for_elderly	NATURAL_CAPITAL.natural_capital_perception*natural_capital_weight_for_elderly/5		dmnl
natural_capital_factor_for_WA	natural_capital_weight_for_WA*0,52* NATURAL_CAPITAL.natural_capital_perception/5		dmnl
natural_capital_factor_for_young	natural_capital_weight_for_young*NATURAL_CAPITAL.natural_capital_perception/5		dmnl

natural_capital_weight_for_elderly	0,1		dmnl
natural_capital_weight_for_WA	0,15		dmnl
natural_capital_weight_for_young	0,5-(housing_accessibility_weight_for_young/2)		dmnl
normal_max_attraction_ratio_for_commuters	0,07		dmnl/year
people_applying_employment_gap	0,9		person/year/job
PS_moving	IF EMPLOYMENT.employment_gap>0 THEN (EMPLOYMENT.employment_gap*people_applying_employment_gap)* (housing_accessibility_factor_for_young+ natural_capital_factor_for_young) ELSE 0		person/year
WA_moving	IF EMPLOYMENT.employment_gap>0 THEN SMTH1 (((EMPLOYMENT.employment_gap*people_applying_employment_gap*(housing_accessibility_factor_for_WA+natural_capital_factor_for_WA+cultural_appeal_factor_for_WA))+ (potential_commuters_moving)); 2) ELSE SMTH1 (potential_commuters_moving; 2)		person/year
RURAL_RETENTION_CAPACITY:			
broadband_factor_for_WA	broadband_weight_for_WA*QUALITY_OF_LIFE.broadband_effect_on_retention		dmnl
broadband_factor_for_young	broadband_weight_for_young*QUALITY_OF_LIFE.broadband_effect_on_retention		dmnl
broadband_weight_for_WA	0,3		dmnl
broadband_weight_for_young	0,05		dmnl
c&r_connections_weight	0,35		dmnl
c&r_factor	QUALITY_OF_LIFE.city_and_regional_connections_access*c&r_connections_weight/5		dmnl
effect_of_employment_in_PS_leaving_ratio	GRAPH(EMPLOYMENT.relative_employment_gap) Points: (-1,000, 0,000753551790299), (-0,800, 0,00437679818215), (-0,600, 0,0253331466673), (-0,400, 0,143742479633), (-0,200, 0,733951699007), (0,000, 2,500), (0,200, 4,26604830099), (0,400, 4,85625752037), (0,600, 4,97466685333), (0,800, 4,99562320182), (1,000, 4,99924644821)		dmnl
effect_of_employment_in_WA_leaving_ratio	GRAPH(EMPLOYMENT.relative_employment_gap) Points: (-1,000, 1,98661429815), (-0,800, 1,96402758008), (-0,600, 1,90514825364), (-0,400, 1,76159415596), (-0,200, 1,46211715726), (0,000, 1,000), (0,200, 0,53788284274), (0,400, 0,238405844044), (0,600, 0,0948517463551), (0,800, 0,0359724199242), (1,000, 0,0133857018486)		dmnl
elderly_leaving_ratio	maximum_ratio_elderly_population_leaving* (1-medical_and_care_factor+ social_capital_factor_for_elderly)		dmnl/year

employment_factor_for_young	(employment_weight_for_young/5)*effect_of_employment_in_PS_leaving_ratio		dmnl
employment_weight_for_young	0,7		dmnl
higher_education_factor	(QUALITY_OF_LIFE.VT_centers_accessibility+QUALITY_OF_LIFE.University_Accessibility)*higher_education_weight/10		dmnl
higher_education_weight	0,1		dmnl
housing_accessibility_weight_for_young	0,05		dmnl
housing_factor_for_young	housing_accessibility_weight_for_young*RURAL_ATTRACTIVENESS.housing_accessibility/5		dmnl
maximum_ratio_elderly_population_leaving	0,07		dmnl/year
medical_and_care_factor	medical_and_care_weight*QUALITY_OF_LIFE.health_centers_accessibility/5		dmnl
medical_and_care_weight	0,7		dmnl
post_school_leaving_ratio	1- (higher_education_factor+ broadband_factor_for_young+ social_capital_factor_for_young+ housing_factor_for_young+ employment_factor_for_young)		dmnl
retention_factor	social_capital_factor_for_WA+broadband_factor_for_WA+c&r_factor		dmnl
social_capital_factor_for_elderly	social_capital_weight_for_elderly*QUALITY_OF_LIFE.social_capital_effect_on_retention		dmnl
social_capital_factor_for_WA	(social_capital_weight_for_WA/5)*QUALITY_OF_LIFE.social_capital_effect_on_retention		dmnl
social_capital_factor_for_young	social_capital_weight_for_young*QUALITY_OF_LIFE.social_capital_effect_on_retention		dmnl
social_capital_weight_for_elderly	0,3		dmnl
social_capital_weight_for_WA	0,35		dmnl
social_capital_weight_for_young	0,1		dmnl
WA_leaving_ratio	(1-retention_factor)* effect_of_employment_in_WA_leaving_ratio		dmnl

Table 3 PoliRural SDM ed.3, equations and units

Run Specs	
Start Time	2010
Stop Time	2040
DT	1/4
Fractional DT	True
Save Interval	0,25
Sim Duration	1,5
Time Units	Years
Pause Interval	0
Integration Method	Euler
Keep all variable results	True
Run By	Run
Calculate loop dominance information	True
Exhaustive Search Threshold	1000

Table 4 Model Run Specifications