Appendices

Appendix 1. Data inputs

Appendix 1.1. Data for population aging chain

We used population estimates for Peru in 2019 from INEI to inform baseline population variables for each age group in the model. INEI uses estimates from the UN Population Division and extrapolation approaches to estimate population by calendar year and single year of age (Instituto Nacional de Estadística e Informática, 2020). We used Peru-specific estimates on fertility rate, defined as the number of births per woman over her childbearing years, and female population percentage in 2019 from the World Bank. Finally, we used modelled estimates of age-specific mortality rates in 2019 in Peru from the World Bank and the UN to represent mortality rates for each population stock in our model. Specifically, we used World Bank data on infant mortality rate for infants 0-12 months, which is defined as the number of infants dying each year before reaching the age of one. We used under-5 mortality rate for children 1-5 years, which is estimated by the World Bank using age-specific mortality rates and is defined as the probability that a newborn baby will die before reaching the age of five. We assumed that under-5 mortality rate is equal to 1-5 mortality rate. We used estimates of mortality rates for children 5-15 from the UN, which are defined as the probability of a child dying between the ages 5-15. Finally, we informed mortality rate for adults of reproductive age (15-49) using adult mortality rate estimates from the World Bank, defined as the probability of a 15-year old dying before reaching the age of 60. As only sex-stratified rates were available, we used the mean of male and female mortality rates in our simulation. All exogenous variables used in the population aging chain and their sources are presented in Appendix Table 1.

Appendix Table 1. Exogenous variables of population aging chain

Variable	**Value**	**Source**
Baseline population children 0-1	568,862	INEI
Baseline population children 1-5	2,211,089	INEI
Baseline population children 5-15	5,387,265	INEI
Baseline population adults 15-49	16,825,998	INEI
Fertility rate	2.233	World Bank
Female percentage	0.503	World Bank
Infant mortality rate	0.0126	World Bank
Under-5 mortality rate	0.013	World Bank
Mortality rate 5-15	0.003	UN Inter-agency Group for Child Mortality Estimation
Adult mortality rate	0.114	World Bank

Appendix 1.2. Data for stunting/short stature and overweight co-flows

We used data from the ENDES 2019 to describe baseline prevalence of stunting and overweight in children 0-5 years old, and short stature and overweight in adults of reproductive age (15-49). Stunted was defined as height-for-age Z score 2 Standard Deviations (SD) below the average Z score according to the WHO's 2006 Child Growth Standards (World Health Organization (WHO), 2006). Adult short stature was defined as height below 145 cm for women, to reflect categorisation in employed RRs, and 157 cm for men, based on previously estimated average difference in male and female height globally (Bentham *et al.*, 2016). Overweight in children was defined as weight-for-height Z score 2SD below WHO's average Z score, and for adults as BMI≥25Kg/m^2. For children aged 5-15, primary data were not available, so we used estimates from published literature. Stunted prevalence estimates were obtained from a recent analysis of the 'The Peruvian Health and Optimist Growth Study', a cross-sectional study of children and adolescents in three regions in Peru, carried out between 2009 and 2010 (Santos *et al.*, 2020). We used the mean of male and female stunting prevalence provided. Overweight estimates were obtained from a cross-sectional analysis of a subsample of Peru's household survey (ENAHO), conducted in 2013-2014 and included 2,801 schoolchildren aged 5-13 years (Tarqui-Mamani, Alvarez-Dongo and Espinoza-Oriundo, 2018). Baseline gestational age and size were obtained from published data from Peru's national birth registries between 2012 and 2019 (Carrillo-Larco *et al.*, 2021). SGA and LGA were defined as birth weight <10th and >90th percentile for gestational age respectively, using international growth curves (INTERGROWTH-21st), while preterm was defined as birth before the 37th week of gestation.

We obtained relative risks (RR) that quantify associations between maternal, neonatal, and childhood malnutrition indicators from relevant meta-analyses. Kozuki et al. performed a meta-analysis of 12 cohort studies from LMICs, using individual data, to quantify associations between maternal short stature (<145 cm vs >155 cm) and SGA, preterm, and their combination (Kozuki *et al.*, 2015). Christian et al. pooled data from 19 longitudinal birth cohorts to quantify associations between stunting at 12-60 months and SGA, preterm, and their combination (Christian *et al.*, 2013). A recent meta-analysis of 31 longitudinal cohort studies quantified the association between maternal overweight and large for gestational age (LGA) (Vats *et al.*, 2021). Finally, a meta-analysis of 66 cohort and case-control studies showed that high birth weight (>4,000 kg) was associated with increased risk of overweight at later life (ages 1-75 years) (Schellong *et al.*, 2012). We assumed no difference between LGA and high birth weight.

Appendix Table 2. Exogenous variables of stunting/short stature and overweight aging chains

Variable	**Value**	**Source**
Baseline characteristics		
Baseline stunting prevalence children 0-1	10.07%	Own estimates from ENDES, 2019
Baseline stunting prevalence children 1-5	13%	
Baseline stunting prevalence children 5-15	11.3%	Santos et al, 2020
Baseline short stature prevalence adults 15-49	8.17%	Own estimates from ENDES, 2019
Ratio of female to male short stature prevalence	0.76	

Baseline overweight prevalence children 0-1	12.77%	
Baseline overweight prevalence children 1-5	10.73%	
Baseline overweight prevalence children 5-15	18.1%	Tarqui-Mamani et al, 2018
Baseline overweight prevalence adults 15-49	61.2%	Own estimates from ENDES, 2019
Ratio of female to male overweight prevalence	1.14	
Baseline SGA and preterm prevalence	0.69%	Own estimates from Carrillo-Larco, 2021
Baseline SGA and term prevalence	4.77%	
Baseline AGA and preterm prevalence	5.91%	
Baseline LGA	16.16%	
Relative Risks		
RR between maternal short stature and AGA & preterm	1.44	Kozuki et al., 2015
RR between maternal short stature and SGA & term	2.03	
RR between maternal short stature and SGA & preterm	2.13	
RR between AGA & preterm and stunting	1.93	Christian, 2013
RR between SGA & term and stunting	2.43	
RR between SGA & preterm and stunting	4.51	
RR between maternal overweight & LGA	1.67	Vats, 2021
RR between LGA & child overweight	1.66	Schellong, 2012
Transition probabilities		
Stunting recovery rate 1-5	33.12%	Own estimates from Young Lives study
Stunting faltering rate 1-5	19.89%	
Stunting recovery rate 5-15	62.87%	
Stunting faltering rate 5-15	4.92%	
Overweight recovery rate 1-5	5.33%	
Overweight faltering rate 1-5	20.76%	
Overweight recovery rate 5-15	54.68%	
Overweight faltering rate 5-15	16.57%	
Overweight recovery rate 15-49	0.0%	Own estimates using data from ENDES and heuristic by Miesel, 2018
Overweight faltering rate 15-49	18.46%	

References for Appendix 1.

Bentham, J. *et al.* (2016) ‘A century of trends in adult human height’, *eLife*. eLife Sciences Publications Ltd, 5(2016JULY). doi: 10.7554/ELIFE.13410.001.

Carrillo-Larco, R. M. *et al.* (2021) ‘National and subnational trends of birthweight in Peru: Pooled analysis of 2,927,761 births between 2012 and 2019 from the national birth registry’, *The Lancet Regional Health - Americas*. Elsevier BV, 1, p. 100017. doi: 10.1016/j.lana.2021.100017.

Christian, P. *et al.* (2013) ‘Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries’, *International Journal of Epidemiology*. Int J Epidemiol, 42(5), pp. 1340–1355. doi: 10.1093/ije/dyt109.

Instituto Nacional de Estadística e Informática (2020) *Perú: Estimaciones y Proyecciones de Población Departamental por Años Calendario y Edad Simple 1995-2030*. Lima. Available at: https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1722/.

INTERGROWTH-21st (no date) *INTERGROWTH-21st Applications and Calculators*. Available at: https://intergrowth21.tghn.org/intergrowth-21st-applications/.

Kozuki, N. *et al.* (2015) ‘Short maternal stature increases risk of small for-gestational-age and preterm births in lowand middle-income countries: Individual participant data meta-analysis and population attributable fraction’, *Journal of Nutrition*. American Society for Nutrition, 145(11), pp. 2542–2550. doi: 10.3945/jn.115.216374.

Meisel, J. D. *et al.* (2018) ‘Towards a novel model for studying the nutritional stage dynamics of the Colombian population by age and socioeconomic status’, *PLOS ONE*. Public Library of Science, 13(2), p. e0191929. doi: 10.1371/JOURNAL.PONE.0191929.

Santos, C. *et al.* (2020) ‘Stunting and Physical Fitness. The Peruvian Health and Optimist Growth Study’, *International Journal of Environmental Research and Public Health*. Multidisciplinary Digital Publishing Institute (MDPI), 17(10). doi: 10.3390/IJERPH17103440.

Schellong, K. *et al.* (2012) ‘Birth Weight and Long-Term Overweight Risk: Systematic Review and a Meta-Analysis Including 643,902 Persons from 66 Studies and 26 Countries Globally’, *PLoS ONE*. Public Library of Science, 7(10), p. e47776. doi: 10.1371/journal.pone.0047776.

Tarqui-Mamani, C., Alvarez-Dongo, D. and Espinoza-Oriundo, P. (2018) ‘Prevalence and factors associated with overweight and obesity in peruvian primary school children’, *Revista de Salud Publica*. Rev Salud Publica (Bogota), 20(2), pp. 171–176. doi: 10.15446/rsap.v20n2.68082.

Vats, H. *et al.* (2021) ‘Impact of maternal pre-pregnancy body mass index on maternal, fetal and neonatal adverse outcomes in the worldwide populations: A systematic review and meta-analysis’, *Obesity Research & Clinical Practice*. Elsevier, 15(6), pp. 536–545. doi: 10.1016/J.ORCP.2021.10.005.

World Health Organization (WHO) (2006) ‘Child growth standards’. Available at: https://www.who.int/tools/child-growth-standards (Accessed: 8 February 2021).

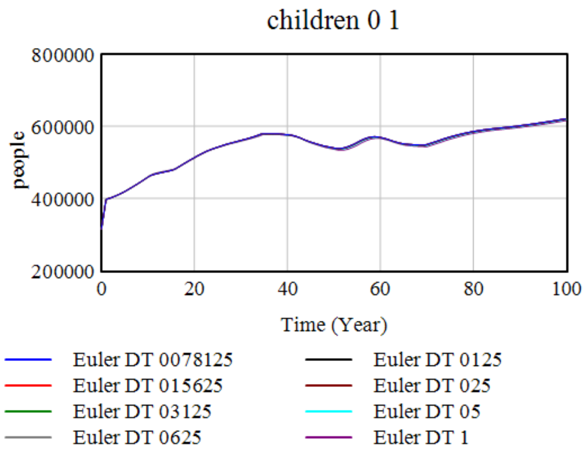
Appendix 2. Model validation

2.1. Integration error

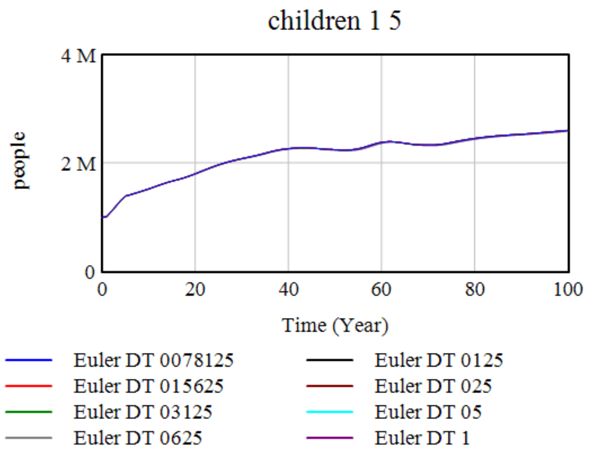
System Dynamics models are systems of simultaneous differential equations that are solved algorithmically by numerical methods such as the Euler or Runge-Kutta fourth-order method. Additionally, when running these models, the size of the interval in which the corresponding calculations are made must be defined, that is, the size of the step (also known as DT). This test assesses whether the results produced by the model are sensitive to changes in the integration method and in the DT value.

2.1.1. Euler method

We first ran the model using Euler´s method and changing the values of the DT from 1 to 0,0078127 (in total 8 simulations). Results show that there is no behavioral change when DT varies. The numerical differences at time 100 are less than 1%.

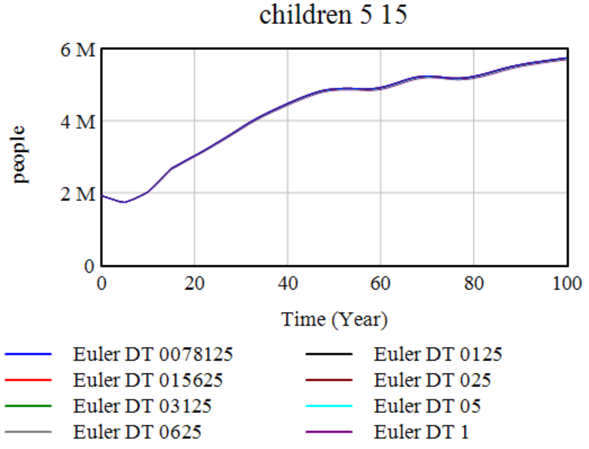
<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr>
<td>Population aging chain</td>
<td>Simulation of population stock of children 0-1 with Euler method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td>
<td>


<table>
<tr><th colspan="3">Children 0-1</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Children 0-1 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Euler; DT 0.0078125</td><td>621345</td><td>0</td></tr>
</table>
</td>
<td>There is no change in behavioral patterns when the DT changes. For all DT values the % error at time 100 is less than 1%.</td>
</tr>
</table>

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Euler; DT 0.015625</td><td>621302</td><td>-0.006920471</td></tr>
<tr><td>Euler; DT 0.03125</td><td>621217</td><td>-0.020600472</td></tr>
<tr><td>Euler; DT 0.0625</td><td>621046</td><td>-0.048121414</td></tr>
<tr><td>Euler; DT 0.125</td><td>620705</td><td>-0.103002358</td></tr>
<tr><td>Euler; DT 0.25</td><td>620021</td><td>-0.213086128</td></tr>
<tr><td>Euler; DT 0.5</td><td>618648</td><td>-0.434058373</td></tr>
<tr><td>Euler; DT 1</td><td>615880</td><td>-0.879543571</td></tr>
</table>
</td><td></td></tr>
<tr><td>Population aging chain</td><td>Simulation of population stock of children 1-5 with Euler method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td><td>


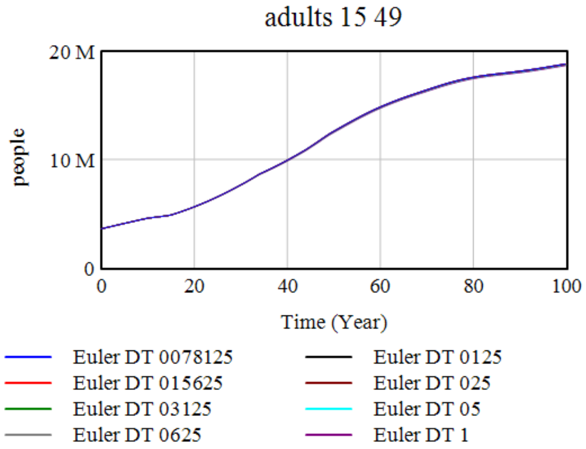
<table>
<tr><th colspan="3">Children 1-5</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Children 1-5 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Euler; DT 0.0078125</td><td>2601970</td><td>0</td></tr>
<tr><td>Euler; DT 0.015625</td><td>2601850</td><td>-0.00461189</td></tr>
<tr><td>Euler; DT 0.03125</td><td>2601600</td><td>-0.014219995</td></tr>
<tr><td>Euler; DT 0.0625</td><td>2601100</td><td>-0.033436204</td></tr>
<tr><td>Euler; DT 0.125</td><td>2600090</td><td>-0.072252947</td></tr>
<tr><td>Euler; DT 0.25</td><td>2598090</td><td>-0.149117784</td></tr>
<tr><td>Euler; DT 0.5</td><td>2594080</td><td>-0.303231782</td></tr>
</table>
</td><td>There is no change in behavioral patterns when the DT changes. For all DT values the % error at time 100 is less than 1%.</td></tr>
</table>

Model sector	Description	Simulation results	Observations
		Euler; DT 1 — 2586070 — -0.611075454	
Population aging chain	Simulation of population stock of children 5-15 with Euler method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.	see chart and table below	There is no change in behavioral patterns when the DT changes. For all DT values the % error at time 100 is less than 1%.



Children 5-15

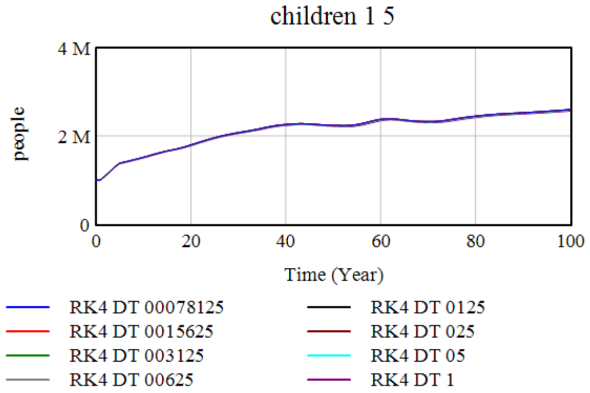
Integration type; Time step (DT)	Simulated population Children 5-15 at t=100	% Error (compared to smallest DT result)
Euler; DT 0.0078125	5748370	0
Euler; DT 0.015625	5747960	-0.007132457
Euler; DT 0.03125	5747140	-0.02139737
Euler; DT 0.0625	5745500	-0.049927197
Euler; DT 0.125	5742230	-0.106812888
Euler; DT 0.25	5735690	-0.22058427
Euler; DT 0.5	5722670	-0.44708326
Euler; DT 1	5696830	-0.896601993

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td>Population aging chain</td><td>Simulation of population stock of adults 15-49 with Euler method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td><td>

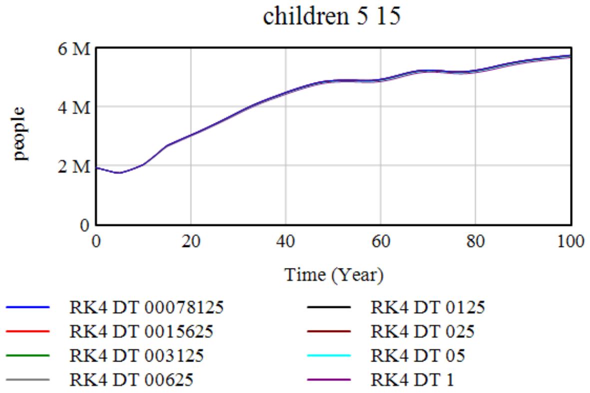
<table>
<tr><th colspan="3">Adults 15-49</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Adults 15-49 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Euler; DT 0.0078125</td><td>18842200</td><td>0</td></tr>
<tr><td>Euler; DT 0.015625</td><td>18841000</td><td>-0.006368683</td></tr>
<tr><td>Euler; DT 0.03125</td><td>18838600</td><td>-0.019106049</td></tr>
<tr><td>Euler; DT 0.0625</td><td>18833900</td><td>-0.044050058</td></tr>
<tr><td>Euler; DT 0.125</td><td>18824400</td><td>-0.094468799</td></tr>
<tr><td>Euler; DT 0.25</td><td>18805500</td><td>-0.194775557</td></tr>
<tr><td>Euler; DT 0.5</td><td>18767700</td><td>-0.395389073</td></tr>
<tr><td>Euler; DT 1</td><td>18692200</td><td>-0.796085383</td></tr>
</table></td><td>There is no change in behavioral patterns when the DT changes. For all DT values the % error at time 100 is less than 1%.</td></tr>
</table>

2.1.2. Runge-Kutta fourth order

We then ran the model using Runge-Kutta´s fourth-order method and changing the values of the DT from 1 to 0,0078127. Results show that only for the children 0-1 stock there are significant numerical variations in results, although behavioral patterns are the same. This difference can be explained by the fact that this stock has a small delay of 1 year so using DT values close to 1 result in significant differences.

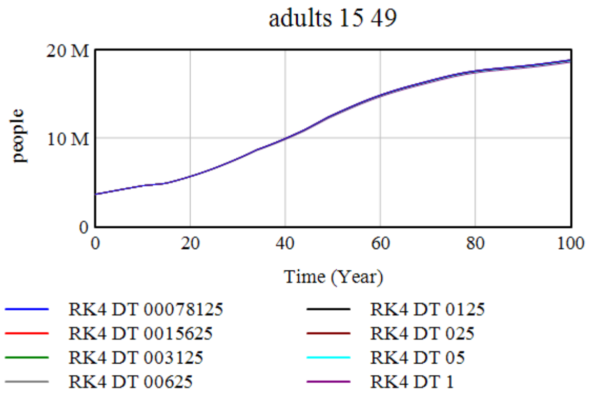
<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr>
<td>Population aging chain</td>
<td>Simulation of population stock of children 1-5 with Runge-Kutta 4 method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td>
<td>


<table>
<tr><th colspan="3">Children 1-5</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Children 1-5 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Runge-Kutta 4; DT 0.0078125</td><td>2601800</td><td>0</td></tr>
<tr><td>Runge-Kutta 4; DT 0.015625</td><td>2601500</td><td>-0.011530479</td></tr>
<tr><td>Runge-Kutta 4; DT 0.03125</td><td>2600900</td><td>-0.034591437</td></tr>
<tr><td>Runge-Kutta 4; DT 0.0625</td><td>2599700</td><td>-0.080713352</td></tr>
<tr><td>Runge-Kutta 4; DT 0.125</td><td>2597310</td><td>-0.172572834</td></tr>
<tr><td>Runge-Kutta 4; DT 0.25</td><td>2592530</td><td>-0.356291798</td></tr>
<tr><td>Runge-Kutta 4; DT 0.5</td><td>2583000</td><td>-0.722576678</td></tr>
<tr><td>Runge-Kutta 4; DT 1</td><td>2564110</td><td>-1.448612499</td></tr>
</table>
</td>
<td>There is no change in behavioral patterns when the DT changes. For most of DT values the % error at time 100 is less than 1%. For a DT of 1 the error is above 1% which indicates that it is advisable to use lower values of DT to capture correctly the dynamics of this stock.</td>
</tr>
</table>

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr>
<td>Population aging chain</td>
<td>Simulation of population stock of children 5-15 with Runge-Kutta 4 method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td>
<td>


<table>
<tr><th colspan="3">Children 5-15</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Children 5-15 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Runge-Kutta 4; DT 0.0078125</td><td>5748120</td><td>0</td></tr>
<tr><td>Runge-Kutta 4; DT 0.015625</td><td>5747470</td><td>-0.011308045</td></tr>
<tr><td>Runge-Kutta 4; DT 0.03125</td><td>5746160</td><td>-0.034098105</td></tr>
<tr><td>Runge-Kutta 4; DT 0.0625</td><td>5743550</td><td>-0.079504255</td></tr>
<tr><td>Runge-Kutta 4; DT 0.125</td><td>5738320</td><td>-0.170490526</td></tr>
<tr><td>Runge-Kutta 4; DT 0.25</td><td>5727910</td><td>-0.351593217</td></tr>
<tr><td>Runge-Kutta 4; DT 0.5</td><td>5707190</td><td>-0.712058899</td></tr>
<tr><td>Runge-Kutta 4; DT 1</td><td>5666220</td><td>-1.424813678</td></tr>
</table>
</td>
<td>There is no change in behavioral patterns when the DT changes. For most of DT values the % error at time 100 is less than 1%. For a DT of 1 the error is above 1% which indicates that it is advisable to use lower values of DT to capture correctly the dynamics of this stock.</td>
</tr>
</table>

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr>
<td>Population aging chain</td>
<td>Simulation of population stock of adults 15-49 with Runge-Kutta 4 method changing DT from 1 to 0,0078125 (8 simulations). % Error calculated with respect to simulated value at time 100 of the simulation with smallest DT.</td>
<td>



<table>
<tr><th colspan="3">Adults 15-49</th></tr>
<tr><th>Integration type; Time step (DT)</th><th>Simulated population Adults 15-49 at t=100</th><th>% Error (compared to smallest DT result)</th></tr>
<tr><td>Runge-Kutta 4; DT 0.0078125</td><td>18841300</td><td>0</td></tr>
<tr><td>Runge-Kutta 4; DT 0.015625</td><td>18839300</td><td>-0.010614979</td></tr>
<tr><td>Runge-Kutta 4; DT 0.03125</td><td>18835300</td><td>-0.031844936</td></tr>
<tr><td>Runge-Kutta 4; DT 0.0625</td><td>18827300</td><td>-0.074304852</td></tr>
<tr><td>Runge-Kutta 4; DT 0.125</td><td>18811200</td><td>-0.159755431</td></tr>
<tr><td>Runge-Kutta 4; DT 0.25</td><td>18779100</td><td>-0.330125841</td></tr>
<tr><td>Runge-Kutta 4; DT 0.5</td><td>18715200</td><td>-0.669274413</td></tr>
<tr><td>Runge-Kutta 4; DT 1</td><td>18588200</td><td>-1.343325567</td></tr>
</table>

</td>
<td>There is no change in behavioral patterns when the DT changes. For most of DT values the % error at time 100 is less than 1%. For a DT of 1 the error is above 1% which indicates that it is advisable to use lower values of DT to correctly capture the dynamics of this stock.</td>
</tr>
</table>

2.1.3. Comparison between Euler´s method and Runge-Kutta 4

We then compared the results obtained when using the same DT value but changing the integration method (Euler and Runge-Kutta 4). Results only show significant differences in the children 0-1 stock for DT values higher than 0.0625. This is consistent with the previous results.

Model sector	Description	Simulation results			Observations
Population aging chain	Simulation of population stock of children 0-1 with same DT but changing simulation method (Euler vs Rinke-Kutta4). % Error calculated with respect to Runge-Kutta 4 at time 100	**Children 0-1**			The table shows that for DT values from 0.0625 and higher the numerical difference between Euler and Runge-Kutta 4 are higher than 1%. This is consistent with previous results that indicate that it is advisable to use DT values smaller than 0.0625.
		Comparison of Euler and Runge Kutta, same DT	**Difference at t=100**	**% difference**	
		DT 0.0078125	-953	-0.153142064	
		DT 0.015625	-1906	-0.305836896	
		DT 0.03125	-3810	-0.609573666	
		DT 0.0625	-7617	-1.211618944	
		DT 0.125	-15220	-2.393363997	
		DT 0.25	-30382	-4.671257666	
		DT 0.5	-60536	-8.913048599	
		DT 1	-120167	-16.32599549	
Population aging chain	Simulation of population stock of children 1-5 with same DT but changing simulation method (Euler vs Rinke-Kutta4). % Error calculated with respect to Runge-Kutta 4 at time 100	**Children 1-5**			The numerical difference when using either integration method is not significant for this stock. For all DT values the % difference at time 100 is less than 1%.
		Comparison of Euler and Runge Kutta, same DT	**Difference at t=100**	**% difference**	
		DT 0.0078125	170	0.006533938	
		DT 0.015625	350	0.013453777	
		DT 0.03125	700	0.026913761	
		DT 0.0625	1400	0.053852368	
		DT 0.125	2780	0.107033816	
		DT 0.25	5560	0.214462321	
		DT 0.5	11080	0.428958575	
		DT 1	21960	0.856437516	

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td>Population aging chain</td><td>Simulation of population stock of children 5-15 with same DT but changing simulation method (Euler vs Rinke-Kutta4).

% Error calculated with respect to Runge-Kutta 4 at time 100</td><td><table>
<tr><th colspan="3">Children 5-15</th></tr>
<tr><th>Comparison of Euler and Runge Kutta, same DT</th><th>Difference at t=100</th><th>% difference</th></tr>
<tr><td>DT 0.0078125</td><td>250</td><td>0.004349248</td></tr>
<tr><td>DT 0.015625</td><td>490</td><td>0.00852549</td></tr>
<tr><td>DT 0.03125</td><td>980</td><td>0.017054868</td></tr>
<tr><td>DT 0.0625</td><td>1950</td><td>0.033951128</td></tr>
<tr><td>DT 0.125</td><td>3910</td><td>0.06813841</td></tr>
<tr><td>DT 0.25</td><td>7780</td><td>0.135826156</td></tr>
<tr><td>DT 0.5</td><td>15480</td><td>0.271236808</td></tr>
<tr><td>DT 1</td><td>30610</td><td>0.540219053</td></tr>
</table></td><td>The numerical difference when using either integration method is not significant for this stock. For all DT values the % difference at time 100 is less than 1%.</td></tr>
<tr><td>Population aging chain</td><td>Simulation of population stock of adults 15-49 with same DT but changing simulation method (Euler vs Rinke-Kutta4).

% Error calculated with respect to Runge-Kutta 4 at time 100</td><td><table>
<tr><th colspan="3">Adults 15-49</th></tr>
<tr><th>Comparison of Euler and Runge Kutta, same DT</th><th>Difference at t=100</th><th>% difference</th></tr>
<tr><td>DT 0.0078125</td><td>900</td><td>0.00477674</td></tr>
<tr><td>DT 0.015625</td><td>1700</td><td>0.00902369</td></tr>
<tr><td>DT 0.03125</td><td>3300</td><td>0.017520294</td></tr>
<tr><td>DT 0.0625</td><td>6600</td><td>0.035055478</td></tr>
<tr><td>DT 0.125</td><td>13200</td><td>0.070170962</td></tr>
<tr><td>DT 0.25</td><td>26400</td><td>0.140581817</td></tr>
<tr><td>DT 0.5</td><td>52500</td><td>0.280520646</td></tr>
<tr><td>DT 1</td><td>104000</td><td>0.559494733</td></tr>
</table></td><td>The numerical difference when using either integration method is not significant for this stock. For all DT values the % difference at time 100 is less than 1%.</td></tr>
</table>

2.1.4. Conclusions

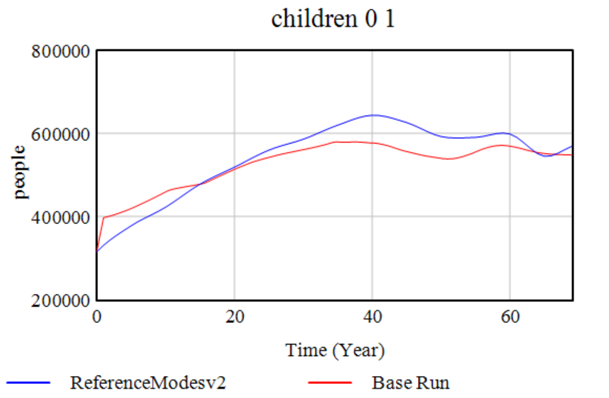
a. Behavioral patterns do not change when varying the integration method or the DT value, however simulations show numerical differences. These numerical differences are especially evident in the children 0-1 stock that has a delay time of 1 year; the tests show that for DT values higher than 0.0625 the numerical differences can be of at least 1%.

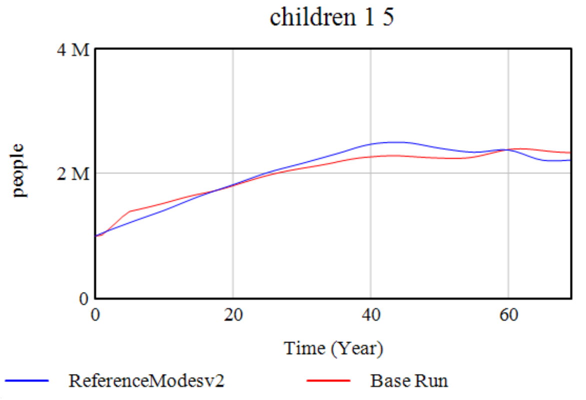
b. Sterman (2000) suggests that if there is no significant change between Euler or a higher order integration method (in this case Runge-Kutta 4) then Euler is a good choice. Hence we will use Euler´s method.
c. As results using DT values higher than 0.0625 show numerical differences higher than 1% we will use a DT of 0.03125.

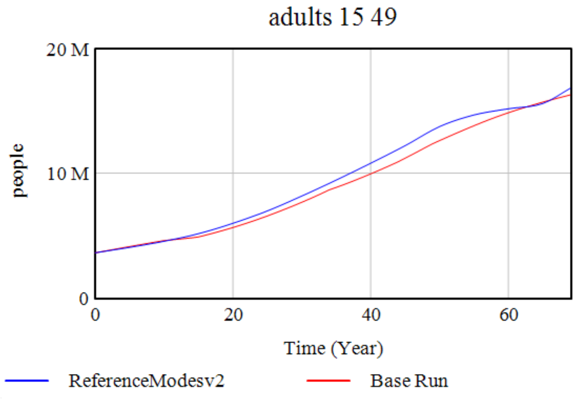
2.2. Behavior reproduction

This test assesses if the model reproduces the behavior of interest in the system, if it endogenously generates the problem being assessed, if it generates various modes of behavior observed in the real system and if the frequencies and phase relationships among the variables match the data. In this case we will compare simulation results with historical data for Peruvian populations between ages 0-1, 1-5, 5-15 and 15-49 between the years 1950 and 2019 (source: INEI - PERU: Estimaciones y Proyecciones de la Población).

These simulations are produced using model "stunting_ow_v5" using Euler´s integration method with DT = 0.03125.

Model sector	Variable	Results	Observations
Population aging chain	Children 0-1 Reference mode (blue line) vs Simulation (red line)		Overall the simulation shows similar patterns of behavior to the ones in the reference mode. Both graphs show an initial increase between years 0 and 40, although the simulation seems to increase slower than the reference mode. From the year 40 and on the reference mode shows an oscillatory decrease which is partially captured by the simulation with smaller oscillations. In terms of numerical results, the average % error between the values of the reference mode and those of the simulation between 1950 and 2019 is of 6.2%. Also, at time 69 (year 2019) the % error between the reference mode value and the simulation is 3.7%.

Model sector	Variable	Results	Observations
	Children 1-5 Reference mode (blue line) vs Simulation (red line)		Overall the simulation shows similar patterns of behavior to the ones in the reference mode. Both graphs show an initial increase between years 0 and 44. However the reference mode begins decreasing from year 45 and on in an oscillatory way which differs from the simulated behavior that shows and oscillatory increase. In terms of numerical results, the average % error between the values of the reference mode and those of the simulation between 1950 and 2019 is of 5.3%. Also, at time 69 (year 2019) the % error between the reference mode value and the simulation is 5.44%.
	Children 5-15 Reference mode (blue line) vs Simulation (red line)		Overall the simulation shows similar patterns of behavior to the ones in the reference mode. At the beginning the simulation shows a decrease that does not correspond to the reference mode data; this could be associated with uncertainties related to death rates of this stock. From year 6 and on both graphs increase with numerical differences. However from the year 52 and on the reference mode shows an oscillatory decrease that is not captured by the simulation that keeps on increasing. In terms of numerical results, the average % error between the values of the reference mode and those of the simulation between 1950 and 2019 is of 16.7% (the highest of all the population stocks). Also, at time 69 (year 2019) the % error between the reference mode value and the simulation is 2.85%.

Model sector	Variable	Results	Observations
	Adults 15-49 Reference mode (blue line) vs Simulation (red line)		Overall the simulation shows similar patterns of behavior to the ones in the reference mode. Both graphs increase throughout the time horizon, although the reference mode shows some oscillations at the end that the simulation does not capture. In terms of numerical results, the average % error between the values of the reference mode and those of the simulation between 1950 and 2019 is of 4.7%. Also, at time 69 (year 2019) the % error between the reference mode value and the simulation is 3.17%.

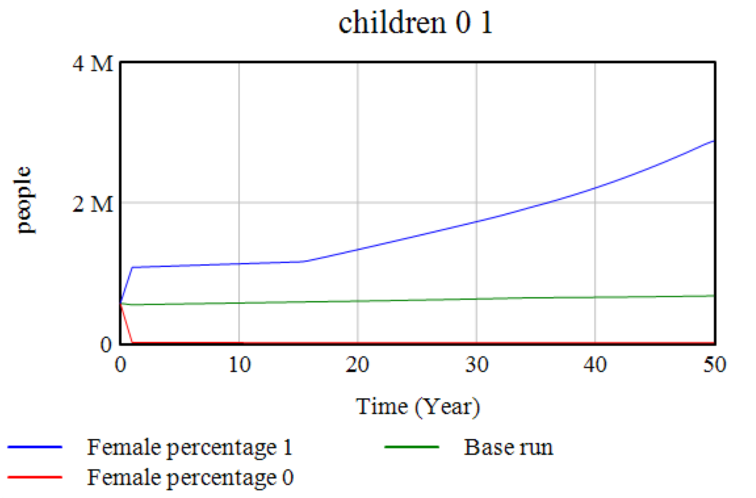
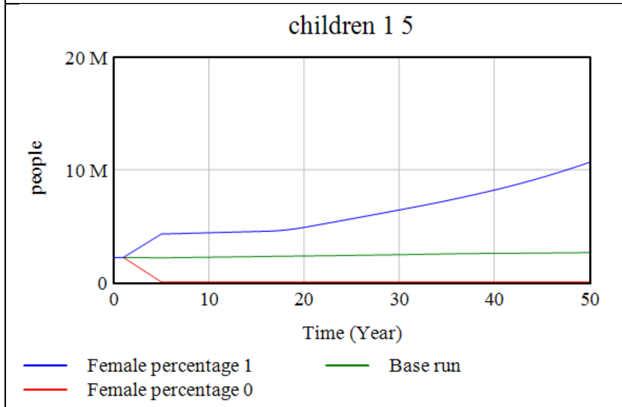
Conclusions

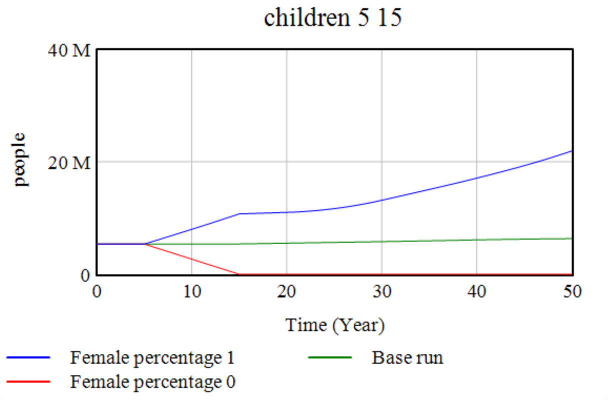
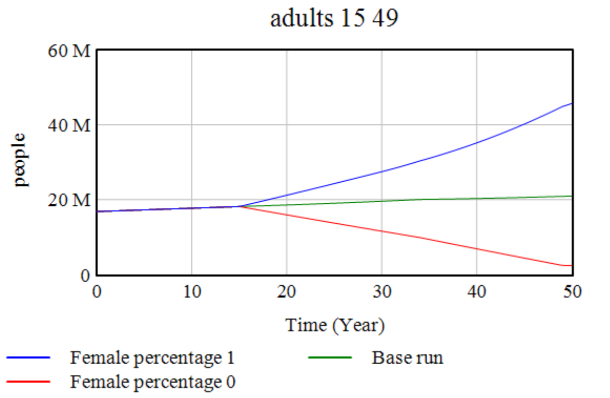
a. Overall the simulations capture a similar behavior as the ones in the corresponding reference mode of historical data.
b. For stocks of populations of children 1-5, 5-15 and adults 15-49 the reference mode shows decreasing or oscillatory behaviors that are not completely captured by the simulations. These differences happen around year 50 of the simulation (year 2000). Other tests should be run (like sensitivity analysis or extreme conditions) to check if these differences are associated to model specification or data uncertainties.
c. Although this test aims at looking at behavioral patterns, in numerical terms the numerical differences between the historical data and the simulation results are not so big. On average the % error is less than 10% except for the stock of children 5-15 that has a % average error of 16.7%.

2.3. Extreme conditions

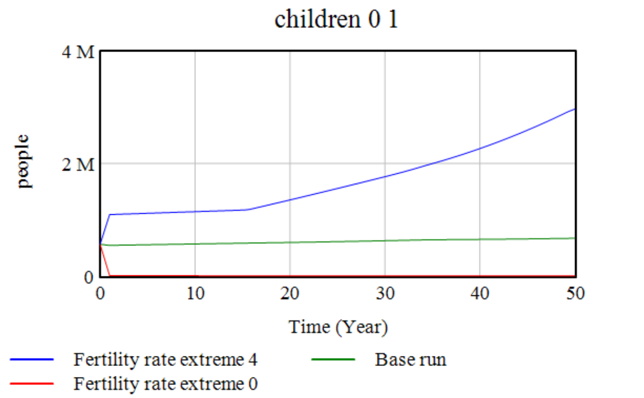
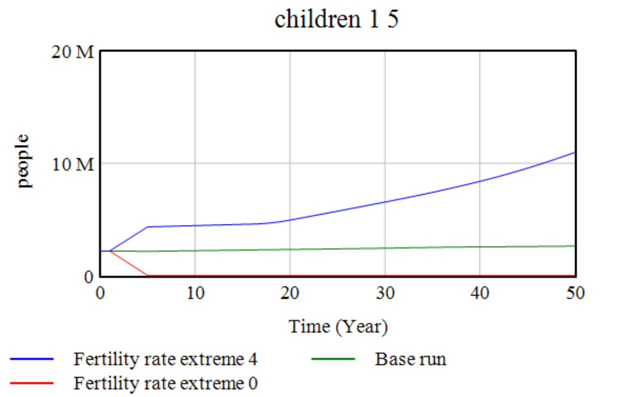
This test assesses whether the equations and results of the model make sense when subjected to extreme values, parameters, and policies.

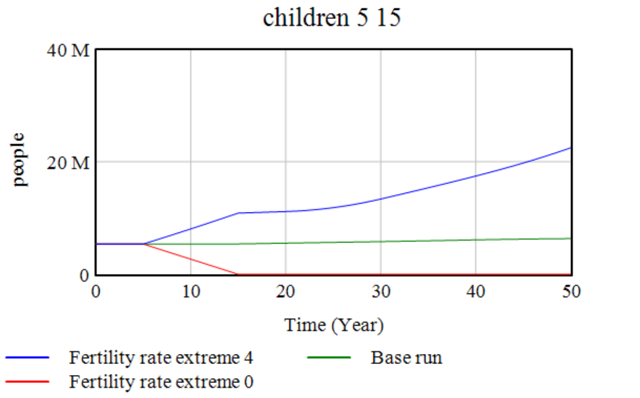
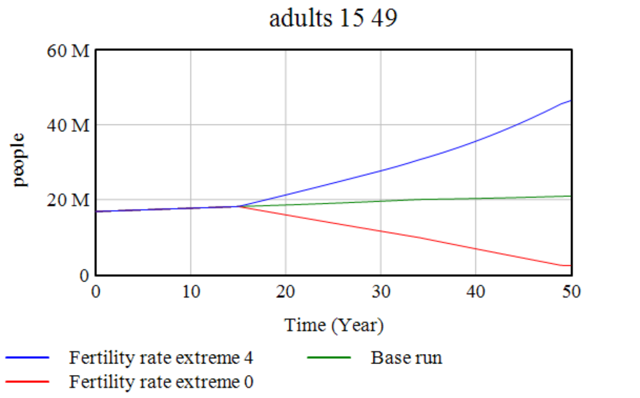
2.3.1. Female percentage

Model sector	Description	Simulation results	Observations
Population aging chain	Female percentage is varied to take values of 0 and 1. This means that for the value of 0 it is expected that no births occur and hence population stocks should decrease through time and take values close to 0. For the value of 1 it is expected that all populations increase through time as more babies are born each year.	 	Results for all population stocks are consistent with expectations. None of the stocks take negative values when subjected to a value of 0 female percentage and increase accordingly when female percentage is 100%.

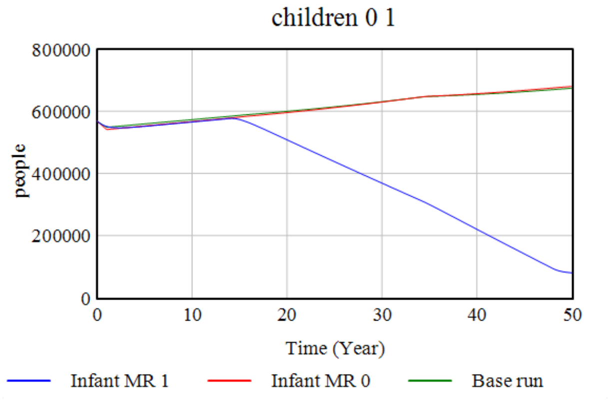
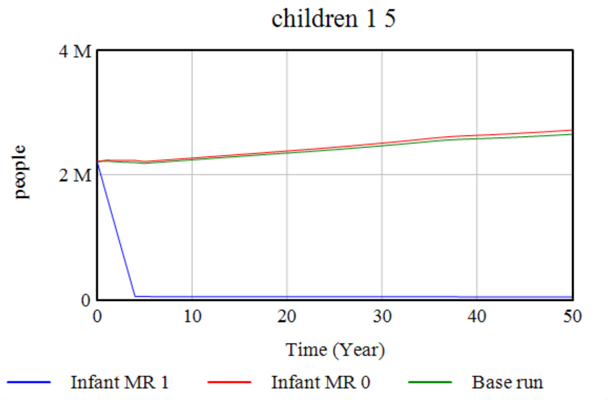
Model sector	Description	Simulation results	Observations
		 	

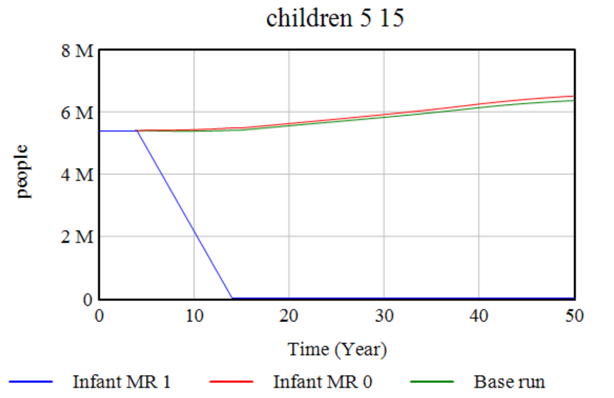
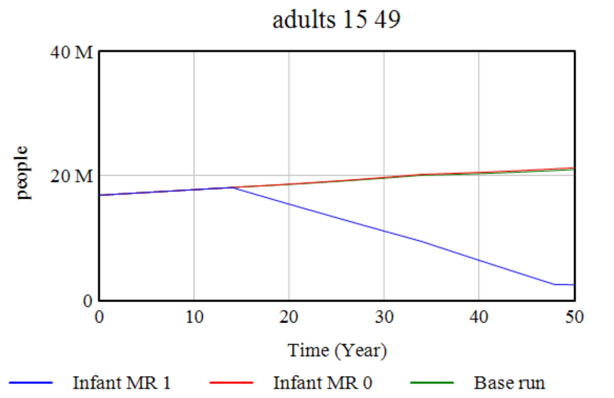
2.3.2. Fertility rate

Model sector	Description	Simulation results	Observations
Population aging chain	Fertility rate is varied to take values of 0 and 4.5 (doble of actual value). This means that for the value of 0 it is expected that no births occur and hence population stocks should decrease through time and take values close to 0. For the value of 4.5 it is expected that all populations increase through time as more babies are born each year.	 	Results for all population stocks are consistent with expectations. None of the stocks take negative values when subjected to a value of 0 fertility rate and increase accordingly when fertility rate is doubled.

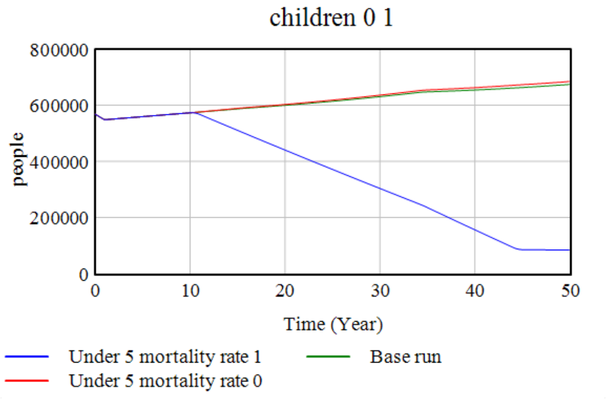
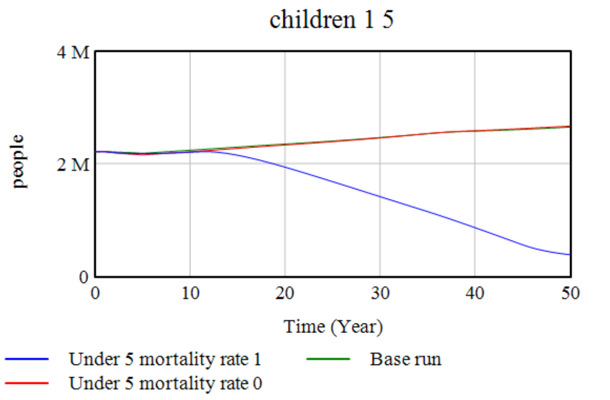
Model sector	Description	Simulation results	Observations
		 	

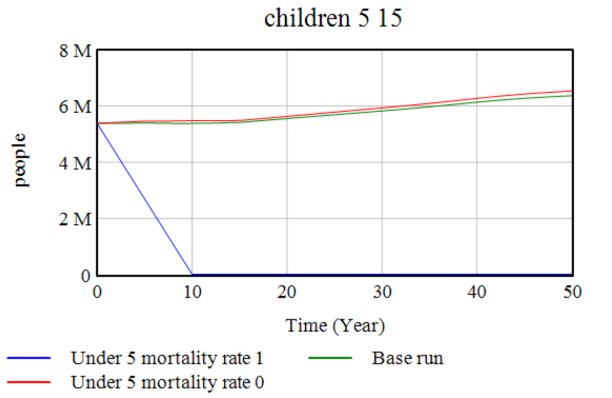
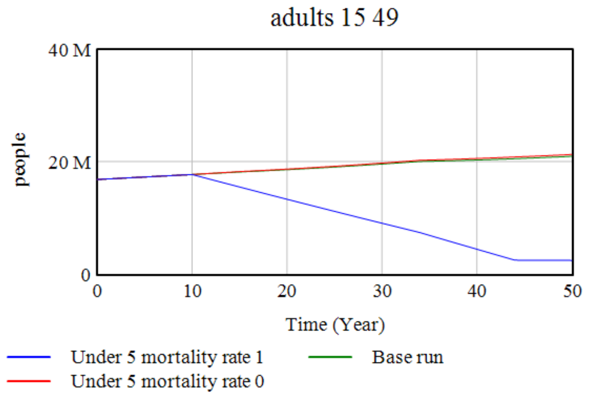
2.3.3. Infant mortality rate

Model sector	Description	Simulation results	Observations
Population aging chain	Infant mortality rate is varied to take values of 0 and 1. This means that for the value of 0 it is expected that no infants die hence population stocks should take similar values that the current values. For the value of 1 it is expected that all infants die so it is expected for all stocks to decrease through time.		When the Infant Mortality rate takes a value of 1 the population stock of infants 0-1 decreases through time as expected. However it should be noted that this decrease only happens when adults of ages 15-49 start decreasing as this causes for the inflow of births to also decrease and take lower values than those of the deaths outflow. For the Infant Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0126.
			When the Infant Mortality Rate takes a value of 1 the stock of Children 1-5 decreases immediately as no children go into this stock. This is consistent with expectations. For the Infant Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0126.

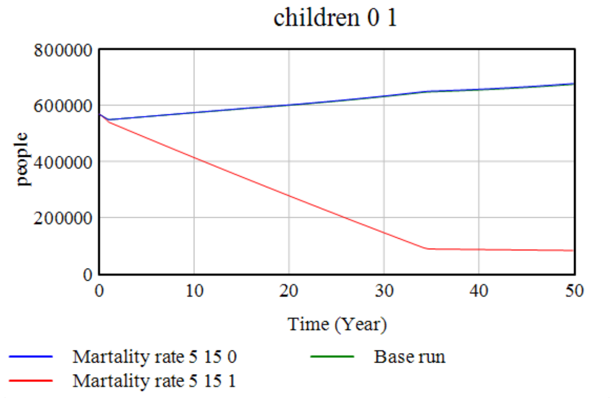
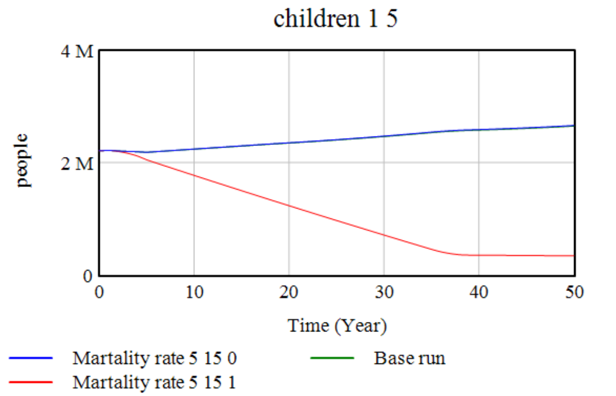
Model sector	Description	Simulation results	Observations
			When the Infant Mortality Rate takes a value of 1 the stock of Children 5-15 decreases after year 5 as from this moment there are no children in the Children 1-5 stock. This is consistent with expectations. For the Infant Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0126.
			When the Infant Mortality Rate takes a value of 1 the stock of adults 15-49 decreases after year 15 as from this moment there are no children in the Children 5-15 stock. This is consistent with expectations. For the Infant Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0126.

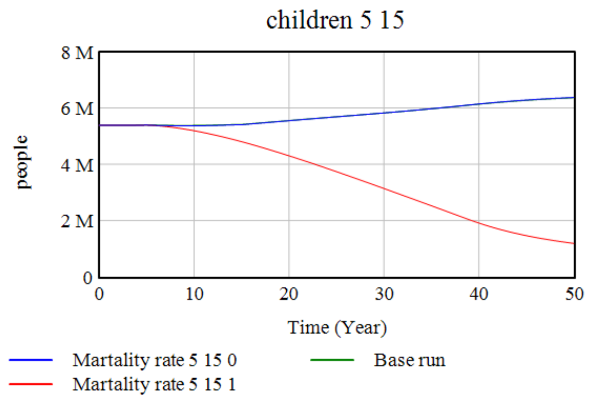
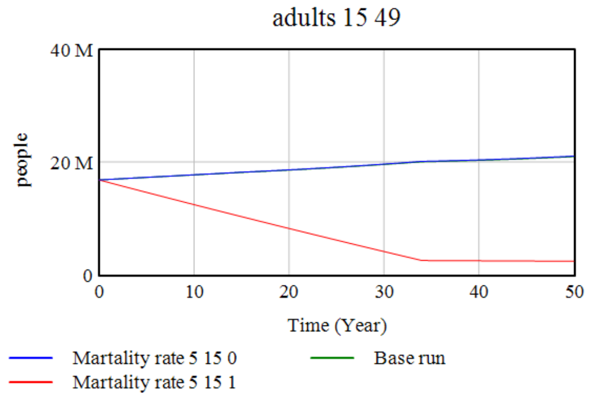
2.3.4. Under 5 mortality rate

Model sector	Description	Simulation results	Observations
Population aging chain			When the Children under 5 Mortality Rate takes a value of 1 the stock of Children 0-1 decreases after year 12 as from year 10 there are no children in the Children 5-15 stock hence adults 15-49 start decreasing and this makes the stock of children 0-1 to decrease as there are lower births. This is consistent with expectations. For the Under 5 mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0132.
			When the Children under 5 Mortality Rate takes a value of 1 the stock of Children 1-5 decreases after year 13 as from year 10 there are no children in the Children 5-15 stock hence adults start decreasing and this makes the stock of children 0-1 to decrease as there are lower births; this makes the children 1-5 to decrease. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0132.

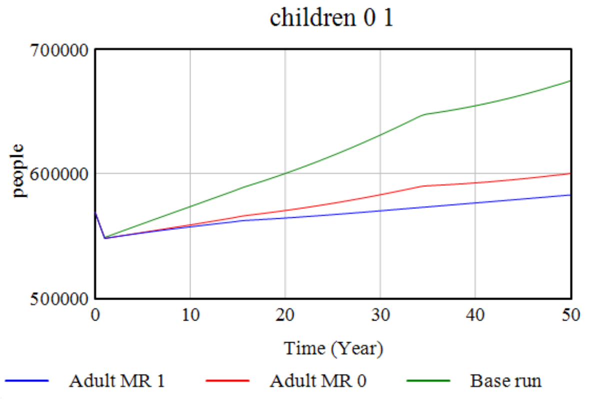
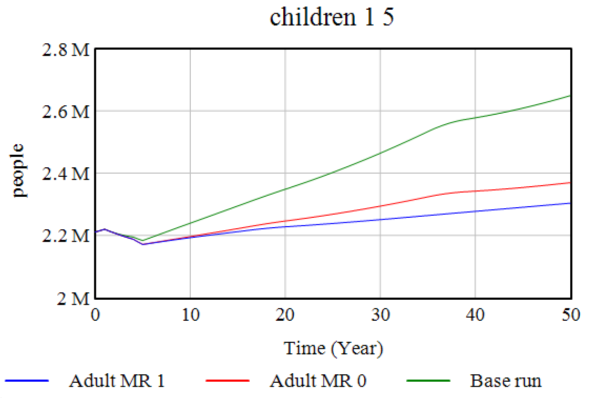
			When the Children under 5 Mortality Rate takes a value of 1 the stock of Children 5-15 decreases from time 0 as they all die. This decrease takes time as children 0-1 keep on aging. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0132.
			When the Children under 5 Mortality Rate takes a value of 1 the stock of Adults 15-49 decreases after year 11 as from year 10 there are no children in the Children 5-15 stock hence adults 15-49 start decreasing (as there is no inflow for this stock). This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.0132.

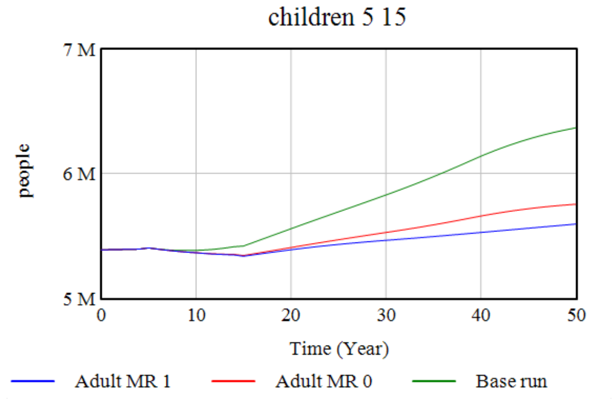
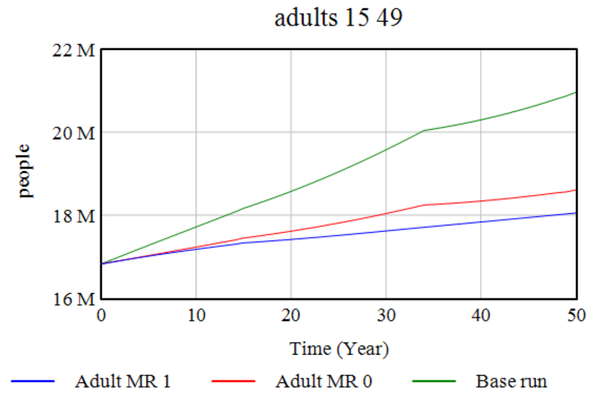
2.3.5. Mortality rate 5- 15

Model sector	Description	Simulation results	Observations
Population aging chain			When the Mortality Rate of children 5-15 takes a value of 1 the stock of Children 0-1 decreases from the beginning as the adults 15-49 also decreases (there is no inflow for this stock) hence births decrease. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.00259.
			When the Mortality Rate of children 5-15 takes a value of 1 the stock of Children 1-5 decreases from the beginning as the adults 15-49 also decreases (there is no inflow for this stock) hence births decrease and children 0-1 decrease. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.00259.

			When the Mortality Rate of children 5-15 takes a value of 1 the stock of Children 1-5 decreases from the beginning as the adults 15-49 also decreases (there is no inflow for this stock) hence births decrease and children 0-1 decrease. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.00259.
			When the Mortality Rate of children 5-15 takes a value of 1 the stock of Adults 15-49 decreases from the beginning there is no inflow for this stock. This is consistent with expectations. For the Under 5 Mortality rate of 0 there is no significant change as this variable has currently a small value of 0.00259.

2.3.6. Adult mortality rate

<table>
<tr><th>Model sector</th><th>Description</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td rowspan="2">Population aging chain</td><td rowspan="2"></td><td>
</td><td>When the Adult mortality rate takes a value of 1 the stock of Adults 15-49 the death flow of adults 15-49 is not taking 100% of the stock as the death rate is divided by 34 years. This is due to the formulation used to overcome software limitations when using the Delay fixed function. Also the level of aggregation of this stock is significant as it captures the dynamic of population for 34 years. This is a model limitation that for now we cannot fix in order to assure non-negativity of stocks. This affects the behavior of the other stocks that continue to grow even though there is a high mortality rate for adults.</td></tr>
<tr><td>
</td><td></td></tr>
</table>

2.3.7. Conclusion:

- For extreme variations of female percentage and fertility rate the population stocks behave according to expectations.
- Extreme variations in mortality rates of children 0-1, children 1-5 and children 5-15 produce consistent behaviors.
- For extreme variations in adult mortality rate the model does not show the expected behavior. This shows a model limitation that has to do with: software limitations while using delay fixed function, level of aggregation of the adults 15-49 stock and assuring no-negativity.

2.4. Sensitivity analysis

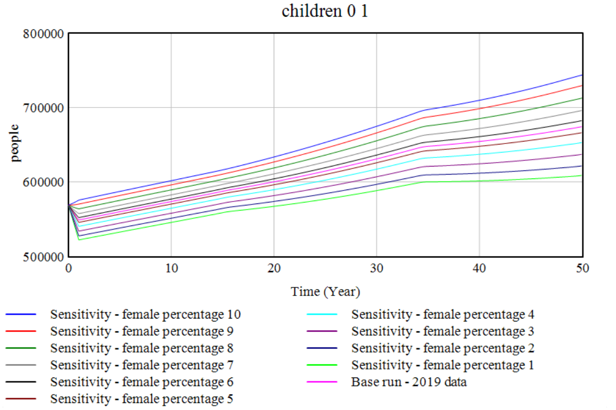
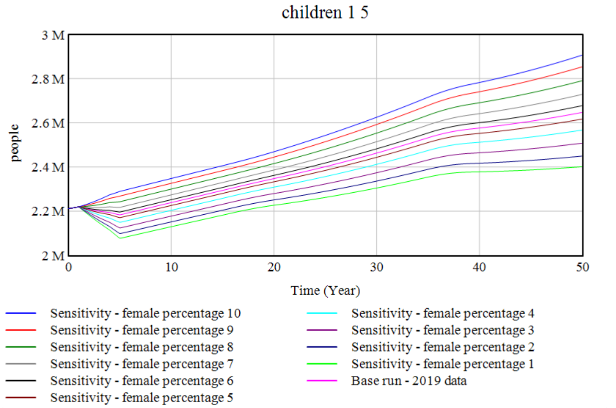
This test assesses whether varying the assumptions of the model changes the results and conclusions. Sensitivity is established in terms of numerical, behavioral patterns, and policy sensitivity.

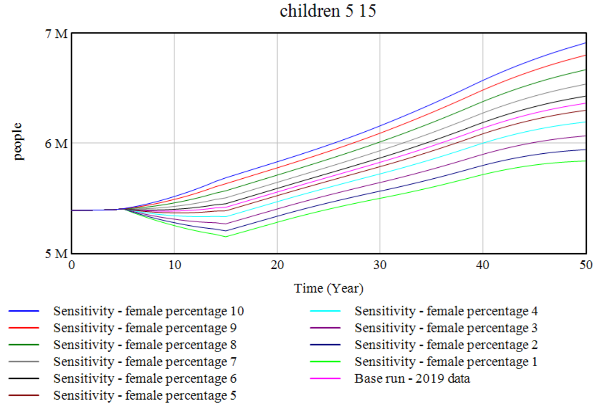
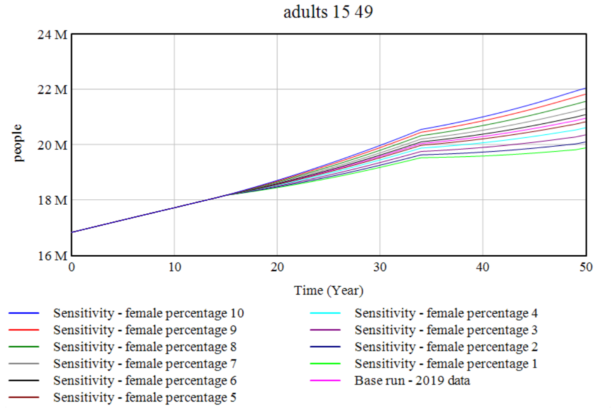
For the population model we will tests model sensitivity related to the fertility rate and the death rates for all population stocks as we have made some assumptions from existing data regarding these parameters and are both highly uncertain and likely to be influential in the population dynamics (Sterman, 2000). For this test we use constant data of 2019 (if not available then the closest data there is) as initial values of: Fertility rate, female percentage, death rates, initial population baselines. We simulate for 50 years as the aging chain considers the population dynamic ranging from age 0 to 49 (from 2019 to 2069).

2.4.1. Female percentage

Female percentage is varied in an interval from 0.478 to 0.528. 10 simulations are run.

Female percentage													
Initial value 2019	Variation range interval (5%)		Step size (10 steps)	Simulation 1	Simulation 2	Simulation 3	Simulation 4	Simulation 5	Simulation 6	Simulation 7	Simulation 8	Simulation 9	Simulation 10
0.503	0.478	0.528	0.006	0.478	0.483	0.489	0.495	0.500	0.506	0.511	0.517	0.523	0.528

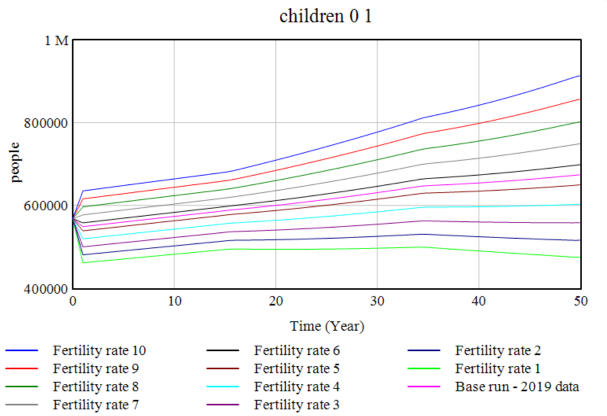
Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in female percentage produce numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 134,827 **Behavioral mode sensitivity:** In the range [0.478-0.517] simulations show the same behavioral pattern through all the time horizon. However for the range [0.523-0.528] there is behavior mode sensitivity for the first year, as it increases instead of decreasing.
		**Numerical sensitivity:** For the children 1-5 stock variations in female percentage produce numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 505,290 **Behavioral mode sensitivity:** In the range [0.478-0.506] simulations show the same behavioral pattern through all the time horizon. However for the range [0.511-0.528] there is behavior mode sensitivity from year 1 - 5, as it increases instead of decreasing.

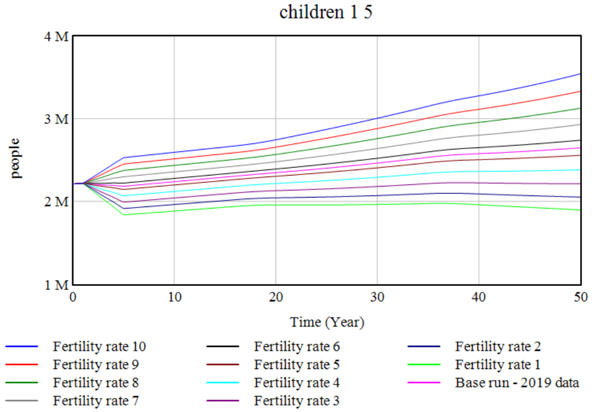
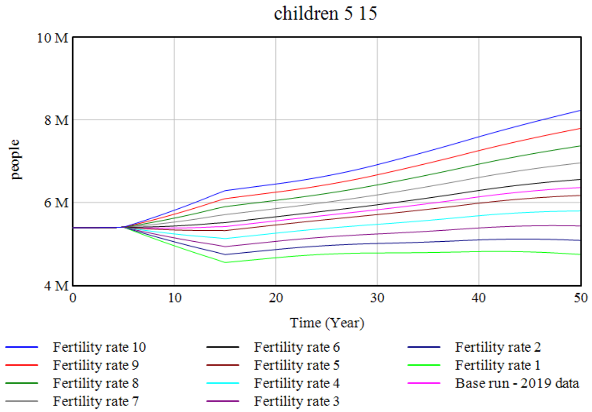
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the children 5-15 stock variations in female percentage produce numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 1,073,440 **Behavioral mode sensitivity:** In the range [0.478-0.495] simulations show behavioral changes showing a sustained decrease in years 5-15 instead of increasing through the last half of this interval. In the interval [0.500-0.506] simulations show the same behavioral pattern through all the time horizon. For the interval [0.511-0.528] there is behavior mode sensitivity from year 5-15, as it continuously increases instead of decreasing in the beginning of this period.
		**Numerical sensitivity:** For the adults 15-49 stock variations in female percentage produce numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 2,162,200 **Behavioral mode sensitivity:** Simulations do not show behavioral changes associated with changes in female percentage.

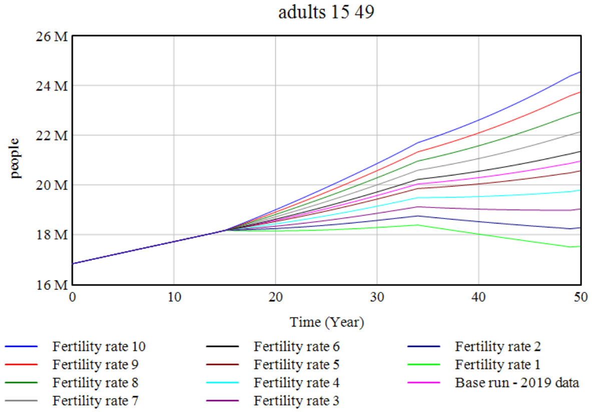
2.4.2. Fertility rate

Fertility rate is varied in an interval from 1.872 to 2.594. The higher value of this interval corresponds to fertility rate in 2009. The lower value is calculated by subtracting the interval length from the higher value and the initial value in 2019 from the 2019 value. 10 simulations are run.

Fertility rate (last 10 years interval)													
Initial value 2019	Variation range interval		Step size (10 steps)	Simulation 1	Simulation 2	Simulation 3	Simulation 4	Simulation 5	Simulation 6	Simulation 7	Simulation 8	Simulation 9	Simulation 10
2.233	1.872	2.594	0.080	1.872	1.952	2.032	2.113	2.193	2.273	2.353	2.434	2.514	2.594

Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in fertility rate produce numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 438,112 **Behavioral mode sensitivity:** In the range [1.872-1.952] there is behavior mode sensitivity from year 35 on as simulations decrease instead of increasing. In the range [2.032-2.273] simulations show the same behavioral pattern through all the time horizon. In the range [2.353-2.594] there is behavior mode sensitivity up to year 1 as it increases instead of decreasing.

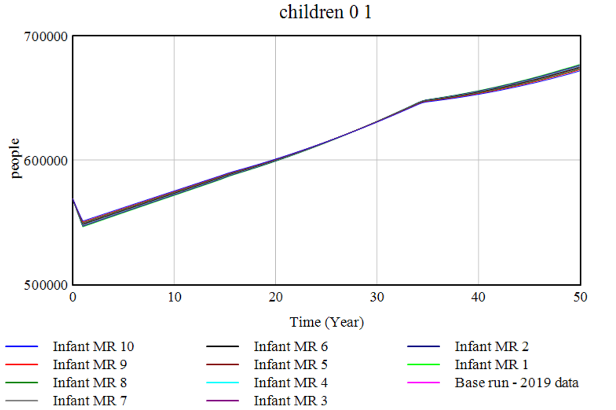
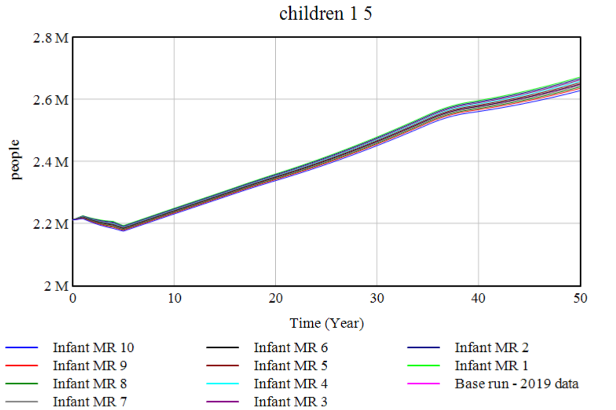
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the children 1-5 stock variations in fertility rate produce numerical sensitivity in all cases from year 1 and on. Numerical difference at time 50 between simulation 10 and simulation 1: 1,641,890 **Behavioral mode sensitivity:** In the range [1.872-2.032] there is behavior mode sensitivity from year 36 on as simulations decrease instead of increasing. In the range [2.113-2.273] simulations show the same behavioral pattern through all the time horizon. In the range [2.353-2.594] there is behavior mode sensitivity up to year 5 as it increases instead of decreasing.
		**Numerical sensitivity:** For the children 5-15 stock variations in fertility rate produce numerical sensitivity in all cases from year 5 and on. Numerical difference at time 50 between simulation 10 and simulation 1: 3,485,360 **Behavioral mode sensitivity:** In the range [1.872-2.193] simulations show behavioral changes showing a sustained decrease in years 5-15 instead of increasing through this interval. In the interval [2.273-2.345] simulations show the same behavioral pattern through all the time horizon.

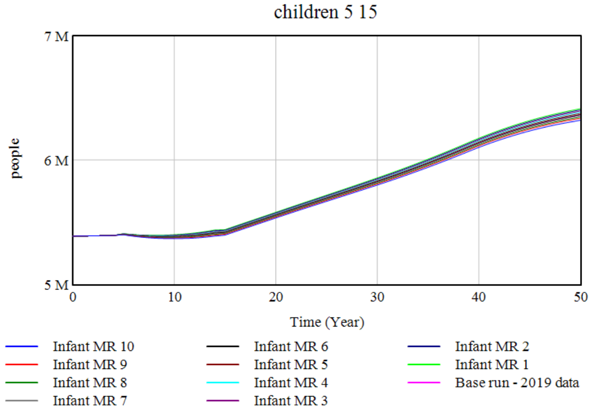
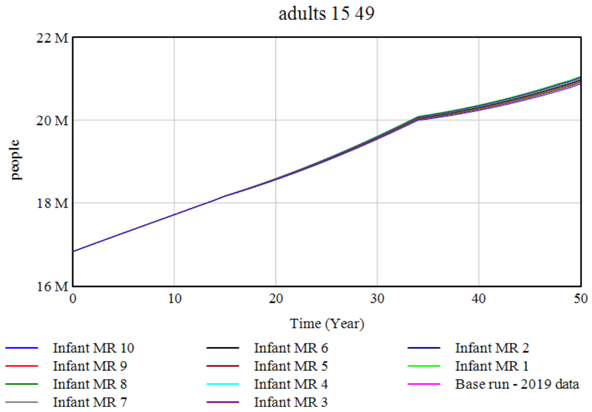
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the adults 15-49 stock variations in fertility rate produce numerical sensitivity in all cases form year 15 and forward. Numerical difference at time 50 between simulation 10 and simulation 1: 7,016,400 **Behavioral mode sensitivity:** In the range [1.872-2.032] there is behavior mode sensitivity from year 36 on as simulations decrease instead of increasing. In the range [2.113-2.594] simulations show the same behavioral pattern through all the time horizon.

2.4.3. Infant mortality rate

Infant mortality rate is varied in an interval from 0.009 to 0.0167. The higher value of this interval corresponds to infant mortality rate in 2009. The lower value is calculated by subtracting the interval length from the higher value and the initial value in 2019 from the 2019 value. 10 simulations are run.

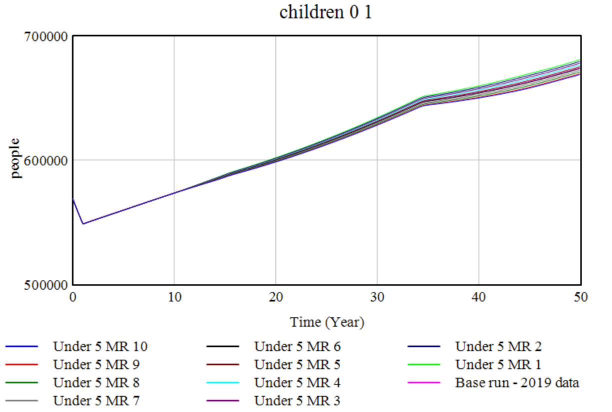
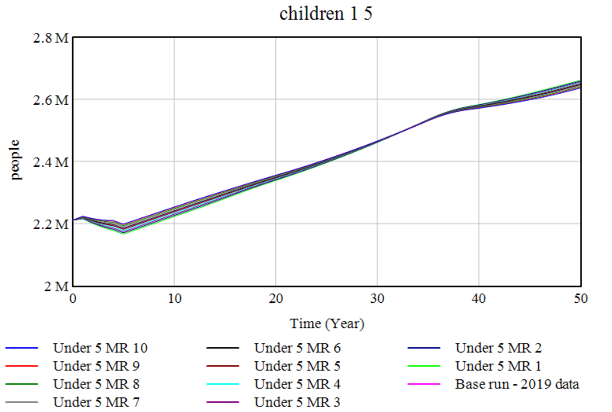
Infant mortality rate (last 10 years interval)													
Initial value 2019	**Variation range interval**		**Step size (10 steps)**	**Simulation 1**	**Simulation 2**	**Simulation 3**	**Simulation 4**	**Simulation 5**	**Simulation 6**	**Simulation 7**	**Simulation 8**	**Simulation 9**	**Simulation 10**
0.0126	0.009	0.0167	0.0009	0.0085	0.0094	0.0103	0.0112	0.0121	0.0131	0.0140	0.0149	0.0158	0.0167

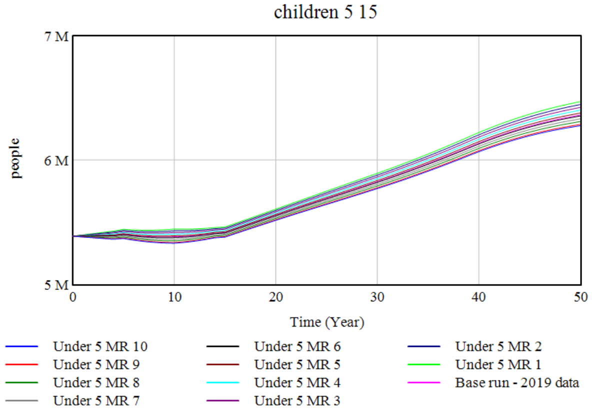
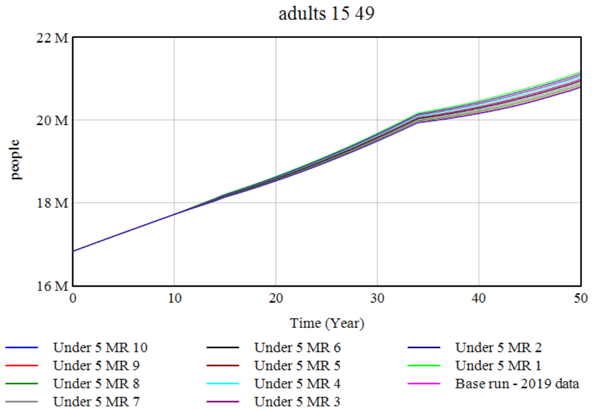
Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in infant mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -5,192 **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.
		**Numerical sensitivity:** For the children 1-5 stock variations in infant mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -43,730 **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

<table>
<tr><th>Model sector</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td></td><td>
</td><td> Numerical sensitivity: For the children 5-15 stock variations in infant mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -93,230
Behavioral mode sensitivity:
There is no behavioral mode sensitivity in any simulation. </td></tr>
<tr><td></td><td>
</td><td> Numerical sensitivity: For the adults 15-49 stock variations in infant mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -186,300.
Behavioral mode sensitivity:
There is no behavioral mode sensitivity in any simulation. </td></tr>
</table>

2.4.4. Under 5 mortality rate

Under 5 mortality rate is varied in an interval from 0.005 to 0.0210. The higher value of this interval corresponds to under 5 mortality rate in 2009. The lower value is calculated by subtracting the interval length from the higher value and the initial value in 2019 from the 2019 value. 10 simulations are run.

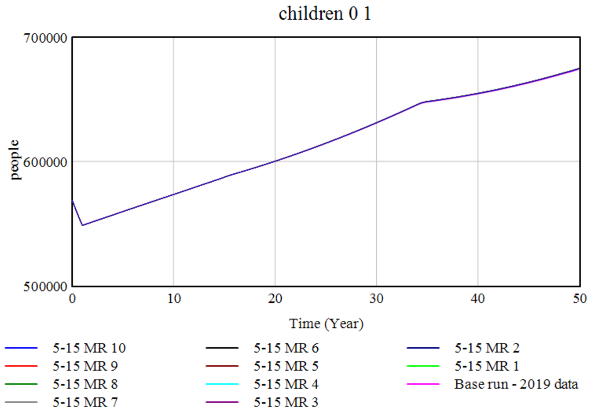
Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in under 5 mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -12,046. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.
		**Numerical sensitivity:** For the children 1-5 stock variations in under 5 mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -24,980. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

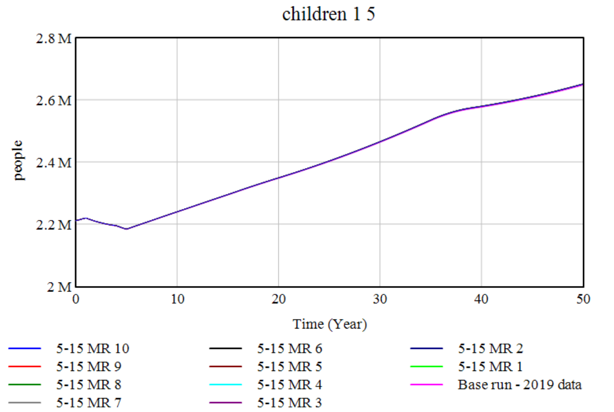
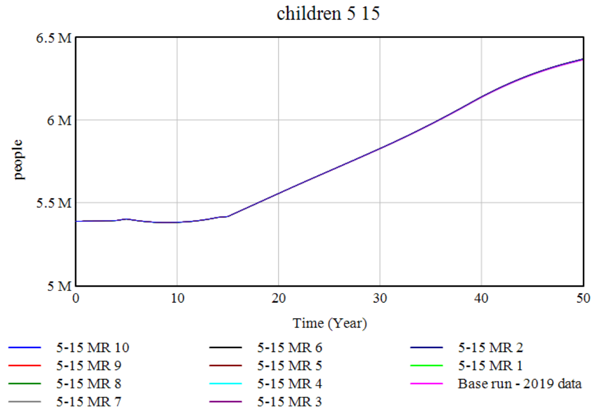
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the children 5-15 stock variations in under 5 mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -193,790. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.
		**Numerical sensitivity:** For the adults 15-49 stock variations in under 5 mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -381,700. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

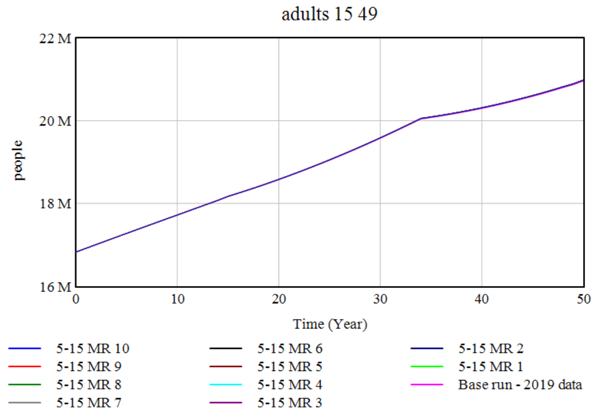
2.4.5. Mortality rate 5-15

Mortality rate 5-15 is varied in an interval from 0.00246 to 0.00272. The higher value of this interval corresponds to a 5% increase of 2012 value and the lower value is a 5% decrease of 2012 value. This interval is different from other parameters because there is not enough data for this parameter and its behavior over the las 10 years has changed over time (it increases and decreases in a 10 year interval). 10 simulations are run.

Mortality rate 5-15 (10% interval)													
Initial value 2012	Variation range interval		Step size (10 steps)	Simulation 1	Simulation 2	Simulation 3	Simulation 4	Simulation 5	Simulation 6	Simulation 7	Simulation 8	Simulation 9	Simulation 10
0.00259	0.00246	0.00272	0.00003	0.0025	0.0025	0.0025	0.0025	0.0026	0.0026	0.0026	0.0027	0.0027	0.0027

Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in mortality rate 5-15 produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -278. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

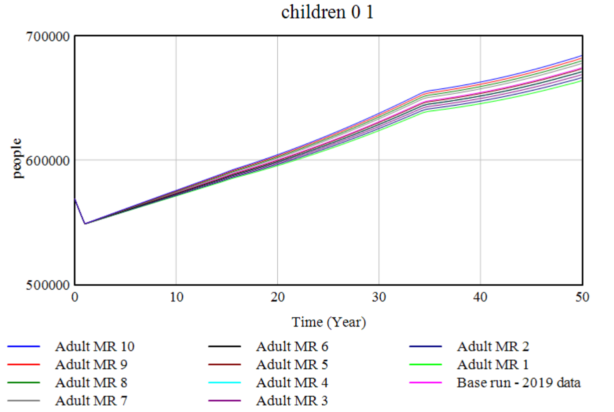
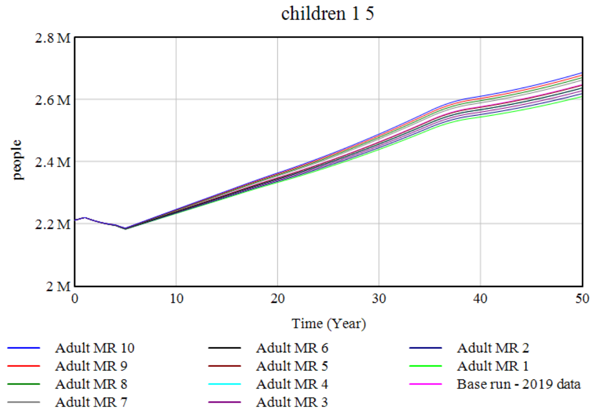
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the children 1-5 stock variations in mortality rate 5-15 produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -1020. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.
		**Numerical sensitivity:** For the children 5-15 stock variations in mortality rate 5-15 produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -1050. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

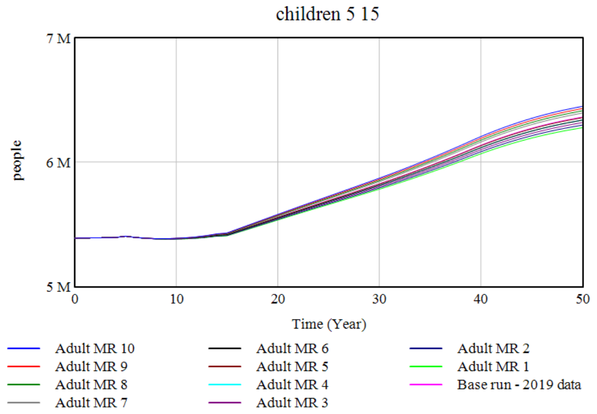
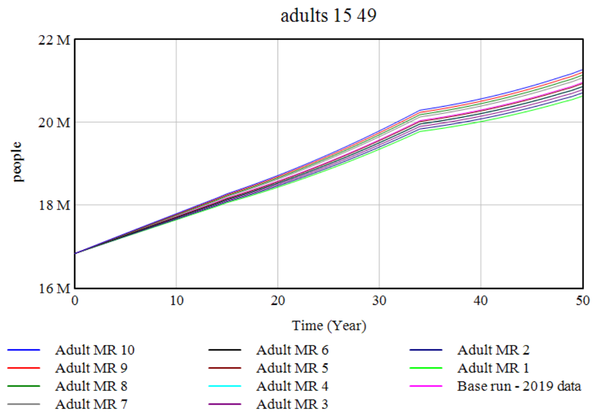
Model sector	Simulation results	Observations
		**Numerical sensitivity:** For the adults 15-49 stock variations in mortality rate 5-15 produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: -8800. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

2.4.6. Adult mortality rate

Adult mortality rate is varied in an interval from 0.0938 to 0.1340. The higher value of this interval corresponds to adult mortality rate in 2009. The lower value is calculated by subtracting the interval length from the higher value and the initial value in 2019 from the 2019 value. 10 simulations are run.

Adult mortality rate (last 10 years interval)													
Initial value 2019	**Variation range interval**		**Step size (10 steps)**	**Simulation 1**	**Simulation 2**	**Simulation 3**	**Simulation 4**	**Simulation 5**	**Simulation 6**	**Simulation 7**	**Simulation 8**	**Simulation 9**	**Simulation 10**
0.1139	0.0938	0.1340	0.0045	0.0938	0.0983	0.1027	0.1072	0.1117	0.1161	0.1206	0.1251	0.1295	0.1340

Model sector	Simulation results	Observations
Population aging chain		**Numerical sensitivity:** For the children 0-1 stock variations in adult mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 20,231. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.
		**Numerical sensitivity:** For the children 1-5 stock variations in adult mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 76,510. **Behavioral mode sensitivity:** There is no behavioral mode sensitivity in any simulation.

<table>
<tr><th>Model sector</th><th>Simulation results</th><th>Observations</th></tr>
<tr><td></td><td>
</td><td>Numerical sensitivity: For the children 5-15 stock variations in adult mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 171,680.
Behavioral mode sensitivity:
There is no behavioral mode sensitivity in any simulation.</td></tr>
<tr><td></td><td>
</td><td>Numerical sensitivity: For the adults 15-49 stock variations in adult mortality rate produce small numerical sensitivity in all cases. Numerical difference at time 50 between simulation 10 and simulation 1: 638,500.
Behavioral mode sensitivity:
There is no behavioral mode sensitivity in any simulation.</td></tr>
</table>

2.4.7. Conclusion:

- The model produces numerical and behavior mode sensitivity for variations in fertility rate and female percentage.
- The model does not produce behavioral sensitivity for variations in death rates.

Appendix 3.

Table. Estimated overweight transition rates by age group and quadratic differences between observed prevalence of overweight and non-overweight, according to ENDES 2020, and estimated 2020 prevalence of overweight and non-overweight, using the heuristic described by Meisel et al. (Meisel *et al.*, 2018)

Age group	Overweight faltering rate	Overweight recovery rate	Quadratic difference between observed and estimated normal weight prevalence	Quadratic difference between observed and estimated overweight prevalence
15-19	20.19%	7.59E-39%	-	-
20-24	19.82%	3.31E-22%	0.23%	1.14%
25-29	20.80%	0.00E-00%	0.26%	0.53%
30-34	20.19%	3.31E-22%	0.07%	0.40%
35-39	19.02%	1.73E-16%	0.02%	0.27%
40-44	10.21%	1.65E-22%	0.09%	0.37%
45-49	18.99%	2.72E-18%	0.35%	0.01%

Note: for local optimisation, the Augmented Lagrangian algorithm was used for all age groups except from the 25-29 years age group for which the Constrained Optimization by Linear Approximations (COBYLA) algorithm was used.