No milk without meat: Dynamic implications of the biological link between milk and bovine meat production on nutrition guidelines

Supplementary material – technical documentation

This supplement describes the model structure and provides full documentation of the model. The simulation model is implemented in Stella Architect (© isee systems), version 2.1.5. The files needed to run the model and replicate the analyses are appended to this supplement and can be viewed and run with the isee Player, https://www.iseesystems.com/soft-wares/player/iseeplayer.aspx.

1 Model structure

Our model is a simplified version of the meat supply and demand policy model by [BLINDED FOR REVIEW], designed to specifically capture the biological link between milk and bovine meat production.

Our model uses the same herd structure as the comprehensive model. Yet, different from it, our model is initialized to equilibrium, meaning that all model parameters and therefore also the behavior remain unchanged throughout the simulation horizon in the absence of shocks or stressors. This enables users to better analyze impacts on model behavior as changes in consumption patterns are not confounded by other processes. Effects on production are thus more clearly visible. To further highlight production effects of consumption changes, we present simulation results in the paper, the STELLA model, and the accompanying online simulator as relative values where the reference or 2020 value of a variable is equal to 1.

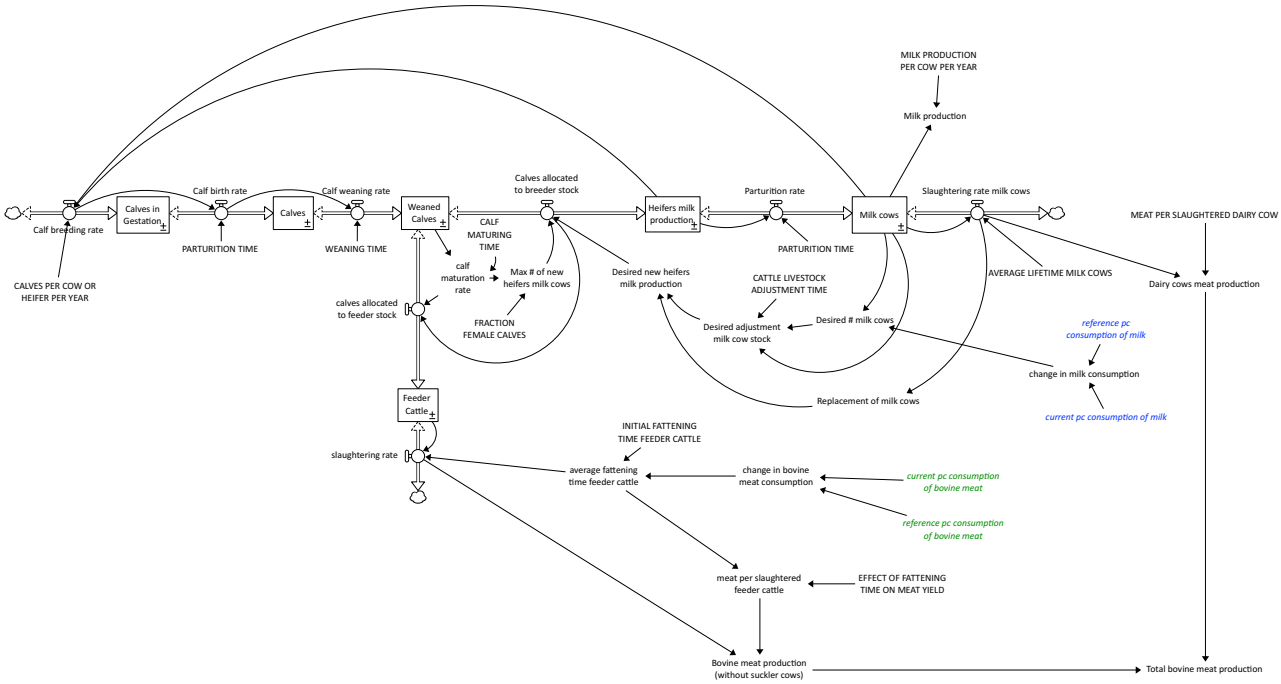

Figure A-1: Structure of the model: Main herd structure with milk and bovine meat production

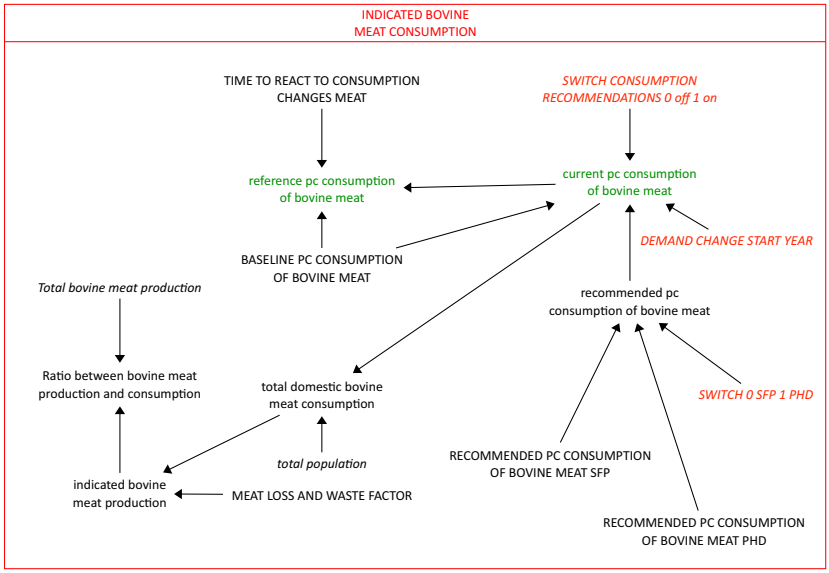

Figure A-2: Structure of the model: Meat demand

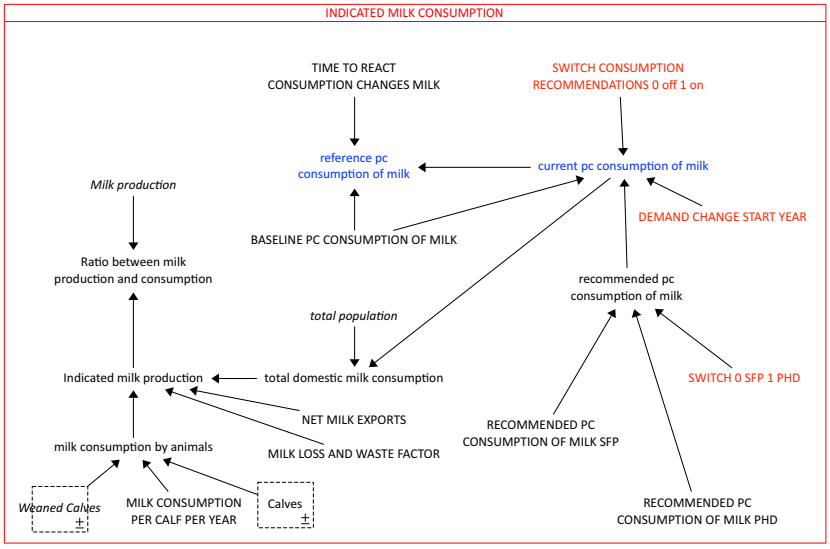

Figure A-3: Structure of the model: Milk demand

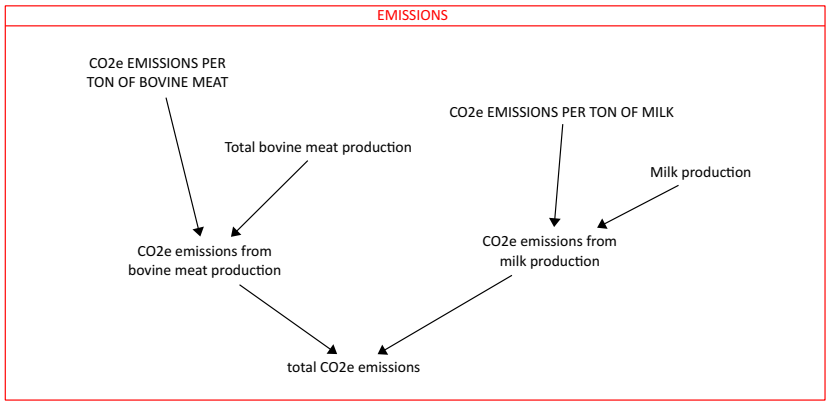

Figure A-4: Structure of the model: Emissions

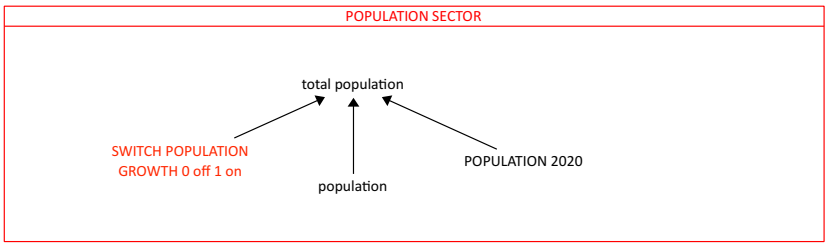

Figure A-5: Structure of the model: Population

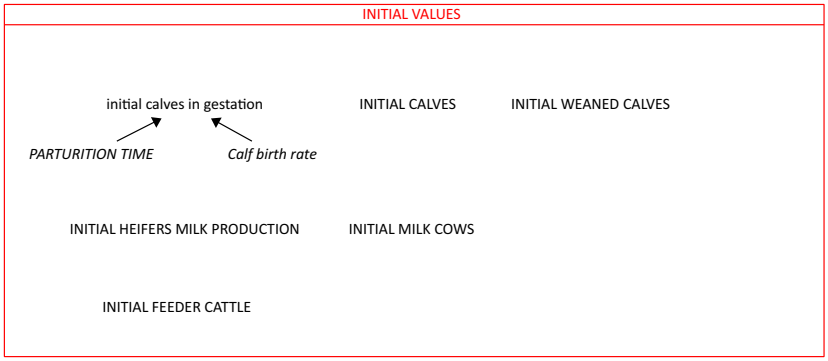

Figure A-6: Structure of the model: Initial values

2 Model equations

Table A.1 List of Model Equations – Stocks

Where to find	Variable Name	Equation	Units	Interpretation	Initial
Herd structure	**Calves**	Calves(t) = Calves(t - dt) + (Calf_birth_rate - Calf_weaning_rate) * dt	animal	This is a stock variable that calculates the number of calves at each point in time based on the initial value of calves plus the integrated difference between calf birth rate and calf weaning rate over time.	INITIAL_CALVES
Herd structure	**Calves in Gestation**	Calves_in_Gestation(t) = Calves_in_Gestation(t - dt) + (Calf_breeding_rate - Calf_birth_rate) * dt	animal	This is a stock variable that calculates the calves in gestation at each point in time based on the initial value of calves in gestation plus the integrated difference between calf breeding rate and calf birth rate over time.	INIT Calves_in_Gestation = initial_calves_in_gestation
Herd structure	**Feeder Cattle**	Feeder_Cattle(t) = Feeder_Cattle(t - dt) + (calves_allocated_to_feeder_stock - slaughtering_rate) * dt	animal	The stock of cattle who are fattened and later slaughtered.	INIT Feeder_Cattle = INITIAL_FEEDER_CATTLE
Herd structure	**Heifers milk production**	Heifers_milk_production(t) = Heifers_milk_production(t - dt) + (Calves_allocated_to_breeder_stock - Parturition_rate) * dt	animal	This is a stock variable that calculates the number of heifers at each point in time based on the initial value of heifers plus the integrated difference between the calves allocated to the breeder stock and the parturition rate over time.	INIT Heifers_milk_production = INITIAL_HEIFERS_MILK_PRODUCTION
Herd structure	**Milk cows**	Milk_cows(t) = Milk_cows(t - dt) + (Parturition_rate - Slaughtering_rate_milk_cows) * dt	animal	This is a stock variable that calculates the number of dairy cows at each point in time based on the initial value of milk cows plus the integrated difference between the parturition rate and the slaughtering rate over time.	INIT Milk_cows = INITIAL_MILK_COWS

Herd structure	**Weaned calves**	Weaned_Calves(t) = Weaned_Calves(t - dt) + (Calf_weaning_rate - Calves_allocated_to_breeder_stock - calves_allocated_to_feeder_stock) * dt	animal	This is a stock variable that calculates the number of weaned calves at each point in time based on the initial value of weaned calves plus the integrated difference between calf weaning rate and calf maturation rate over time.	INIT Weaned_Calves = INITIAL_WEANED_CALVES

Table A.2 List of Model Equations - Flows

Where to find	Variable Name	Equation	Units	Interpretation
Herd structure	**Calf birth rate**	Calf_birth_rate = DELAY3(Calf_breeding_rate, PARTURITION_TIME)	animal/Year	The number of calves born each year after a delay equal to the average parturition time.
Herd structure	**Calf weaning rate**	Calf_weaning_rate = DELAY3(Calf_birth_rate, WEANING_TIME)	animal/Year	The number of calves weaned each year after a delay equal to the average weaning time.
Herd structure	**Calf breeding rate**	Calf_breeding_rate = (Milk_cows+Heifers_milk_production)*Calves_per_cow_or_heifer_per_year	animal/Year	The number of calves that are born each year depends on the size of the stocks of cows and heifers and on the number of calves that each cow and heifer produce per year.
Herd structure	**Calf birth rate**	Calf_birth_rate = DELAY3(Calf_breeding_rate, PARTURITION_TIME)	animal/Year	The number of calves born each year after a delay equal to the average parturition time.
Herd structure	**Calves allocated to feeder stock**	calves_allocated_to_feeder_stock = calf_maturation_rate-Calves_allocated_to_breeder_stock	animal/Year	The number of matured calves each year that are allocated to the feeder stock. the number is calculated from the total number of weaned calves.
Herd structure	**Slaughtering rate**	slaughtering_rate = Feeder_Cattle/average_fattening_time_feeder_cattle	animal/Year	This is the outflow to the stock of feeder cattle. Feeder cattle are slaughtered when they reach the average fattening time. The average fattening time is not constant but depends on the profitability of meat. In this simplified model, we equate profitability with demand (desired meat consumption).
Herd structure	**Calves allocated to breeder stock**	Calves_allocated_to_breeder_stock = MIN(Desired_new_heifers_milk_production, Max_#_of_new_heifers_milk_cows)	animal/Year	The desired number of calves that are allocated to the breeding stock can be higher than the maximum possible number of new breeder calves given the existing herd structure. Under such extreme conditions, the minimum function makes sure that not more calves are allocated to the breeding stock than are physically available (the "maximum number of new heifers milk cows").
Herd structure	**Parturition rate**	Parturition_rate = Heifers_milk_production/PARTURITION_TIME	animal/Year	This flow describes the process of heifers becoming dairy cows after having their first calf.
Herd structure	**Slaughtering rate milk cows**	Slaughtering_rate_milk_cows = Milk_cows/AVERAGE_LIFETIME_MILK_COWS	animal/Year	This is the outflow from the stock of dairy cows. Dairy cows are slaughtered when they reach their average lifetime.
Herd structure	**Calf maturation rate**	calf_maturation_rate = Weaned_Calves/CALF_MATURING_TIME	animal/Year	This is the outflow from the stock of weaned calves. Calves are weaned

				when they reach the average calf maturing time. The number of weaned calves each year is subsequently allocated to either the breeder or the feeder stock.
Herd structure	**Calf weaning rate**	Calf_weaning_rate = DELAY3(Calf_birth_rate, WEANING_TIME)	animal/Year	The number of calves weaned each year after a delay equal to the average weaning time.
Herd structure	**Calves allocated to breeder stock**	Calves_allocated_to_breeder_stock = MIN(Desired_new_heifers_milk_production, Max_#_of_new_heifers_milk_cows)	animal/Year	The desired number of calves that are allocated to the breeding stock can be higher than the maximum possible number of new breeder calves given the existing herd structure. Under such extreme conditions, the minimum function makes sure that not more calves are allocated to the breeding stock than are physically available (the "maximum number of new heifers milk cows").
Herd structure	**Calves allocated to feeder stock**	calves_allocated_to_feeder_stock = calf_maturation_rate-Calves_allocated_to_breeder_stock	animal/Year	The number of matured calves each year that are allocated to the feeder stock. the number is calculated from the total number of weaned calves.

Table A.3 List of Model Equations – Other Variables

Where to find	Variable Name	Equation	Units	Interpretation
Herd structure	**Average fattening time feeder cattle**	average_fattening_time_feeder_cattle = initial_fattening_time_feeder_cattle*change_in_bovine_meat_consumption	Year	The average fattening time of feeder cattle depends on the demand for bovine meat. if de-mand increases, cattle are fattened for longer than if demand decreases.
Herd structure	**Bovine meat production**	"Bovine_meat_production_(without_suckler_cows)" = slaughtering_rate*meat_per_slaughtered_feeder_cattle	ton/Year	Tons per year produced by the slaughtered feeder cattle withing the bovine livestock but excluding the suckler cow line.
Herd structure	**Change in bovine meat consumption**	change_in_bovine_meat_consumption = current_pc_consumption_of_bovine_meat/reference_pc_consumption_of_bovine_meat	Dmnl	The change in demand, i.e., the current demand relative to the reference demand. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Herd structure	**Change in milk consumption**	change_in_milk_consumption = current_pc_consumption_of_milk/reference_pc_consumption_of_milk	Dmnl	The change in demand, i.e., the current demand relative to the reference demand. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Emissions	**CO2e emissions from bovine meat production**	CO2e_emissions_from_bovine_meat_production = CO2_emissions_per_ton_of_bovine_meat*Total_bovine_meat_production	ton co2/Year	The total number of tons of CO_2 equivalents per year resulting from bovine meat production.

Emissions	**CO2e emissions from milk production**	CO2e_emissions_from_milk_production = CO2_emissions_per_ton_of_milk*Milk_production	ton co2/Year	The total number of tons of CO_2 equivalents per year resulting from milk production.
Meat demand	**Current per capita consumption of bovine meat**	current_pc_consumption_of_bovine_meat = (IF TIME < demand_change_start_year THEN baseline_pc_consumption_of_bovine_meat ELSE (1-switch_consumption_recommendations_0_off_1_on)*baseline_pc_consumption_of_bovine_meat+recommended_pc_consumption_of_bovine_meat*switch_consumption_recommendations_0_off_1_on)	ton/(person*Year)	The per capita consumption of bovine meat per year in the activated scenario.
Milk demand	**Current per capita consumption of milk**	current_pc_consumption_of_milk = (IF TIME < demand_change_start_year THEN baseline_pc_consumption_of_milk ELSE (1-switch_consumption_recommendations_0_off_1_on)*baseline_pc_consumption_of_milk+recommended_pc_consumption_of_milk*switch_consumption_recommendations_0_off_1_on)	ton/(person*Year)	The per capita consumption of milk per year in the activated scenario.
Herd structure	**Dairy cows meat production**	Dairy_cows_meat_production = Meat_per_slaughtered_dairy_cow*Slaughtering_rate_milk_cows	ton/Year	Tons of bovine meat per year produced by the slaughtered dairy cows.
Herd structure	**Desired number of milk cows**	Desired_#_milk_cows = Milk_cows*change_in_milk_consumption	animal	The desired number of milk cows is calculated by adjusting the current number of milk cows upward if the demand for milk products increases and downward if the demand for milk products decreases. in this simplified model, we assume that a change in consumption will lead to the same change in production. the more advanced version of this model considers a series of additional factors such as price elasticity of demand and supply, fodder availability and environmental regulations.
Herd structure	**Desired adjustment milk cow stock**	Desired_adjustment_milk_cow_stock = (Desired_#_milk_cows-Milk_cows)/Cattle_livestock_adjustment_time	animal/Year	The desired adjustment of the milk cow stock compares desired and available numbers of milk cows and adjusts this difference not immediately, but over the cattle livestock adjustment time.
Herd structure	**Desired_new_heifers milk production**	Desired_new_heifers_milk_production = MAX(0, Desired_adjustment_milk_cow_stock+Replacement_of_milk_cows)	animal/Year	The desired new heifers are the sum of the calves needed for replacing the current milk cow stuck plus the desired adjustment of the milk cow stock.
Meat demand	**Indicated bovine meat production**	indicated_bovine_meat_production = total_domestic_bovine_meat_consumption*MEAT_LOSS_AND_WASTE_FACTOR	ton/Year	indicated bovine meat production represents demand. in this simplified model, price does not mitigate desired consumption. total demand is the domestic consumption, adjusted for the meat loss and waste along the entire value chains. net exports in the case of bovine meat are negligible, especially compared to net milk exports.

Milk demand	**Indicated milk production**	Indicated_milk_production = (total_domestic_milk_consumption+NET_MILK_EXPORTS+milk_consumption_by_animals)*MILK_LOSS_AND_WASTE_FACTOR	ton/Year	indicated milk production represents demand. in this simplified model, price does not mitigate desired consumption. total demand is the sum of domestic consumption, consumption by animals and exports, adjusted for the milk loss and waste along the entire value chains.
Initial values	**Initial calves in gestation**	initial_calves_in_gestation = Calf_birth_rate*PARTURITION_TIME	animal	The initial value of calves in gestation, calculated to initialize the model in equilibrium.
Herd structure	**Maximum number of new heifers milk cows**	Max_#_of_new_heifers_milk_cows = calf_maturation_rate*FRACTION_FEMALE_CALVES	animal/Year	The maximum number of new heifers is the number of female weaned calves each year.
Herd structure	**Meat per slaughtered feeder cattle**	meat_per_slaughtered_feeder_cattle = LOOKUP(effect_of_fattening_time_on_meat_yield, average_fattening_time_feeder_cattle)	ton/animal	The meat per slaughtered feeder cattle depends on the age of the animal and the value of meat per animal is read from the table “effect of fattening time on meat yield”.
Milk demand	**Milk consumption by animals**	milk_consumption_by_animals = (Calves+Weaned_Calves)*MILK_CONSUMPTION_PER_CALV_PER_YEAR	ton/Year	The amount of milk consumed by calves every year. in the more elaborate model, also pigs are fed with milk from dairy cows.
Herd structure	**Milk production**	Milk_production = Milk_cows*MILK_PRODUCTION_PER_COW_PER_YEAR	ton/Year	This variable calculates milk production per year as a function of both, the number of milk cows and the average milk production per cow per year.
Meat demand	**Ratio between bovine meat production and consumption**	Ratio_between_bovine_meat_production_and_consumption = Total_bovine_meat_production/indicated_bovine_meat_production	Dmnl	this ratio compares supply and demand. the total demand is adjusted for the bovine meat loss and waste along the entire value chains. net exports in the case of bovine meat are negligible, especially compared to net milk exports.
Milk demand	**Ratio between milk production and consumption**	Ratio_between_milk_production_and_consumption = Milk_production/Indicated_milk_production	Dmnl	this ratio compares supply and demand. the total demand is the sum of domestic consumption, consumption by animals and exports, adjusted for the milk loss and waste along the entire value chains.
Meat demand	**Recommended per capita consumption of bovine meat**	recommended_pc_consumption_of_bovine_meat = recommended_pc_consumption_of_bovine_meat_SFP*(1-switch_0_sfp_1_phd)+switch_0_sfp_1_phd*recommended_pc_consumption_of_bovine_meat_phd	ton/(Year*person)	The recommended per capita consumption of bovine meat for one of the two nutrition recommendation scenarios: Swiss Food Pyramid or Planetary Health Diet.
Milk demand	**Recommended per capita consumption of milk**	recommended_pc_consumption_of_milk = recommended_pc_consumption_of_milk_SFP*(1-switch_0_sfp_1_phd)+recommmended_pc_consumption_of_milk_PHD*switch_0_sfp_1_phd	ton/(person*Year)	The recommended per capita consumption of milk for one of the two nutrition recommendation scenarios: Swiss Food Pyramid or Planetary Health Diet.
Meat demand	**Reference per capita consumption of bovine meat**	reference_pc_consumption_of_bovine_meat = SMTH3(current_pc_consumption_of_bovine_meat, TIME_TO_REACT_TO_CONSUMPTION_CHANGES_MEAT, baseline_pc_consumption_of_bovine_meat)	ton/(person*Year)	The reference demand represents the per capita demand of bovine meat in the recent past. the time horizon over which demand changes are taken into consideration for adjusting pro-duction is indicated by the parameter "time to react to consumption changes meat".
Milk demand	**Reference per capita consumption of milk**	reference_pc_consumption_of_milk = SMTH3(current_pc_consumption_of_milk, TIME_TO_REACT_CONSUMPTION_CHANGES_MILK, baseline_pc_consumption_of_milk)	ton/(person*Year)	The reference demand represents the per capita demand of milk in the recent past. the time horizon over which demand changes are taken into consideration for adjusting production is indicated

				by the parameter "time to react to consumption changes milk".
Herd structure	**Replacement of milk cows**	Replacement_of_milk_cows = Slaughtering_rate_milk_cows	animal/Year	This variable calculates the number of dairy cows needed to replace the dairy cows that are slaughtered.
Meat demand, Milk demand	**Switch between Swiss Food Pyramid and Planetary Health Diet**	switch_0_sfp_1_phd = 0	Dmnl	This is a scenario switch that allows alternating between the Swiss Food Pyramid recommendations (switch = 0) and the recommendations of the Planetary Health Diet (switch = 1).
Meat demand, Milk demand	**Switch between consumption recommendations**	switch_consumption_recommendations_0_off_1_on = 0	Dmnl	This is a switch that allows alternating between current and recommended consumption pat-terns. 0 means current consumption patterns, 1 means recommended consumption patterns.
Population	**Switch between population growth and no growth**	switch_population_growth_0_off_1_on = 0	Dmnl	This is a switch that allows alternating between a constant population size and a time-dependent population size. 0 means constant population, 1 takes population from historical and projected data.
Herd structure	**Total bovine meat production**	Total_bovine_meat_production = "Bo-vine_meat_production_(without_suckler_cows)"+Dairy_cows_meat_production	ton/Year	The total amount of bovine meat produced in one year. this variable only calculates bovine meat production from the dual-purpose meat/dairy stock but excludes bovine meat from the suckler cow line.
Emissions	**Total CO2e emissions**	total_CO2e_emissions = CO2_emissions_from_bovine_meat_production+CO2_emissions_from_milk_production	ton co2/Year	The total number of tons of CO_2 equivalents per year resulting from milk and bovine meat pro-duction.
Meat demand	**Total domestic bovine meat consumption**	total_domestic_bovine_meat_consumption = to-tal_population*current_pc_consumption_of_bovine_meat	ton/Year	The total amount of bovine meat consumed per year by the Swiss population.
Milk demand	**Total domestic milk consumption**	total_domestic_milk_consumption = total_population*current_pc_consumption_of_milk	ton/Year	the total amount of milk consumed per year by the Swiss population
Population	**Total population**	total_population = (1-switch_population_growth_0_off_1_on)*population_2020+switch_population_growth_0_off_1_on*population	person	The total population of Switzerland, used to calculate total milk and bovine meat consumption.

Table A.4 List of Model Equations – Parameters, their Values and Sources

Where to find	Parameter name	Name in model	Value	Units	Interpretation	Source
Herd structure	**Average lifetime of milk cows**	AVERAGE_LIFETIME_MILK_COWS	4	Year	The number of years, on average, that a milk cow is kept on lactation	Agridea/FiBL, 2019, section Tierhaltung
Meat demand	**Baseline per capita consumption of bovine meat**	BASELINE_PC_CONSUMPTION_OF_BOVINE_MEAT	0.01044	ton/(person*Year)	Per capita consumption under baseline conditions.	SBV, 2021
Milk demand	**Baseline per capita consumption of milk**	BASELINE_PC_CONSUMPTION_OF_MILK	0.3189	ton/(person*Year)	Per capita consumption under baseline conditions.	SBV, 2021

Herd structure	**Calf maturing time**	CALF_MATURING_TIME	0.56	Year	The time it takes for calves to fully mature. the constant assumes the value of the remaining 205 days until calves reach the age of 1 year, where the female animals destined for milk production get inseminated for the first time	SBV, 2021
Herd structure	**Calves per cow or heifer per year**	CALVES_PER_COW_OR_HEIFER_PER_YEAR	1.02	1/Year	The number of calves that, on average, each cow and heifer produce per year.	Agridea/FiBL, 2019, section Tierhaltung
Herd structure	**Cattle livestock adjustment time**	CATTLE_LIVESTOCK_ADJUSTMENT_TIME	10	Year	The long adjustment time is rooted in the long lifetime of cattle livestock buildings and related infrastructure, which limit the flexibility with which farmers enter and exit the cattle sector.	[BLINDED FOR REVIEW]
Emissions	**CO2e emissions per ton of bovine meat**	CO2E_EMISSIONS_PER_TON_OF_BOVINE_MEAT	13	ton co2/ton	tons of CO2 equivalents produced per ton of bovine meat. data source: FAOSTAT	FAOSTAT, Climate Change, Emission Intensities: https://www.fao.org/faostat/en/#data/EI
Emissions	**CO2e emissions per ton of milk**	CO2E_EMISSIONS_PER_TON_OF_MILK	1.6	ton co2/ton	tons of CO2 equivalents produced per ton of milk.	Bussa et al., 2020
Meat demand, Milk demand	**Demand change start year**	DEMAND_CHANGE_START_YEAR	2022	Year	this is a scenario variable that allows defining the year in which consumption changes start.	User choice.
Herd structure	**Fraction of female calves**	FRACTION_FEMALE_CALVES	0.5	Dmnl	The fraction, on average, of calves that are female.	Agridea/FiBL, 2019, section "Tierhaltung".
Initial values	**Initial number of calves**	INITIAL_CALVES	304353	animal	The initial value of calves	Calculated to initialize the model in equilibrium
Herd structure	**Initial fattening time feeder cattle**	INITIAL_FATTENING_TIME_FEEDER_CATTLE	0.43	Year	An average of the average fattening time for veal fattening and bull fattening, weighted by the livestock units of calves and bulls in the initial year of the simulation and estimated to keep the model in equilibrium	Agridea/FiBL, 2019, section "Tierhaltung".
Initial values	**Initial feeder cattle**	INITIAL_FEEDER_CATTLE	240197	animal	The initial number of feeder cattle	SBV, 2021 Cattle aged 365-730 days
Initial values	**Initial heifers milk production**	INITIAL_HEIFERS_MILK_PRODUCTION	135005	animal	The initial value of heifers.	Milk production per dairy cow (7 ton/year; SBV, 2020) and livestock numbers (total of 677863 cows - of which 542857 must be dairy cows and the rest heifers for milk production; SBV, 2021).

Initial values	**Initial number of milk cows**	INITIAL_MILK_COWS	542857	animal	The initial value of milk cows	SBV, 2021
Initial values	**Initial number of weaned calves**	INITIAL_WEANED_CALVES	391800	animal	The initial value of weaned calves	Calculated to initialize the model in equilibrium
Meat demand	**Meat loss and waste factor**	MEAT_LOSS_AND_WASTE_FACTOR	1.1	Dmnl	calculated from SBV. (2021).	SBV, 2021 total production (incl. net exports) vs. total consumption 2020.
Herd structure	**Meat per slaughtered dairy cow**	MEAT_PER_SLAUGHTERED_DAIRY_COW	0.3	ton/animal	Meat yield is set at 38% of the live weight (700kg).	Agridea/FiBL, 2019, section "Tierhaltung".
Milk demand	**Milk consumption per calf per year**	MILK_CONSUMPTION_PER_CALF_PER_YEAR	0.6	ton/(animal*Year)	calculated from SBV (2021)	SBV, 2021 Kälber bis 160 Tage, Jungvieh 160-365 Tage; total milk consumption by calves and weaned calves: 400'000 ton/year.
Milk demand	**Milk loss and waste factor**	MILK_LOSS_AND_WASTE_FACTOR	1.13		calculated from SBV (2021)	SBV, 2021
Milk demand	**Milk production per cow per year**	MILK_PRODUCTION_PER_COW_PER_YEAR	7	ton/(animal*Year)	The amount of milk produced, on average, per cow and year	SBV, 2020
Milk demand	**Net milk exports**	NET_MILK_EXPORTS	189000	ton/Year	the net amount of milk exported per year.	SBV, 2020
Herd structure	**Parturition time**	PARTURITION_TIME	1	Year	The parturition time is 9 months but heifers and cows only get inseminated once per year.	Agridea/FiBL, 2019
Population	**Population**	POPULATION_2020	8.67054 e+06	person	the population in Switzerland in 2020	BfS, 2021
Meat demand	**Recommended per capita consumption of bovine meat (Planetary Health Diet)**	RECOMMENDED_PC_CONSUMPTION_OF_BOVINE_MEAT_PHD	0.00511	ton/(person*Year)	recommended per capita consumption of bovine meat according to the planetary health diet.	The data is from the integrated model developed in the NRP69 project, described in [BLINDED FOR REVIEW].
Meat demand	**Recommended per capita consumption of bovine meat (Swiss Food Pyramid)**	RECOMMENDED_PC_CONSUMPTION_OF_BOVINE_MEAT_SFP	0.00544	ton/(person*Year)	per capita consumption in the Swiss Food Pyramid Scenario	The data is from the integrated model developed in the NRP69 project, described in [BLINDED FOR REVIEW].
Milk demand	**Recommended per capita consumption of milk (Swiss Food Pyramid)**	RECOMMENDED_PC_CONSUMPTION_OF_MILK_SFP	0.2788	ton/(person*Year)	per capita consumption in the Swiss Food Pyramid Scenario	The data is from the integrated model developed in the NRP69 project, described in [BLINDED FOR REVIEW].
Milk demand	**Recommended per capita consumption of milk (Planetary Health Diet)**	RECOMMMENDED_PC_CONSUMPTION_OF_MILK_PHD	0.09125	ton/(person*Year)	recommended per capita consumption of milk according to the planetary health diet	The data is from the integrated model developed in the NRP69 project, described in [BLINDED FOR REVIEW].
Milk demand	**Time to react to consumption change - milk**	TIME_TO_REACT_CONSUMPTION_CHANGES_MILK	10	year	the time horizon over which demand changes are taken into consideration for adjusting pro-duction. The lower value for meat than for milk reflects the capital	[BLINDED FOR REVIEW].

					intensity of bovine meat production compared to milk production (stables and milking equipment)	
Meat demand	**Time to react to consumption change – meat**	TIME_TO_REACT_TO_CONSUMPTION_CHANGES_MEAT	5	Year	the time horizon over which demand changes are taken into consideration for adjusting pro-duction.	[BLINDED FOR REVIEW].
Herd structure	**Weaning time**	WEANING_TIME	0.44	Year	The time it takes to wean calves	SBV, 2021 Calves aged up to 160 days.

Table A.5 List of Model Equations – Nonlinear Functions

Where to find	Parameter name	Name in model	Points	Units	Interpretation	Source
Herd structure	**Effect of fattening time on meat yield**	effect_of_fattening_time_on_meat_yield = GRAPH(0+0)	(0.3400, 0.0700), (0.4300, 0.1050), (1.2000, 0.1970)	ton/animal	Meat yield is set at 38% of the live weight of animals. The low value is for veal fattening and the high value for bull fattening.	Agridea/FiBL, 2019, section "Tierhaltung".
Population	**Population**	population= GRAPH(TIME)	(2000.00, 7164440), (2001.00, 7197640), (2002.00, 7255650), (2003.00, 7313850), (2004.00, 7364150), (2005.00, 7415100), (2006.00, 7459130), (2007.00, 7508740), (2008.00, 7508740), (2009.00, 7701860), (2010.00, 7785810), (2011.00, 7870130), (2012.00, 7954660), (2013.00, 8039060), (2014.00, 8139630), (2015.00, 8339510), (2020.00, 8757650), (2025.00, 9159870), (2030.00, 9541470), (2035.00, 9856970), (2040.00, 10044300), (2045.00, 10176100)	person	the total population in Switzerland	Historical data: BfS, 2021 Future projections: BfS, 2015; Referenzszenario A-00-2015.

3 Information on model testing

Given that we initialize the model in equilibrium, we work with constant parameter values from the year 2020 for consumption, livestock numbers—that translate into production quantities—, and population size throughout the simulation period. Assumption on the latter can be relaxed by changing parameters according to Table A.4)

For testing the model, we followed the standard procedure for assessing model structure and behavior (Sterman, 2000). We calculated analytically (e.g., in the case of initial calves in gestation) and/or numerically the initial values of those animal stocks for which no statistical data is available such that for each stock the inflow is equal to the outflow and thus ensures dynamic equilibrium.

4 References

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