The Transportation of Milk - How is it Impacting our Environment?

Silver Circle Paper

by

Henry Li

Model Construction Team:
Will Palmer & Henry Li

Wilson High School
Modeling Dynamic Systems

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System Dynamics Advisor: Diana Fisher
Mathematics Department
Wilson High School
Portland, Oregon

Outside Advisors:
Hyung Nam
Wilson High School

Madeline MacGregor
Oregon Department of Agriculture

Introduction

Global warming is an extremely critical problem that humanity faces. It has many causes, of course, but most of us have heard only a few of them. Car emissions, the burning of fossil fuels, poor building designs, etc...

One of the least told - and tragic - stories regarding global warming is the transportation of goods and food across the world:

"...trade-related transportation is one of the fastest growing sources of greenhouse gas emissions. But because emissions resulting from international air and sea freight are not included in national inventories...and the Kyoto Protocol...there is no incentive for them to be reduced..." (Millstone 66)

By modeling some key points and aspects of the this global exchange with accurate data and accurate use of logic, we can gain better insight of how human beings are polluting the Earth in ways that would not be possible without the mind-boggling speed and efficiency of a computer.

Reference Graphs

For Transportation of Good Across the World

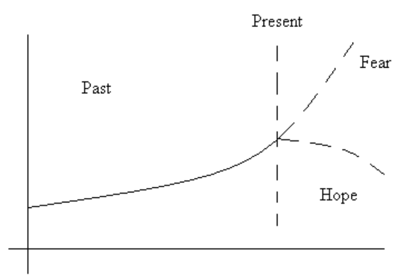

FIGURE A: AS THE WORLD GLOBALIZES, SHIPPING AND FREE TRADE HAVE BECOME THE NORM. AS MORE AND MORE GOODS ARE SHIPPED, CO_2 EMISSION WILL ALSO INCREASE (SEE GRAPH BELOW).

For Carbon Dioxide Emissions

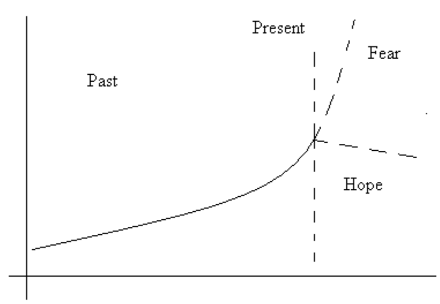

FIGURE B: HUMANS HAVE EMITTED MORE AND MORE CO_2 OVER THE PAST YEARS, THIS NEEDS TO STOP IF GLOBAL WARMING IS TO BE RELIABLY HALTED.

The Process of Model Building

An early decision that Will and I made before we actually began to build the model itself was that to model just *food* in general would be too big and too complicated. In order to shorten and simplify the process, we decided to just use the transportation of milk, liquid or powdered, as the variable we're modeling.

We started out nice and simple. Because our model was a reflection based on the interaction between human beings and nature, a population component of our model was the first thing that Will and I designed. To keep it plain and simple for the time being, we just had a flat population – 300 million people. No births, no deaths, no anything.

FIGURE 1: THE VERY FIRST COMPONENT – POPULATION (THOUGH IT'S REALLY VERY SIMPLE)

Next, Will and I expanded the model, so that it included the U.S. domestic milk production part and of all of it's subcomponents.

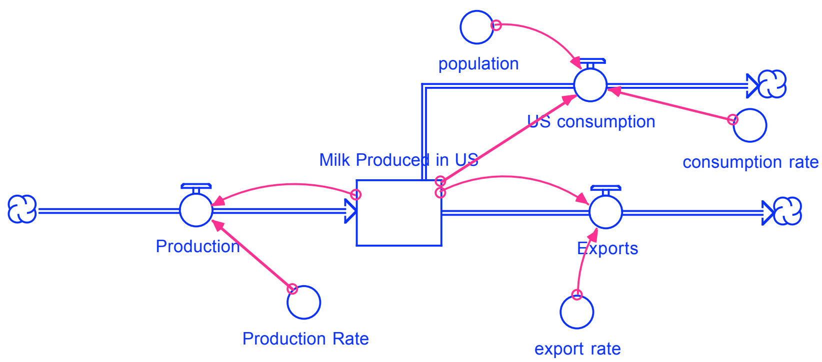

FIGURE 2: THIS IS JUST THE MOST BASIC OUTLINE OF ONE OF THE MAIN SECTIONS OF OUR MODEL: U.S. DOMESTIC MILK PRODUCTION. WE HAVE A STOCK LABELED AS "MILK PRODUCED IN THE U.S.,"AND THREE FLOWS TIED IN WITH THAT STOCK: PRODUCTION (DETERMINED BY PRODUCTION RATE), U.S. CONSUMPTION (DETERMINED BY THE POPULATION AND THE CONSUMPTION RATE), AND EXPORTS TO OTHER COUNTRIES (DETERMINED BY THE EXPORT RATE)

Of course, the United States also imports it's milk from foreign countries. Will and I designed a temporarily-simple part to address this issue. It's the Imports section of the model.

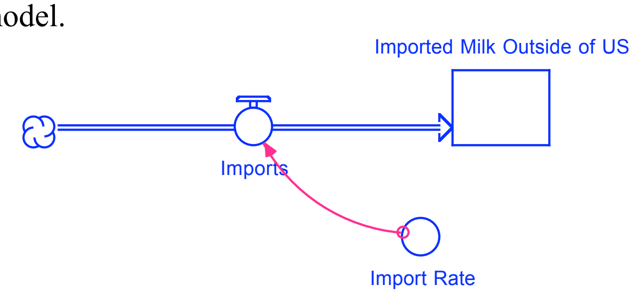

Figure 3: This part is (temporarily) very simple. The amount of milk the U.S. imports will be a stock, with a flow of Imports that is determined by the Import Rate.

The construction of the above sections of the model set the stage for the building of one of the most important parts of the entire model, and arguably the focus point of why our project began in the first place: greenhouse gas emissions. Specifically carbon dioxide.

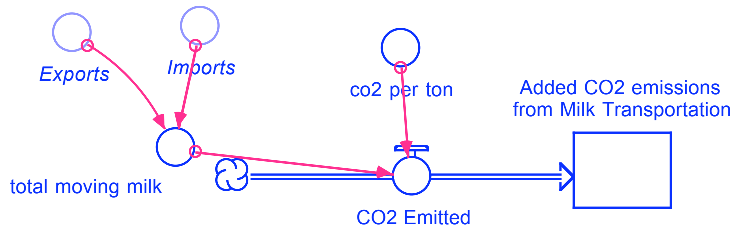

Figure 4: Here, the total amount of carbon dioxide spewed into the atmosphere is represented as a stock, with a flow of CO2 Emitted. That flow is determined by how much milk is being transported (Exports plus Imports) in tons, multiplied by the amount of carbon dioxide released per ton of milk shipped.

Put those three main parts together and that's the preliminary model (see diagram below). Of course there are still many more converters to add (and maybe a few stocks or flows too…), and the actual values of the components themselves have to be researched and then checked for their accurateness.

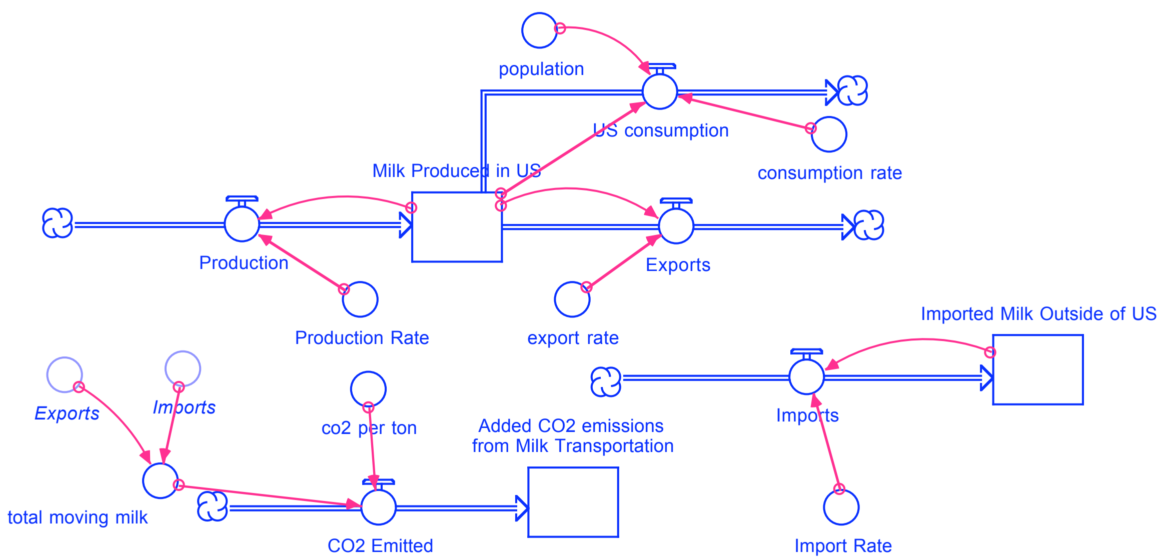

Figure 5: The entire preliminary model. One of the most important things that I know will have to be added later on are two graphical converters, which will enable the model to change the values of some of the converters above according to specific changes as time goes on in our model.

Extra

To tell the truth though, Will and I made some drastic, even laughable errors during the first stages of preliminary model construction. We took a few wrong turns. One, not working model is shown below:

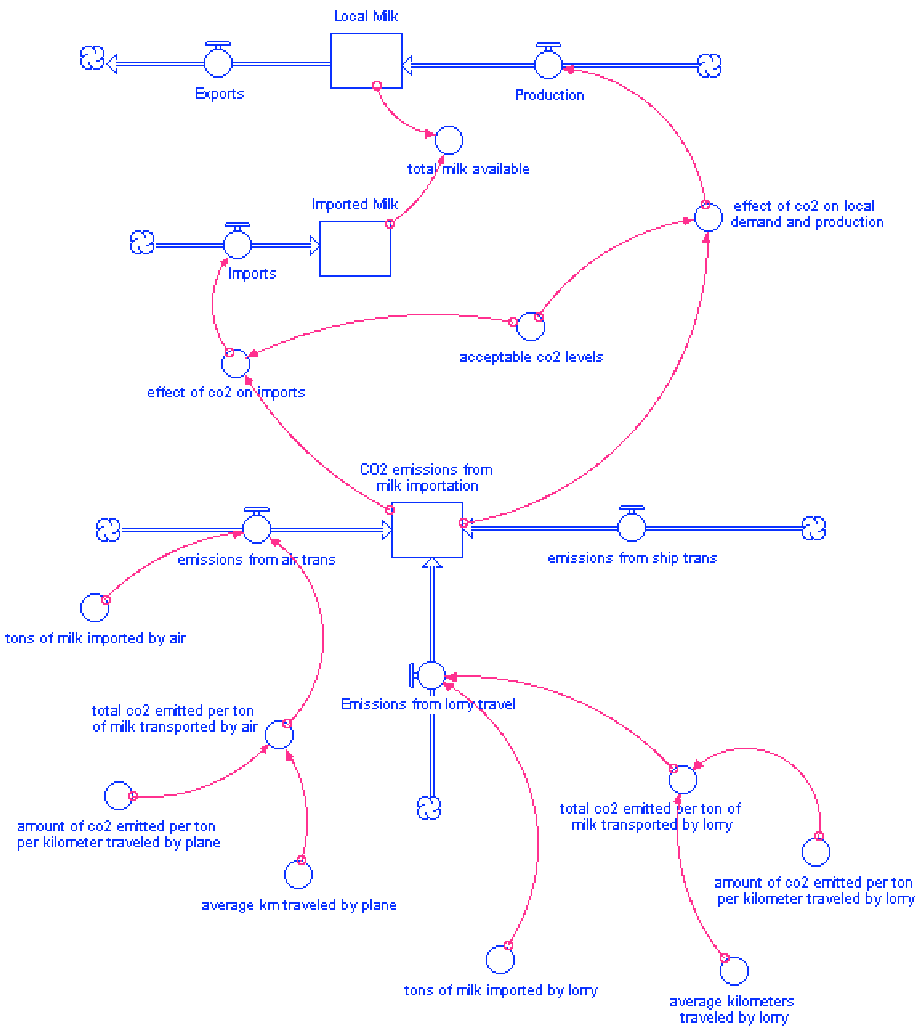

FIGURE 6: AN ERRONEOUS EARLY VERSION OF OUR PRELIMINARY MODEL, ERRORS EXPLAINED BELOW.

The above, erroneous model is actually in some ways more advanced than the working preliminary model in Figure 5. It already has two graphical functions put in, and it's pretty big. But it doesn't work, and one of the main reasons for that is because Will and I tried to break down imported milk into three kinds: imported by lorry (truck), imported by plane, and imported by ship. This was because we had some data on milk transportation for each mode of travel (from The Penguin

Atlas of Food). In the end however, it proved way too complex, because Will and I decided just to group the 3 import kinds into one.

The Finished Model and How It Works

As expected, Will and I only had to add about a dozen or so more converters and a few more stocks and flows to obtain the structure of the final model, which is shown on page 9, in Figure 10.

The *Effect* Converters – Effect of Milk Needed on Imports and Production

First of all, I would like to talk about the *Effect* graphical function converters. There are two of them in the final model. Both are extremely important for the model to be realistic. I will talk about both converters in detail.
This structure below is what I like to call the "Effect of Milk needed on Imports and Production" part of the model. This not only includes the *Effect…* converter itself, but also the other parts of the model that give it it's value *and* the two converters that it itself affects (the actual production and import rates).

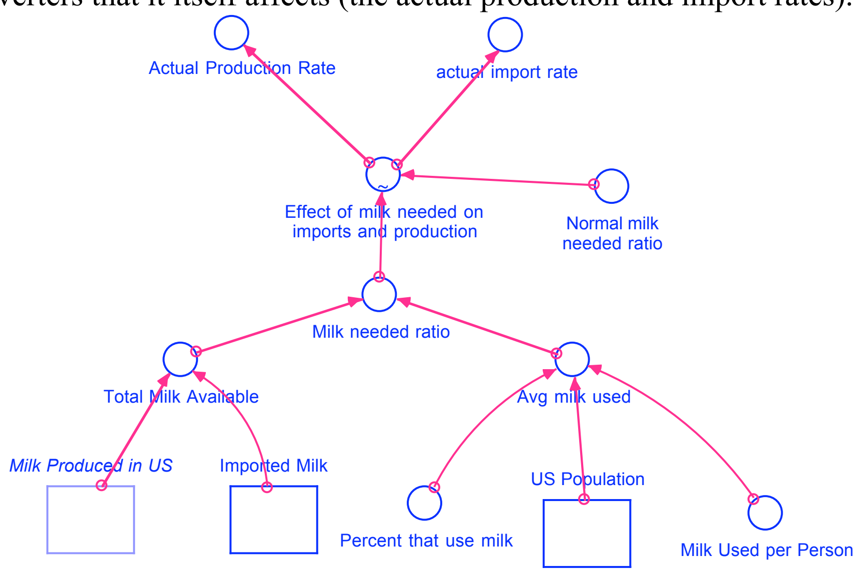

FIGURE 7: THIS SECTION OF THE MODEL LOOKS DIFFERENT FROM ANY PART OF THE FINAL MODEL IN FIGURE 10, EVEN THOUGH IT REALLY IS A SUB-SECTION OF THE FINAL MODEL. THE REASON FOR THIS IS BECAUSE ALL COMPONENTS THAT ARE CLOSE TO THE EFFECT OF MILK NEEDED ON IMPORTS AND PRODUCTION CONVERTER HAVE BEEN REVAMPED INTO A SHAPE THAT EASILY REVEALS HOW THE EFFECT CONVERTER HERE IS BEING AFFECTED BY OTHER COMPONENTS IN THE MODEL AND HOW IT ITSELF AFFECTS THE OTHERS COMPONENTS.

I have changed this sub-section to resemble a sort-of "hierarchy pyramid;" that is, each "layer" of model components depends on the layer below it. For example, the Total Milk Available converter is the sum of and thus depends on the components beneath it: which are Milk Produced in US and Imported Milk. Similarly, Avg Milk Used, which is the total amount of milk used in the U.S., is the product of the United States population, what percentage of that population use milk, and how much milk on average is used per person by that percentage of the population.

One level above that, and we come to the Milk Needed Ratio, which divides the Avg Milk Used value, which is how much milk U.S. consumers want to use, and the Total Milk Available value, which is how much milk is actually available for use.

One more level up and the core part of this section of the model arrives: the Effect of milk needed on Imports and Production. This converter is a *graphical function*, which means that it's ultimate output value isn't fixed, but instead is determined by the component value *before* it, in this case the Milk Needed Ratio.

The Effect of milk needed on Imports and Production, like the Milk Needed Ratio, compares two values: how much milk is present in the US and how much milk the US needs. If the amount of milk present versus milk needed is too small (that is, if the fraction "Avg Milk Used/Total Milk Available" is bigger than one), this graphical function will raise the production and import rates (which is the next level up in the pyramid) in an attempt to boost milk levels. Similarly, if there is a surplus of milk (the fraction "Avg Milk Used/Total Milk Available" is smaller than one), this graphical converter will lower those two values.

The *Effect* Converters – Effect of CO2 Emissions on Imports and Consumption

As I said before, the final model has two graphical function converters. The second one is the Effect of CO2 Emissions on Imports and Consumption, of which the components surrounding it are shown below.

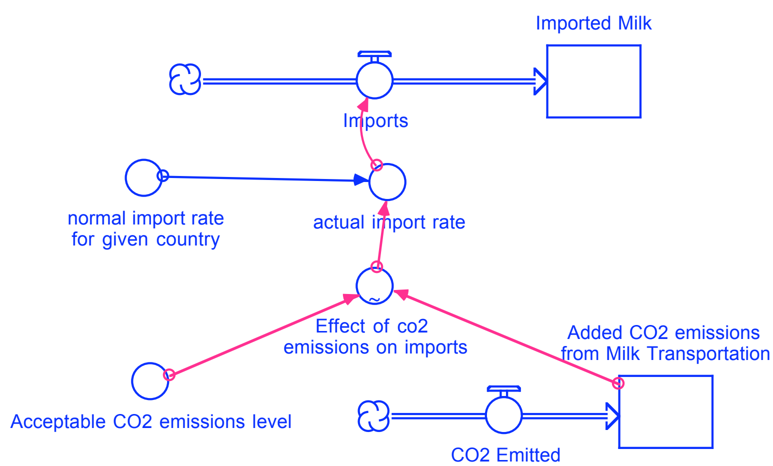

FIGURE 8: AGAIN, I HAVE REVAMPED THE PIECES SURROUNDING THE EFFECT OF CO2 EMISSIONS ON IMPORTS AND CONSUMPTION SO THAT IT SHOWS A HIERARCHY PYRAMID THAT MAKES IT EASIER TO SEE THE RELATIONSHIP BETWEEN THE EFFECT CONVERTER AND THE OTHER COMPONENTS.

This sub-section of the model revolves around the Effect of CO2 Emissions on Imports and Consumption graphical function converter. This converter compares (divides) the values it receives from Added CO2 Emissions from Milk Transportation, and the Acceptable CO2 Emissions level in much the same way that I already talked about with the previous *Effect* converter. The Effect of CO2 Emissions on Imports and Consumption compares (divides) two values: the total amount of CO2 released, and how much CO2 released is "acceptable." If too much carbon dioxide is being released (the "fraction" is bigger than one), this converter will lower the imports and consumption rate.

The United States Domestic Milk Production Section

Another major section of the final model that I feel is important enough to explain specifically about is what I call the "milk production section." That this, this section models how the United States produces it's own, domestic milk from dairy cows and dairy farms. The section is shown below.

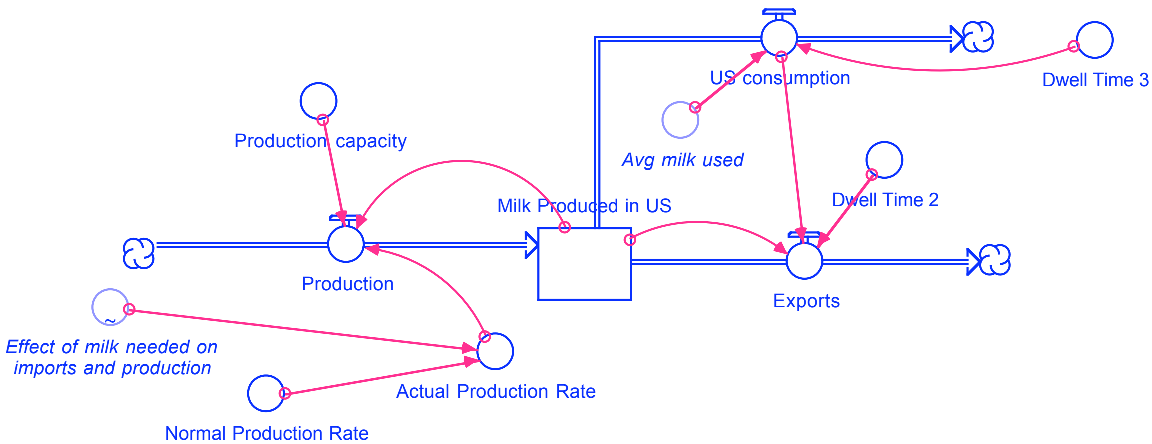

FIGURE 9: THIS PIECE OF THE MODEL IS A GENERAL REPRESENTATION OF U.S. MILK PRODUCTION. IT INCLUDES THREE FLOWS AND NUMEROUS CONVERTERS, THE EXPLANATIONS OF WHICH I WILL EXPLAIN BELOW. (NOTE: THE TWO DWELL TIMES WHICH ARE PRESENT IN THIS SECTION ARE ONLY THERE TO MAKE THE UNITS OF THE FLOWS WORK. BOTH HAVE VALUES SIMPLY OF 1)

The centerpiece of this section of the model is the stock "Milk Produced in US," which represents the total amount of milk that is being domestically harvested on dairy farm strictly within U.S. territory. There are three flows total: Production, (which is an inflow), US consumption (which is an outflow), and Exports (which is also an outflow). The internal workings of this section are as follows:

- "Effect of Milk Needed on Imports and Production" – can affect the actual imports and production rate values based on how much the U.S. needs at a certain given time.
- "Production" - the amount of milk produced in the United States is the Actual Production Rate times Milk Produced in US. But because there is a production capacity in place here, the total production amount cannot exceed the production capacity. If it does, then the model automatically reduces it so that it is equal to the production capacity.
- "Production Capacity" – the cap or limit on how much milk the U.S. can produce domestically, value is 48,000,000,000 pounds per year.

- “Exports” - for this value, Will and I assumed that the leftover domestically produced milk that had not been consumed would be exported. Thus, the value for the Exports flow is the amount of milk produced in the U.S. subtracted by how much U.S. milk consumers consumed.
- “US Consumption” – the total milk consumed in the United States is simply the Avg Milk Used (see Figure 7 if you’ve forgotten what or where Avg Milk Used is), no more and no less.

Actual Final Model Diagram:

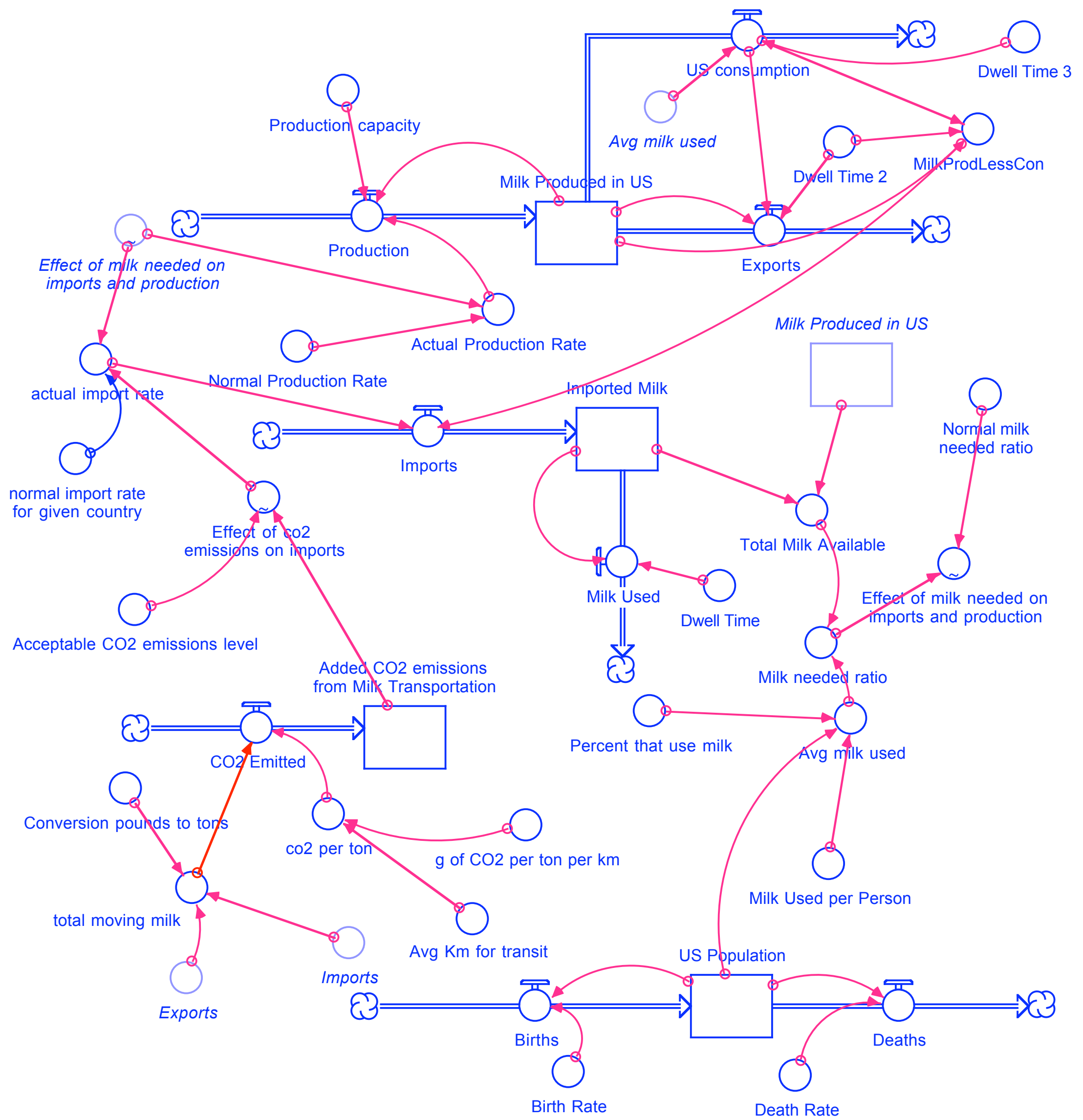

FIGURE 10: THE STRUCTURE ABOVE IS WHAT THE FINAL MODEL LOOKS LIKE. IT HAS BEEN GREATLY EXPANDED, AND NOW INCLUDES A U.S. POPULATION SECTION, AND MORE THAN A DOZEN NEW CONVERTERS THAT ENHANCE THE PERFORMANCE OF THE MODEL.

Explanation of the Entire Final Model as a Whole

The final model is essentially just a more complex, built-up version of the core components that Will and I first constructed in the preliminary model. We have added numerous converters, stocks, and flows, the inner workings of all of which (the ones that haven't already been explained already) I will explain below.

Stocks

- Imported Milk

Will and I assumed that the U.S. at the beginning of the model doesn't import any milk. We felt that this would be best for the model after many trials. Also, we were able to see the import amount grow as time wore on.

- Milk Produced in US

The initial amount of milk produced in the United States is the average amount of milk used. Will and I couldn't have used zero for this value, because that would mean no production or exports, so we just assumed that U.S. dairy farmers would be ready to produce as much milk as initially demanded by American consumers.

- Added CO2 emissions from Milk Transportation

Initially, Will and I assumed that there weren't any carbon dioxide emissions from shipments of milk. This seemed best to fit the model, because we could see this value grow over time as more and more milk was shipped.

- US Population

This value is generally well known. The United States recently passed the 300 million people mark.

Flows

- CO2 Emitted

The amount of carbon dioxide spewed into the atmosphere can be determined by the amount of milk that is moved (in tons) multiplied by the amount of carbon dioxide released per ton.

- Imports

How much milk we import depends on the actual import rate. This is multiplied with the MilkProdLessCon value.

- Milk Used

Will and I assumed that the U.S. used all the milk it imported. Otherwise, why would it import at all?
Also, this value is divided by a dwell time of 1 in order to make the units work.

- Production

The amount of milk produced in the United States is the production rate times Milk Produced in US. But because there is a production capacity in place here, the total production amount cannot exceed the production capacity. If it does, then the model automatically reduces it so that it is equal to the production capacity.

- Exports

For this value, Will and I assumed that the leftover domestically produced milk that had not been consumed would be exported. Thus, the value for the Exports flow is the amount of milk produced in the U.S. subtracted by how much U.S. milk consumers consumed. We could have just used the MilkProdLessCon value, but we just made it like this.

- US consumption

The total consumption of milk in the United States is the average amount of milk used. In order to make the units in this flow work, it was neccessary to add a dwell time (whose value is just 1) and divide the Avg milk used by this dwell time.

Important Converters

- Acceptable CO2 emissions level

After many trials, this value seemed to fit the model's performance best. It's a value Will and I just made up, because the notion that there is an "acceptable" CO2 emissions level is so varied in the world. Some people may argue that CO2 emissions are not even a problem, while others maintain that the only good CO2 emissions level is a zero emissions level.

- Actual import rate

The import rate that is ultimately factored into the imports flow is the actual, true import rate. This value depends on what the import would normally be (hence normal import rate for given country), times the graphical converter Effect of co2 emissions on imports and consumption.

- Actual Production Rate

The production rate that is ultimately factored into the production flow is the actual, true production rate. This value depends on what the production would normally be (hence normal production rate), times the graphical converter Effect of Milk needed on imports and production.

- Avg milk used

The total amount of milk used in the U.S. is the product of the United States population, what percentage of that population use milk, and how much milk on average is used per person by that percentage of the population.

- CO2 per ton

The amount of carbon dioxide released per ton of milk shipped is the product of how many kilometers on average you ship the milk, and how many grams of CO2 you release every time you ship a ton of milk one kilometer.

- MilkProdLessCon

This value is just what it's name implies: it's the amount of Milk Produced in the United States minus the U.S. consumption amount the production amount was divided by a dwell time, but that dwell time, whose value is 1, is only there to make the flows' units work out).

- Milk needed ratio

The true, actual milk-available-to-milk-need ratio is the total amount of milk used compared to (divided by) how much milk is actually available for use.

- Normal import rate for given country

This value was made up, in part because it best fit the results and performance of the model, but also because there is essentially no such thing as a "normal," maintained and constant import rate of milk to the U.S. The values we found were so varied and held so much room for error that we just ignored them.

- Normal milk needed ratio

Quite simple, the normal amount of milk needed would be, in the case of utopia, exactly one, whereas there is exactly the same amount of milk available for use as how much is needed.

- Normal Production Rate

For this value, which we made up, Will and I just couldn't find any data. We looked everywhere, from the United States Department of Agriculture's website to the National Agriculture Statistics Service. One reason could be because the U.S. is so big - the "normal" (if there's such a thing as normal) production rate is extremely varied and just too hard to pinpoint down on one website.

- Total Milk Available

The total amount of milk available for use is the sum of how much milk has been produced in the U.S. and the total amount of milk imported to the U.S. from outside countries.

- Total moving milk

The total amount of milk that is moved is the sum of Exports of milk and Imports of milk, a value in tons. To convert this into pounds, multiply the original value by 2000, the conversion rate.

The Model Feedback & Loop Story

The feedback and the feedback loops in the final model really constitute the basis of how the model works as a whole, entire unit, instead of just a few major parts (the Milk Production section, the CO2 Emissions section, the *Effect* sections, etc.) strung together with a few, red connecting arrows. They not only determine how these parts affect each other, but also how those effects will eventually travel throughout the model and come back to the original place to affect the part of the model where the change first started, hence the feedback "loop."

Will and I identified lots and lots of feedback loops in the final model. Two of what I think were the most important ones are below, each with it's own separate explanation.

Feedback Loop Number One – Carbon dioxide emissions

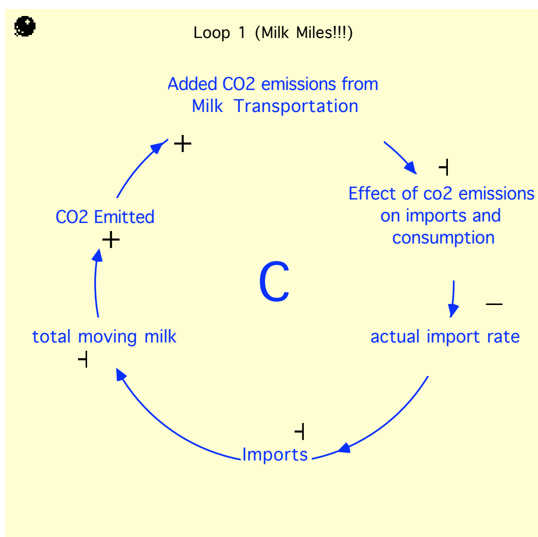

FIGURE 11: THIS COUNTERACTING FEEDBACK LOOP IS FOCUSED ON ADDED CO2 EMISSIONS FROM MILK TRANSPORTATION.

This feedback loop can be summed up in this way: if the Added CO2 emissions go up, the Effect of CO2 Emissions on Imports and Consumption goes down. This subsequently lowers the actual import rate, which decreases imports, which lowers the amount of total milk that is moving, and then the amount of carbon dioxide that is emitted itself will decrease (it comes back full circle), which results in the entire feedback loop being counteracting.

Feedback Loop Number Two – Milk Produced in the United States

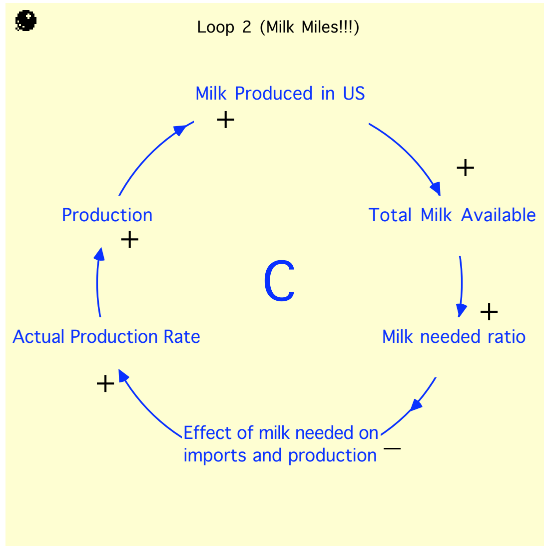

FIGURE 12: THIS COUNTERACTING FEEDBACK LOOP IS FOCUSED ON THE AMOUNT OF MILK THAT IS BEING DOMESTICALLY PRODUCED IN THE UNITED STATES.

The feedback loop can be summed up in this way: if the amount of milk produced in the U.S. rises, the total amount of milk that is available for use also goes up. This subsequently *lowers* the Milk needed ratio, lowers the Effect of Milk Needed on Imports and Production, which decreases the Actual Production Rate, which decreases Production, and finally lowers the amount of Milk Produced in the US, which results in the entire feedback loop being counteracting.

Feedback Influence on Overall Behavior

One important thing to keep in mind as one studies the feedback's loop on the overall behavior of the final model is that there are many more feedback loops that I haven't examined or specifically talked about. It is a sort of "balance of power," where all of the feedback loops are counteracting (excluding the population's births), and they keep each other in check. It's a system of checks and balances (note that phrase from the United States government), where no one, individual, specific feedback loop is dominant. Where no one feedback loop carries the entire model on it's shoulders for the duration of the entire simulation.

The impact of the feedback loops in Figures 10 & 11 have only a slight influence on the ultimate workings of the model as a whole. But multiplied by the many loops that I haven't talked about, and you have the combined power of the entire model. The power these feedback loops do have is some control over the model's milk production and imports of milk.

The Model Boundaries

The most important limitation on our model is that the “Effect of CO_2 Emissions on Imports” graphical function converter affects the actual import rate (as it’s name implies), but it doesn’t affect US consumption or exports.

In real life, a U.S. citizen who was educated enough to know about the impacts on the environment that the transportation of milk has would not only demand that the government reduce the amount of milk it imports (and thus CO_2 emissions from imports), but also exports (because when you export milk, CO_2 is also released) and consumption (reduced demand will result in less imports and production) This would have been another feedback loop. Unfortunately, we did not incorporate such a reduction in our final model. It was an accident.

Reasonable Assumptions for Data Values

- Acceptable CO_2 emissions level – 500,000,000,000 (grams)

After many trials, this value seemed to fit the model's performance best. It's a value Will and I just made up, because the notion that there is an "acceptable" CO_2 emissions level is so varied in the world. Some people may argue that CO_2 emissions are not even a problem, while others maintain that the only good CO_2 emissions level is a zero emissions level.

- Normal Production Rate – 1 (1/year)

For this value, which we made up, Will and I just couldn't find any data. We looked everywhere, from the United States Department of Agriculture's website to the National Agriculture Statistics Service. One reason could be because the U.S. is so big - the "normal" (if there's such a thing as normal) production rate is extremely varied and just too hard to pinpoint down on one website.

- Production capacity – 48,000,000,000 (pounds per year)

This value is made up, again, because Will and I just couldn't find data to solidly support one value for the production capacity. Nobody has ever calculated the production capacity, probably because in real life it doesn't really exist.

Our Choice of Time

Our model did not have a specific time frame. That is, it did not begin in a certain year (1990, 2000, etc.) or end in a specific year.

The main focus of our model was to examine the release of CO_2 as a consequence of global milk transportation, and not to obtain a specific value at a specific year. Will and I did not see any reason to begin the model in, let’s say, 1995 and end it exactly ten years later. Instead, what we did was to just let the model run for 20 years (simply from “Year 1” to “Year 20”), equipped with the most up-to-date data (2009) that we could find.

Model Testing

Our final model did indeed agree with our reference behavior graphs (see Figures A & B for the BOTGs). Generally, the U.S. did import more and more milk (see Figure 14) as it's population/demand grew and as it approached production capacity. This resulted in the skyrocketing increase of CO_2 emissions (see Figure 13), both of which Will and I predicted would happen in the reference behavior graphs as "fears."

An Experiment to Test the Validity of the Final Model

In order to test that our final model was actually correct, Will and I decided to do a sensitivity analysis on one specific component of the model, the "Production Capacity" converter, and do an S-run using three different values for that converter: the first value was 4.6e+10, the second was 4.7e+10, and the third was 4.8e+10.

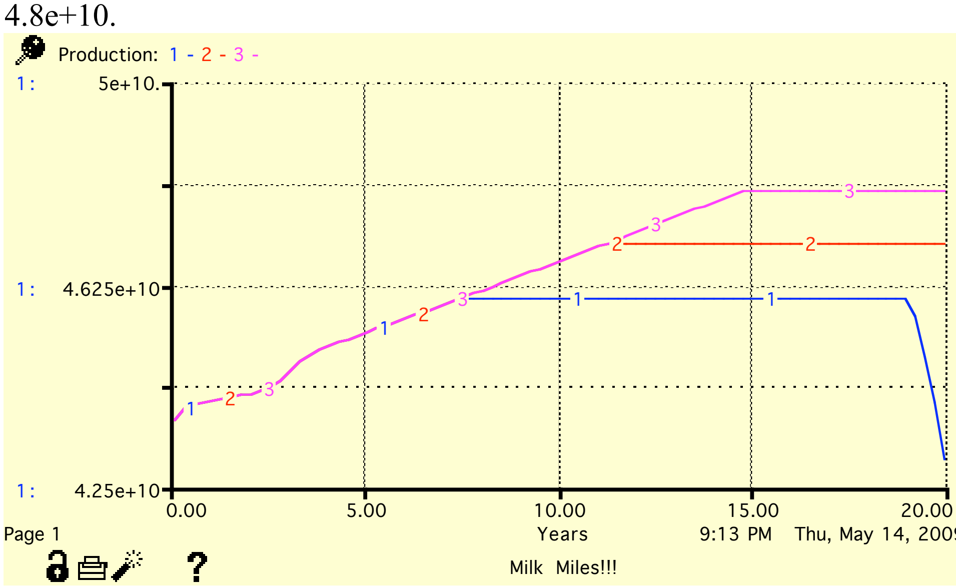

FIGURE 13: A SENSITIVITY RUN WITH PRODUCTION CAPACITY 4.6E10, 4.7E10, 4.8E10

The results of the S-run made perfect sense. If the production capacity (the limit to how much milk the U.S. can produce annually) is bigger (as in the third line of the graph), the United States milk production amount should remain higher for a longer period of time than if the production capacity were a lower amount. This is exactly what happened.

Will and I decided to do a sensitivity analysis of the Production Capacity because we felt it was the simplest and easiest form of test to do *and* it gave a general idea that the model was working correctly. We already knew production of milk was gradually going to increase with the growing population, which happened (this indicates that the population section of our model is working, the milk needed vs. milk available section is working, and the Effect of Milk Needed…section was also working). Also, the production amounts were supposed to flatten out as they got to production capacity, which also happened.

The Results of Modeling and Thinking

The Final Graphs

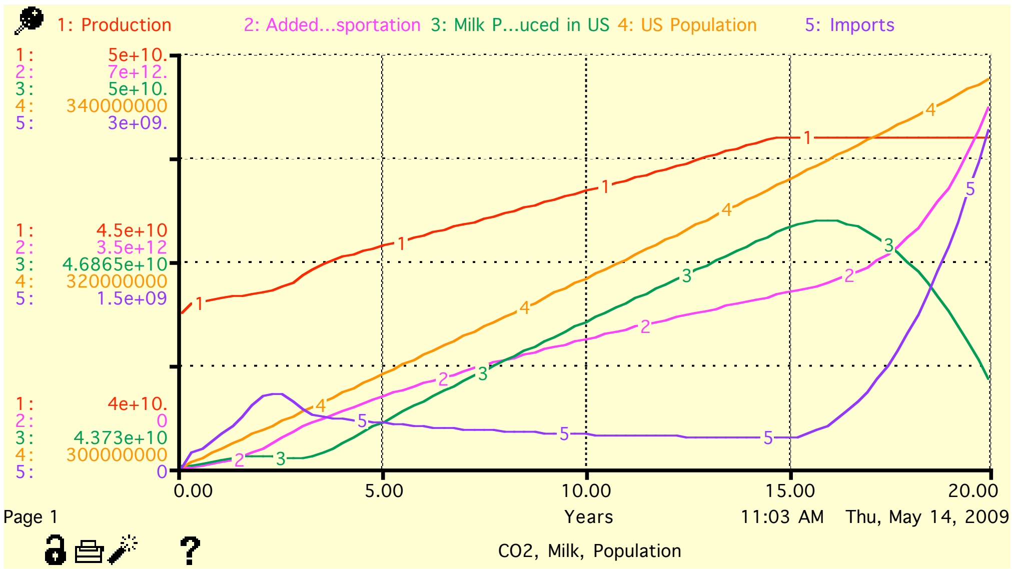

FIGURE 14: COMPARES CO2 EMISSIONS, U.S. MILK CONSUMPTION, AND U.S. MILK PRODUCTION, AND U.S. POPULATION

The rising United States population and thus the rising demand for milk is one of the factors contributing in the steady rise of Production and consumption. The rising demand also increases imports, which results in absolutely absurd levels of carbon dioxide emitted into the atmosphere.

One of the most interesting parts of the model to study is roughly the last 5 years: this is when United States milk production amounts hit production capacity (represented by that flat line in curve 1). The U.S. turns to imports to solve this problem, helping to contribute to a decline in domestic milk levels and adding to the CO2 emissions amount, which has by now gone off the charts.

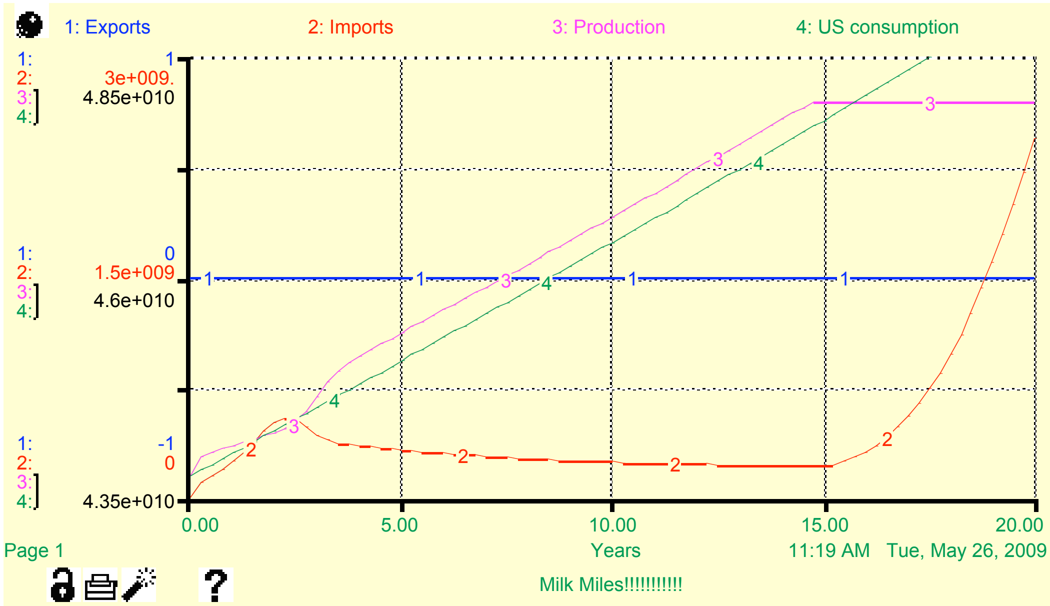

Figure 15: Compares Milk Production, Imports, Exports, and U.S. consumption

Again, the most significant and interesting part to analyze in this graph is towards the end of the model – when U.S. milk production facilities hit production capacity. The CO_2 emissions (graph in Figure 14) jump as imports soar.

What the Graph Results Tell Us

The most important thing to understand about the two main graphs of the final model are these points:

- U.S. population growth was a big factor in the increasing demand for imported milk
- More imported milk released more CO_2 into the air
- Imports soared as the U.S. hit production capacity
- CO_2 emissions soared as imports soared

The Final Table

Years	CO2 Emissions	Imported Milk	Milk Produced	U.S. Population
.00	0	0	43,731,000,000	300,000,000
1.00	73,828,117,926	83,896,155	43,834,926,456	301,776,933
2.00	314,010,003,782	272,274,265	43,883,123,814	303,564,392
3.00	679,278,330,181	431,087,544	43,857,142,154	305,362,437
4.00	951,063,628,978	391,024,827	44,095,178,451	307,171,133
5.00	1,192,524,656,298	351,997,156	44,418,611,255	308,990,541
6.00	1,413,684,634,808	320,632,492	44,733,163,959	310,820,727
7.00	1,618,441,659,100	295,377,467	45,039,900,848	312,661,752
8.00	1,810,073,326,201	275,123,565	45,340,532,958	314,513,683

9.00	1,991,248,516,857	258,949,656	45,636,485,332	316,376,582
10.00	2,164,135,351,703	246,095,299	45,928,936,472	318,250,516
11.00	2,330,491,958,200	235,936,042	46,218,856,113	320,135,549
12.00	2,491,742,001,844	227,961,263	46,507,039,163	322,031,747
13.00	2,649,037,088,120	221,754,819	46,794,135,373	323,939,177
14.00	2,803,308,028,909	216,978,473	47,080,674,782	325,857,905
15.00	2,955,306,775,594	213,357,891	47,367,089,215	327,787,997
16.00	3,121,901,338,463	230,672,676	47,479,432,445	329,729,522
17.00	3,394,437,856,659	346,454,991	47,308,131,771	331,682,546
18.00	3,890,031,238,251	606,062,533	46,851,507,140	333,647,139
19.00	4,741,219,583,338	1,039,023,743	46,107,868,544	335,623,368
Final	6,100,818,352,404	1,674,337,213	45,075,515,969	337,611,302

FIGURE 16: AGAIN, THE MOST IMPORTANT PART OF THE FINAL TABLE IS THE CO2 EMISSIONS AT YEAR 20 (FINAL YEAR). BECAUSE U.S. MILK IMPORTS HAVE SOARED, CO2 EMISSIONS HAVE ALSO SKYROCKETED. HERE, THE MODEL'S DATA CONFIRMS WHAT THE GRAPH (SEE FIGURES 13 &14) SHOWS: A CONTINUED RISE IN EVERYTHING EXCEPT MILK PRODUCTION.

The Results

Key to the final analysis of the final model is the relationship between the U.S. population, production capacity, imports, and CO2. This relationship is probably the most important relationship in the entire model. It works like this: the steadily growing U.S. population places more and more demands for milk. As U.S. milk production facilities hit production capacity, the U.S. is forced to import milk from foreign countries to meet the demand. This results in a *very* significant rise in CO2 emissions, which is easily visible in the graph of Figure 13 (curve number two) and whose final, absurdly high value in the table I have highlighted.

What this tells us is that the U.S. is going to have lots of big problems regarding milk transportation and CO2 emissions if it hits the production capacity of milk *and* it's growing population still demands more. *If* the United States turns to imports to solve this problem: CO2 emissions will skyrocket and the problem of global warming will be accelerated and exacerbated.

The Key Learning from the Modeling Process

Not only did this project Will and I created help us to grow more in our understanding of the STELLA modeling software and help us to cement our modeling and model-building skills, it also helped us to grow more in our understanding of how the world works.

Specific Things About Milk Transportation I Learned:

- U.S milk production has a limit
- To reduce CO2 emissions, imports must be limited

- The growing population of the U.S. (and really throughout the entire globe) is the root cause of many problems
- Population control is essential for the maintenance of a sustainable world

Conclusion

Humans will drink milk for a long time into the future, and as long as that happens, milk imports and milk transportation will also be likely to happen.

Milk transportation releases CO2 and other greenhouse gases, and obviously this impacts the environment by worsening the global warming problem. Modeling this was the only original purpose of the final model.

One very important thing to keep in mind though, is that transportation of milk is only one part of how humans are worsening global warming. Countless other kinds of food and commodities, from tomatoes to pencils, toys to wood, fish to cars, the world has become so globalized that products and commodities manufactured in one place are being regularly shipped around the world to other countries. This shipping is not only bad for the environment; it is also not regulated by international environmental treaties such as the Kyoto Protocol.

That, of course, paves the way for others to use our final model to test other ideas regarding the shipment of other products. Many other common commodities can be modeled in the same that Will and I have modeled the transportation of milk. Add together as many commodities as you can and a general understanding of the environmental impact of the shipping of *all* things can be gained.

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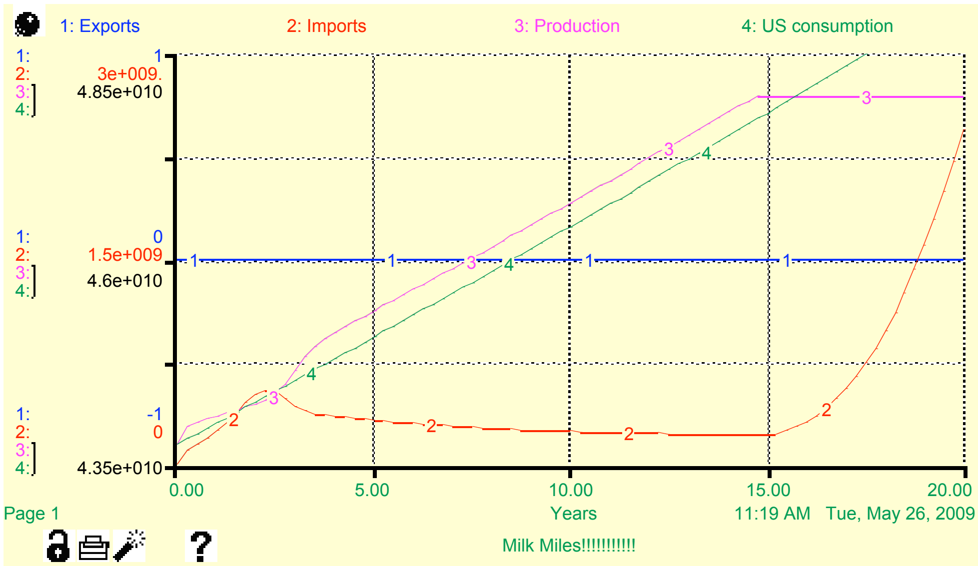
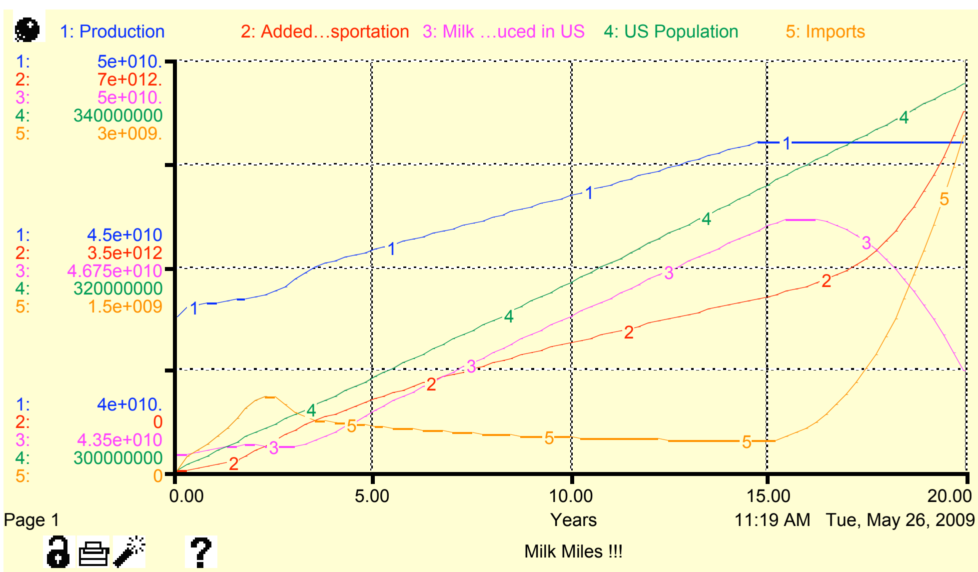
Appendix

Final Graphs of the Model





Full Model Diagram