World Dynamics

Motivation

In his introduction to the second edition of *World Dynamics* (1973), Jay W. Forrester writes:

> *World Dynamics* was first published in June 1971. The successor book, *The Limits to Growth,* became available in March 1972. The two have received an unexpected amount of attention from the public press. Before publication, *World Dynamics* seemed assured of little public notice — the book has 35 pages of equations in the main text, much of the remainder is computer graphical printout, it was distributed by a new and unknown publisher, and it deals not with the present by with issues of several decades hence. The two books, however, have become the center of spirited controversy. Reviews of *World Dynamics* have appeared in such diverse publications as *The Observer* (London), *Fortune, The Wall Street Journal, Science, Playboy, The Christian Science Monitor* and the underground press. The debate over *World Dynamics* and *The Limits to Growth* has become international in extent. The books are now available in several languages.
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> The responses have tended to be bipolar, some actively supporting and others taking strong exception. Support has come from environmentalists who share the concerns of *World Dynamics*. Many engineers and scientists have found the methodology understandable and based on familiar theory. Contrary to common expectations, many corporate managers, especially senior executives, accept the basic proposition that continued industrialization and population growth will only lead to increased stresses, although the implications for altered present action are not yet clear.
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> The strongest criticism has come from some economists. The objections range from simple misunderstanding, through belief that essential structures have been omitted from the world model, to concern over the costs and feasibility of halting economic growth. Although there is a basis for the criticisms, they have not had sufficient substance to dismiss the central issues.

Limits was translated into at least 22 languages. It is hard to imagine now the depth of popular and scholarly controversy the two books generated in the early 1970s. [I can supply some reprints of critical articles if you are interested.] But we can easily understand the origins of the controversies:

- suggestions that economic growth would have to slow down for the health of the planet were upsetting to pro-growth believers;
- assertions that third world countries might not be able to achieve the material standard of living of "first world" countries were seen as efforts to hold back less developed nations from achieving a fair share of the global pie;
- the arguments were based on quantitative models, but not the sort of statistical or econometric models that scholars, business people, and government analysts were used to;
- the discussions in the books were frequently couched in circular causal terms unfamiliar to most readers;
- and the policy implications frequently ran counter to people's intuitions.

So to explore the simpler of the two works, *World Dynamics,* is to get a glimpse of an important controversy about the future of the globe. We can learn something from the controversy about how to improve in our formulation and use of models for policy. But

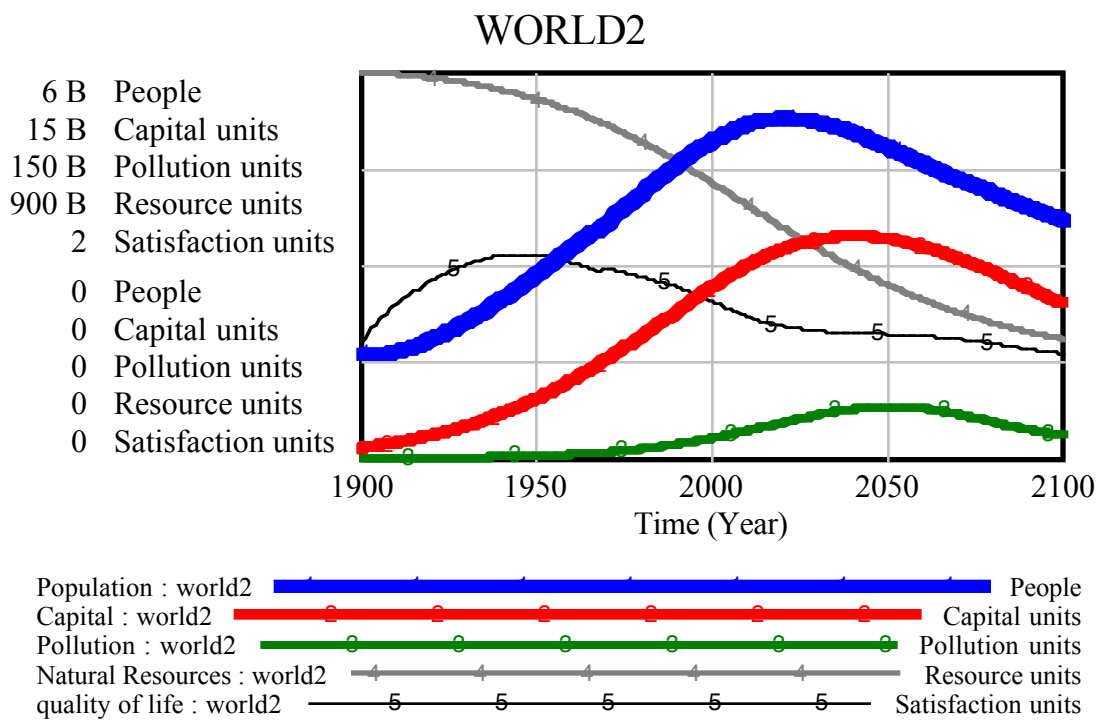
more than that, it is a chance to look at an accessible work from the founder of system dynamics. And it will be the largest model you have experimented with to date, providing an interesting setting in which to develop and exercise more model analysis skills.

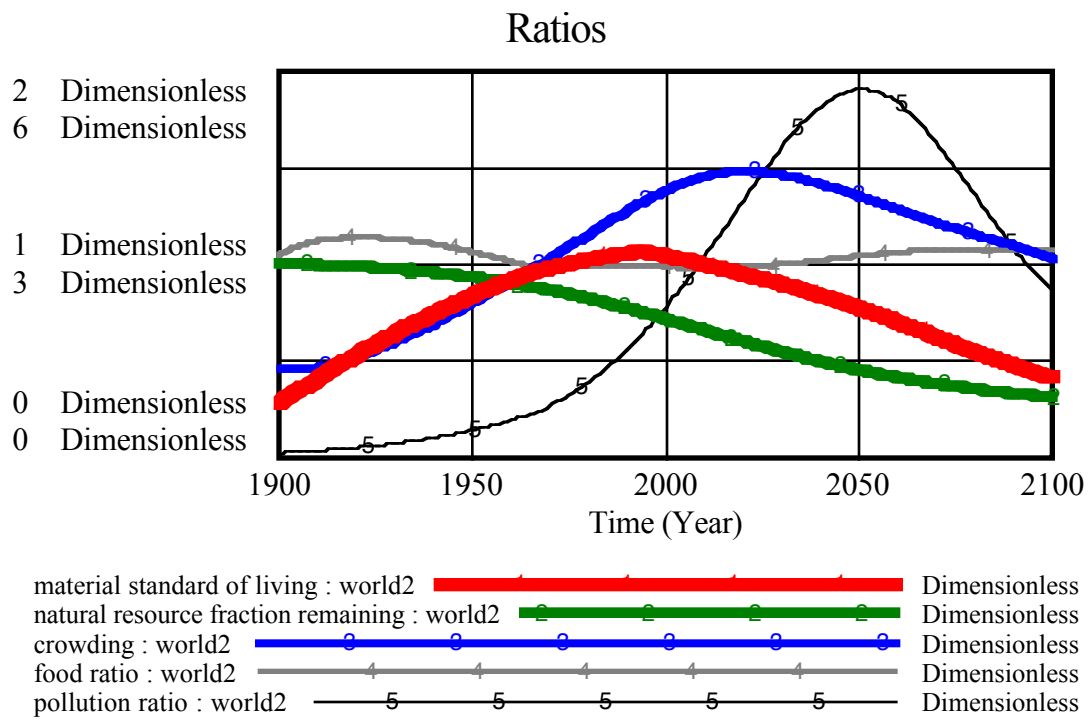
The Tasks

The first task is to replicate and analyze a number of Forrester's simulation runs with *World2*, the model written up in *World Dynamics*. The second task is to see if you can produce a sustainable world with policy initiatives begun in 1970, the year of Forrester's various policy experiments. [If you chose to look at *World Dynamics,* please stop reading before Chapter 6, in which Forrester gives his suggestions for a global equilibrium.] The third task is to reformulate WORLD2 to evolve to the new sustainable pattern you found in the second task and to show its structure and dynamics.

Task 1 - Replicating Forrester's simulations

1) <u>The base run.</u> Run the World2 model obtained from the class web page. Name the base run World2. Create two custom graphs like the following (set the scales as shown on these graphs for everything excpet the pollution ratio, which should be allowed to set its own scale).





Forrester asserted that the peak and decline in population was traceable to declining nonrenewable natural resources.

- Use Vensim's causal strip graph tool to examine births and deaths and show that the rise in deaths per year over births per year is indeed traceable mainly to the influence of the material standard of living, and that decline traces to declining natural resources. Explain concisely how your graphs prove the claim.
- Use Vensim's loop tool to find one or more feedback loops that link Population and Natural Resources. Sketch the loop(s) you find and comment briefly on how they appear to be instrumental in the peak and decline of population in this base run.

2) <u>Reduced natural resource use.</u> Now simulate the model again using the SET button to change the value of "NRUN 1970" from 1 to 0.25. This change drops the basic natural resource utilization per capita by 75% beginning in 1970. Call this run something appropriate, like Lower NR Use. The idea is that if using up natural resources is creating a limit to growth, then lower our rate of using up natural resources in an effort to side-step that limit.

- What happens? [Show a telling graph and comment briefly.]
- Analyse the behavior using causal strip graphs. [As above, use Vensim's causal strip graph to uncover the causal sequence that leads to the dynamics you observe.]
- What loops are instrumental in the behavior? [As above, use Vensim's loop tool to find one or more loops that link the variables that appear to be important. Usually, that will be Population and one or more other levels, acting through births or deaths. Here, in addition, there is an interesting positive loop involving Pollution, as you

might guess when you see the steep exponential growth in pollution that appears in this run.] Please be selective about which, if any, graphs you show here; concentrate on a concise loop-based explanation.

3) Increased capital investment. Simulate the model and change the constant "Cap Inv Rate 1970" to 0.06, an increase of 20% from capital investment per capita in the base run (0.05). Give the run an appropriate name.

- What happens?
- Analyse the behavior using causal strip graphs.
- What loops are instrumental in the behavior?

4) Lower birth rates. Simulate the model changing the constant "Birth rate normal 1970" to 0.028. That value is exactly the right amount to create the conditions of zero population growth in 1970.

- What happens?
- Analyse the behavior using causal strip graphs.
- What loops are instrumental in the behavior? [Remember that you can control the graphs that appear in strip graphs and custom graphs by moving simulation runs around by selecting Datasets in the Control Panel.]

5) Higher agricultural productivity. Simulate the model with the "Food Coeff 1970" changed from 1 to 1.25, to represent an increase in global food production of 25%, from higher productivity.

- What happens?
- Analyse the behavior using causal strip graphs.
- What loops are instrumental in the behavior?

Task 2 - Achieving a sustainable globe with policy initiatives begun in 1970.
Experiment with combinations of policies that you think have a chance of avoiding the overshoot and decline in global population -- follow the procedures you followed above changing only constants in 1970.

If you feel that you would like to be able to change some other constant in 1970 than those set up with IF-THEN-ELSE functions for that purpose, you can edit the model equations to embed the original and new 1970 constants in a statement of the form

IF THEN ELSE (time < 1970, original constant, new constant)
See the equation for Births or Capital Investment for examples.

You will want to be as sure as you can that you have taken *realistically possible* values for your policy constants. For example, it is probably impossible for pollution generated per capita to be zero, or the lifetime of capital to be more than 50 or 60 years.

Furthermore, you will want to be sure that you are changing parameters that reflect *implementable policies* (under some plausible scheme that you don't have to specify). Possible policy parameters are shown at the right.

Policy Parameters
Birth rate normal 1970
Cap Inv Rate 1970
Capital agri frac adj time
Capital depreciation norm
Capital inv rate 1970
Food coeff 1970
NRUN 1970 (Natural resources utlization normal 1970)
Pollution per cap 1970

To properly assess whether you have achieved sustainability, you will probably have to extend some of your runs further in time, say the year 2300 (but I wouldn't bother to go beyond that).

Hand in your favorite simulation, together with the parameter changes that created it. Describe your policy for sustainability in words that a nonmodeler can understand. Comment as you see fit.

Task 3 - Delaying your favorite policy.
What happens to your favorite policy (from Task 2) if it is not implemented until 2000 or 2010?

To answer this, simulate your favorite policy again, but first change the year 1970 in all the IF-THEN-ELSE expressions active in your simulation to 2000 or 2010.

What happens? Why?