

Interdependency and Infrastructure

Lecture 3 –Applications Modeling of Interdependency I

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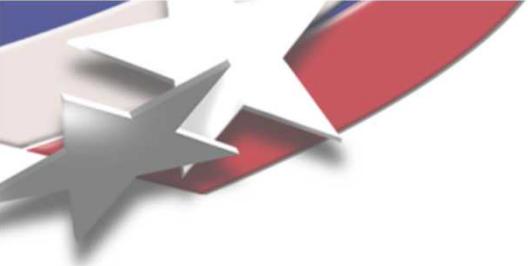
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Overview

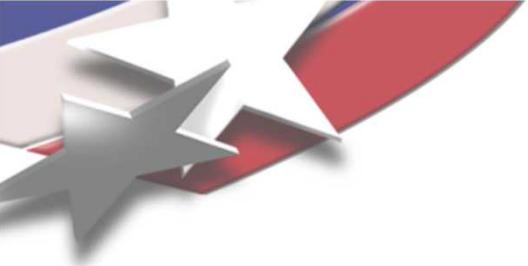
- **Modeling**
- **Simulation**
- **Simulation Methods**
- **Modeling and Simulation**
- **Application**



Modeling

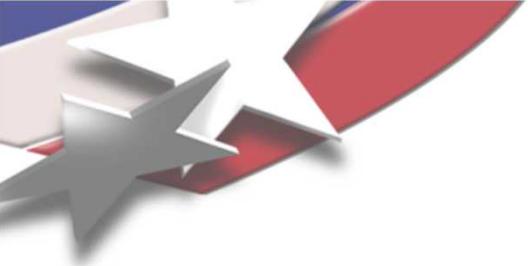
- An abstraction or representation of an object, system, etc.
- We model
 - what we cannot observe, but need to understand
 - Exists beyond current time
 - Spans beyond observational time
 - what we can observe, but cannot tinker with





Simulation

- **Imitating**
 - a real thing
 - a process
 - characteristics or behaviors of a physical or abstract system
- so as to better understand that which is imitated
- **Simulation <>> Modeling**
 - Model is presence
 - Simulation is realization

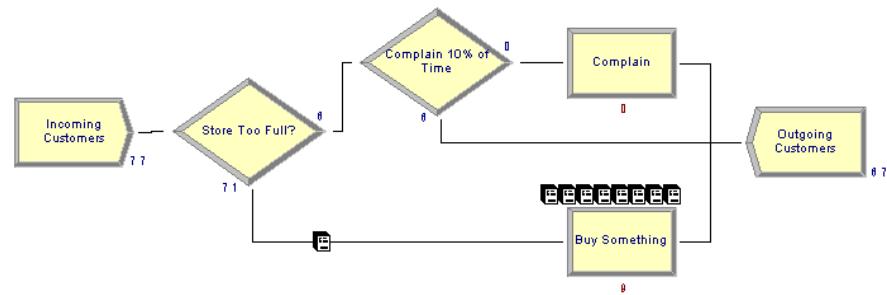


Simulation Methods

- **Discrete Event Simulation**
- **Agent-Based Simulation**
- **System Dynamics**
- **Economic Modeling**

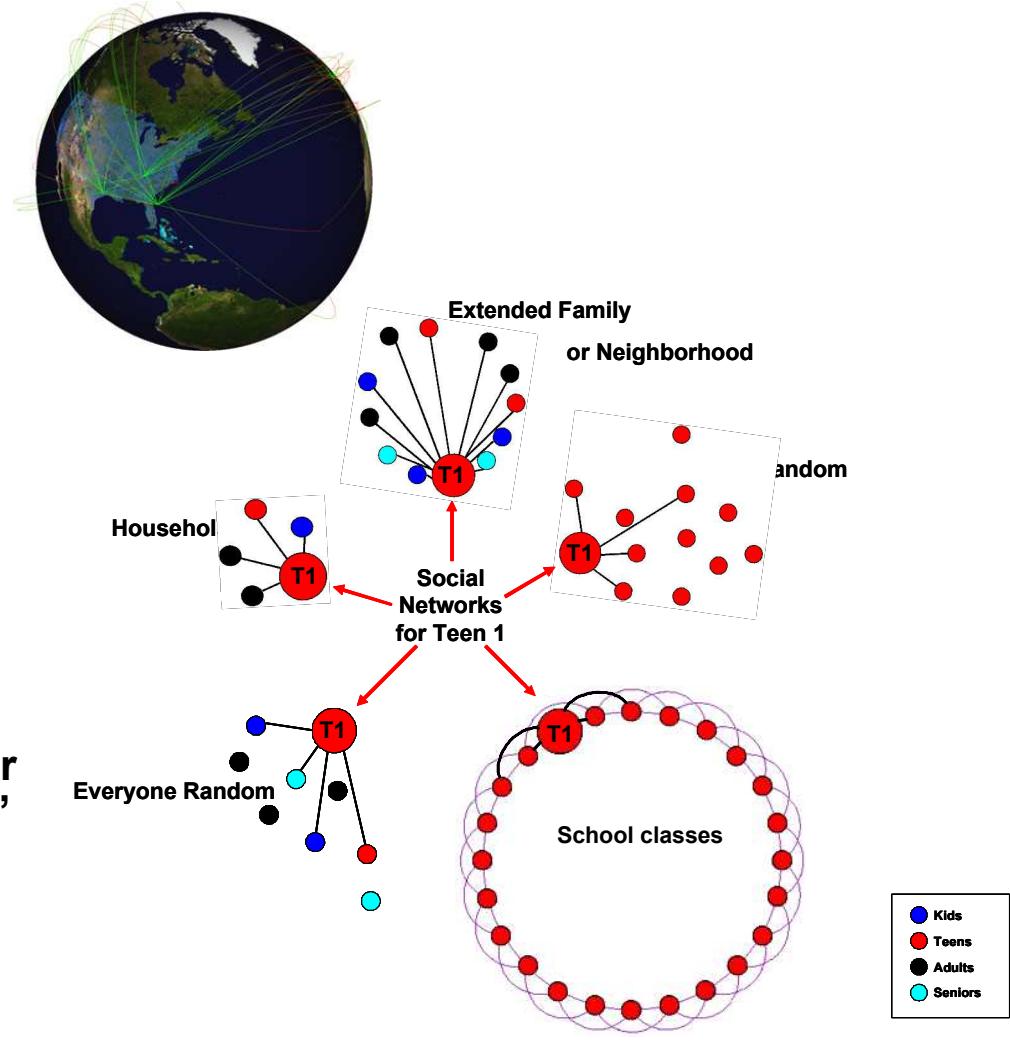
Simulation Methods

- **Discrete Event Simulation (DES)**
 - aka Monte Carlo Simulation
 - Discrete event based
 - Stochastic processes
 - Events are random or structured variables
 - Queue – Seize – Delay – Release
 - Used in simulating
 - Banks (tellers, customers)
 - Factories (processing of raw materials into parts)
 - Definitive read
 - Law & Kelton, *Simulation Modeling and Analysis*



Simulation Methods

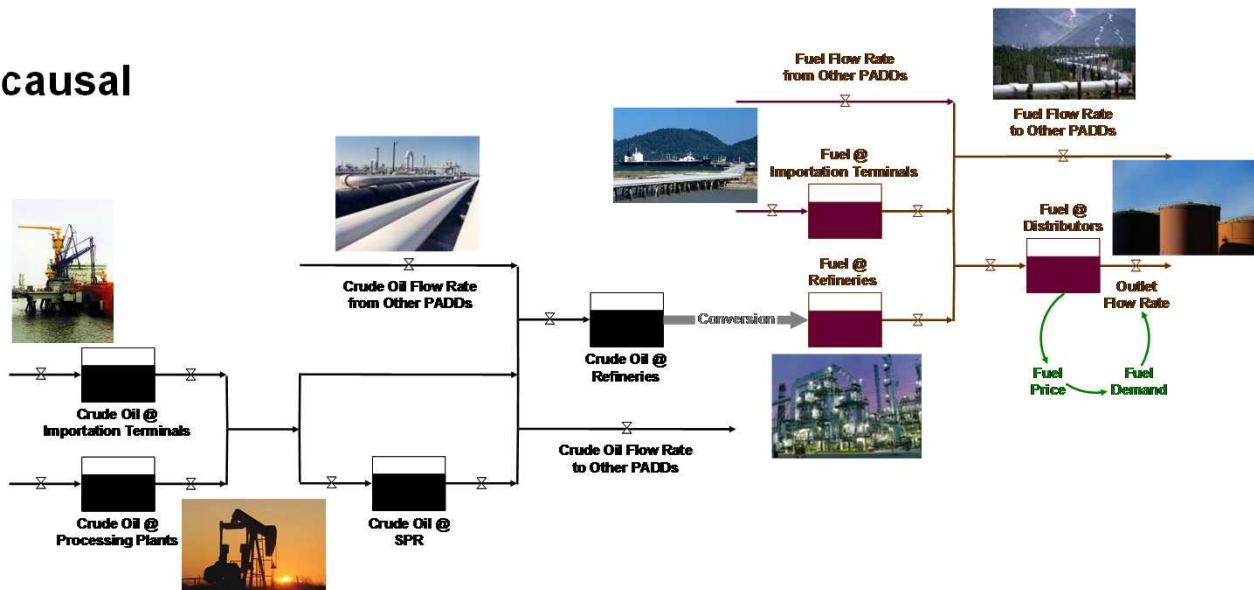
- **Agent-Based Simulation**
 - Has elements of DES (randomness)
 - Communal in nature (social networking)
 - **Agents**
 - are intelligent
 - have purpose/goal
 - are spatially and temporally situated
 - interact with each other and their ‘environment’
 - **Definitive read**
 - Buchanan, *Ubiquity*



Simulation Methods

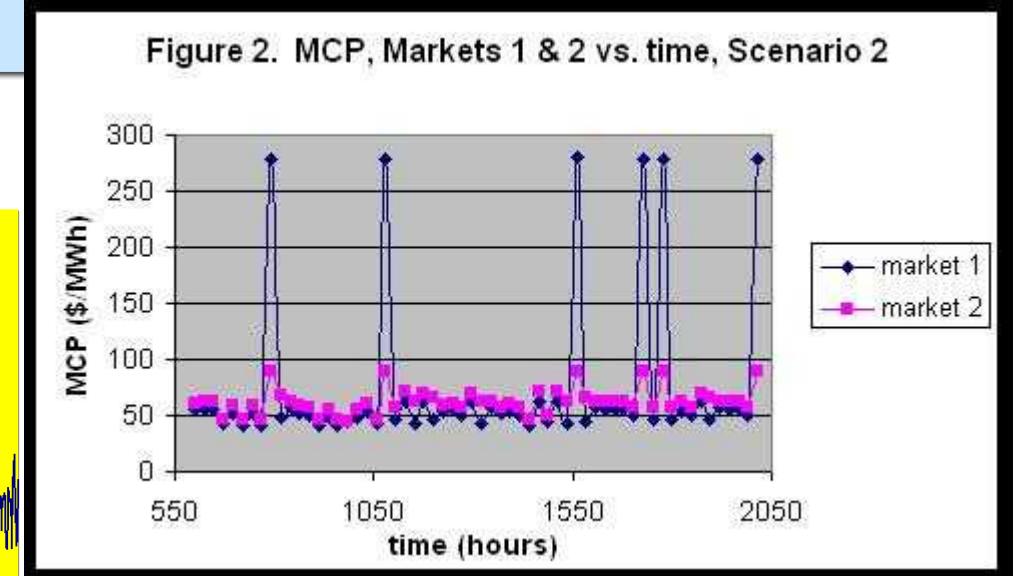
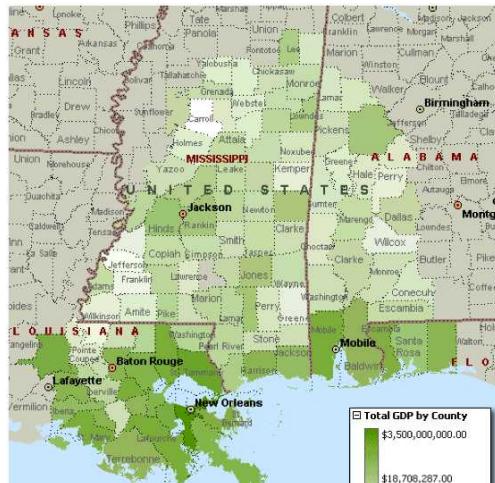
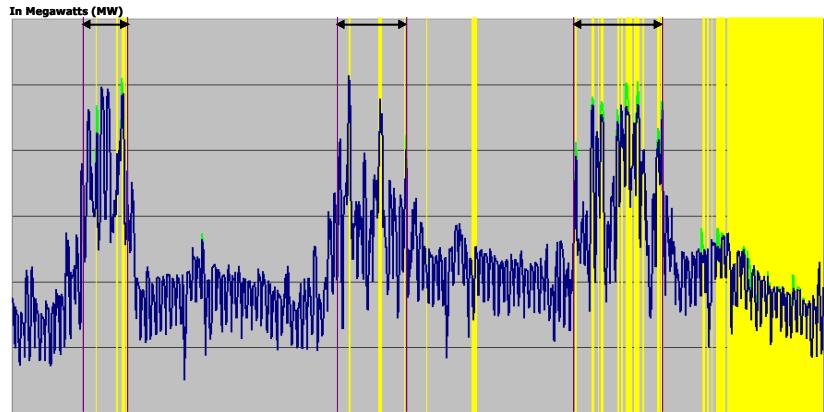
- **System Dynamics**

- aka 'Stock and Flow', 'causal loops'
- Deterministic
- Continuous
 - Differential equations rather than random variates
- Definitive reads
 - Forrester, *Industrial Dynamics*
 - Sterman, *Business Dynamics*
 - Radzicki & Taylor, *Introduction to System Dynamics*

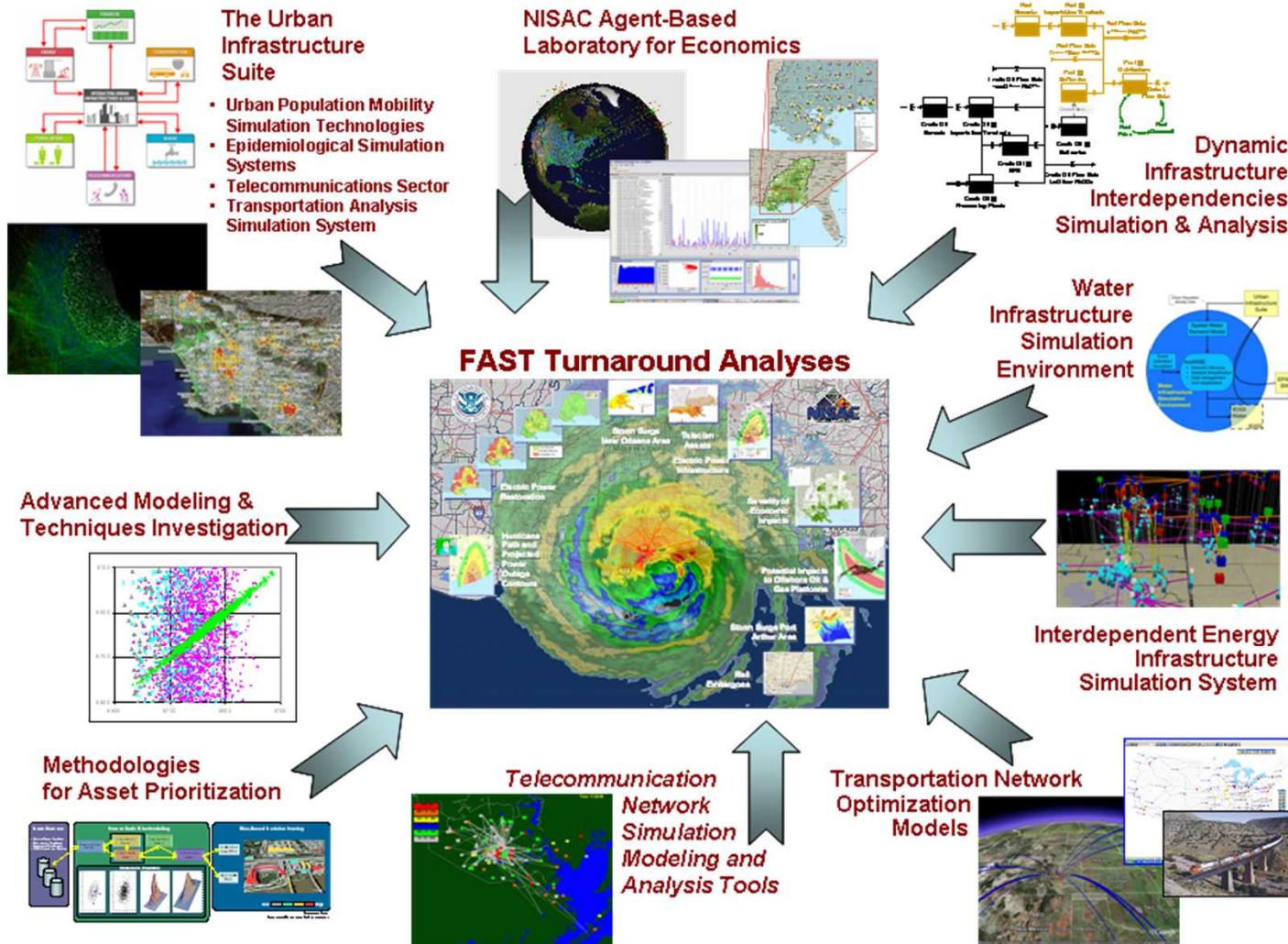


Simulation Methods

- **Economic Modeling**
 - Many ‘flavors’
 - Macroeconomic
 - Microeconomic
 - I/O
 - Agent



Modeling and Simulation





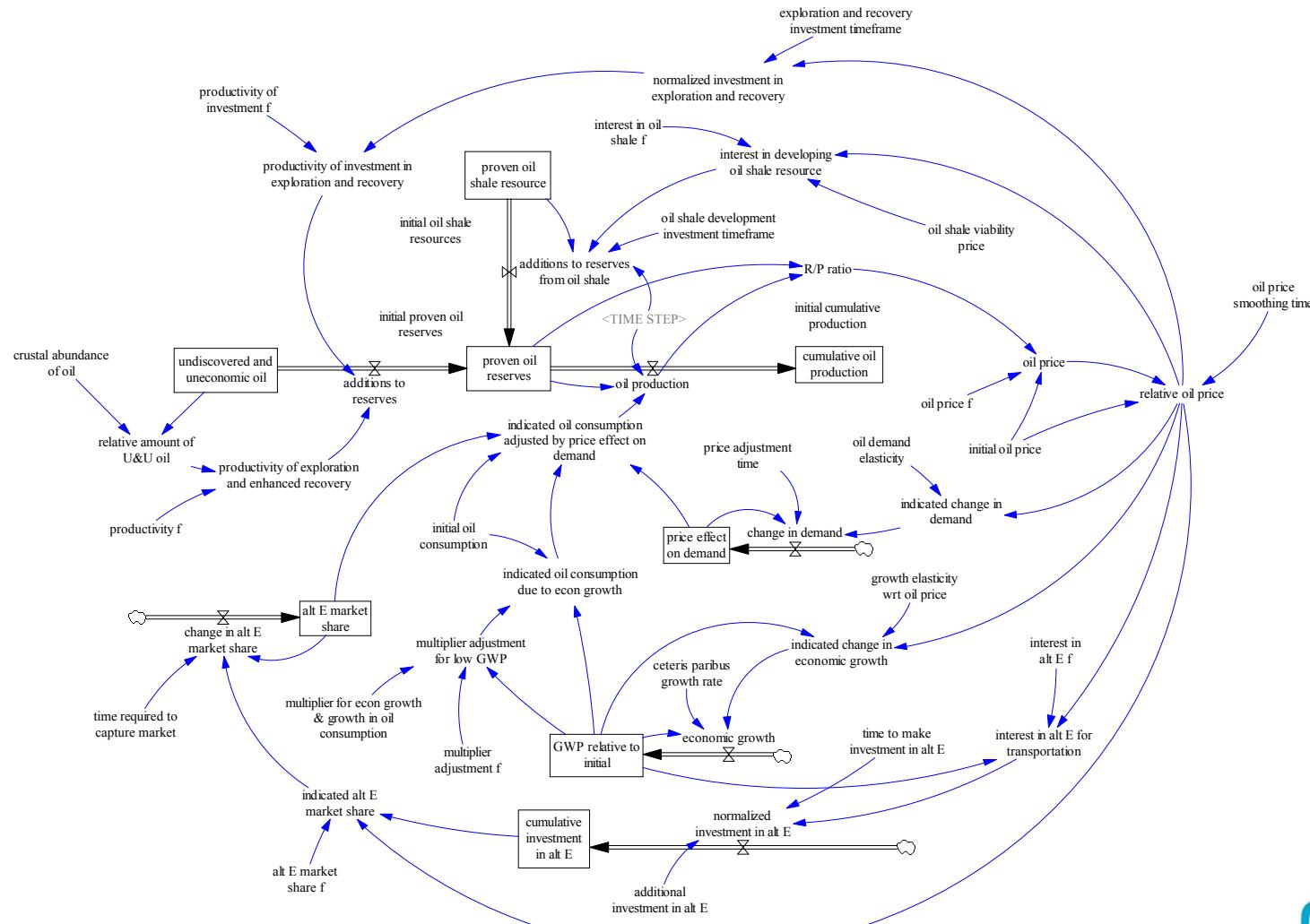
Application

World Peak Oil Issues Utilizing System Dynamics*

- **In the past, in the world's energy evolution performance, not scarcity, was the driver**
Wood → Coal
Coal → Oil
- **For the first time, we are driven by scarcity. Oil → ???**
- **Will the next generation of transportation fuels be available when oil production begins to decline?**

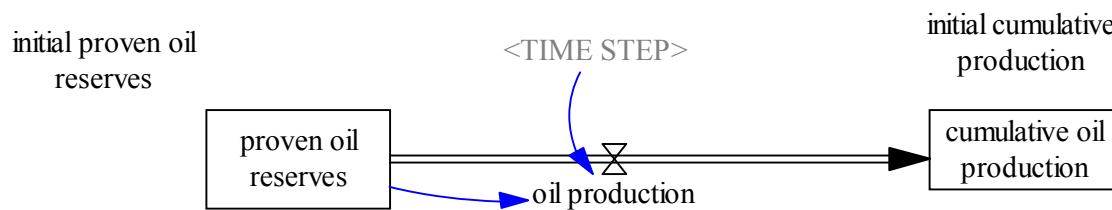
* from Conrad, Blankenship, and Madrid, *World Oil: A Simple Dynamic Model*

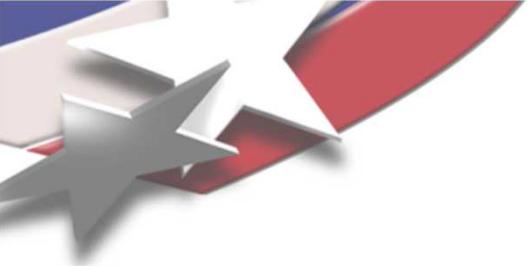
The Whole Enchilada (only about 55 variables)



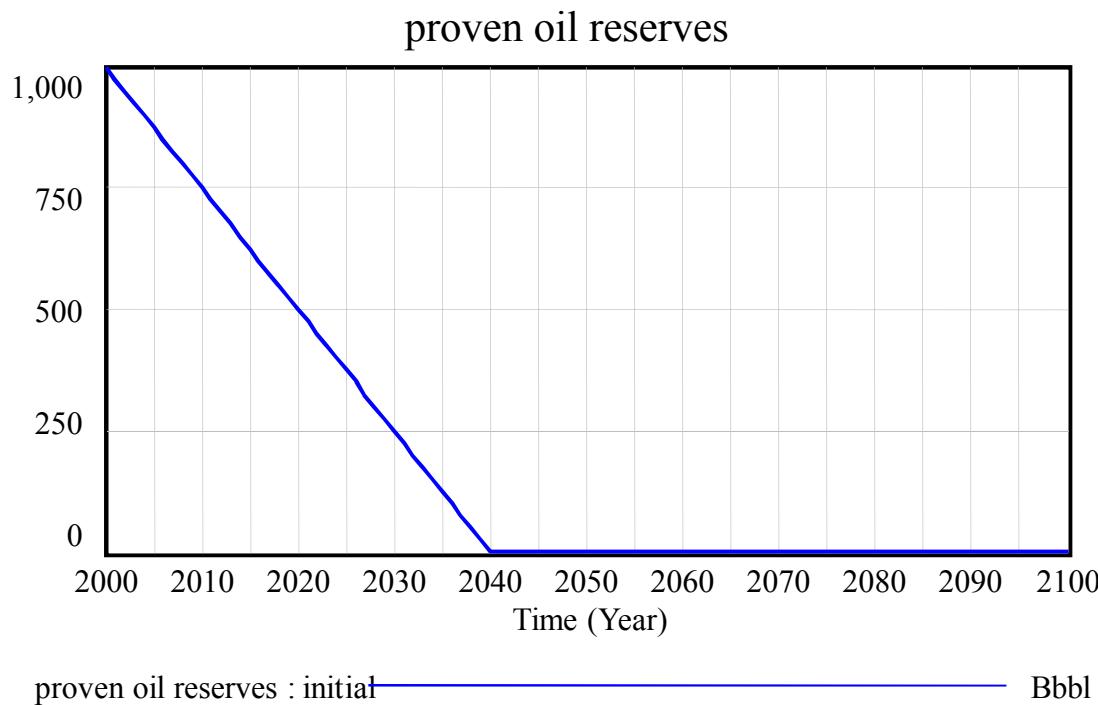


In the beginning: We start with constant reserves and constant demand

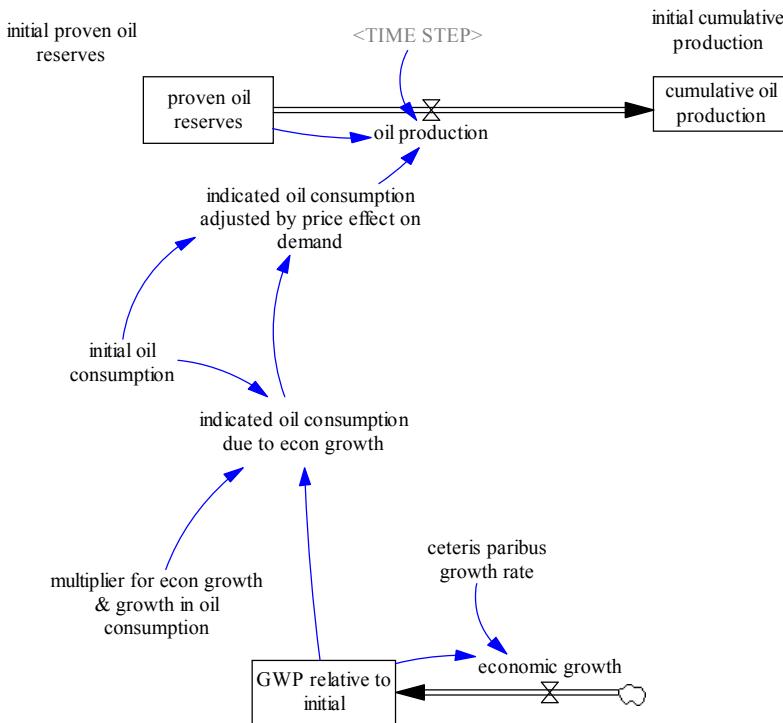




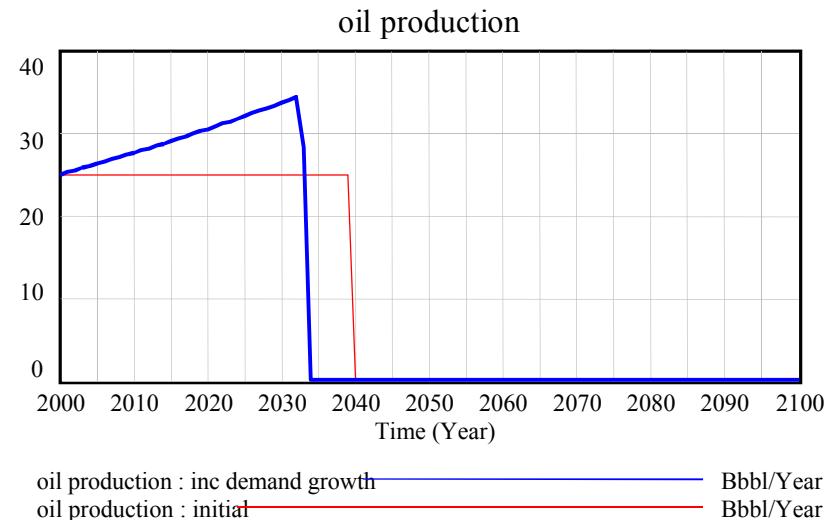
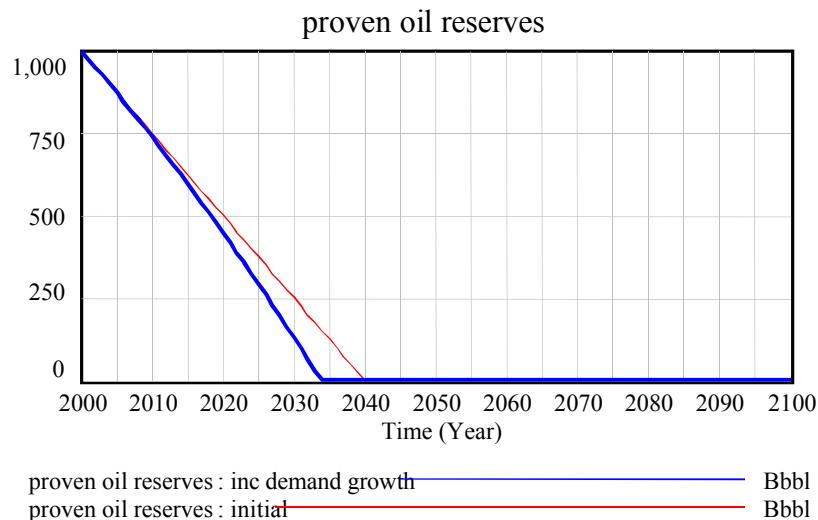
Depletion of reserves



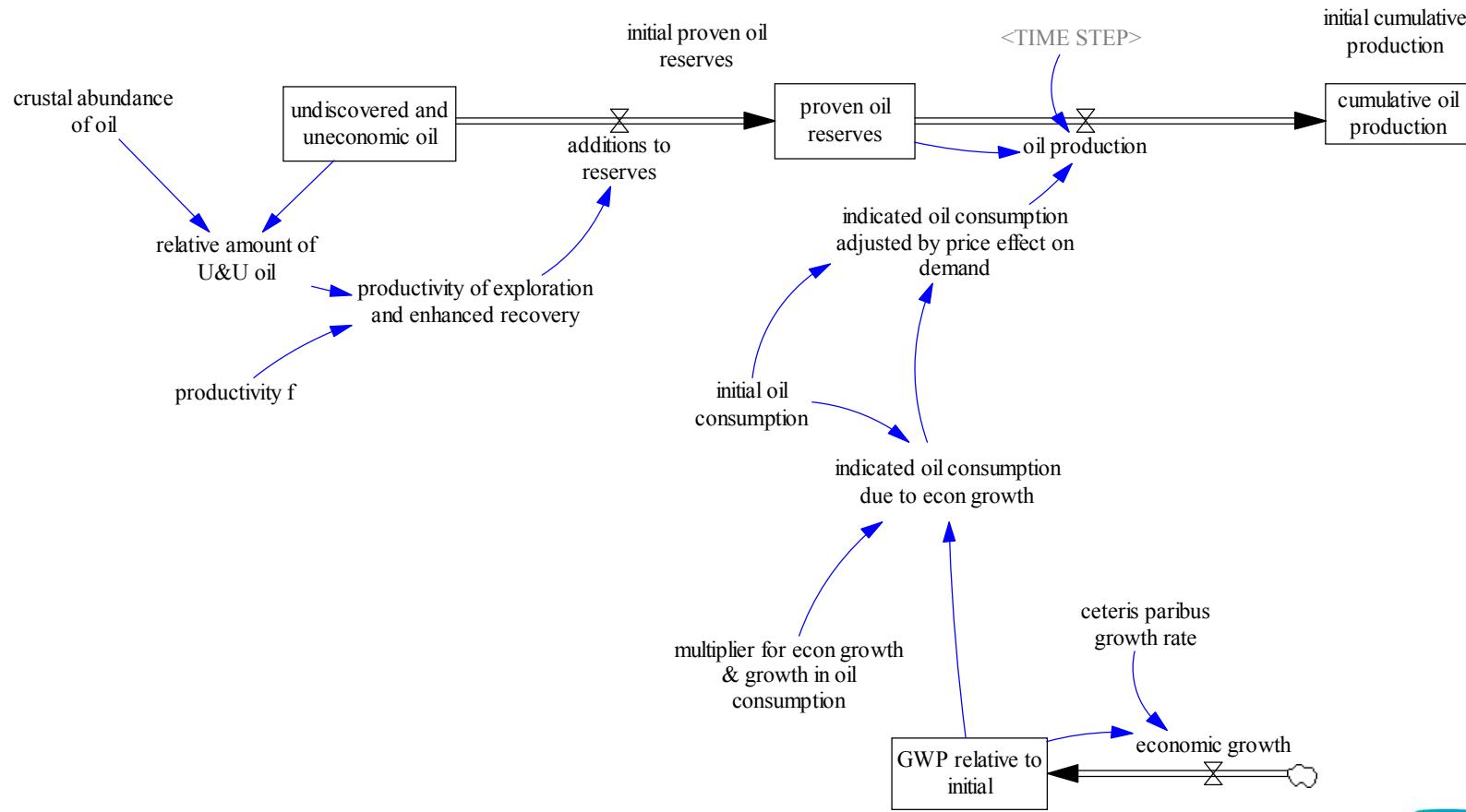
First, we allow demand to increase over time



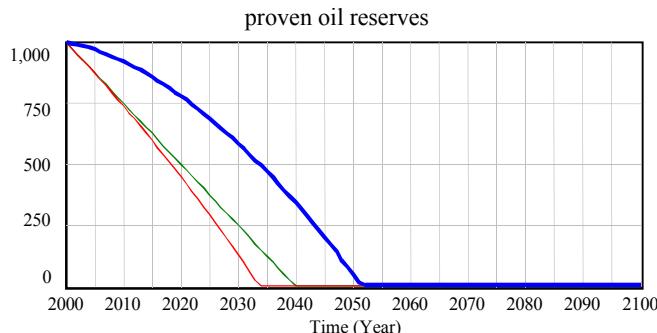
Reserves are depleted faster



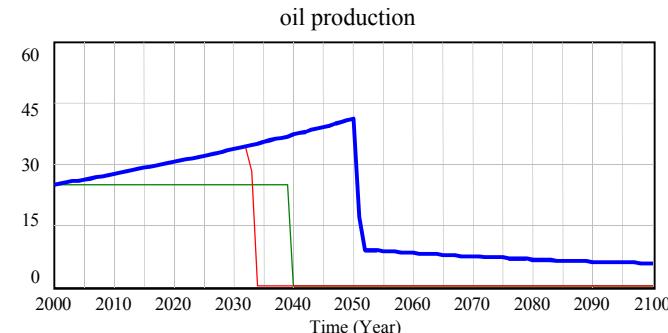
But we know that continued discovery and advances in recovery will add to reserves



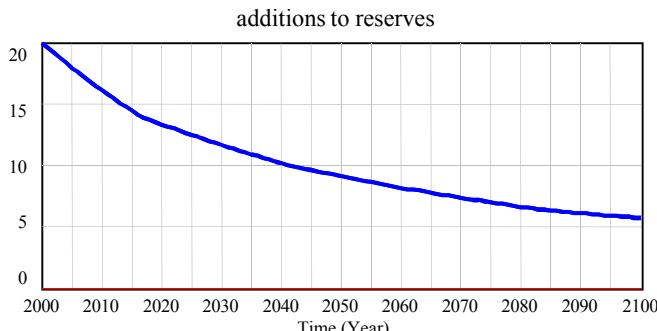
Reserves now last a bit longer



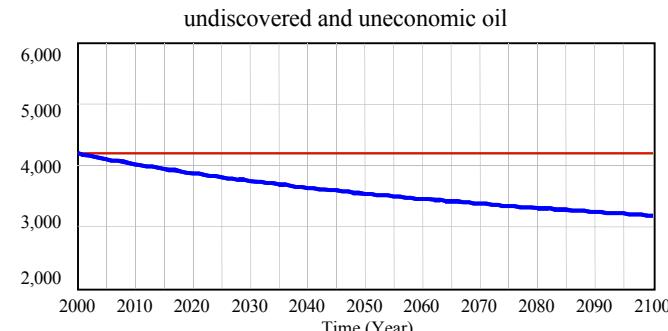
proven oil reserves : discovery adds reserves Bbbl
 proven oil reserves : inc demand growth Bbbl
 proven oil reserves : initial Bbbl



oil production : discovery adds reserves Bbbl/Year
 oil production : inc demand growth Bbbl/Year
 oil production : initial Bbbl/Year

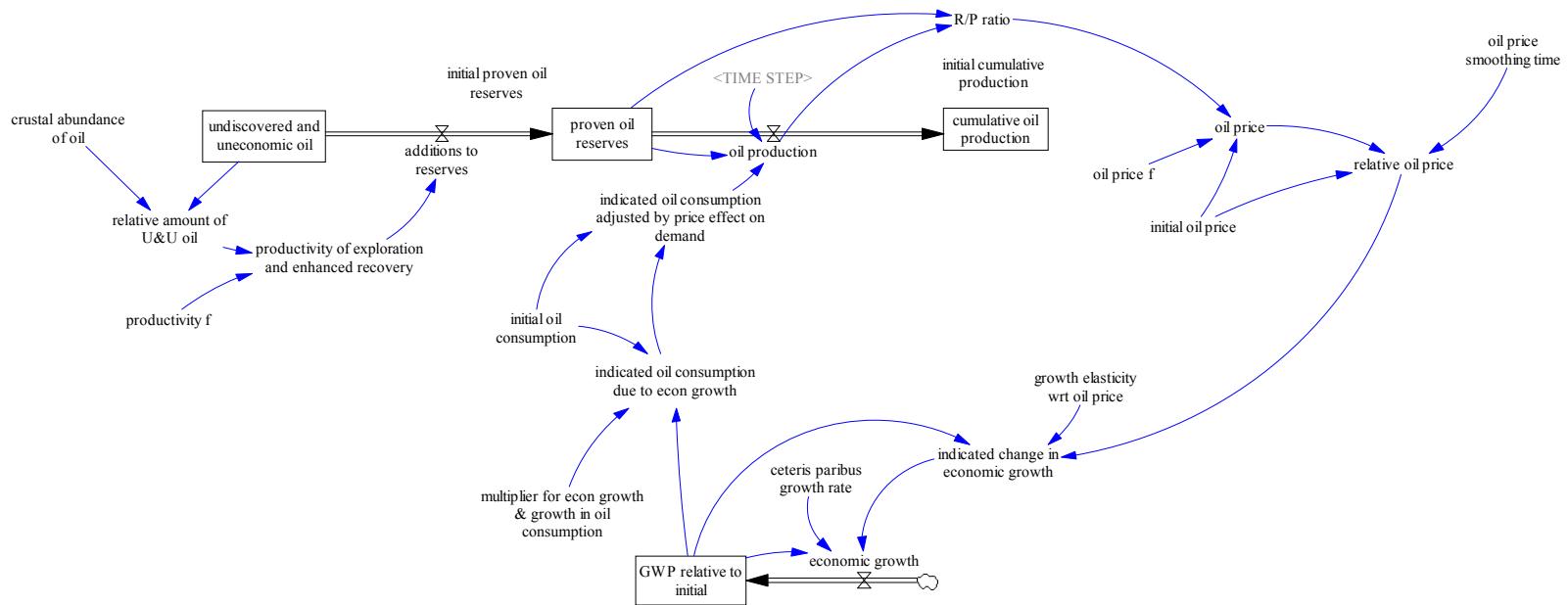


additions to reserves : discovery adds reserves Bbbl/Year
 additions to reserves : inc demand growth Bbbl/Year
 additions to reserves : initial Bbbl/Year

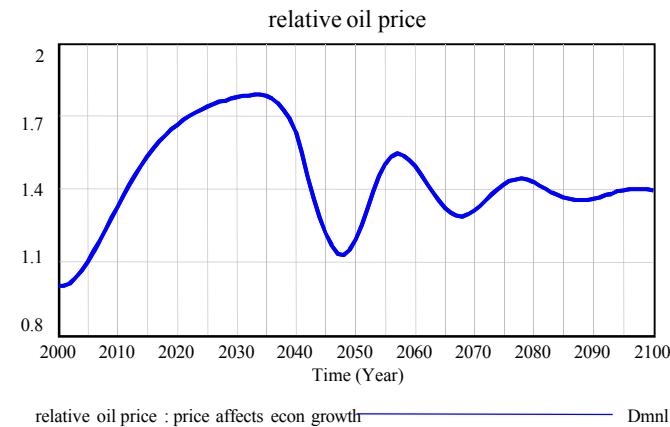
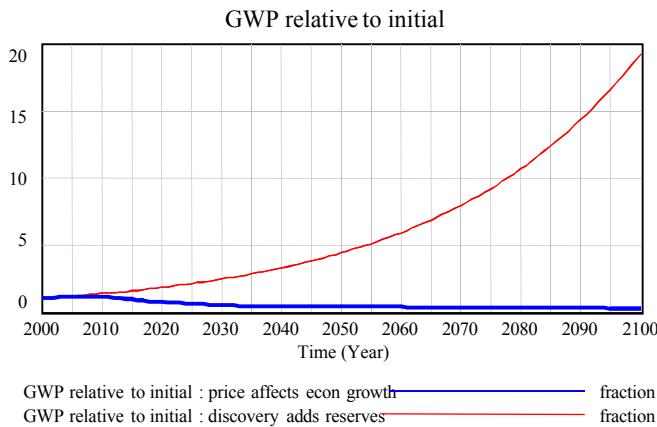
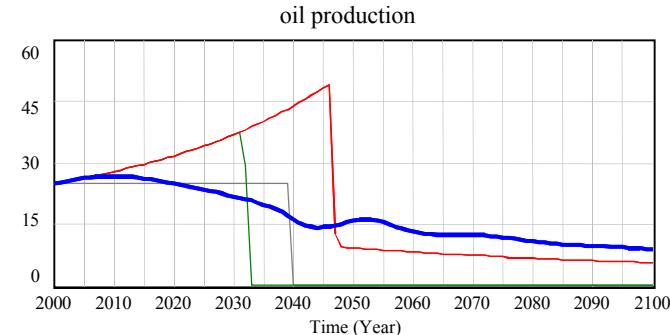
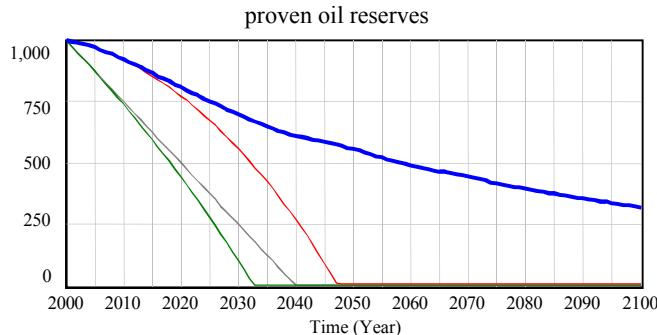


undiscovered and uneconomic oil : discovery adds reserves Bbbl
 undiscovered and uneconomic oil : inc demand growth Bbbl
 undiscovered and uneconomic oil : initial Bbbl

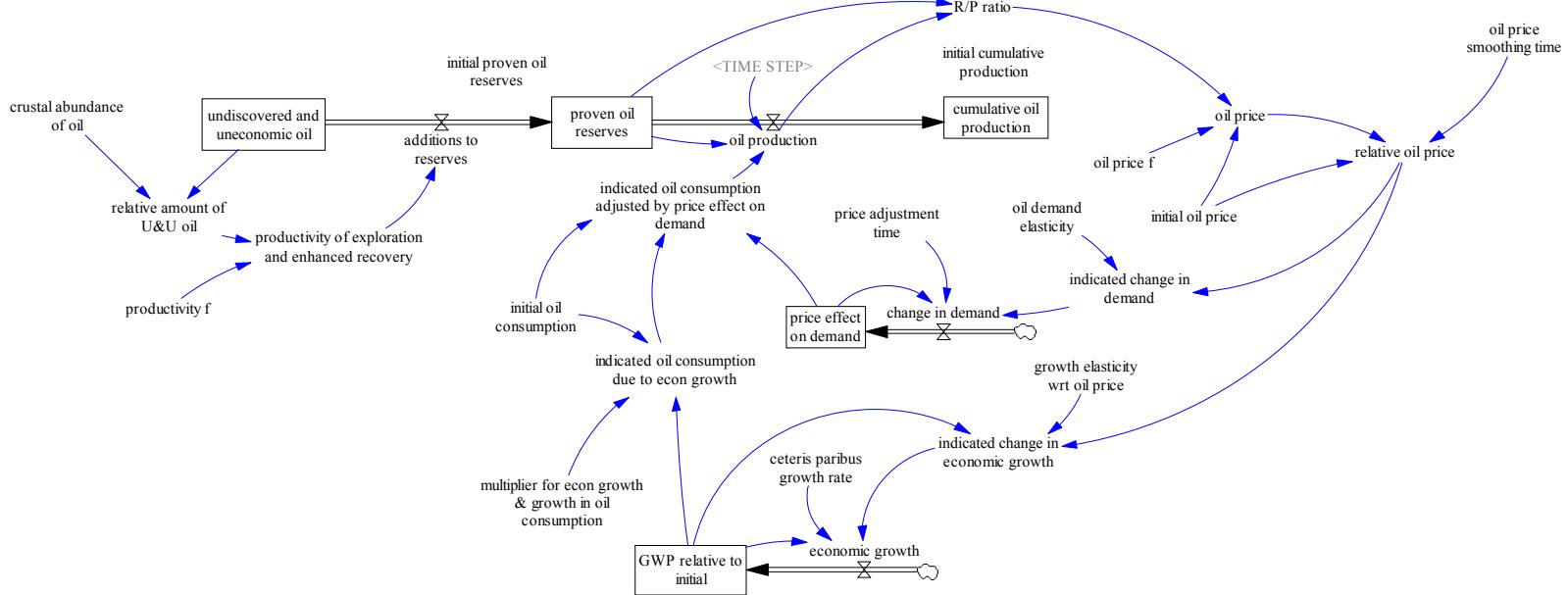
Oil price affects economic growth, which affects the demand for oil



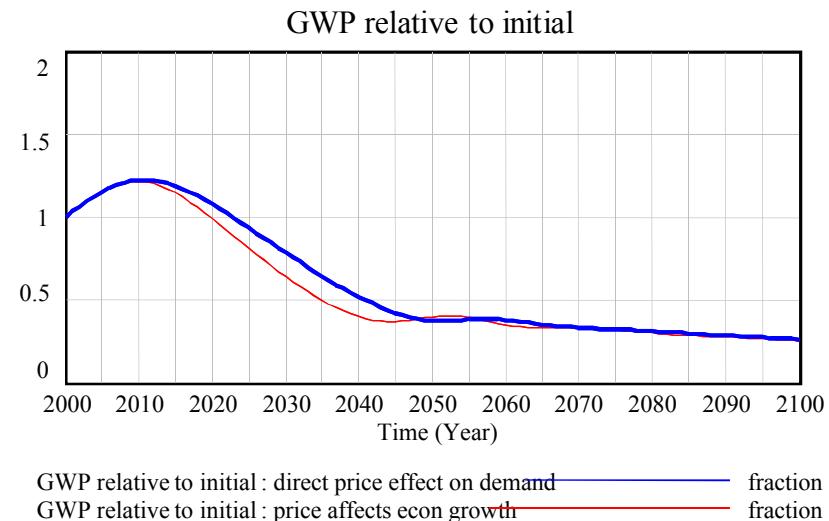
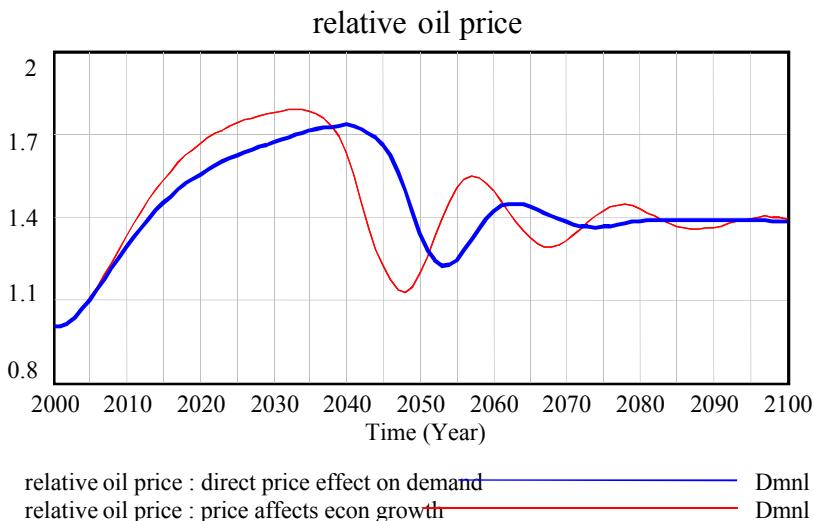
Price response allows reserves to last, but high prices depresses GWP



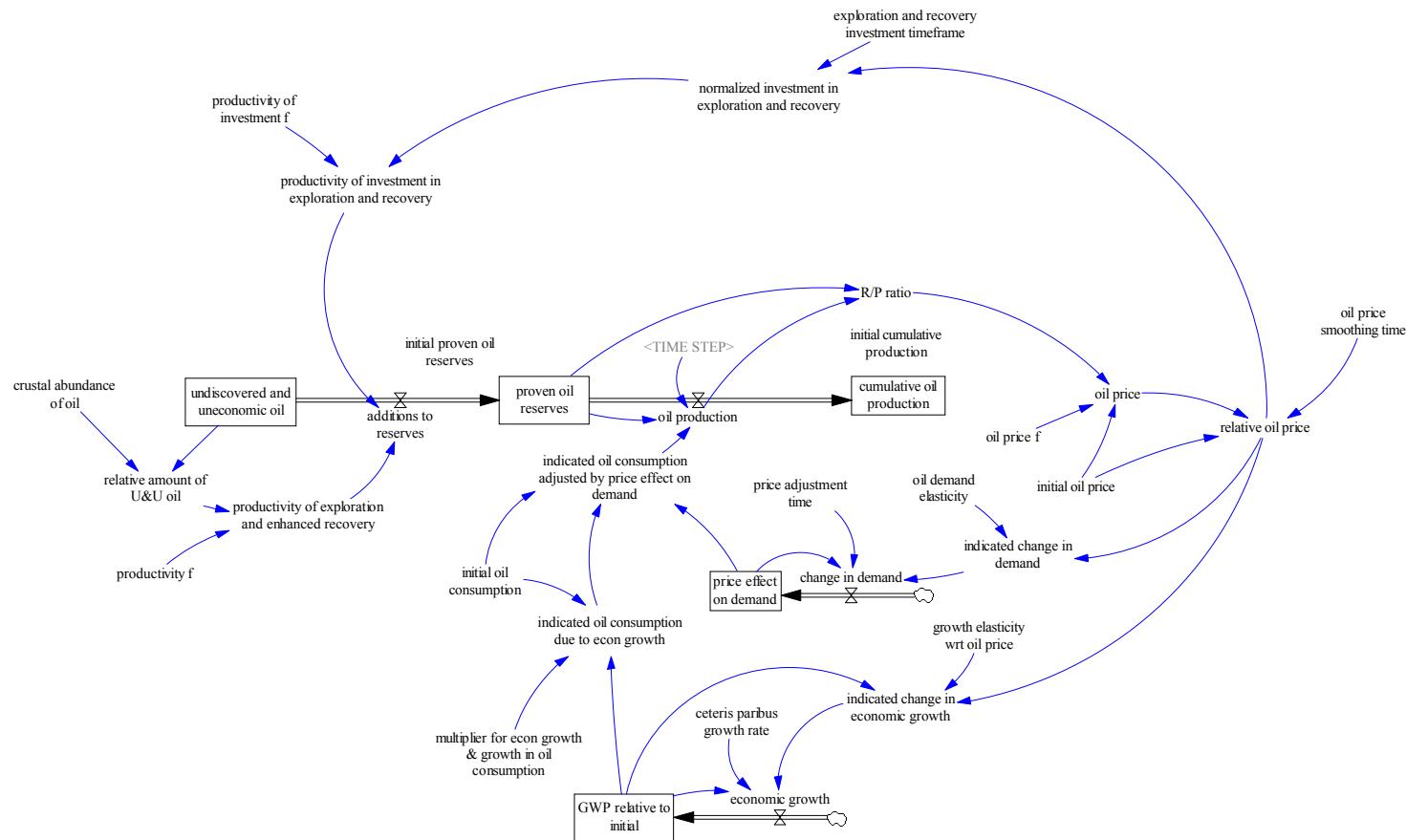
Oil price also affects demand directly

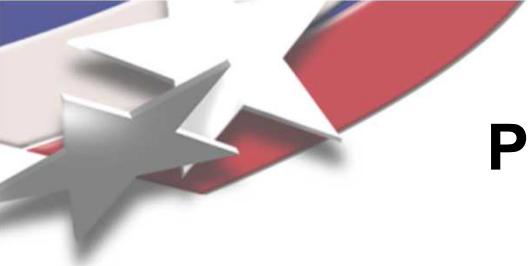


Relatively inelastic demand has little overall effect

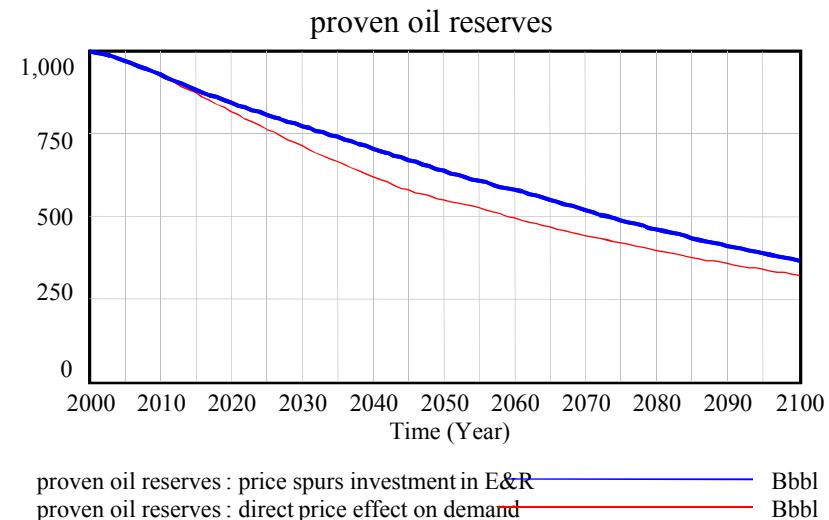
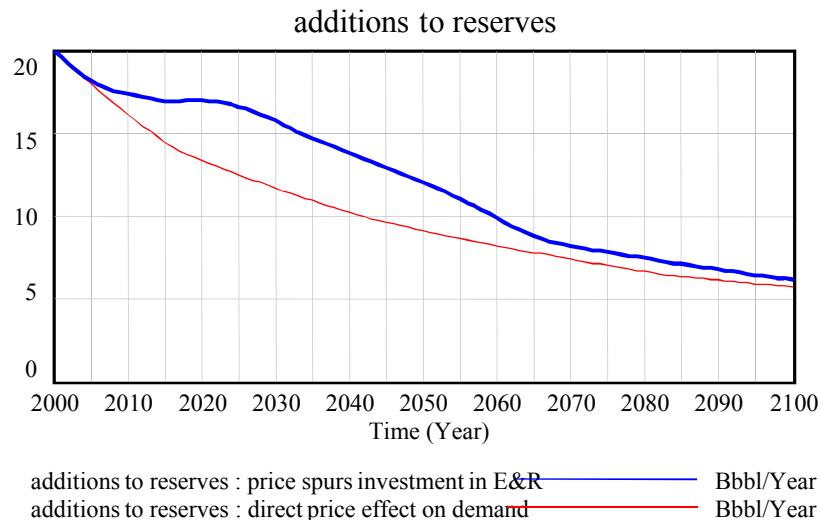


But, oil price also spurs investment in exploration and recovery, adding to reserves

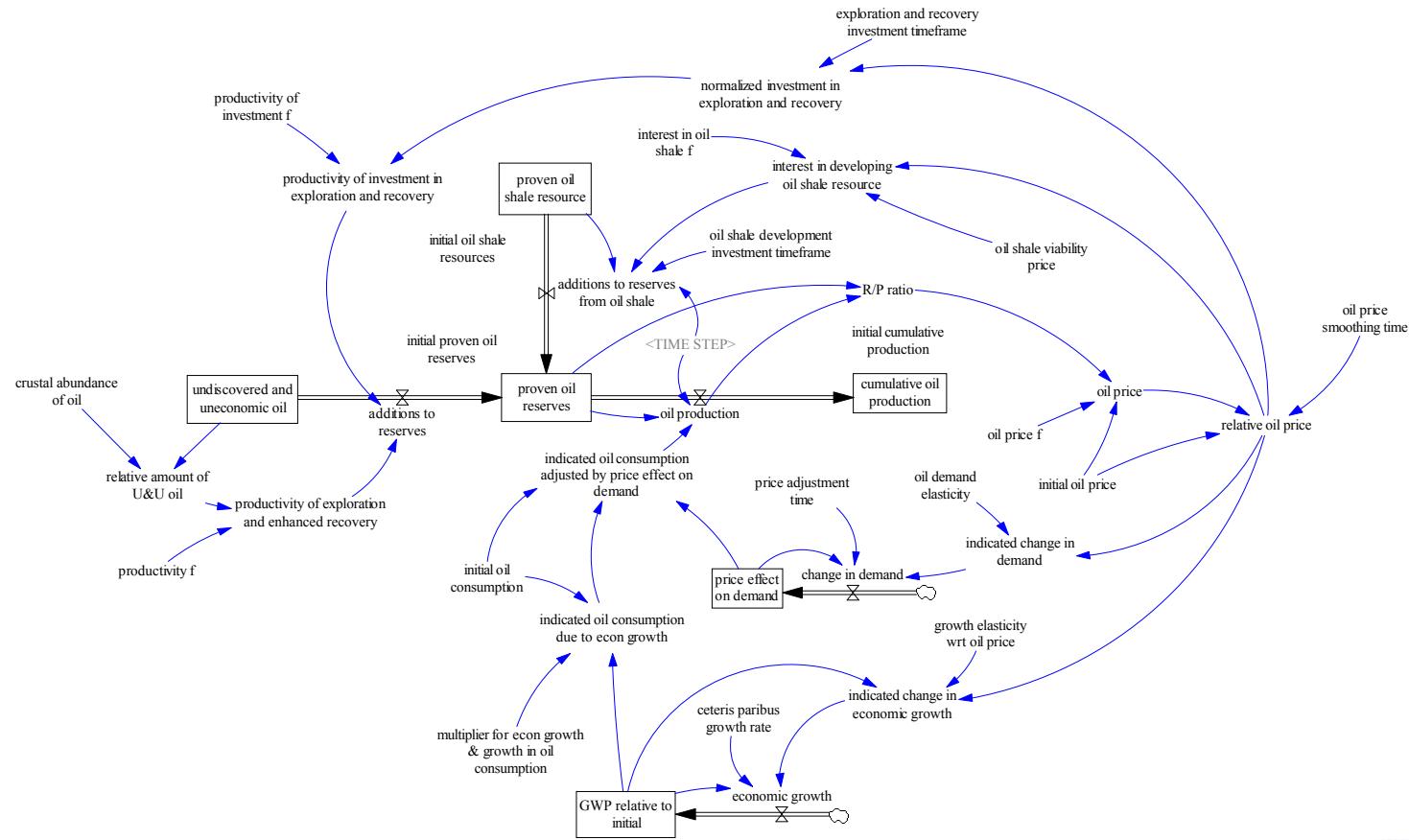




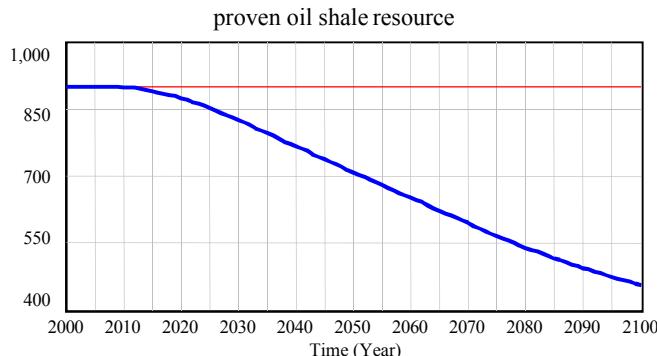
Price spurs investment in E&R marginally adding to reserves



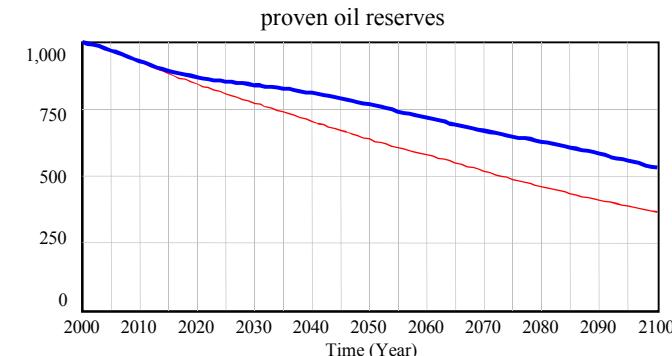
When the price of oil gets high enough, oil shale resources begin to be developed



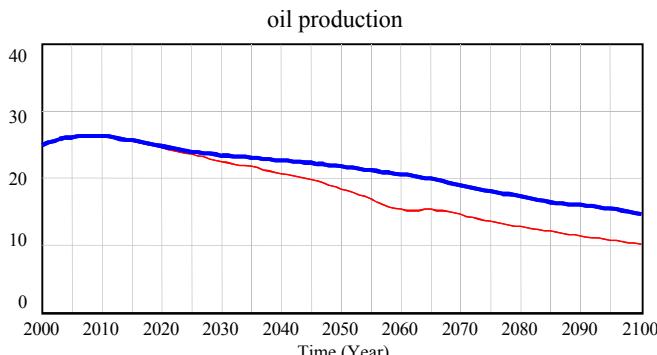
Oil shale development helps -- somewhat



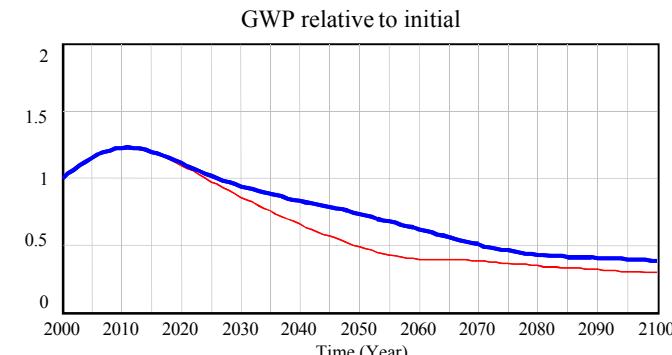
proven oil shale resource : oil shale development Bbbl
 proven oil shale resource : price spurs investment in E&R Bbbl



proven oil reserves : oil shale development Bbbl
 proven oil reserves : price spurs investment in E&R Bbbl

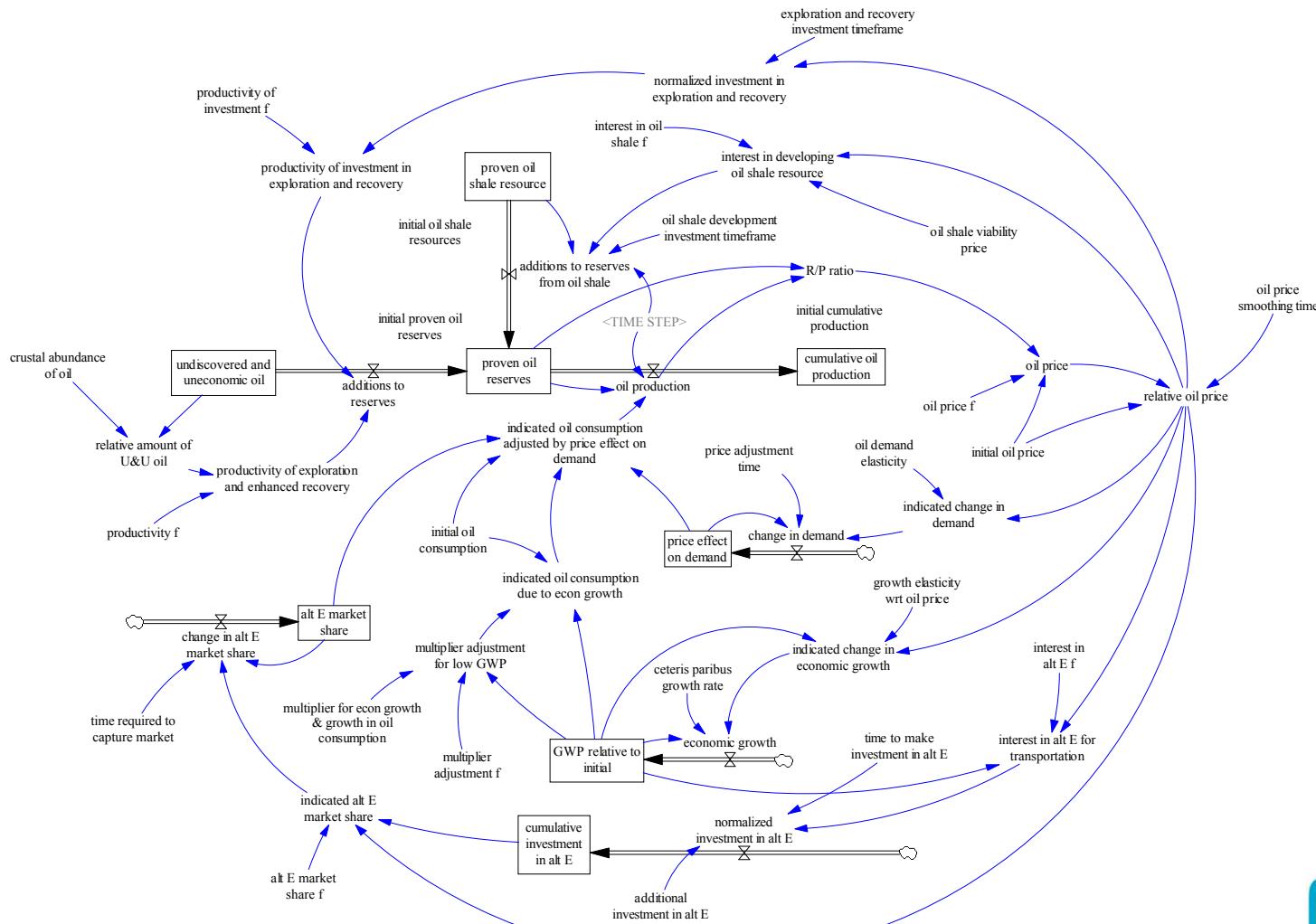


oil production : oil shale development Bbbl/Year
 oil production : price spurs investment in E&R Bbbl/Year

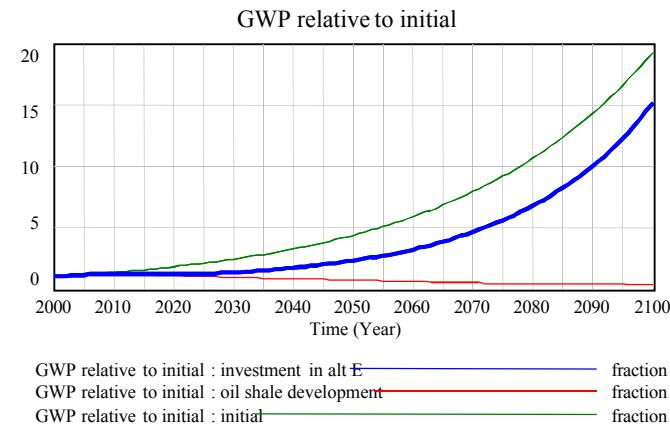
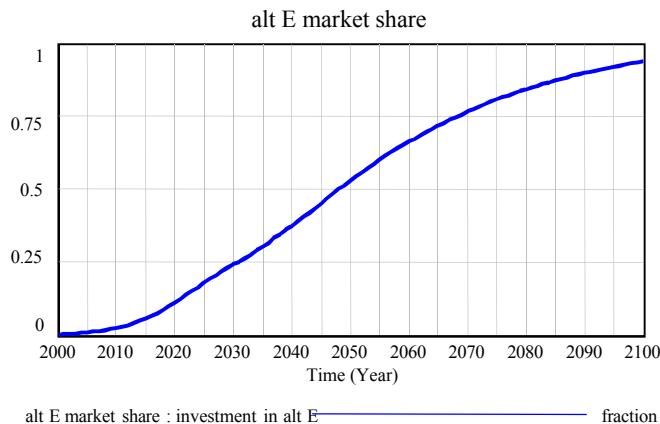
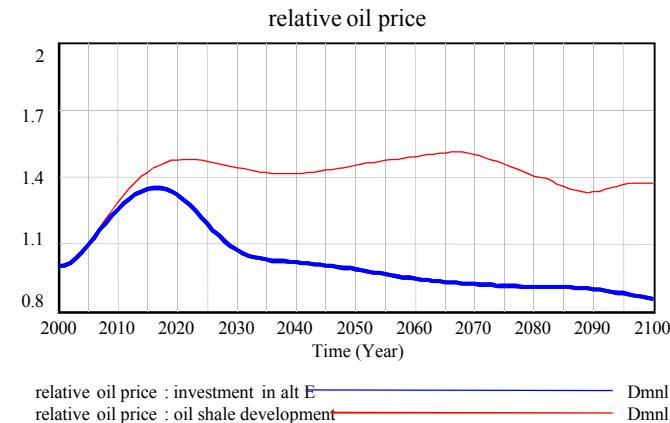
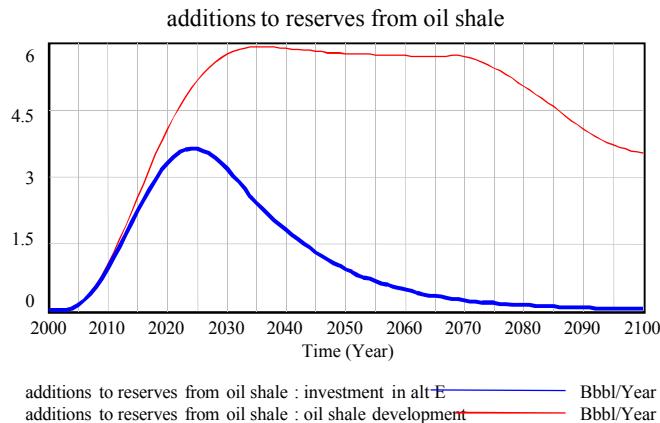


GWP relative to initial : oil shale development fraction
 GWP relative to initial : price spurs investment in E&R fraction

Finally, we consider the effect of alternative energy technologies in capturing the market for oil

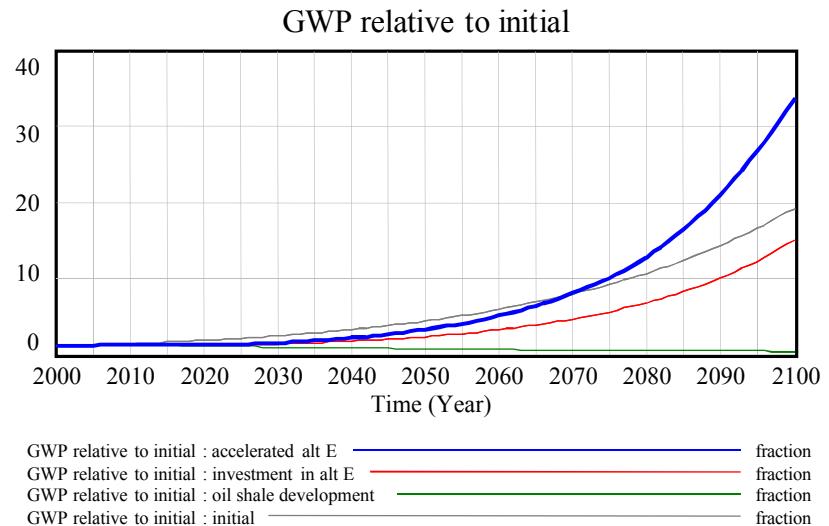
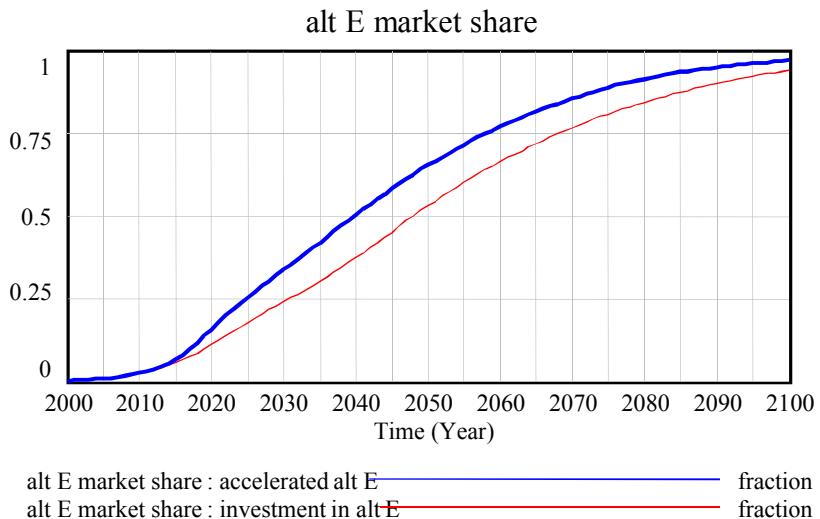


Oil shale provides a bridge until alternate transportation fuels are able to capture significant market share





Doubling transportation fuel RDT&E in this decade allows for enhanced long-term economic growth



Conclusions

- **WARNING: Don't believe these results too much. There are lots of hidden parameters and response functions.**
- **The model has more value for generating insights than for generating predictions**
- There are no rosy scenarios without significant development of alternative transportation fuels.
- **Unlike both the Hubbert and EIA/USGS oil production curves, our peaks occur sooner, but decline is much more gradual.**

