T21-USA: Business as Usual Scenario

Threshold 21–USA: Behavior Description

Andrea M. Bassi
Modeler, Millennium Institute
ab@millennium-institute.org

This paper provides an overview of the projections simulated by the base case of the Threshold 21 (T21) model customized to the United States of America, v. 3.3 July 2006. The present study highlights the main results of the simulation of the model for the three spheres, society, economy and environment and shows more in detail the behavior of the energy sector.

"We've learned that the forecasts have been wrong for a hundred years… (these forecasts) miss out on the fundamental dynamics of markets and technology."

John Felmy, Chief Economist at the American Petroleum Institute (2005)

"The EIA forecasts of Saudi Arabia production are based on the projected needs of energy consumers. The figures simply assumed that Saudi Arabia would be able to produce whatever the United States needed it to produce."

Peter Maass, The Breaking Point (2005)

Introduction

T21 is an integrated model created for national policy analysis and planning. Its structure is based on three spheres, society, economy and environment. The Threshold 21 customized to the U.S. is built up on a set of energy-related issues and its structure is enriched with numerous energy sectors belonging to the environmental sphere.

The behavior analysis of T21-USA concentrates on energy and its interconnections with the three spheres. Nevertheless, given the dynamic nature of the model and the existence of numerous feedback loops acting among the sectors of the model, results and projections generated by T21-USA are shown for each sphere.

The results produced by the interconnection of society, economy and environment, are presented graphically for the period 1980 – 2050. This long time frame has been chosen to represent energy transition in the U.S. and its consequences in the medium and long term.

The simulated behavior of the model is compared to historical data (1980 – 2005) and projected until 2050. The first 25 years of simulation allows for the validation of the model. If the model is able to replicate historical behavior of the sectors considered, it can be assumed that its structure can produce reasonable projections for the future. In addition, a number of validation tests have been run to prove and guarantee the soundness of the model.

Behavior of the Social Sphere

The main outputs of the Social Sectors included in T21-USA are population, its distribution into age cohorts, and life expectancy (the main endogenous factor affecting population development). In addition, highly dependent on population are total labor supply, employment and unemployment. The last indicator analyzed in this section is labor cost, which is influenced by labor availability and it is used as an input for labor-related technology development.

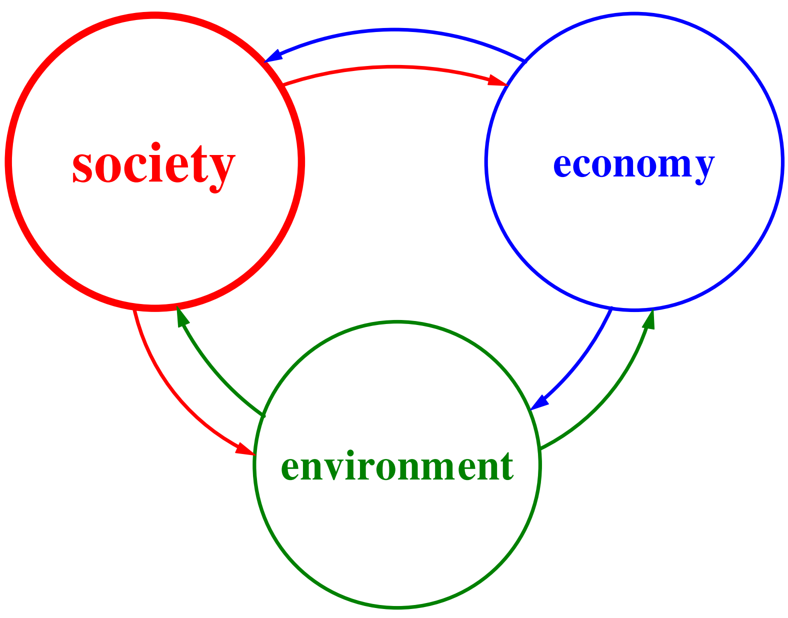


Figure 1: Conceptual overview of T21, with emphasis on the Social Sphere.

Population

The projection of the Total population is shown in Figure 2. Historical data, represented by the red line, are taken from the United Nations Population Division database). Total population in the U.S. is projected to grow by 38% in the period 2005 – 2050, reaching 414 million people. Population growth per se should not considered an issue if the economy and environment guarantee a similar improvement of the overall quality of life. In the U.S., a population-related problem is represented by the sustainability of social security and medicare.

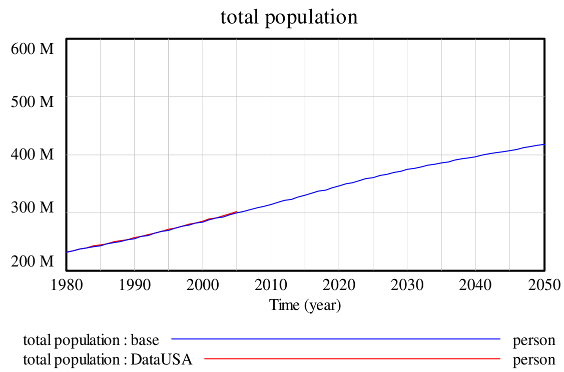


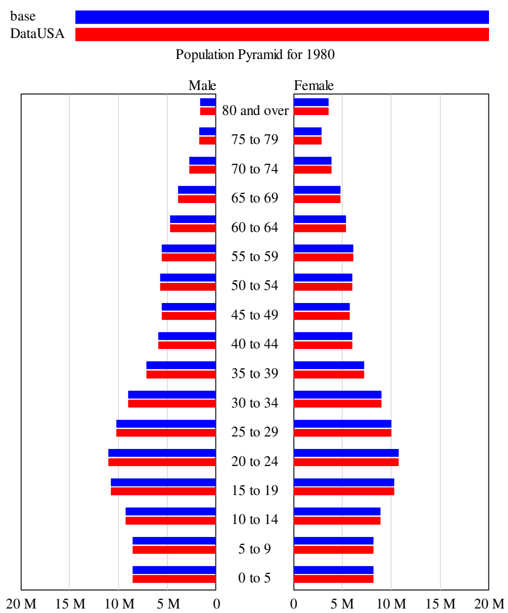
Figure 2: Comparing total population in T21-USA to historical data

Population pyramid

The population pyramid is calculated on the basis of initial values of population associated with each of the age cohorts for the year 1980, births and deaths (both endogenously calculated). An aging chain included in the population module determines the shift from one cohort to the next one each year. The total population results from the sum of all the age cohorts, both for males and females. Four population pyramids are reported below; for 1980, 2000, 2020 and 2040 respectively. These diagrams show that the number of people aged 65 and older will increase over the years more than the total population (especially if compared to those younger). In particular, two waves of population are evident in the medium term and contribute to the growth of the elderly population. The first one is clearly visible in the pyramid for 1980 (age 10 to 34) and 2000 (age 30 to 54), while the second one is visible in the pyramid for 2000 (age 0 to 19) and 2020 (age 25 to 39). The accumulation of these two waves, coupled with the improvement of health condition and, therefore, life expectancy, reinforces the growth of the elderly population in the U.S.

These projections of the population (which are in line with the U.N. projections) increase the concerns associated with the sustainability of social security and medicare.

Furthermore, population - energy linkages include the effect of air concentration of fossil fuels-related emissions. The relationship between fossil fuel emissions per hectare of land (CO2 emissions per hectare is assumed to be a good proxy for PM10 emissions) and mortality has been estimated based on data from a study by AEA Technology Environment, commissioned by the EU.



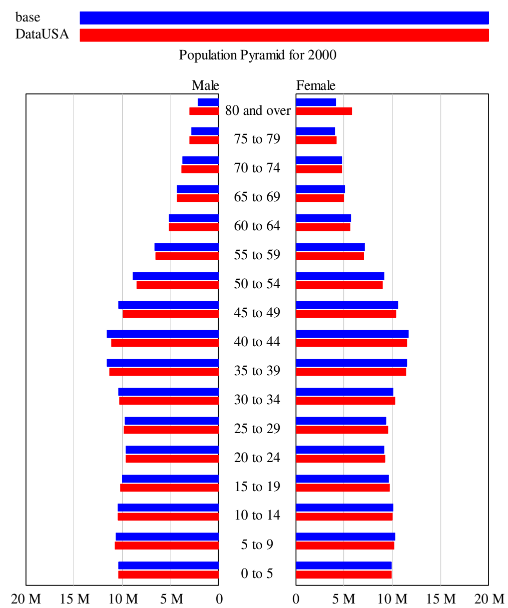
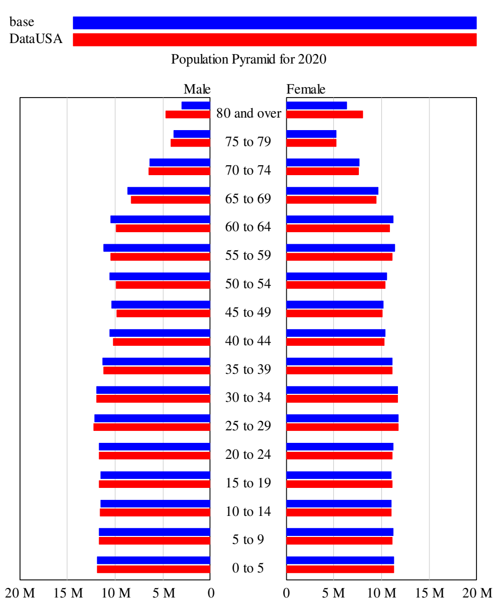


Figure 3, Figure 4: Comparing population pyramid in T21-USA to historical data (1980 – 2000)



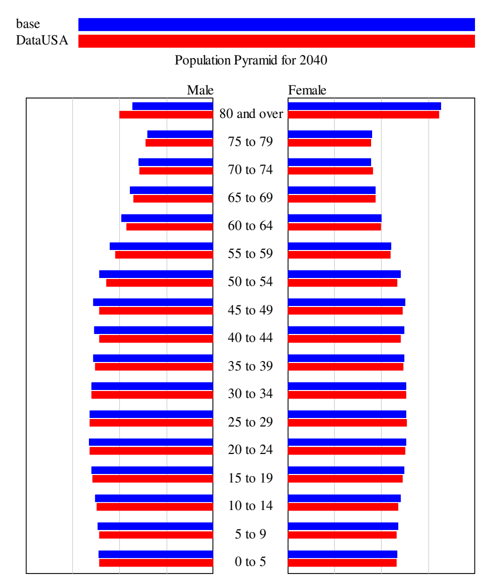


Figure 5, Figure 6: Comparing population pyramid in T21-USA to U.N. projections (2020 – 2040)

Life Expectancy

The development of life expectancy in the model is mainly determined by income per capita. Its value is projected to grow, for females from 79 years in 2005 to 82.5 in 2050, and for males from 73.5 years in 2005 to 78 in 2050.

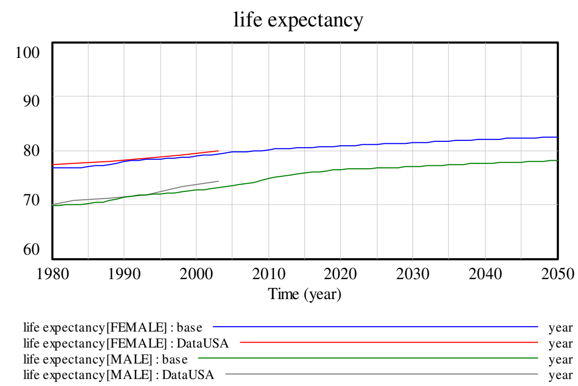
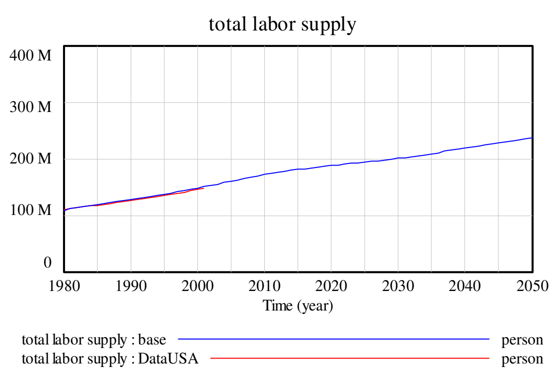


Figure 7: Comparing life expectancy in T21-USA to historical data

Labor Supply and Employment

Labor supply and employment are both projected to increase, in line with a positive trend in place since 1980. Simulated labor supply increases by 48% (reaching 237 millions) during the period 2005 – 2050 and employment rises by 58% reaching 234 millions. Intuitively, employment increases faster than the labor force due to the projected growth of the economy, which is greater than the one of the population.



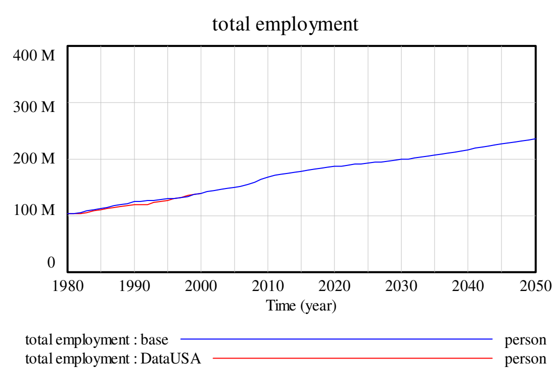


Figure 8, Figure 9: Comparing labor supply and total employment in T21-USA to historical data

Unemployment

The Unemployment Rate shows an interesting pattern of behavior. Oscillations are clearly visible in both historical and simulated values, but magnitude and cycles (influenced by delays) do not always correspond. The unemployment rate decreases from 7% in 2005 to 1% in 2050 due to the higher increase in production than in labor force. Even though the projection indicates a low unemployment rate for the years to come, a faster improvement of technology associated with labor, increased immigration, and a reduction of the growth rate of the economic production can eventually increase the unemployment rate in the U.S. in the medium and long term. The model endogenously calculates all these factors and their effects on the unemployment rate can be tested by simulating alternative policies.

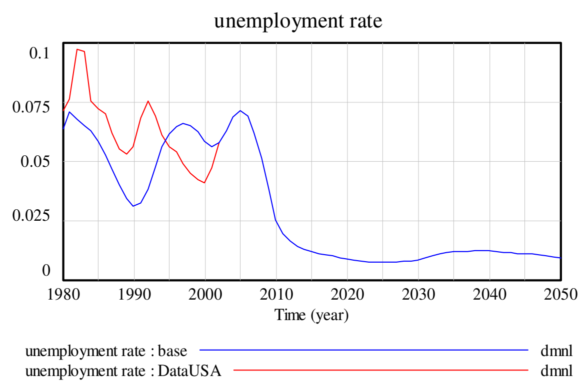


Figure 10: Comparing unemployment rate in T21-USA to historical data

Labor Cost

Labor cost is projected to increase by 70% during the period 2005 – 2050. This is due to the limited availability of labor force, and generates in turn labor technology improvement.

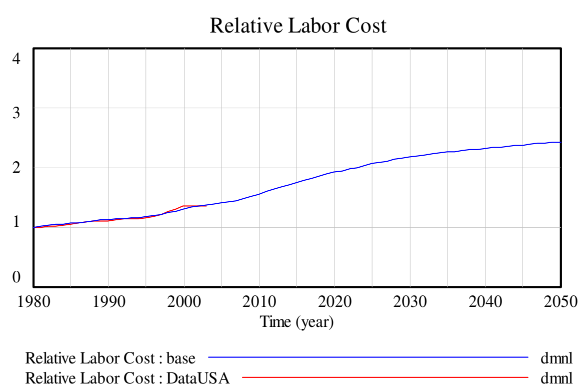


Figure 11: Comparing relative labor cost in T21-USA to historical data

Behavior of the Economic Sphere

The main outputs of the Economic Sectors included in T21-USA are related to the four agents acting in the U.S. economy; households, government, producers and the rest of the world (ROW). A few indicators are shown per each agent:

- Households: private investment;
- Government: revenues, expenditure, investment, debt and trust funds;
- Producers: production (GDP) and its components (agriculture, industry and services);
- ROW: balance of payments, trade balance and net services.

The base case scenario has been calibrated to reproduce a reasonable tax policy that implies a smooth increase in the actual tax rate, especially on income and profits, over the next few years (taxes are assumed to increase by +3% reaching the level of the year 2000 by 2008).

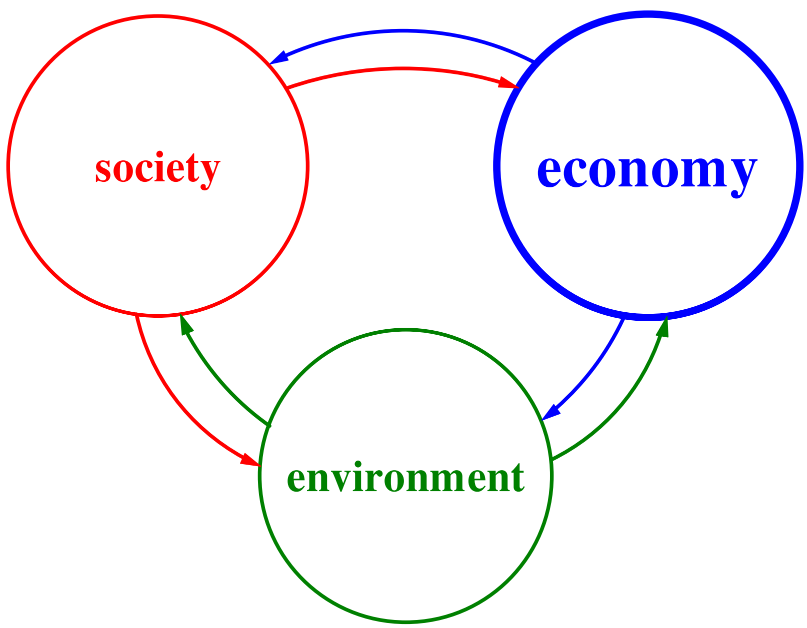


Figure 12: Conceptual overview of T21, with emphasis on the Economy Sphere.

Gross Domestic Product

The projections of Gross Domestic Product and value added produced by each sector (agriculture, industry and services) are shown below. The real GDP at factor cost is projected to become four times as much as it was in 2005 by 2050, reaching 4.18 trillion USD (using 2000 as base year). More interesting are the projections about each sector contributing to GDP: agriculture is projected to grow by 70%, industry by 125%, and services by 345%. In the economic sectors, historical comparison is mainly made with data series published by the International Monetary Fund (IMF) and the Bureau of Economic Analysis (BEA).

From the analysis of the GDP at Factor Cost is it also possible to calculate the weight of each sector on GDP: agriculture accounted for 1.5% in 2005 and is projected to decrease to 0.7% by 2050; industry reduces its share from 23% to 13%; services increase it's from 75% to 86%.

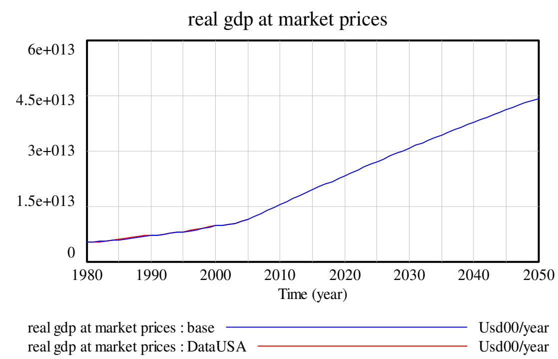
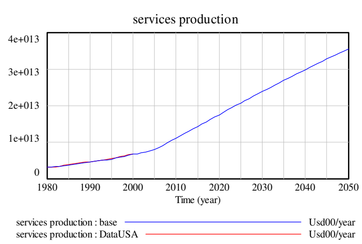
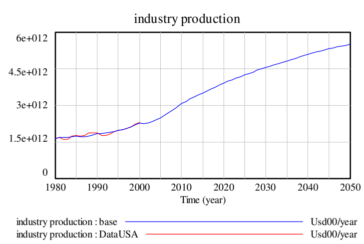


Figure 13: Comparing real GDP at market prices in T21-USA to historical data





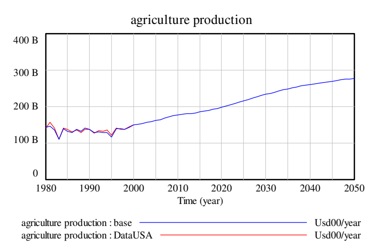


Figure 14, Figure 15, Figure 16: Comparing services, industry, and agriculture production in T21-USA to historical data

Investment

Real private investment increases by 250% in the period 2005 – 2050, while public investment grows by almost 300%, showing that about 90% of the total investment is provided by the private sector (its increase is of 260%). In fact, the share of public investment over the total is smaller than 10% over the whole period of simulation.

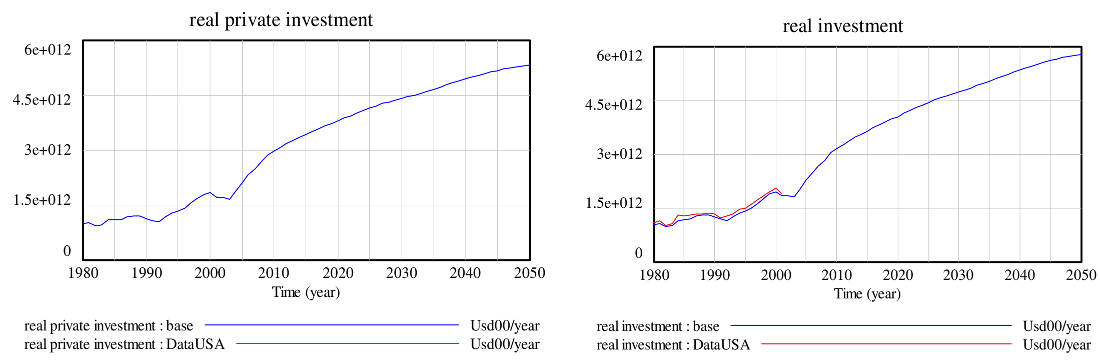


Figure 17: Comparing real private investment and total investment in T21-USA to historical data

The behavior of investments clearly exhibits the effect of September 11 on the U.S. economy. Investments were reduced, the growth rate of the economy declined generating a reduction of revenues for the government and, in turn even lower investments. Domestic demand and foreign funds then returned to normal levels and GDP started growing again.

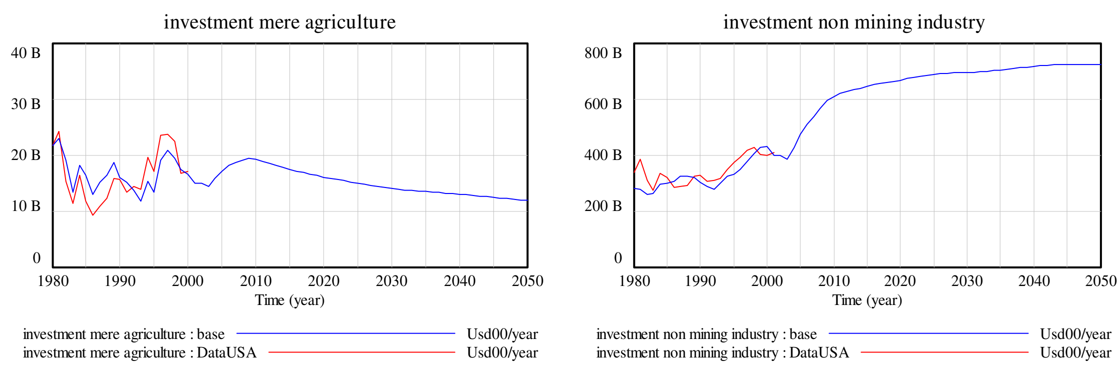
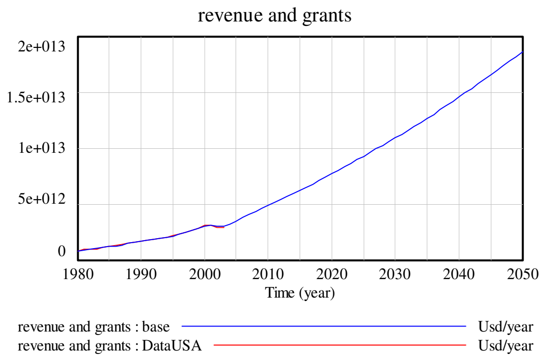


Figure 18, Figure 19: Comparing investment in mere agriculture and in non-mining industry in T21-USA to historical data

Government revenues and expenditure

Government revenues and expenditure are projected to increase as much as five times higher than their value in 2005. Therefore, the overall fiscal balance will remain negative throughout the simulation and will increase in absolute values.



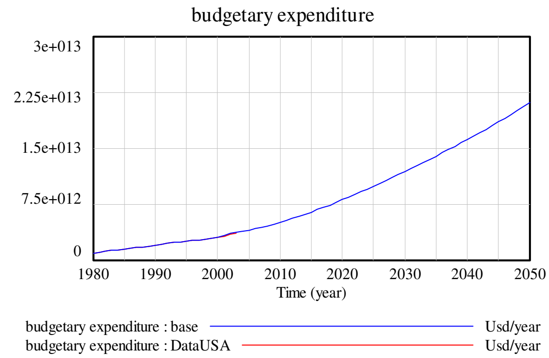
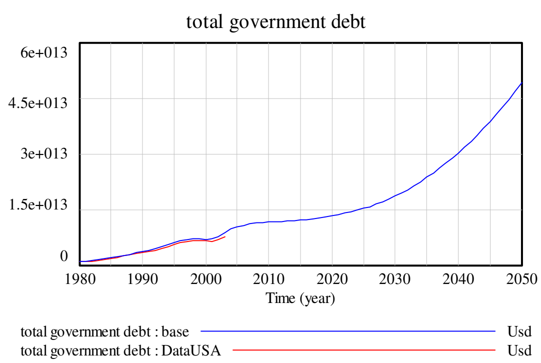


Figure 20, Figure 21: Comparing revenues and grants and budgetary expenditure in T21-USA to historical data

Government Debt

Because of the negative performance of the overall fiscal balance, government debt is projected to increase by almost five times, reaching 4.9 Trillion USD in 2050. Its simulated ratio to GDP (about 80% in 2005) will decrease until 2027 (at 37%) and then rise again to 56% in 2050.



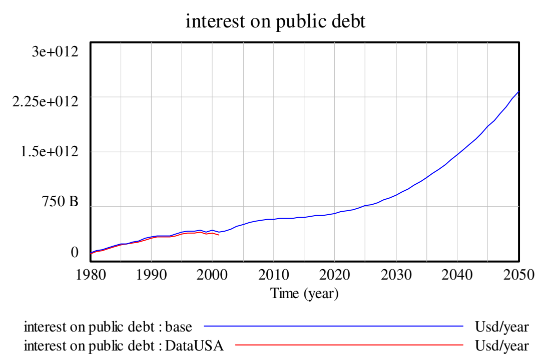


Figure 22, Figure 23: Comparing total government debt and its interest in T21-USA to historical data

Balance of Payments

The Balance of Payments is projected to grow slowly in the medium and long term. The historical fit of the simulated data is encouraging and the projection is in line with the positive economic results shown above.

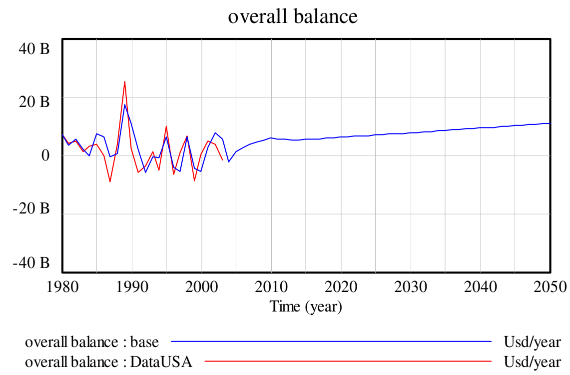
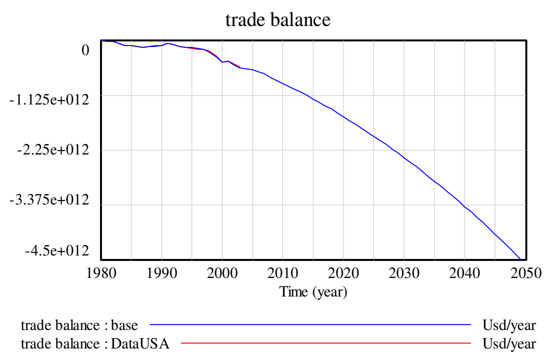


Figure 24: Comparing overall balance of the BOP in T21-USA to historical data

Import and Export

By looking at the resources balance (trade balance and net services), new insights emerge: the overall balance presented above is positive because of the growth in capital and finances, while the resource balance is negative and decreasing.



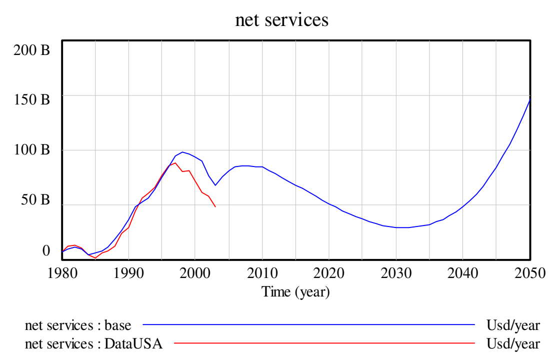
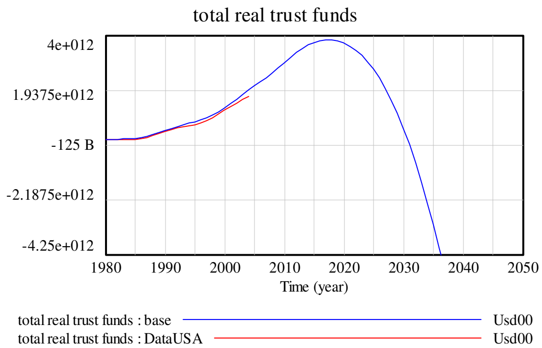


Figure 25, Figure 26: Comparing trade balance and net services in T21-USA to historical data

Trust Funds

The development of the Trust Funds is an important issue for the government of the United States. In fact both social security and medicare funds are projected to peak and turn negative in the next 20 to 40 years. The projections obtained with T21 are in line with the ones published by the Congressional Budget Office (CBO). Policy variables on taxation, expenditure per beneficiary and retirement age have been added to the structure of the model to allow for the evaluation of new scenarios generated by alternative policies.



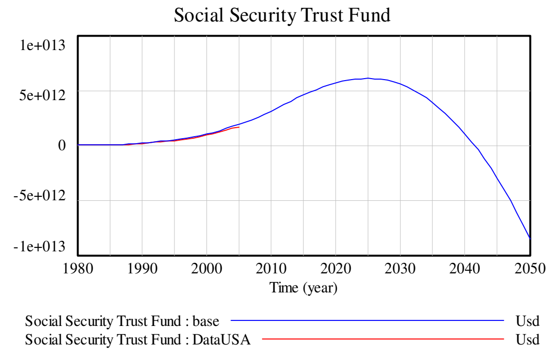


Figure 27, Figure 28: Comparing total real trust funds and social security fund in T21-USA to historical data

Behavior of the Environmental Sphere

The energy sectors in T21 are built taking into account the physical structure of the energy market, therefore they emphasize and represent the dynamics of energy resources and are included in the Environmental Sphere of the model. In addition, the utilization of exogenous inputs is limited and the full process of demand and production is endogenously represented in the model. This modeling technique is necessary when one of the main issues to be analyzed with T21-USA is the energy transition. Therefore, the behavior of the model tends to reproduce the medium term trend, without taking into consideration short term oscillations of speculation (e.g. oil and fossil fuels prices).

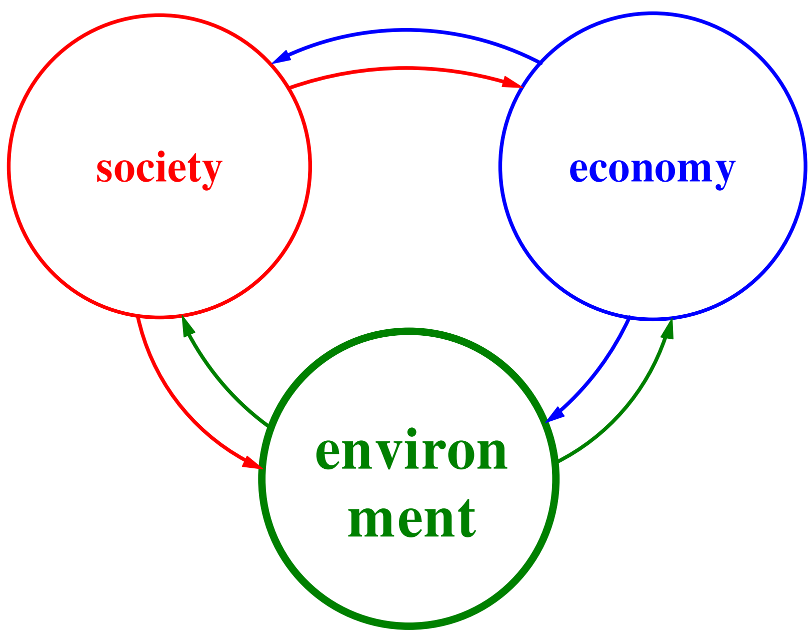


Figure 29: Conceptual overview of T21, with emphasis on the Environmental Sphere.

The main outputs of the Environmental Sectors included in T21-USA are related to energy and can be divided in tow main categories: national and international indicators. Demand, production, price and cost of fossil fuels, and generation of emissions are calculated for both U.S. and the rest of the world (ROW). Sectoral energy demand (residential, commercial, industrial and transportation), investment, expenditure, carbon cycle and contribution to climate change are represented only for the U.S.

These indicators are calculated as follows:

- Energy demand is generated by GDP, prices and technology;

- Supply is determined by the availability of resources, technology, capital and demand;
- Investments are determined by the availability of a reserve and by the profitability of the market;
- Prices are defined by the availability of the resource and reserves and by the demand supply balance;
- Emissions are generated from fossil fuel consumption and affect the population.

U.S. Energy Demand and Supply

Total energy demand projections indicate a growing trend over the next 50 years. Technology will reduce the intensity of energy on GDP, but energy demand will still increase. In fact, energy demand is projected to increase by 83% by 2050, reaching 180 QDBTU (Quadrillion British Thermal Units), while simulated GDP will increase by 290%, which indicates that the energy intensiveness of the GDP is decreasing significantly. On the other hand, the projection of energy demand per capita shows a growing trend after 2010 that levels off after the world oil production peaks (2020) and the production and consumption of substitutes sets in. Technology improvement is still needed to reduce consumption and ease the transition towards renewable resources.

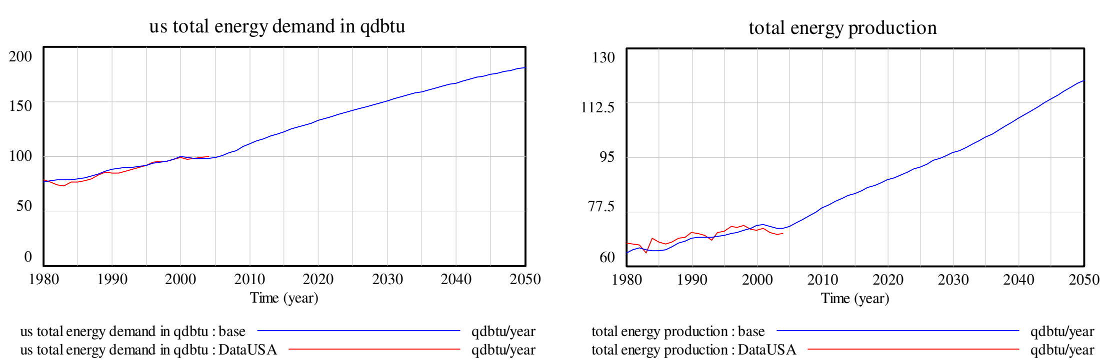


Figure 30, Figure 31: Comparing U.S. domestic energy demand and production in T21-USA to historical data (imports are not shown)

A more interesting analysis regards consumption by energy source, which is going to shift from oil and gas, to coal, nuclear and renewables. In fact, the projected rise of oil prices stimulates substitution from oil towards nuclear and renewable energy sources. Energy sources that are not profitable now may become profitable in the future (e.g. tar sands, solar and wind energy, hydrogen, alcohol fuels, etc.) due to a general increase in energy prices. Despite an increase in total energy demand, the projected share of consumption of oil and natural gas will decrease by 2050 from 40 to 22% and from 23 to 17% respectively. The coal share of total consumption is projected to increase from 23 to 34%, while renewable energy doubles (6 to 12%) and nuclear reaches 15% (starting from 8% in 2005).

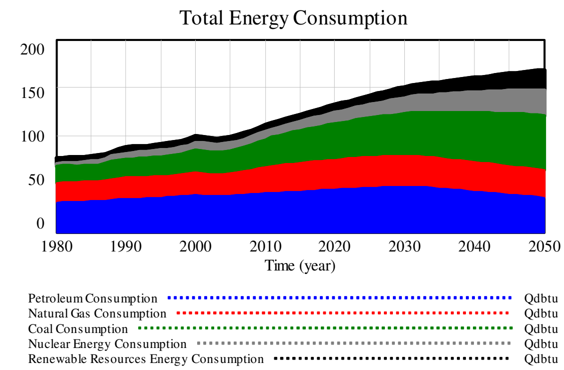


Figure 32: Total energy consumption in T21-USA

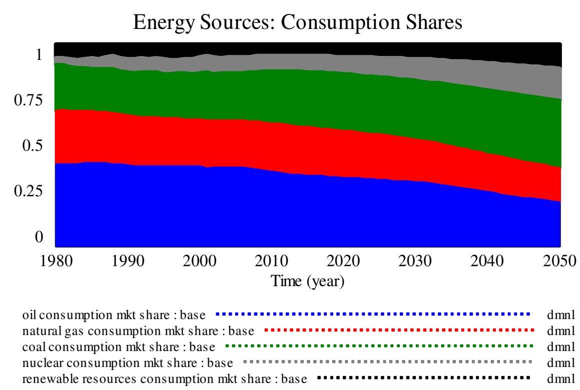


Figure 33: Energy sources consumption shares in T21-USA

Fuel demand and supply are shown below for both U.S. and the rest of the world. This graph shows world demand for oil (and its substitutes) and petroleum production (top part). The area between the red and the blue line represents the indicated need for oil substitutes (e.g. alcohol fuels, renewable resources, hydrogen). The lower part of the graph shows U.S. demand and production.

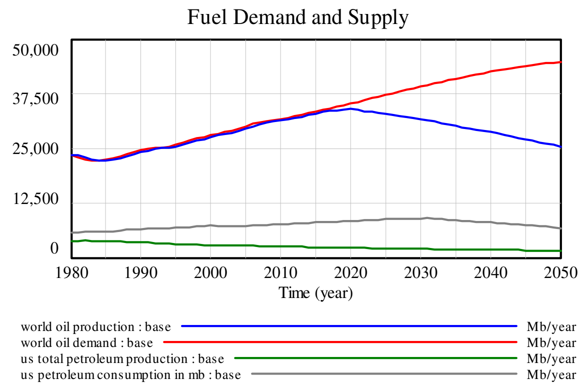


Figure 34: U.S. and world fuel demand and supply in T21

The fuel (oil and its substitutes) dependency factor (calculated as import over consumption) is projected to increase, reaching 82% by 2050. Conversely simulated fossil fuel dependency will peak when oil import is at its maximum (2033), reaching 45%, and will decrease thereafter.

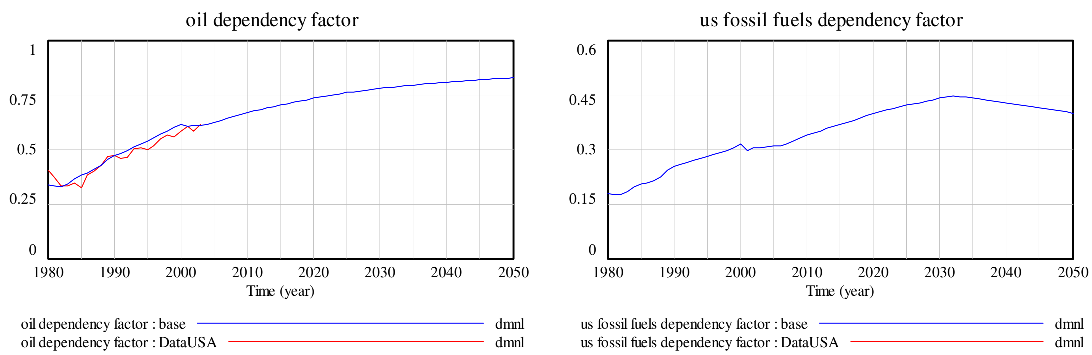
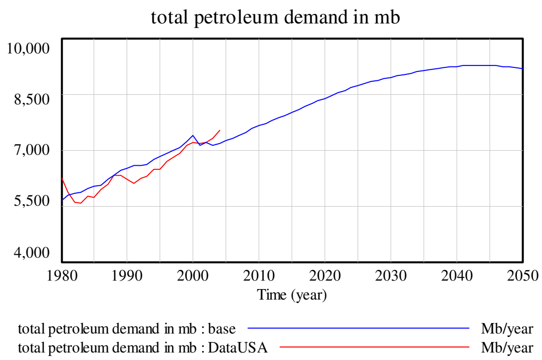


Figure 35, Figure 36: Comparing oil and fossil fuel dependency factor in T21-USA to historical data

U.S. Petroleum Demand and Supply

The projection of national petroleum demand indicates an increase of 28% by 2050 and shows the turning point in oil demand due to substitution in 2044. Nevertheless, the dependency from foreign crude is projected to increase (from 62 to 82% by 2050), mainly due to the incapacity of maintaining domestic production, which is projected to decrease by 40%. The U.S. production has declined since 1970, even after the exploitation of the Prudhoe Bay fields was initiated and peaked in 1988. Simulated oil imports increase as long as petroleum is readily available in the world market. After this moment, crude oil trade will become an issue that is not analyzed by the current version of T21-USA.

Oil addition to identified reserves by discovery and development are also shown. Both are projected to decrease due to the decline of undiscovered resource ad discovered reserves.



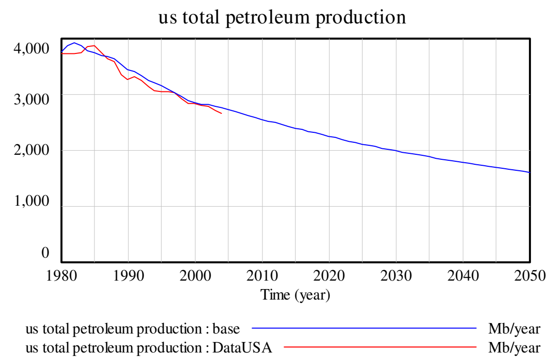
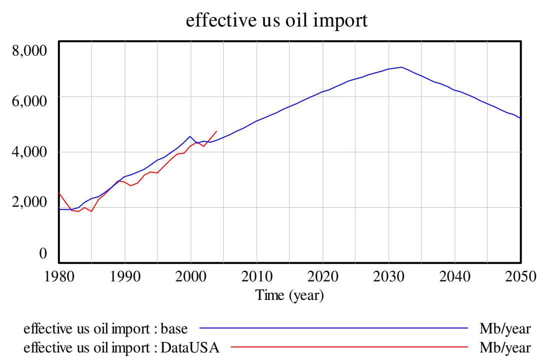


Figure 37, Figure 38: Comparing U.S. petroleum demand and production in T21-USA to historical data



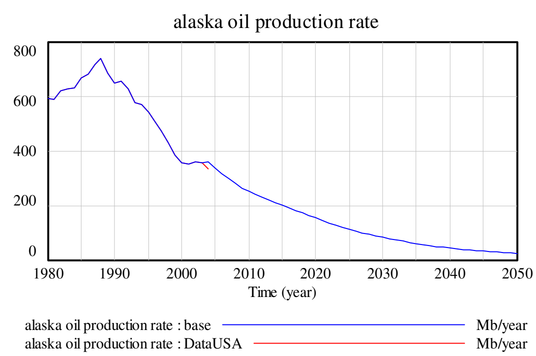
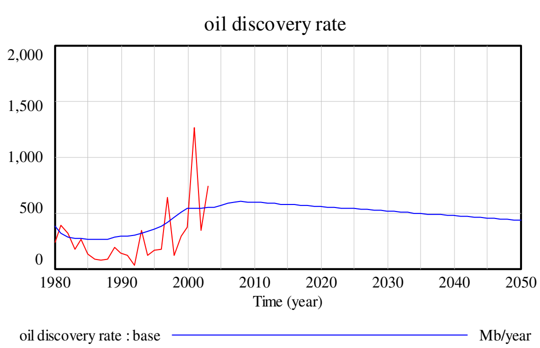


Figure 39, Figure 40: Comparing U.S. indicated import and Alaska production in T21-USA to historical data



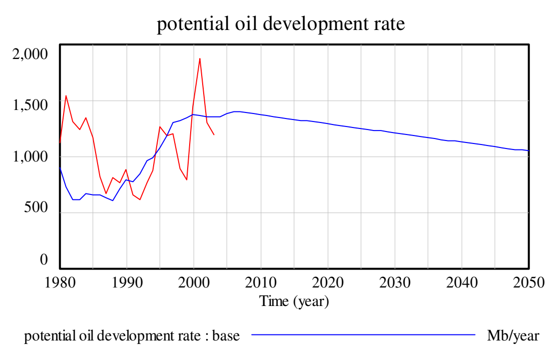


Figure 41, Figure 42: Comparing U.S. oil discovery and development in T21-USA to historical data

Rest of the World Energy Demand and Supply

"The world has never faced a problem like this, previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary."

Science Applications International, a report commissioned by the United States Department of Energy's National Energy Technology Laboratory (2005).

"People who are predicting an imminent peak are simply wrong."

R. Kaufmann, Boston University (2004)

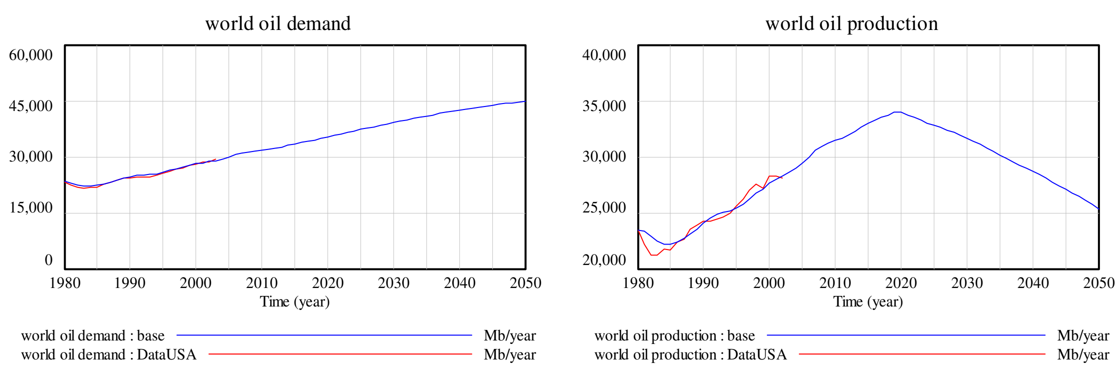


Figure 43, Figure 44: Comparing world oil demand and world oil production rate in T21-USA to historical data

Fossil fuel demand from the rest of the world is projected to increase at a higher rate than in the U.S. (62% relative to 58%), mainly due to demand from fast growing countries such as China and India. Specifically, simulated petroleum demand will increase by 312% in China and by 245% in India, by 2050. The impact of growing demand from large developing countries on the availability of resources for the US is visible. China and India's consumption will reduce the availability of fossil fuels (especially oil and gas) for the US for two main reasons. First, China is taking care of future petroleum needs by buying oil companies and securing availability for the future. Also, the geographical location of China and India is an important asset: these countries are closer to the net exporting countries (e.g. Russia and the Middle East) than America.

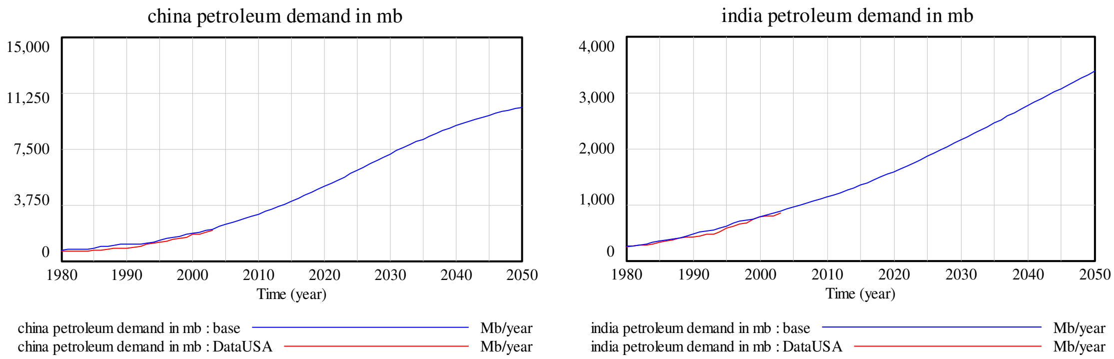


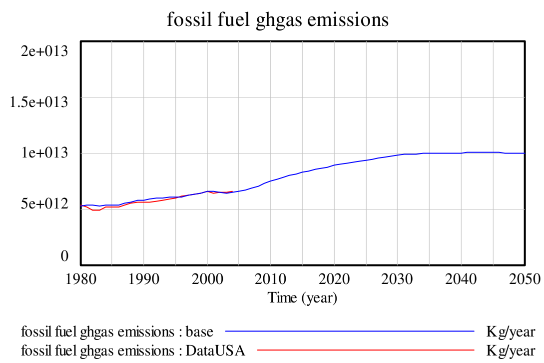
Figure 45, Figure 46: Comparing China and India petroleum demand in T21-USA to historical data

Considering petroleum and its substitutes, simulated world fuel demand doubles by 2050, reaching 44,600 MB/year (Million Barrels per year), while oil production increases by 15% to reach its peak of 33,700 Mb/year in 2020 and declines thereafter.

Various policy variables have been introduced to the T21-USA model to simulate different scenarios for world oil production. According to these simulations, the turning point could be in a few years from now or even as late as in 2040 at 45,000 MB/year.

Fossil Fuel and GHG Emission

Just as the energy consumption, U.S. fossil fuels emissions are projected to increase by 2050. The simulated growing consumption of oil, gas and coal generates 9.9 Million Tons of greenhouse gas per year by 2050 (scoring a +50% with respect to the 2005 level). CO_2 emissions are projected to follow the same path, showing that effective and timely actions must be taken in order to reach the goals set by the Kyoto Protocol. On the other hand, simulated greenhouse gas emissions intensiveness of GDP decreases by 60% over the next 45 years, nonetheless this is not sufficient to reduce the growth of emissions resulting from fossil fuel consumption (which is projected to increase by 28%). Similarly, globally by 2050 GHG emissions are projected to have increased by 70%.



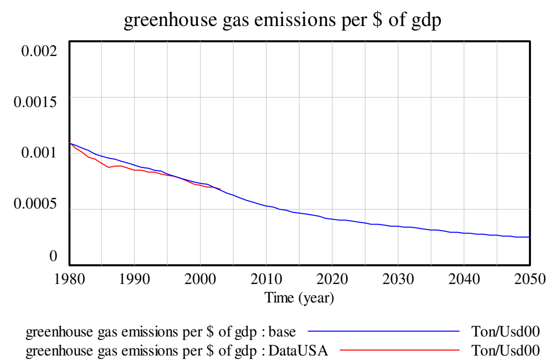
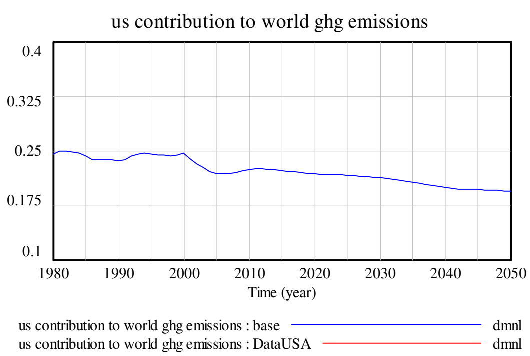


Figure 47, Figure 48: Comparing fossil fuel GHG emissions and GHG emissions per dollar of GDP in T21-USA to historical data



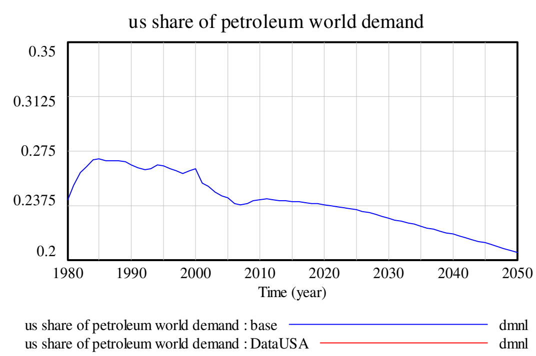


Figure 49, Figure 50: U.S. contribution to world GHG emissions and U.S. share of world oil demand in T21-USA

Oil Price

The real world oil price is projected to increase more than four times by 2050 relative to its 2005 value. This is due to the decreasing availability of resources, growing demand and the process of substitution towards renewable resources. The long delays characterizing the latter, especially for what concerns the substitution of the car fleet, contribute to the creation of an imbalance between demand and supply.

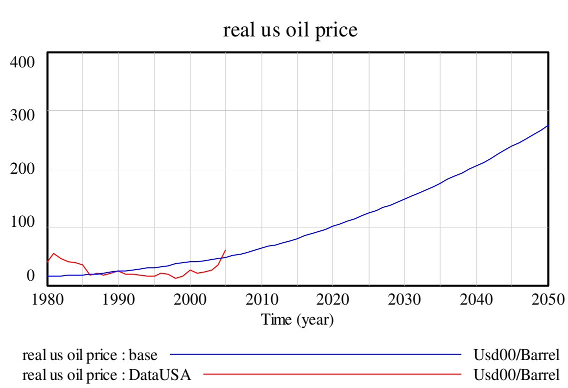


Figure 51: Comparing real domestic petroleum price in T21-USA to historical data

Considering historical data, the oil price has decreased over the years until the price shock of the early 80's. At that time, the petroleum price increased due to an apparent shortage of oil, which unveiled itself after the domestic production peaked in the U.S. As soon as world production increased (especially caused by the Saudi Arabian oil production), prices returned to their original level. Nevertheless, an important factor characterizing the energy market was revealed: the oil resource is finite and, as soon as production reaches its peak, petroleum price will increase. The rise of the oil price can be immediate and steep if substitution is not in place or smooth and gradual (with a tendency to level off) if the production of alternative sources can cope with demand.

The projections shown in Figure 52 represent the behavior of domestic and world oil price when substitution for oil is taken into consideration. In this case, even if the production peak occurs in 2020 (see Figure 43) the shortage of petroleum becomes relevant only 6 years later. This is due to the assumptions that the production of synthetic and biological fuels starts in 2007 and that prices and the lifetime of the car fleet are the main drivers of the demand of alternative fuels. As a consequence the demand-supply balance of fuel remains below one until the production of synthetic and biofuels cannot cope with demand (which happens when world oil production is steadily declining). As soon as the oil price increases, the demand shifts from conventional to alternative gasoline due to the replacement of old cars with new and more efficient ones. At this stage the demand for oil decreases ad its price declines as well. The tendency for the future is an increasing price due to the increasing cost of extracting oil from the reservoirs.

The graph below shows two different patterns of behavior: in the US market (blue line) the oil price remains higher due to the declining imports of crude oil (e.g. when the whole world is facing shortages) and due to the capacity of producing alternative fuels for a very large domestic market; as for the rest of the world the transition is smoother due to a higher availability of substitutes or oil and to a faster replacement of the car fleet.

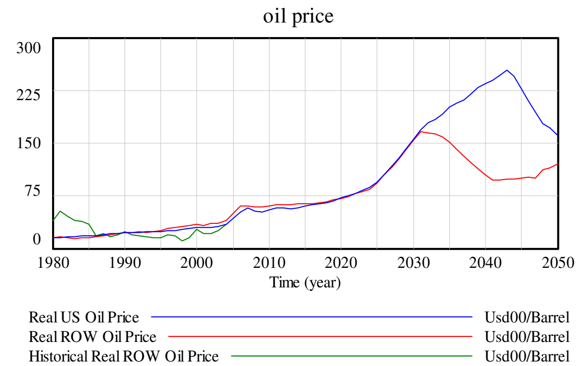


Figure 52: Comparing real domestic and international petroleum price in T21-USA to historical data

The graph below shows the historical behavior of oil price (1986 to present day, Figure 53). Speculation and historical events are not taken into consideration by T21. Therefore the simulated price tends to reproduce the medium term trend of price (Figure 54).

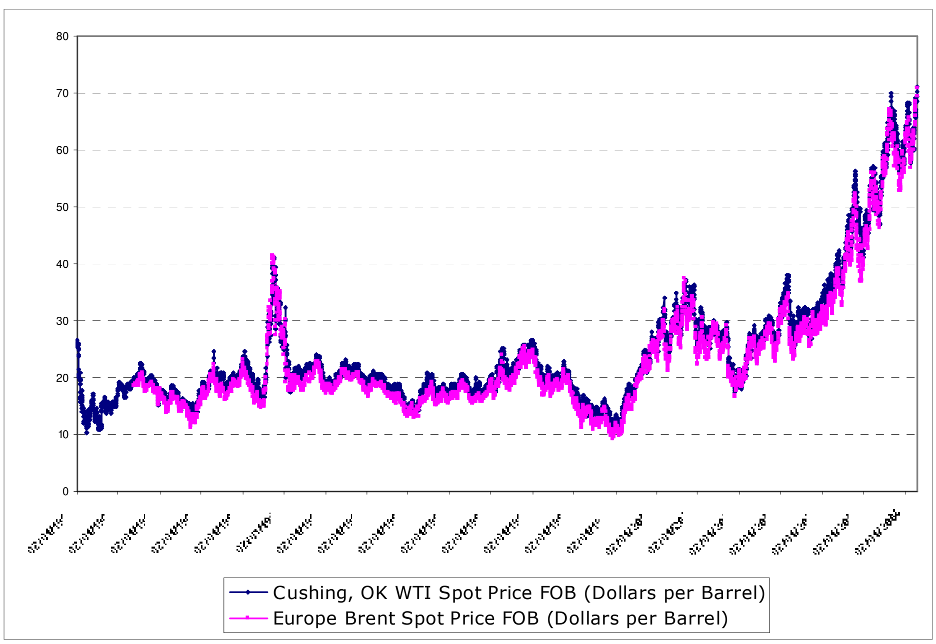


Figure 53: Nominal petroleum price, WTI and Brent (1986 – 2006)

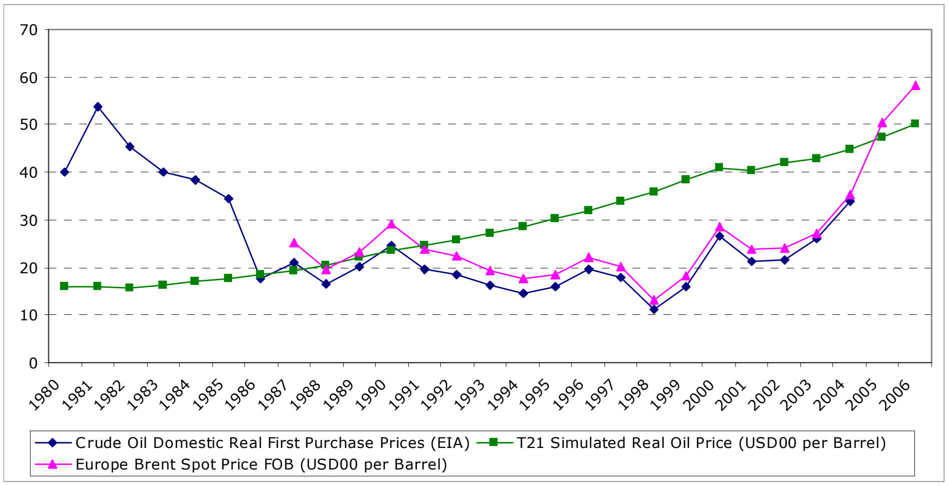


Figure 53

Figure 54: Comparing real petroleum price in T21-USA to historical data (EIA and Brent)

The oil price is influenced by the availability of reserves, petroleum demand and supply. The model endogenously calculates the latter, while the former are highly dependent upon the initial values (for the year 1980) used in the model. Various policies have been introduced to the structure of T21-USA to reduce the uncertainty coupled with the estimation of oil reserves and resource. The following sensitivity analysis shows the ranges of possible results obtained by simulating different assumptions regarding the resource and the reserves.

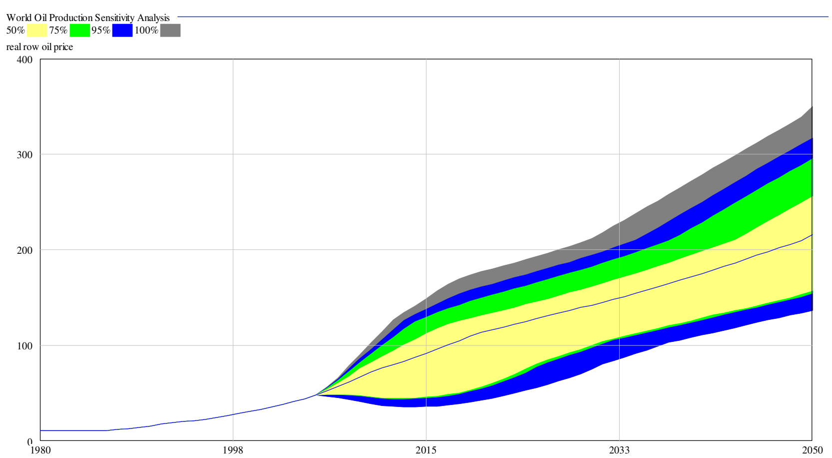


Figure 55: Sensitivity analysis on the real oil price; obtained by varying the amount of the undiscovered resource and the discovered reserve

In the case of high reserve availability in 2005, the simulated oil price decreases until 2015 and then starts increasing gradually (once again due to the reduced availability of reserves and the demand supply balance). If, on the other hand, the reserves deplete quickly, then price suddenly increases due to the lack of substitution (see Figure below and Figure 52).

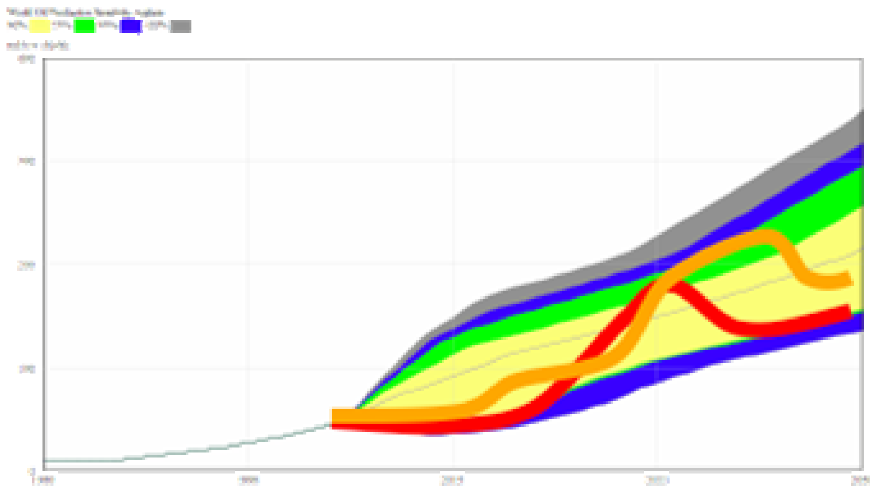


Figure 56: Comparison of the sensitivity analysis on the real oil price and two scenarios including the effect of substitution

Related Analyses

Oil Production Peak

Since T21 is intended to be a tool for integrated policy planning accessible to anyone, one of its most important characteristics is the flexibility it offers in testing assumptions and policies. The following sensitivity analysis, on world oil production, is an example of the behavior that the model exhibits under extreme condition testing. For instance, if Matthew Simmons is right when stating that Saudi Arabia is overproducing its biggest fields, the total amount of recoverable oil would have to be decreased. If recoverable oil decreases, the oil production peak occurs at an earlier time than otherwise expected. This is the worst-case scenario as demonstrated by the sensitivity analyses below; the production peak will be reached in the next few years (by 2010) and oil prices will rise faster than otherwise expected. If, on the other hand, the EIA projections are correct, the production peak will not arrive before 2030 (best-case scenario shown below) and oil prices will remain at a lower level for a few years before rising due to oil scarcity from depletion. Note that in the latter case, oil price will not reach the level of the former case because technology and availability of alternative sources will ease the transition beyond the oil era.

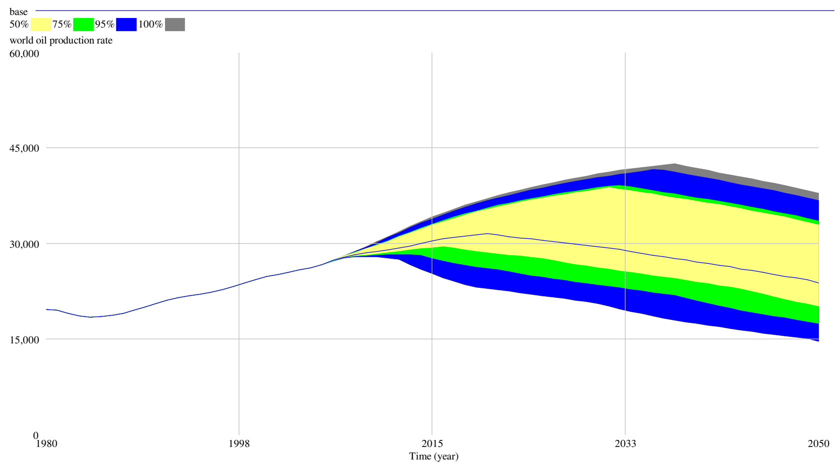


Figure 57: Sensitivity analysis on the world oil production rate; obtained by varying the amount of undiscovered resource and discovered reserve

An oil production peak analysis is hereby proposed, based on comparisons between the EIA, the AAPG (American Association of Petroleum Geologists) and the T21 projections. These can all be reproduced using T21-USA by simulating the model under various assumptions.

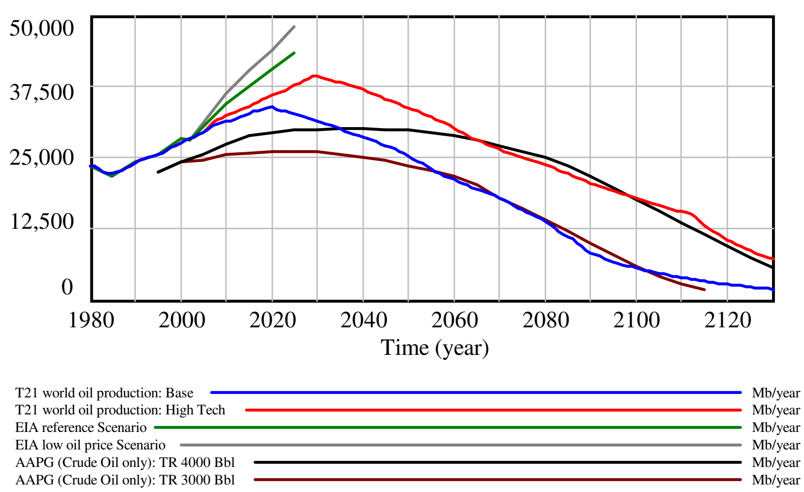


Figure 58: Comparing T21-USA, EIA and AAPG world petroleum production scenarios (AAPG only considers crude oil)

Matthew Simmons' assumptions regarding overproduction in Saudi Arabia and Amory Lovins' theory on technological improvement and substitution for oil have been analyzed with T21-USA. Two graphs reproducing their findings are discussed below.

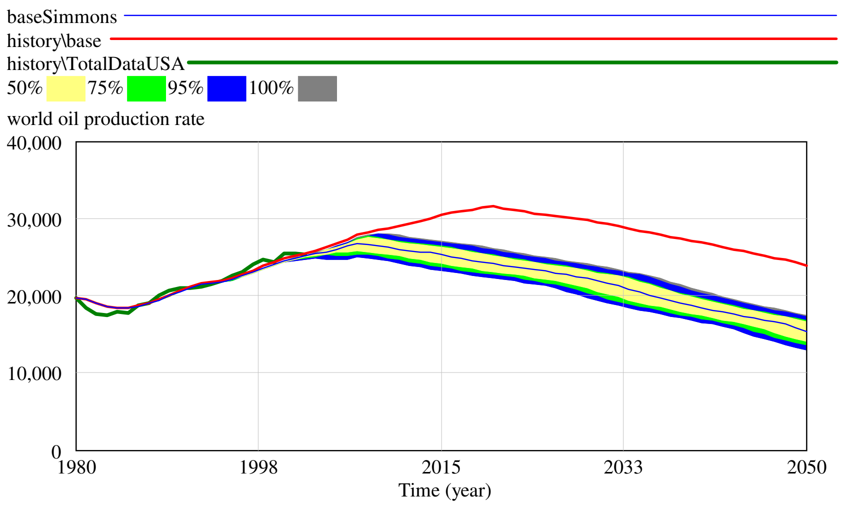


Figure 59: Comparing T21-USA base line scenario, Simmons theory (simulated) and historical data

Matthew Simmons states that up to 80% of Saudi Arabian reserves might have been lost due to overproduction of the fields. He is also forecasting a Saudi Arabian and world peak in the near future[1]. Simmons theory has been tested by introducing in the model a lower amount of reserves available for production in 2005.

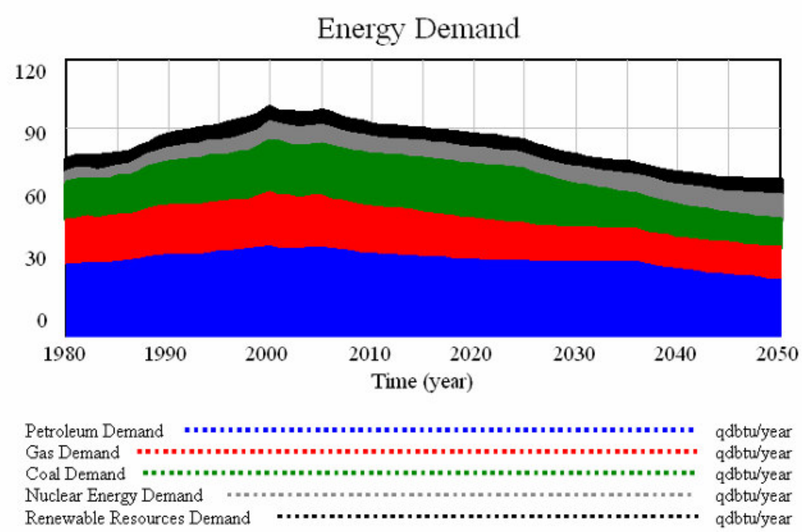


Figure 60: Simulation of Lovins theory with T21-USA

Amory Lovins states: "*The United States can get completely off oil and revitalize it economy led by business for profit, saving and substituting for oil cost less than buying oil. Getting completely off oil makes sense and makes money*."[2] Lovins'

[1] Simmons, M. R., Twilight in the Desert -The Coming Saudi Oil Shock and the World Economy, Wiley & Sons, New Jersey, 2005

[2] Lovins, A. B., et al., Winning the Oil Endgame- Innovation for Profits, Jobs, and Security, Rocky Mountain Institute, Colorado, 2005

theory has been tested by simulating a faster and higher technological improvement for what concerns production (exploration, development and especially recovery) and consumption starting from 2005.

References

- AES Corporation, *An Overview Of The IDEAS MODEL: A Dynamic Long-Term Policy Simulation Model Of U.S. Energy Supply And Demand*, Prepared For The U.S. Department Of Energy Office Of Policy, Planning, And Evaluation, Arlington, VA, October 1993;
- Albert Nyberg, et al., *China Long-Term Food Security*, World Bank Report No. 16469-CHA, July 1997
- Amor Tahari et al, *Sources of growth in Sub-Saharan Africa*, IMF working paper, September 2004
- Backus, G., et al. FOSSIL 79: *Documentation*, Resource Policy Center, Dartmouth College, Hanover NH, 1979;
- Barlas, Y., *Formal aspects of model validity and validation in system dynamics*, System Dynamics Review Vol. 12, 1996;
- Barney, G. O., *Managing a Nation: the Microcomputer Software Catalog*, Institute for 21st Century Studies and Westview Press, 1991;
- Barry Bosworth et al, *Accounting for differences in economic growth*, Conference on "Structural Adjustment Policies in the 1990s: Experience and Prospects" October 5-6, 1995, organized by the Institute of Developing Economies, Tokyo, Japan.
- Barth, Richard, and William, *Hemphill, Financial Programming and Policy*, IMF Institute, 2000.
- Bunn, D. W., E. R. Larsen, eds., *Systems Modelling for Energy Policy*, Wiley, Chichester, 1997;
- Coale, A.J., and Demeny, P., *Regional Model Life Tables and Stable Population*, second edition, New York: Academic Press, 1983.
- Congressional Budget Office (CBO) studies on Social Security: http://www.cbo.gov/ and http://www.cbo.gov/publications/collections/socialsecurity.cfm
- David W. Pearce, *The MIT Dictionary of Modern Economics*, 4th Edition, the MIT Press 1994 (p. 254)
- Davidsen, P. I., J. D. Sterman, G. P. Richardson, *A Petroleum Life Cycle Model for the United States with Endogenous Technology, Exploration, Recovery, and Demand*, System Dynamics Review 6(1), 1990;
- Deffeyes, K. S., *Beyond Oil- The View from Hubbert's Peak*, Hill and Wang, New York, 2005;
- Devarajan, Lewis and Robinson, *From stylized to applied models: Building multi-sector models for policy analysis*, Working paper No. 616, UC Berkeley, September 1991.
- Donald O. Mitchell, and Merlinda D. Ingco, *The World Food Outlook*, The World Bank, November 1993
- Dornbusch, R. and Fischer, S., *Macroeconomics*, 6th edition. McGraw-Hill, Inc. 1994
- Economic Research Service, US Department of Agriculture, *International Agricultural Baseline Projections to 2005*, AER-750, Washington: USDA/ERS.
- Economides, M., R. Oligney, *The Color of Oil- The History, the Money and the Politics of the World's Biggest Business*, Round Oak Publishing Company, Texas, 2000;
- Edmonds, J., J. M. Reilly, *Global Energy- Assessing the Future*, Oxford University Press, Oxford, 1985;
- Energy Information Administration (EIA), *Annual Energy Review 2005*, 2005;
- Energy Information Administration (EIA), Department of Energy, *Annual Energy Outlook 2006*, 2006.
- Energy Information Administration (EIA), Department of Energy, *Assumptions to the Annual Energy Outlook 2005*, 2005;

- Energy Information Administration (EIA), Department of Energy, Integrating Module of the National Energy Modeling System: Model Documentation 2004, 2004;
- Fiddaman, T. S., *Feedback Complexity in Integrated Climate-Economy Models*, Doctoral Thesis, Massachusetts Institute of Technology, Cambridge, MA, 1997;
- Hirsch, R. L., *Six Major Factors in Energy Planning,* Report for SAIC, National Energy Technology Laboratory, 2005;
- Hubbert, M. K., *Exponential Growth as a Transient Phenomenon in Human History*, In Daly, H. E., K. N. Townsend, eds., Valuing the Earth: Economics, Ecology Ethics. MIT Press, Cambridge, MA, 113-126, 1993;
- Hubbert, M. K., *Nuclear Energy and the Fossil Fuels. Drilling and Production Practice,* Washington: American Petroleum Institute, 1956;
- Hughes, B., *International Futures (IFS) Documentation*, Working Draft 1, 1997.
- Hunter Colby, Mark Giordano, and Kim Hjort, *The ERS China CPPA Model: Documentation*, 1997
- IMF: *International Finance Statistics, Government Finance Statistics, Balance of Payments Statistics*, March 2006, on CDROM
- Intergovernmental Panel on Climate Change (IPCC), *IPCC Third Assessment Report: Climate Change 2001*, 2001;
- International Energy Agency (IEA), *World Energy Outlook 2004, Annex C*, WEM (World Energy Model), 2004;
- International Energy Agency (IEA), *World Energy Outlook 2005,*2005;
- International Monetary Fund, *Balance of Payments Manual*, fifth edition, available online at http://www.imf.org/external/np/sta/bop/BOPman.pdf
- International Monetary Fund, *International Finance Statistics, Government Finance Statistics, Balance of Payments Statistics*, 1980 – 2005;
- Laherrère, J., *Modelling Future Oil Production, Population and the Economy*, Aspo Second International Workshop on Oil&Gas, Paris, 2003;
- Lester R. Brown, *Who Will Feed China? Wake up Call for a Small Planet*. New York:W.W. Norton and Co., 1995
- Lovins, A. B., et al., *Winning the Oil Endgame- Innovation for Profits, Jobs, and Security*, Rocky Mountain Institute, Colorado, 2005;
- Mark W. Rosegrant, Mercedita Agcaoili-Sombilla, and Nicostrato D. Perez, *Global Food Projections to 2020: Implications for Investment*. 2020 Vision Discussion Paper No. 5. International Food Policy Research Institute, 1995
- Meadows, D. and et al, *Dynamics of Growth in a Finite World*, Wright-Allen Press 1974.
- Millennium Institute, *Threshold 21 (T21) Overview*, Internal report, 2005;
- Naill, R. F., A., *System Dynamics Model for National Energy Policy Planning*, System Dynamics Review 8(1), 1992;
- Naill, R. F., *Managing the Energy Transition*, Ballinger, Cambridge, MA, 1977;
- Nikos Alexandratos, *World Agriculture: Towards 2010, An FAO Study*, UNFAO and John Wiley & Sons, 1995
- OPEC, World Energy Model (OWEM), *Oil Outlook to 2025*, OPEC Review, September 2004;
- Pedercini, M., *An Assessment of Existing Computer-based Models' Potential Contributions to the Development of a Methodology for Comparing the Development Effectiveness of Large-scale Public Investment Programs in Different Locations or Socio-economic Sectors*, Working paper in System Dynamics, University of Bergen, and Conservation International, 2003;
- Salvador, A., *Energy: A Historical Perspective and 21st Century Forecast*, AAPG Studies in Geology #54, The American Association of Petroleum Geologists, Oklahoma, 2005;

- Sehgal, J., *An Introduction to Techniques of Population and Labor Force Projections*, International Labor Office, Geneva, 1989.
- Shenggen Fan, and Mercedita C. A. Sombilla*, China's Food Supply and Demand in the 21st Century: Baseline Projections and Policy Simulations*, prepared for the post conference workshop of the 1997 American Agricultural Economics Association Annual Meeting on China's Food Economy in the 21st Century, Toronto, Canada, July 31, 1997
- Shorter, F.C., R. Sendek, and Y. Bayoumy, *Computational Methods for Population Projections*, New York: The Population Council, 1995.
- Simmons, M. R., *Twilight in the Desert -The Coming Saudi Oil Shock and the World Economy*, Wiley & Sons, New Jersey, 2005;
- Sterman, J. D., G. P. Richardson, P. I. Davidsen, *Modeling the Estimation of Petroleum Resources in the United States*, Technological Forecasting and Social Change 33, 1988;
- Sterman, John D., *Business Dynamics, system thinking and modeling for a complex world*, Irwin McGraw-Hill, 2000, p. 525.
- Sterman, John D., *The energy transition and the economy: A system dynamics approach*, Ph.D. Thesis, MIT, 1981;
- Stobaugh, R., D. Yergin, eds., *Energy Future- Report of the Energy Project at the Harvard Business School*, Vintage Books Edition, New York, 1983;
- The World Bank, *World Development Indicators 1997*, Washington D.C., 1997
- U.S. Social Security Administration (SSA): http://www.ssa.gov/ and http://www.ssa.gov/OACT/ProgData/funds.html
- UN Population Division, *Sex and Age Annual, 1950-2050* (The 1994 revision) (on disks)
- United Nations, *UN World Population Prospects, The 2004 Revision, Population Database*, 2004;
- US Department of Agriculture, *International Agricultural Baseline Projections to 2005*, AER-750, USDA/ERS
- US Department of Agriculture, *World Agriculture, Trends and Indicators, 1970-91*, USDA, 1993
- US Immigration and Naturalization Service*, 1993 Statistical Yearbook of the Immigration and Naturalization Service*, Washington: US Government Printing Office, 1993.
- Weishuang Qu et al., *A Model for Evaluating the Policy Impact on Poverty, Proceedings of the 19th International Systems Dynamics Conference*, Palermo, Sicily, Italy, August 2002.
- William H. Greene, *Econometric Analysis*, 3rd Edition, Prentice Hall 1993 (p.71)
- Wils, 1996, PDE-Cape Verde: A Systems Study of Population, Development, and Environment, Laxenburg, Austria: IIASA, WP-96-009.
- World Bank*, Model building RMSM-X reference guide*, July 1995.
- World Bank, *World Development Indicators 2000* on CD-ROM.
- World Resources Institute, *World Resources 1998-99: A Guide to the Global Environment*, Oxford: Oxford University Press, 1998.
- Yergin, D., *The Prize- The Epic Quest for Oil, Money & Powe*r, Free Press, New York, 1991.