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An Integrated Global Food and Energy Security System Dynamics model for addressing systemic risk and supporting short term sustainable policy making

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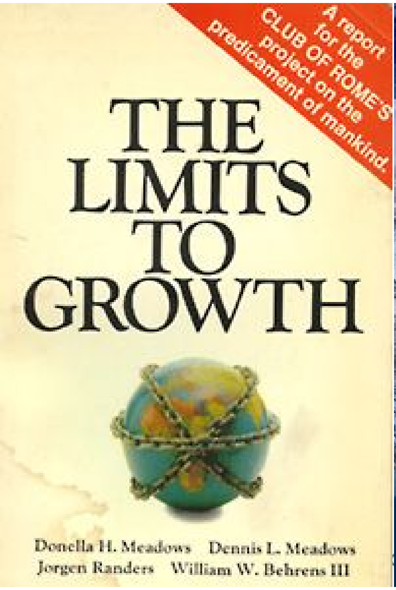
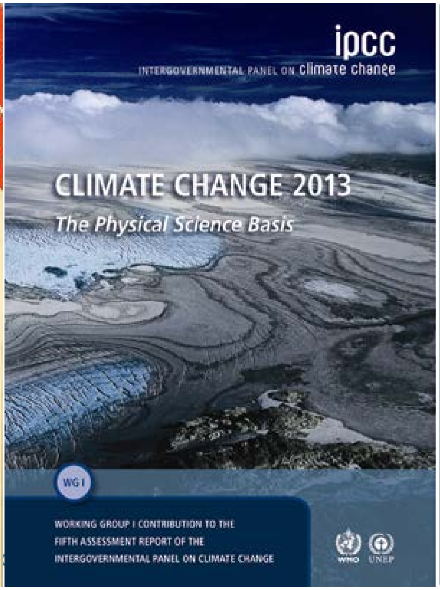
Outline

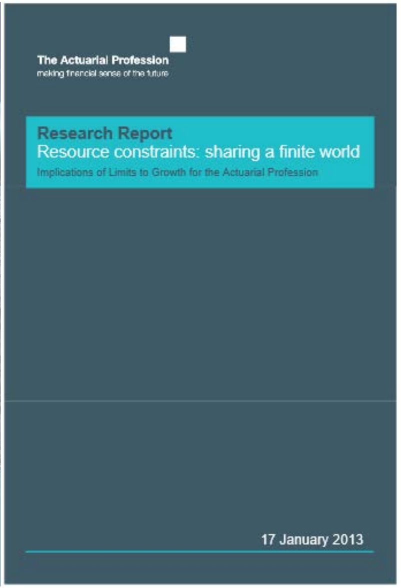
- Limits to growth and surge of resource prices
- Modelling complex systems and System Dynamics as research method
- Global Resource Observatory (GRO) System dynamics model
- Conclusion and next steps

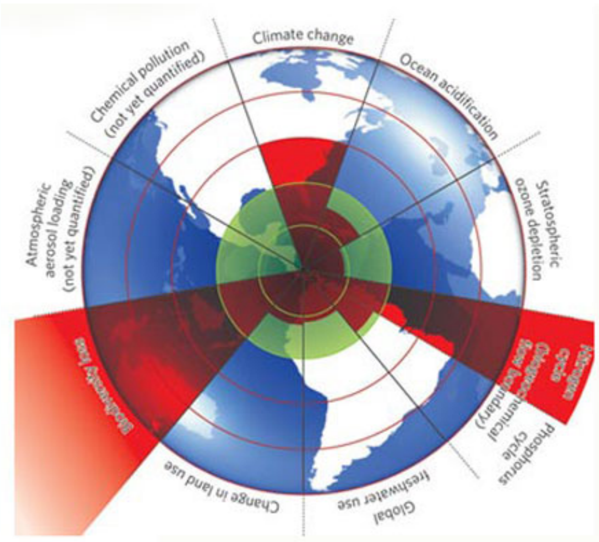
Assuring food security under climate risk: issue at stake

1. We live in a **finite planet** (Rockstrom et al. 2009, Limits to Growth, 1972)
2. **Resources getting scarcer** as environmental depletion, population, urbanization increase (Jones et al., 2013)
3. Implications for food security threaten by climate change risk (IPCC, 2013)

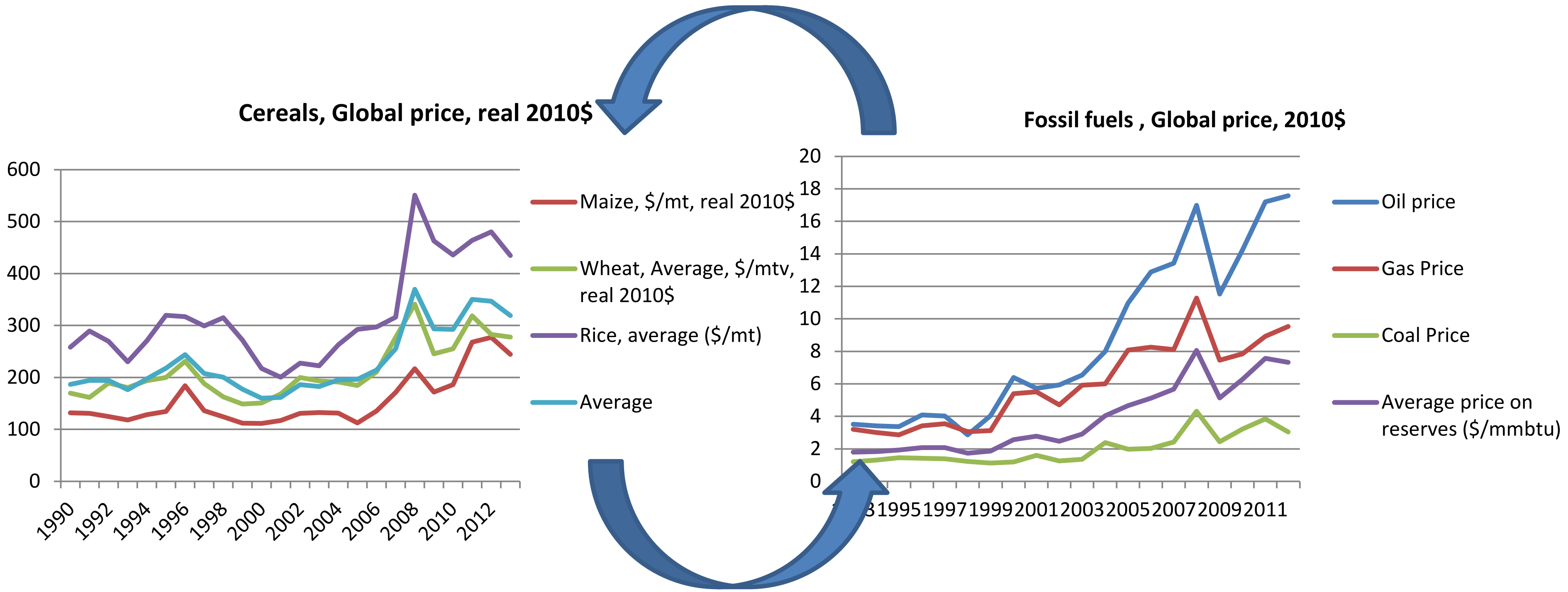








The surge of resource prices



GRO SD is a System dynamics global simulation model which builds around **food-energy price nexus** to study **implications for the global economic-resource-social system**, e.g. **food security**

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Food and energy systems characteristics

- **Must be seen as complex adaptive systems**:
  - Heterogeneous sectors/agents displaying non-linear, non-rational interacting behaviours characterised by feedbacks and time-lags in a **finite** system.
- Affected by multiple sources of **risk** (extreme weather events, commodity price volatility) and **cascade effects on food and energy systems**?
  - **For example: Extreme events** induce land degradation, increasing commodity prices volatility and costs (food, feed, and fuel) → Falling into **poverty**, and inequality rise which increases the risk of **political instability** → Conflicts reduce people's ability to **cope with climate change** by lowering community **resilience** and leading to breakdown of critical services → Increase **risk**: disrupting rural and urban livelihoods … and government budget
- **Decision making under uncertainty regimes** including direction and intensity of causal effects (feedback loops) prevents from **precise forecasts** (increase/decline of agricultural yields, effects on prices of alternative land allocation).

Why System Dynamics

- **Simulation models:** mimic the behaviour of the system they try to reproduce in its functional relationships
- Uses **stocks** (i.e. land, cash, machineries) and **flows** (rate of change in stock: i.e. investments, outlays, land development), and **feedback loops** dynamic interplay, explaining emerging non-linear behavior by multi-level actors (i.e. finance, real , and natural) in complex systems
- Relies on the assumption of **bounded rationality** (Morecroft, 1983)
- Suitable in modelling **Prices**, **Balance sheets** and **Cash flows** (Yamaguchi, 2013, Sterman, 1982)
- Model **non-linear/discrete events** and suitable for ***what-if* scenario analysis** (i.e. shock in prices, or policy change) exogenously or as consequences of feedbacks

Fig. 1 Stock-flow relation

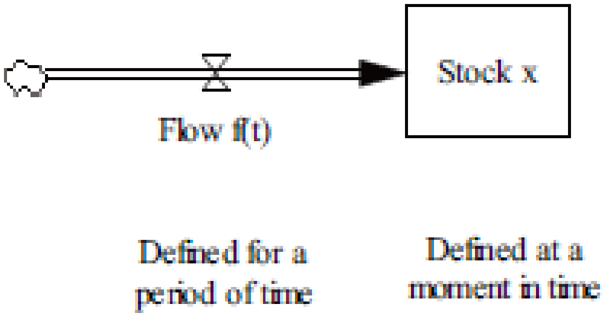
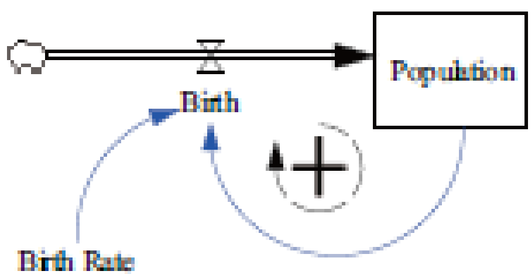


Fig.2 Reinforcing loop



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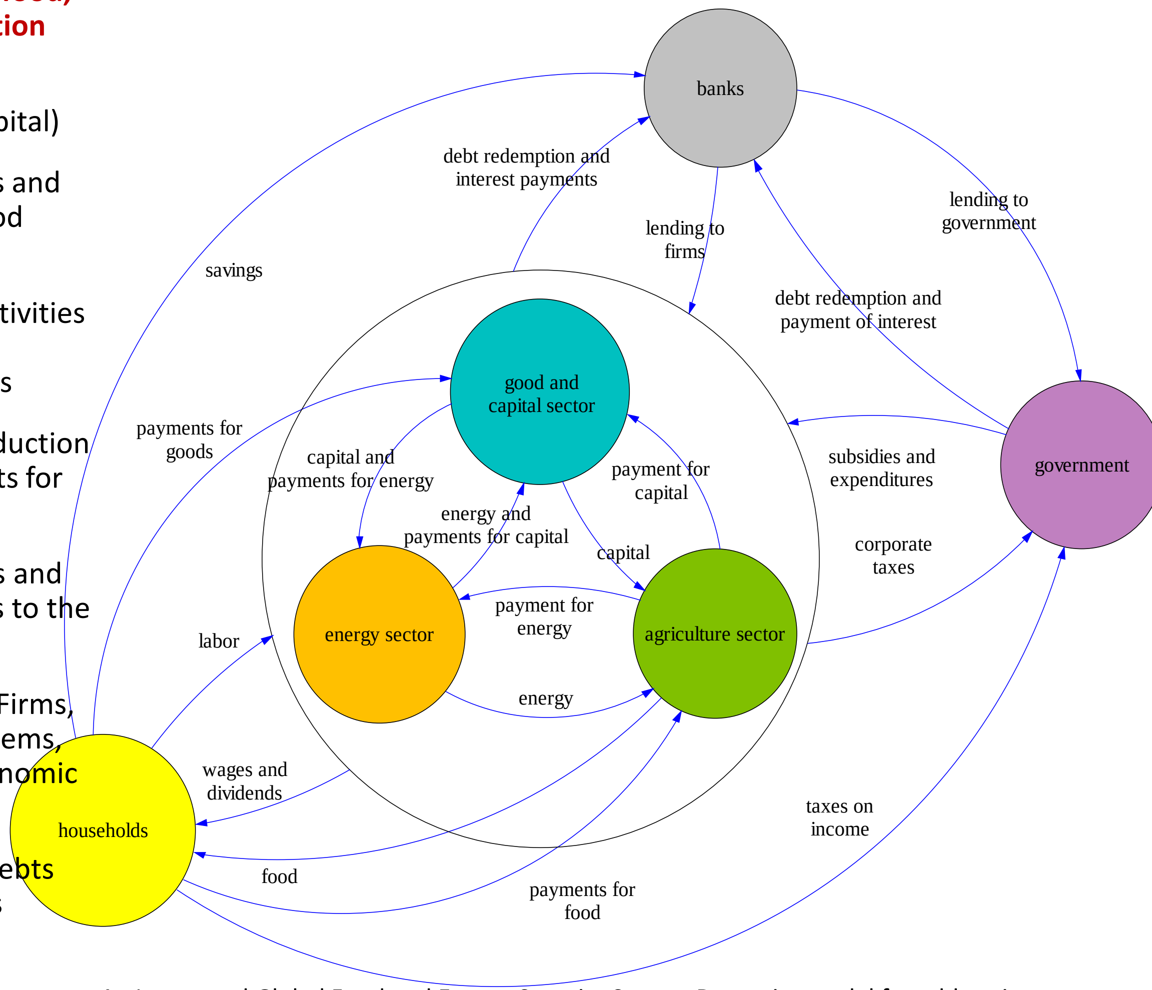
GRO SD model framework

Global system based on consumption and production of food, energy, goods, and real capital, and governed by population growth and Debt Money

1. **3 productive sectors** (Food, Energy, Goods and Capital)
   - the agriculture sector organizes investments and productive decisions to meet demand of food which is driven by population dynamics
   - the energy system organizes investments activities to meet the energy demand endogenously generated by the all three productive sectors
   - the good and capital sector assures the production in order to meet the demand for investments for the other three sectors
2. **Households** provide labour to firms, receive wages and dividends, consume goods and food, and pay taxes to the government
3. **Government** receives taxes from Households and Firms, distributes subsidies to energy and agriculture systems, and generates expenditures to sustain desired economic growth
4. **Banks** lend money to economic actors collecting debts and interests on debt, receives deposits and issues money when necessary



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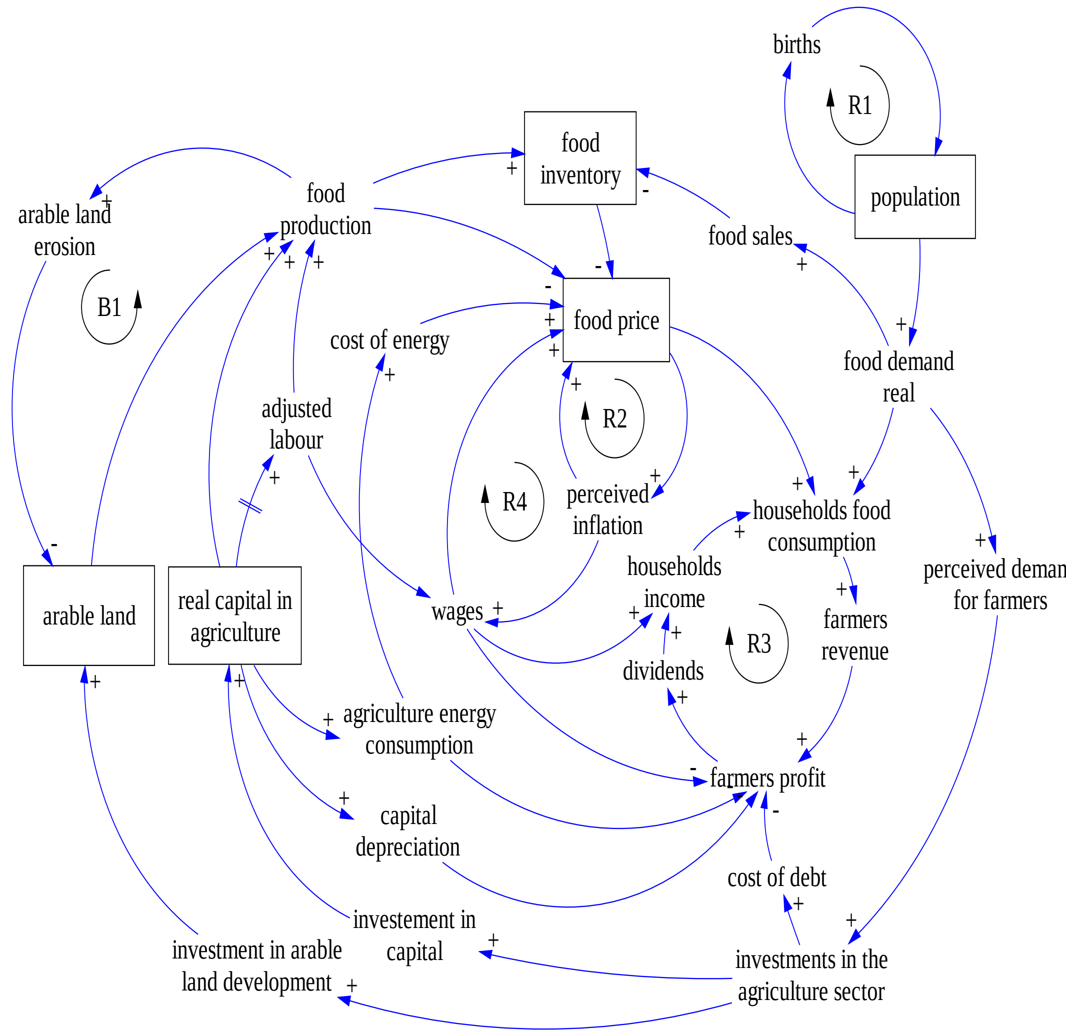
Agriculture Causal loop diagram

1. Agriculture meets population food demand (R1)
2. Households pay agriculture in relation to consumed food, allocating income share
3. Real food is transformed in financial flow trough food prices (i.e. prices **don't adjust to meet any form of equilibrium) (R2, R4)**
4. Capital and Land (productive capacity) adjusts based on investment decisions based on **Long Term** expected demand
5. Production level adjust in the **short term** to meet real demand and desires of inventory level
6. Investments: outflows from farmers' cash, become inflows in Goods sector cash, translated into financial flows through Price of Output of Goods and Capital. c



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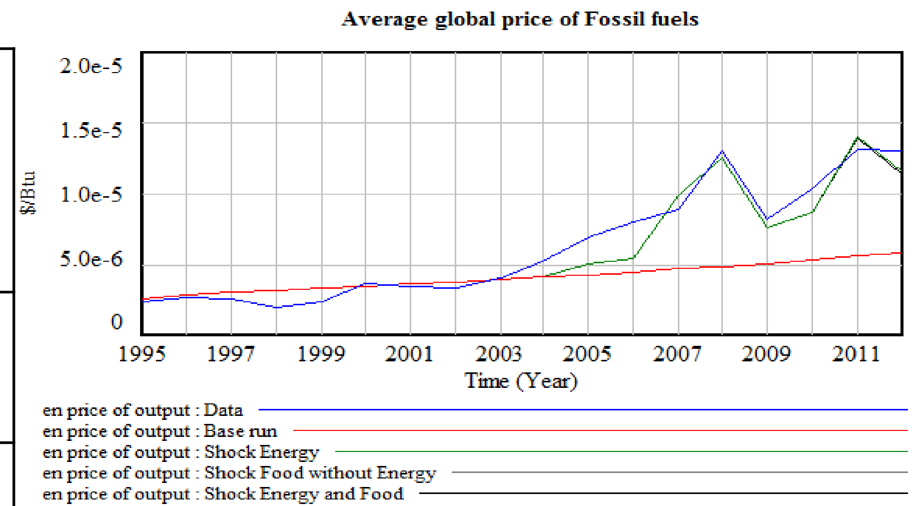
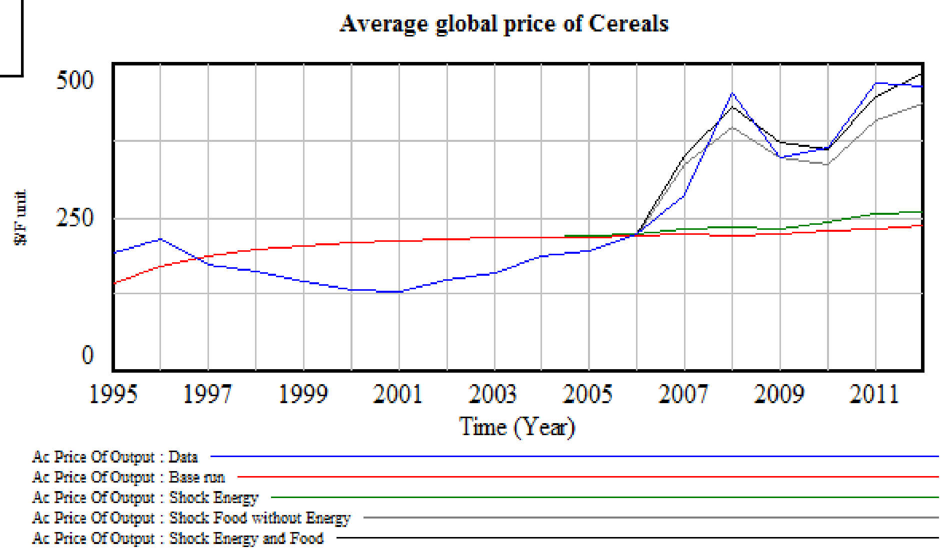
Shocking the system- An example

	Supply shock Intensity [% (year)]	Price shock Intensity [% (year)]	Subsidies Policy Intensity [% (starting year)
Energy	17%(2009)	97% (2006)	90% (2004)
Food	20% (2006)	38% (2010)	60% (2006)





Price of energy and food commodities have been initialized as nominal value of:

- **Average global price of coal, gas and oil (WB GEM Commodities, 2015)** measured in **USD/Btu**
- **Average global food price of cereals (FAOSTAT, 2015)** measured in **USD/Tonne**.

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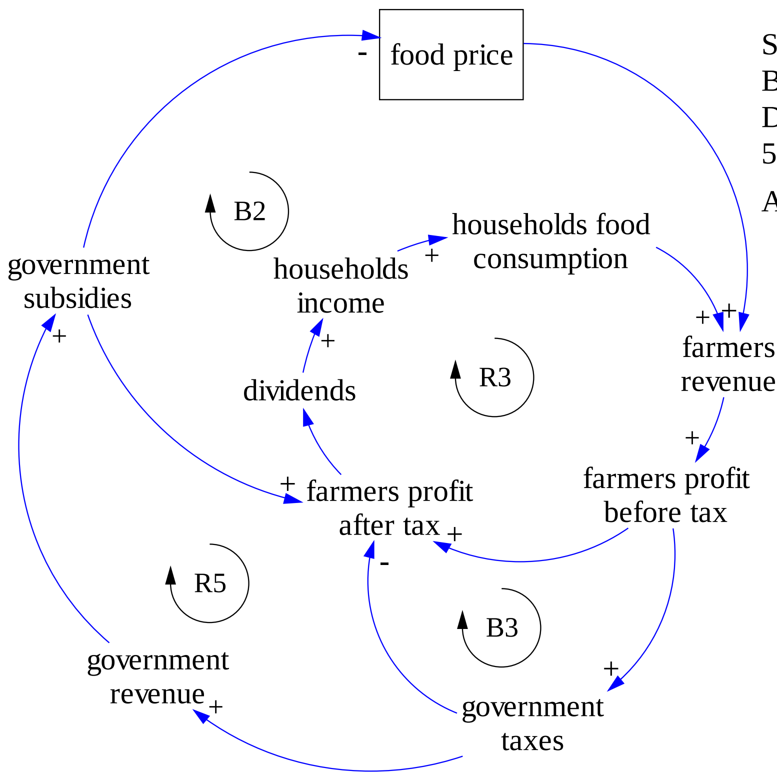
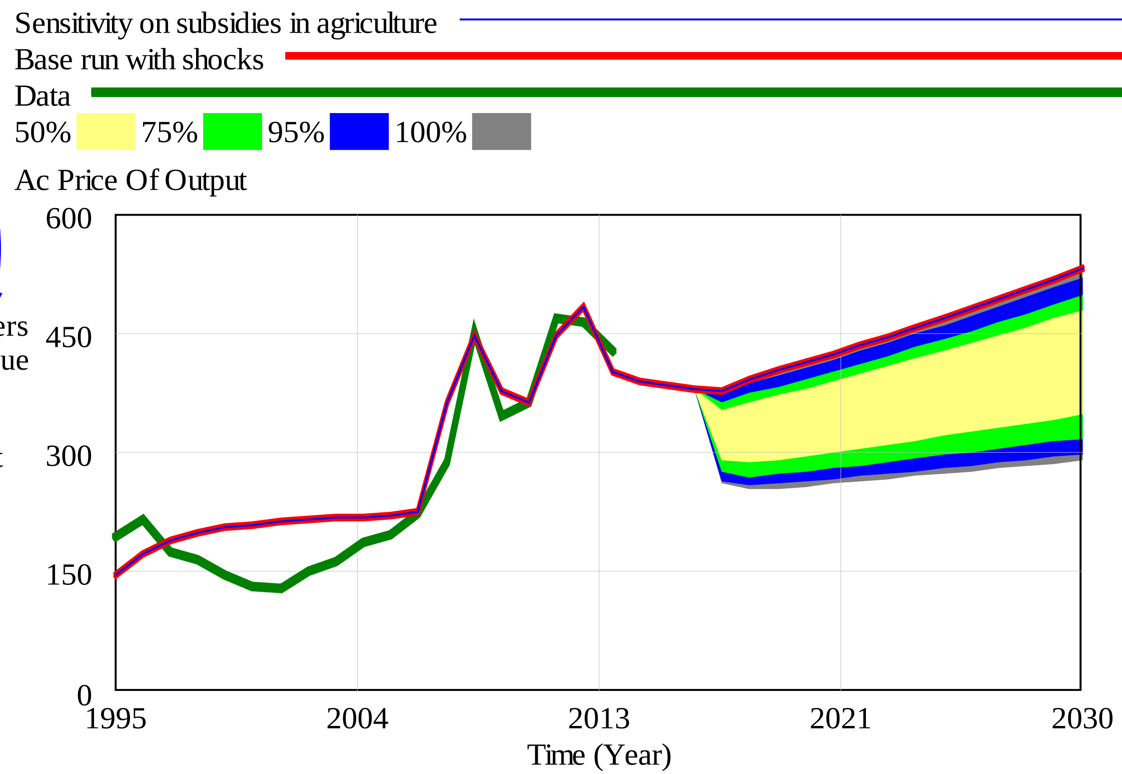
What if we increase subsidies in agriculture in 2016?





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Conclusion

- GRO SD aims at contributing to the development of alternative story telling scenarios to simulate the impact of climate risk and change in green policies towards low carbon development paths in the short term.
- **Preliminary version** but already able to show:
  - the dynamic effects of shocks in the energy and agricultural sectors on the whole system (but not designed endogenously generate shock dynamics)
  - Out of equilibrium behaviour of productive systems (prices endogenously generated for every resource, acting as a unit of conversion between monetary/real flows)
  - Real demand supply data matching with FAO, IEA, WB data
  - Role of inventory and capital investment to adapt/meet demand
  - Role of government in providing subsidies and collecting taxes
  - Role of debt and interest rate on lending/borrowing and to reflect accumulation of risk

Next Steps

- a complete analysis of real past shocks to understand how they affect the system over time, and how such dynamics can be replicated in the future
- test hypotheses on possible direct effects of shock prices on other key variables in the system (i.e. households consumption, investment increase, effect on interest rates)

Thank you for the attention!

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