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GAMS Models in Agricultural Economics

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- CAPRI as an example: what, why and how
- Why GAMS: features, costs, user community
- Limitations of GAMS
- CAPRI GUI: wrapping GAMS
- Summary

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Simulations models in agricultural economics

- Long tradition:
  - 1950ties: LP based farm level optimization, today mostly MIP, fully dynamic, stochastic
  - 1970ties: application to „typical“ or „regional“ farm for policy analysis
  - Branch dried out for a while due to typical problems of LPs (jumpy behaviour, over-specialization) and hunger for data not available from statistics

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Simulations models in agricultural economics

- 1980ties, price endogenous market models:
  - Multi-Commodity models:
    - Global simultaneous equilibrium for many agricultural products and many countries/country blocks
    - Prices, supply, demand and trade endogenous
    - Non-linear CNS or NCP
  - Computable General Equilibrium Models:
    - Simulatenous equilibrium for all markets in an economy (input, outputs, primary factors)
    - Non-linear CNS or MCP

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Simulations models in agricultural economics

- Today:
  - Revival of programming models
    - introduction of (econometrically estimated) non-linearities eases calibration and avoids over-specialization
    - increasing focus on agri-environmental interactions (bio-economic modelling)
  - All model types grow in resolution (products, space, agents) and complexity (policy instrument covered, functional forms, stochastics ..)
  - Combination of different type of models into tools for impact assessment

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CAPRI

- **C**ommon **A**gricultural **P**olicy **R**egionalized **I**mpact:
  - Tool for impact assessment of policies related to the agricultural sector
  - Clients: mainly EU commission, but also national government and industry
  - Combines economic models, matching data bases, IT infrastructure and institutional setting
  - Financed mainly by EU research framework programs and tenders

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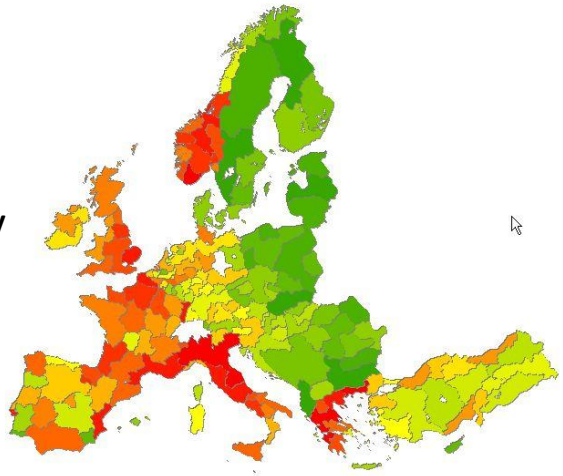
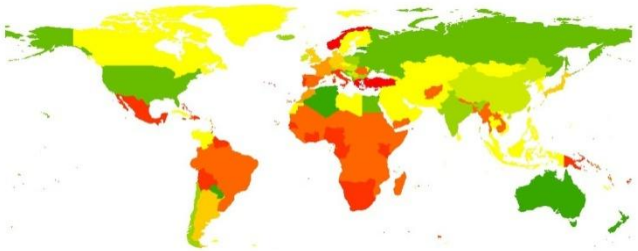
CAPRI as an example

- Two modules, links by sequential calibration
  - About 2000 farm type models with
    (each ~300 vars x ~200 equations, NLPs, independently solved as grid)





  - Global, spatial trade model for agricultural products
    (CNS, in parts highly non linear, 40.000x40.000)
  - One run solves each module ~20 times, ~20-30 minutes, generates ~15 Mio non zeros, in parts post-model calculated economic and environmental indicators

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CAPRI as an example

- Simulates impacts of policy instruments such as tariffs, subsidies, agri-environmental programs
- On various indicators such as
  - Crop areas, yields, herd sizes, production, feed use
  - Human consumption, industrial procesing, trade flows
  - Farm income, EU budget costs, consumer welfare
  - GHG emissions, nutrient balances
- Developped end of the nineties, since then continously expanded, improved and applied
- Open source concept, network based

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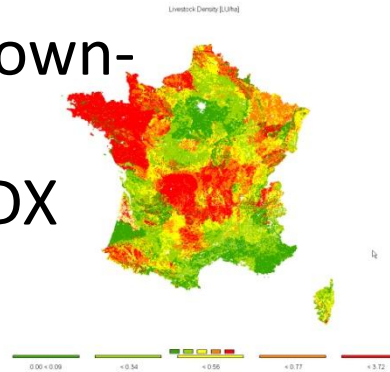
CAPRI in GAMS

- Complete work flow in GAMS
  - Data base generation and model parameterization:
    - Mapping/aggregation/dis-aggregation of raw official data
    - Outlier detection and correction
    - Bayesian estimators to consilidate raw statistical data
    - Estimators for behavioural parameters
  - Generation of „market outlook“ (currently 2020)
  - Model calibration to outlook results
  - Simulation runs
  - Post model processing, including statistical down-scaling to about 200.000 1x1 km clusters
  - Results are passed between worksteps via GDX



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Why GAMS?

- Developped originally from economists for economists:
  - Notation comes close to scientific papers
  - Relatively easy to learn
  - Compact notation for element wise operations, avoids explicit loop and if statements
  - Transparent interface to high performance solvers for different problem types: LP, NLP, MIP, CNS, MCP etc.

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Why GAMS?

- Basic IDE, sufficient for medium sized projects
- Proprietary binary data format (GDX):
  - Fast, safes disk space, tailored for large sparse matrices, link e.g. to EXCEL
  - API support for high-level programming languages, provides bridge to DBMS or tailored GUIs
- Continous development e.g. support for new solvers

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Why GAMS?

- Relatively restricted language features
  - no functions/sub-routines
  - limited number of object classes (set, parameter, equation, variable, model, file ..)
  - all numbers are double precisions (not distinctions between int, long, float, double etc.)
  - no explicit string handling
  - every symbol has global scope

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Why GAMS?

- Consequences of restricted language features:
  - no formal education in IT required – fits typical profile of (agr) economists
  - debugging is typical easy
  - low learning costs
  - dis-advantages for experienced programmers and large-scale projects

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Why GAMS?

- Trial version (often sufficient for didactic purposes) can be downloaded for free
- Relatively modest license fees for degree granting institutions
- Good manuals, active e-mail list
- Long list of example models
- Portable between platforms, can be used without GUI/IDE

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Why GAMS?

- Features explain wide spread use in community as a kind of „lingua franca“:
  - Thaught in courses at master level based on „toy models“, e.g. already in Germany by various ag-econ departments
  - Allows researchers to switch relatively easy between tools and institutions
  - Eases tool linkage

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Why GAMS?

- Many other examples of policy relevant ag-econ models realized in GAMS, e.g.
  - Uni Hohenheim: ESIM
  - Univ. Wageningen, NL: farm type models
  - Texas A&M: FASOM
  - Penn state: PEATSIM
  - Purdue: GTAP in GAMS
  - …

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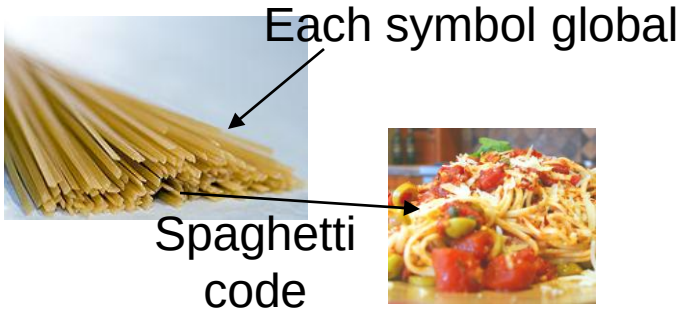
Limitations

- Modular design and exchange of code between projects not easy:
  - Global scope of all symbols, only rudimentary support for functions/subroutines
    - ⇔ namespace conflicts
    - ⇔ no encapsulation
    - ⇔ documentation is tedious



  - IDE not ideal for large-scale projects compared e.g. with Eclipse

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Limitations

- So far no parallel execution in the base module and in some widely solvers such as CONOPT:
  - Multiple cores not used
  - Pre- and post model processing increasinlgy CPU bottleneck
- Parallel model solves supported, but I/O intensive
  - Little gain for a suite of small model intances
  - „hot“ updates in solvers in early stages, applicability not yet clear

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CAPRI GUI

- GAMS alone not appropriate to host complex tools, CAPRI e.g. should allow
  - users to easily define, start and exploit own scenarios (if possible without touching GAMS directly)
  - administrators to steer supporting work steps (such as data base and outlook generation, calibration), best without coding
  - efficiently analysis of huge data sets

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CAPRI GUI

- CAPRI responded by developing its own GUI
  - Realized in Java
  - Steers GAMS work steps by generating „code snippets“ and spawning GAMS
  - comprises powerful exploitation tools (reports as tables, graphs, maps) to analyze results
  - access to GAMS generated data via API bridge to GDX

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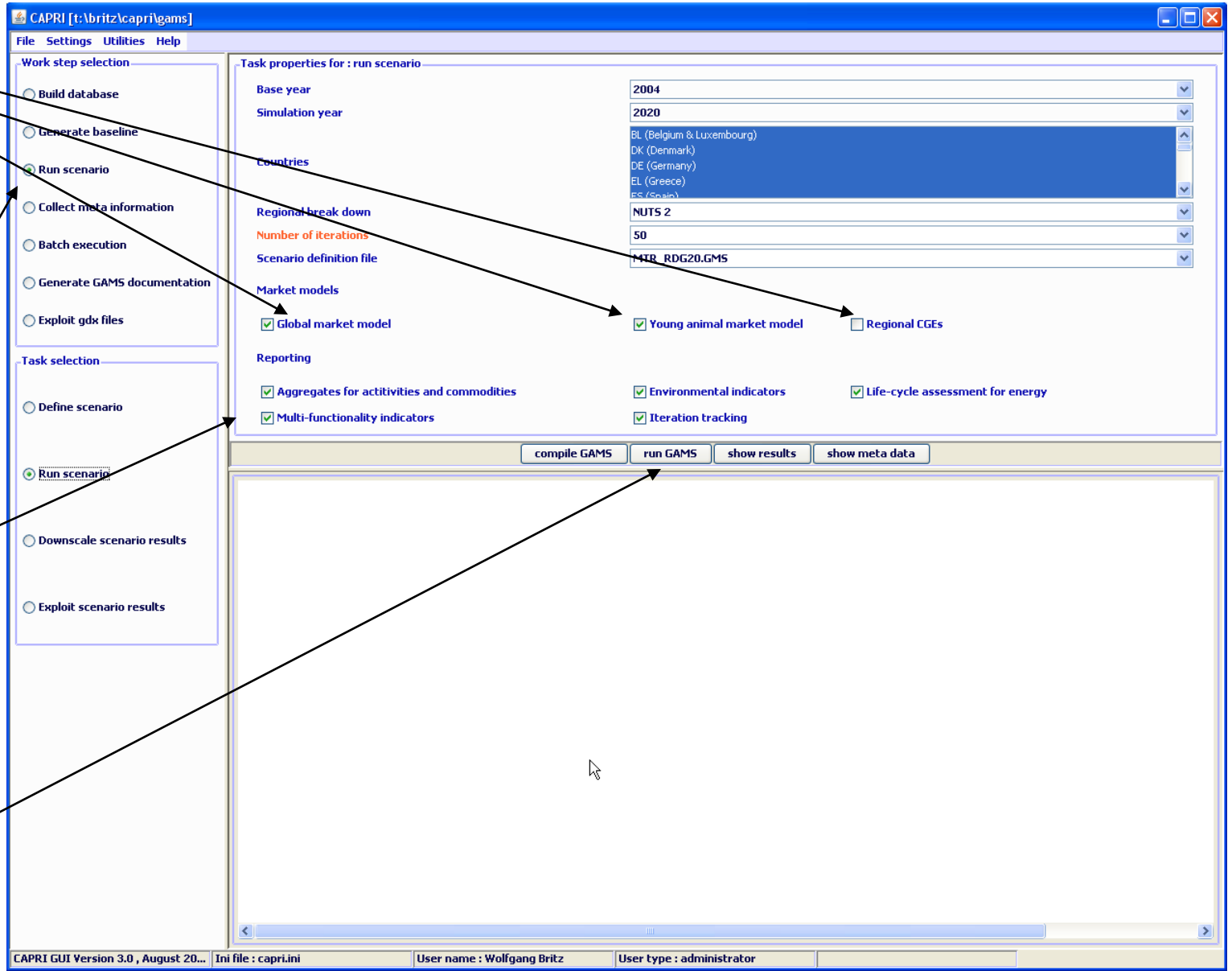
CAPRI GUI

Switch modules on/off

What to do (step & task)

Post-model reporting options

Start GAMS



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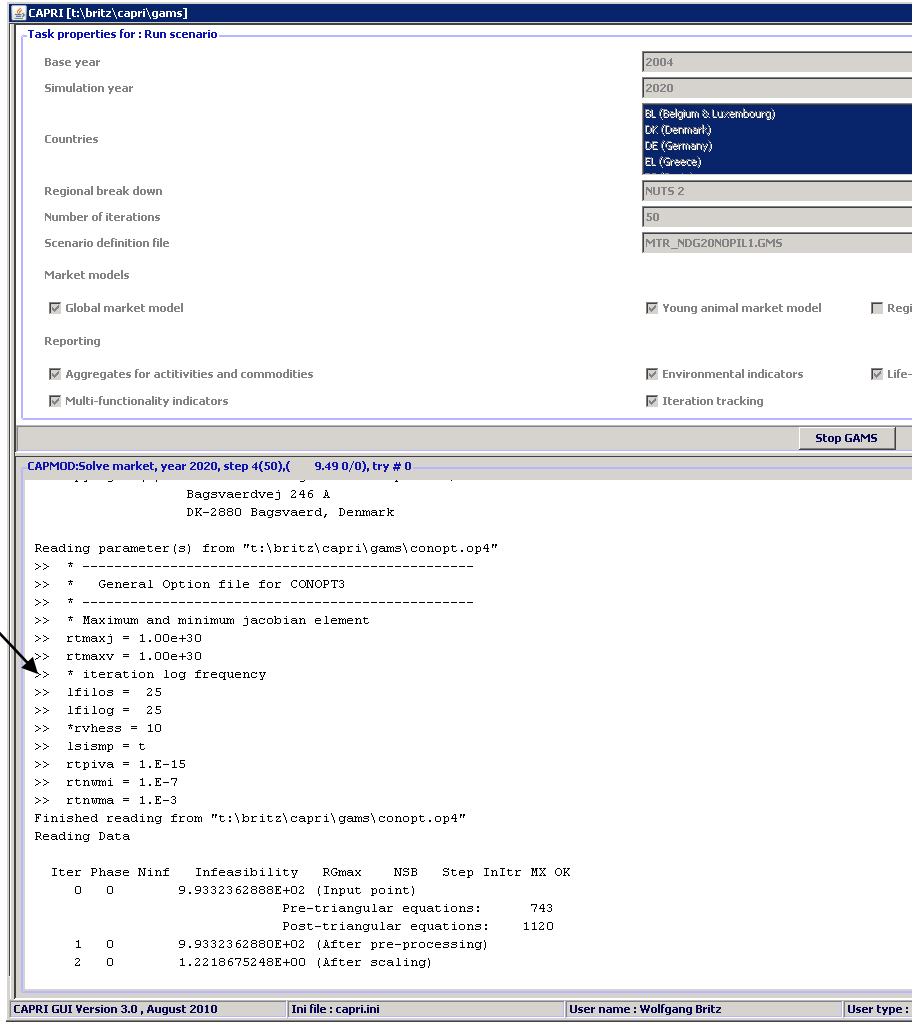
CAPRI GUI

Work step is running …
(GUI has spawned GAMS)

GAMS
output redirected to GUI



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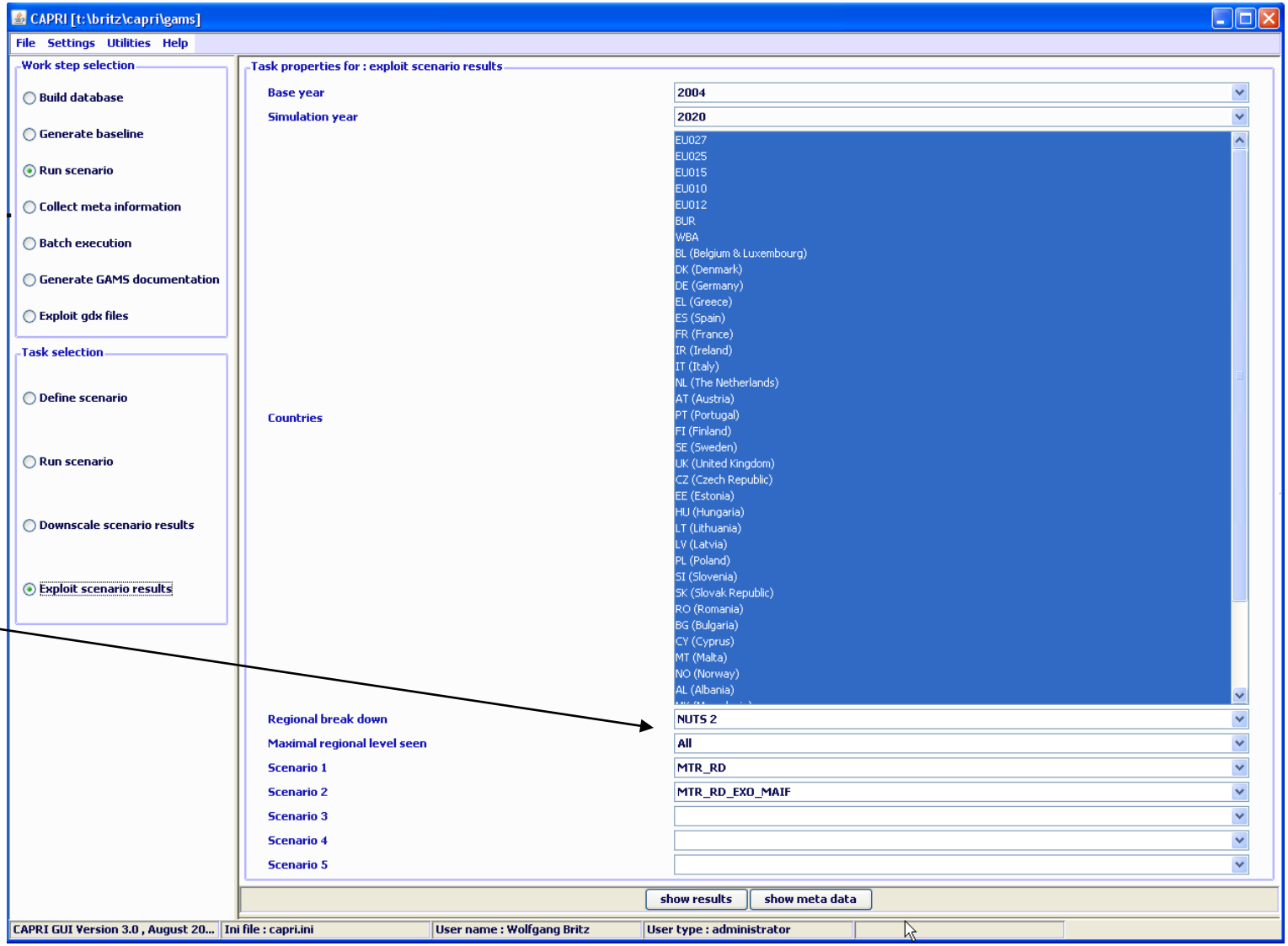
CAPRI GUI

After the run:
Exploit results …

Chose several scenarios



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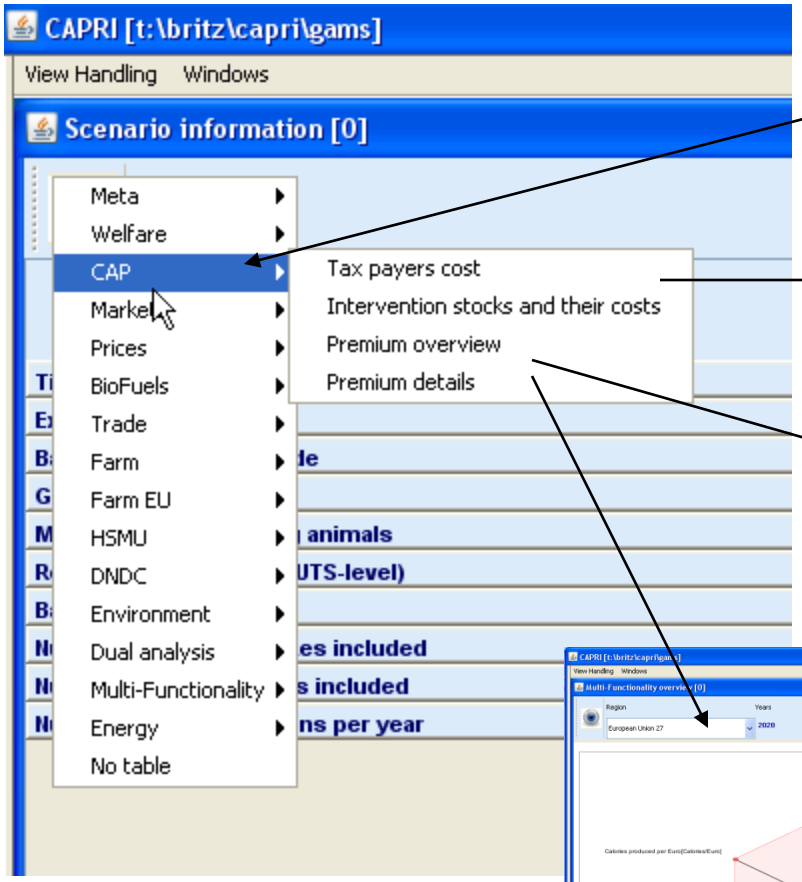
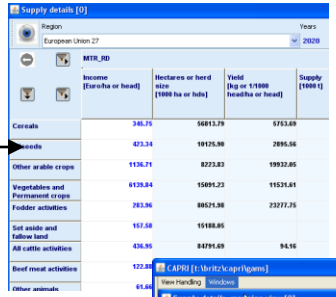
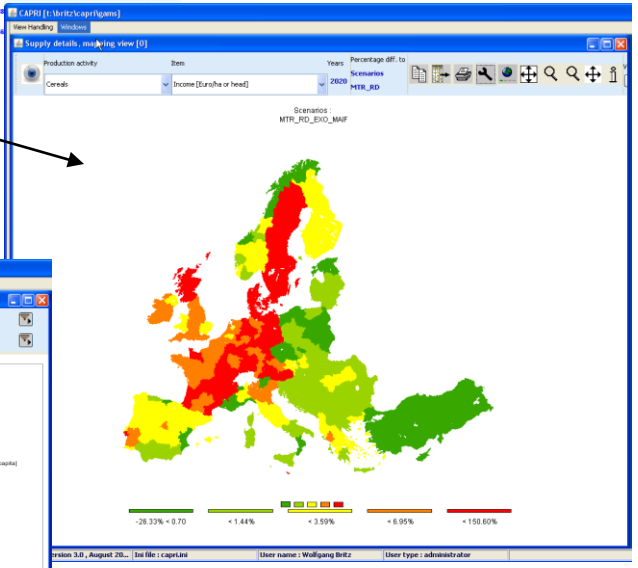
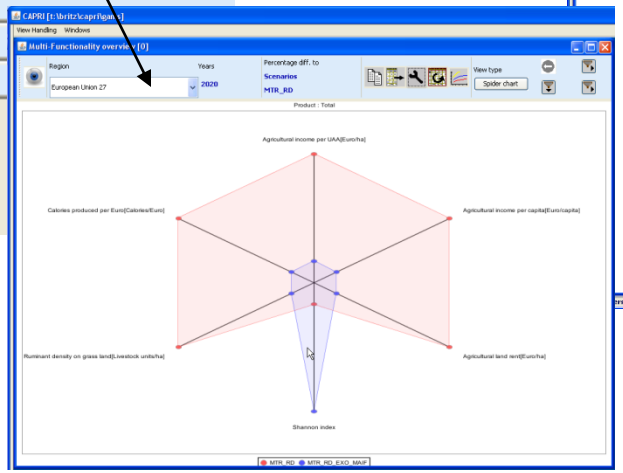
CAPRI GUI

Pre-defined reports
(tables, graphs, maps)









Allows for pivot, selections, comparisons etc. …

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CAPRI in GAMS

- Further GAMS related GUI features:
  - Generation of HTML based documentation of GAMS files à la Javadoc
  - Batch processing mode (check of all work steps after code changes, running packages of scenarios)
  - Meta data generation/handling (are stored along with numerical results in GDX files)

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Summary

- GAMS has currently high market share for agricultural economic simulation models
- Probable reasons
  - Ease of use and convincing basic concept
  - Transparent link to solvers
  - Relatively low cost
  - Existing market penetration
- Larger projects wrap GAMS in applications

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Outlook

- Future market share of GAMS might depend on:
  - Further performance gains (parallel execution, „hot“ solver updates, ...)
  - Combining the appealing simple concept with more advanced features such as scoping, object oriented design, functions/subroutines ... but how?
  - Adding functionalities such as automated generation of project code documentation or link to SVN
  - Development of alternatives such as libraries in Object Oriented Languages (Java, C#) , already now applied for some newer methodologies such as Agent Based Modelling

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Thanks for your attention

more on CAPRI
www.capri-model.org

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