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Introducing foresight to the stadard GTAP model: modeling capital allocation and stockholding under expected policy change

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Introduction

- Dynamic CGE modeling is useful but it is not easy to make such models realistic
- **Problem 1:** Proper linkages between past and the future
  - How much foresight do market players have?
- **Problem 2:** Calibrating models to actual time periods (e.g. years)
  - What is the appropriate closure?
  - How much transformation and substitution may happen in a single year?
- **Goal of this work** Create a dynamic GTAP model with foresight with minimal modifications of the standard model

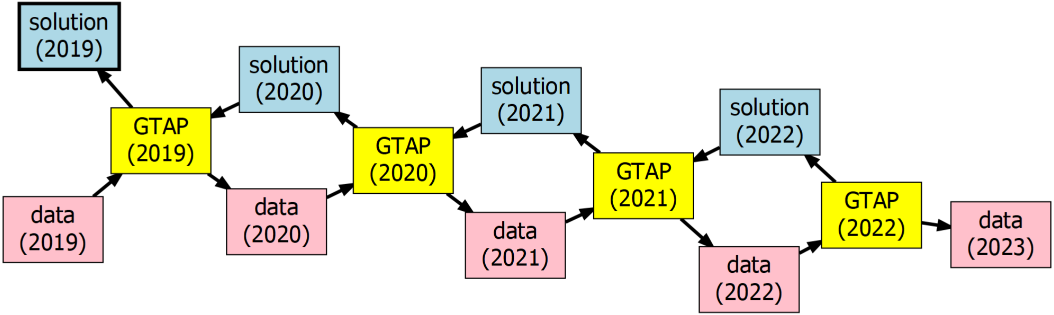
Importance of including foresight in CGE dynamic models

- Market players possess some degree of foresight in the real life
  - Many shocks to the economy are known in advance (e.g., policies are often negotiated for years and implemented at a future date; climate change is predicted for decades)
  - Market players have tools to predict the impact of the future shocks on the markets
- Foresight means that future shocks may induce behavior before the shocks happen
  - For example, importers may increase their stocks before an increase in a tariff
- Modeling foresight is hard and not included in GTAP-RD
  - Many expectations can probably be based on historical trends
  - Future paths may be reasonably predicted
- Excluding foresight from a dynamic model makes it less useful to describe market adjustments induced by policy change

What is needed to turn a static CGE model in a dynamic one with foresight?

- Identify linkages between periods, e.g.:
  - Expected returns on capital may drive investment
  - Expected prices may drive changes in stocks
- Make expected variables exogenous
  - Expected variables become exogenous and supplied by the next period's simulation
- Solve a combined system subject to additional constraints
  - Future values must be consistent with expectation
  - The results of the model solved in period t has to be consistent with the results of the model in $t+1$, $t+2$, $\ldots$
- If foresight is limited (e.g., five years), the system may be solved relatively easily
  - Avoid infinite horizon problem

Illustration of solving a model with four-year foreisght



- Solution in 2019 needs to be solved jointly with solutions for 2020, 2021, 2022

Modifications of variables in the static model

- Variables representing expectations are replaced with exogenous values: e.g.,
  - `pm` $\rightarrow$ `pm_future` where agents decide based on expected values
  - `rorc` $\rightarrow$ `rorc_future` where investment is allocated
- The linkages between future and expectation is established outside the model
- To make the model tractable, we introduce myopia (i.e., agents cannot see beyond a horizon)

$$\forall_{n \in 1,2,\ldots f} \text{future\_variable}_t = \delta_n \text{present\_variable}_{t+1}$$

- the weight δ can take many values: >1 for overreaction, 1 for perfect foresight, 0 for no foresight
- for finite f the system may be solved (models not connected beyond foresight)

How do we solve this thing?

- If we have n future variables and m future periods, we need to solve $m \times n$ equations
  - We need to solve all future variables to be consistent with present values
- We can solve the system in R
  - We can keep the model in the preferred software (GEMPACK, GAMS, R)
  - For GEMPACK, we take advantage of packages allowing the integration of GEMPACK (R package `HARr`)
- In R, we create function `GTAP(data, parameters, exogenous variables)` which returns endogenous values and solve a system of equations (trivially)
  - GEMPACK does not return derivatives→we need to create Jacobian (costly)
  - **However** GTAP is well behaved—the Jacobian may be recycled
  - Solutions times are very good–typically you solve the system in three iterations

Two examples to showcase the system

- In both cases we use the standard GTAP v 6.2 model
  - We only make limited modifications to introduce the dynamic behavior (e.g., replace enogenous variables with future variables)
- **Example 1:** Capital accumulation
  - Investment is distributed based on expected returns
  - No other changes to the model
- **Example 2:** Stockholding
  - Stocks are built and dissolved based on the expected price
  - We added stock demand equations and modified income equations to account for the stocks

Capital accumulation

- Very gentle changes to the model: only replace `rorc` with `rorc_future` in the expectation equation

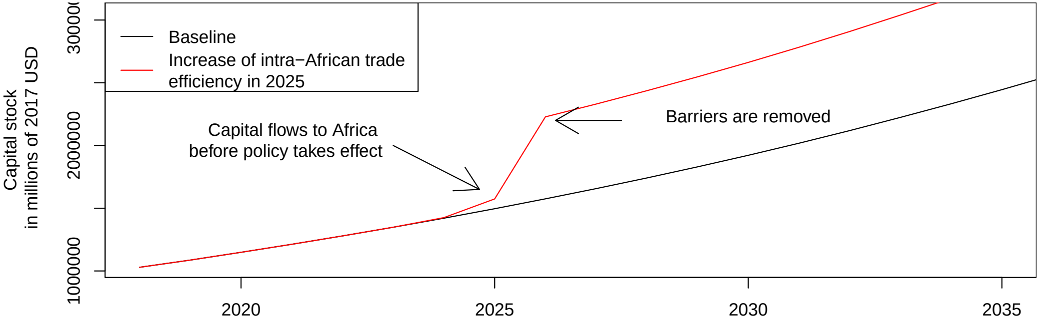
```
variable (all,r,REG) rorc_future(r);

Equation ROREXPECTED

# expected rate of return depends on the current return and investment (HT 58) #

(all,r,REG)

rore(r) = rorc_future(r) - RORFLEX(r) * [ke(r) - kb(r)];
```

- Make `rorc_future(r)` exogenous in the `cmf` file

Capital accumultion scenario

- Dynamic baseline
  - CEPII projected growth from 2018 through 2035
  - Achieve projected GDP and population growth by adjusting productivity
  - Five-year foresight that gets progressively worse ($\delta_1 = 1$, $\delta_1 = .8, \dots$)
- Scenario as a shock to the dynamic system
  - Removal of non-tariff barriers in intra-African trade in 2025
  - increasing trade productivity by 100 percent (ams)
- A small aggregation for illustration only
  - eight regions (continents)
  - eight commodities

Capital accumulation results–capital stock in Africa



- Increased investment in Africa **before** trade is made more efficient

Stockholding

- We incorporate typical stockholding behavior in the standard GTAP model in the dynamic framework
  - Accumulate stocks if future price higher
  - Dissolve stocks if future price lower
- Additionally we assume that there is a target level of stocks
  - We find that we can often reject null hypothesis that stocks are random walk $\rightarrow$ mean reversion

Changes to the GTAP model are minimal—set up new coefficient and variable

```
coefficient (all,i,TRAD_COMM)(all,r,REG)
    STOCKS(i,r);
Read
    STOCKS from file GTAPDATA header "STCK";
update (all,i,TRAD_COMM)(all,r,REG)
    STOCKS(i,r) = qstock(i,r) * pm(i,r);
```

- We obtain stock levels from FAO data

We correct market clearing equations to account for changes in stocks

- When stocks are dissolved or built, they affect availability in the market
  - We modify market clearing equations to account for this
  - We modify both margin and non-margin commodities

```
Equation MKTCLTRD_MARG # eq'n assures market clearing for margins commodities (HT 1) #
(all,i,MARG_COMM)(all,r,REG) [VOM(i,r)+ STOCKS(i,r)  ] * qo(i,r) = STOCKS(i,r) * qstock(i,r)  +
VDM(i,r) * qds(i,r) + VST(i,r) * qst(i,r) + sum(s,REG, VXMD(i,r,s) * qxs(i,r,s)) +
tradslack(i,r);

Equation MKTCLTRD_NMRG # eq'n assures market clearing for the non-margins  commodities (HT 1)

# (all,i,NMRG_COMM)(all,r,REG) [VOM(i,r)+ STOCKS(i,r)  ] * qo(i,r) = STOCKS(i,r) * qstock(i,r)

+ VDM(i,r) * qds(i,r) + sum(s,REG, VXMD(i,r,s) * qxs(i,r,s)) + tradslack(i,r);
```


We correct the income equation to account for changes in stocks

- We make sure that changes in stocks are accounted in the current income
  - Building stocks removes available income in the current period

```
Equation REGIONALINCOME

# regional income = sum of primary factor income and indirect tax receipts #

(all,r,REG) INCOME(r) * y(r) = - sum(i,TRAD_COMM, STOCKS(i,r) * (qstock(i,r)))

        + FY(r) * fincome(r)
        + 100.0 * INCOME(r) * del_indtaxr(r)
        + INDTAX(r) * y(r)
        + INCOME(r) * incomeslack(r);
```

Finally, we introduce the equation of motion

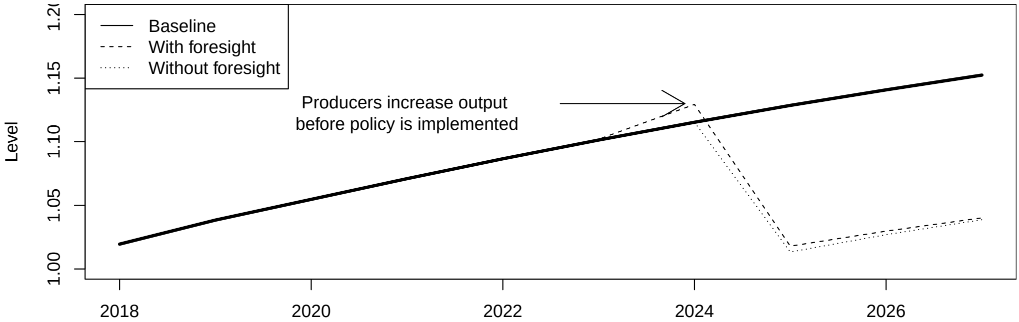
- Make stock change a function of difference between current and future prices
  - Elasticity (STOCKELAS) borrowed from literature (Hertel et al, 2005)
- Add the desire of the policymakers to reach target stocks
  - Elasticity (TARGETSTOCKE) not estimated
  - Need for a `unity` shock to make such behavior operational in GEMPACK

```
equation eq_stocks (all,i,TRAD_COMM)(all,r,REG)
    qstock(i,r) = STOCKELAS(i) * (future_pm(i,r)-pm(i,r))
                - (STOCKS(i,r)/[
                    VDPM(i,r)
                    +VDGM(i,r)
                    +sum(j,PROD_COMM,VDFM(i,j,r))] - TARGETSTOCKS(i,r))
                      * TARGETSTOCKE(i) * unity + qstock_slack(i,r);
```

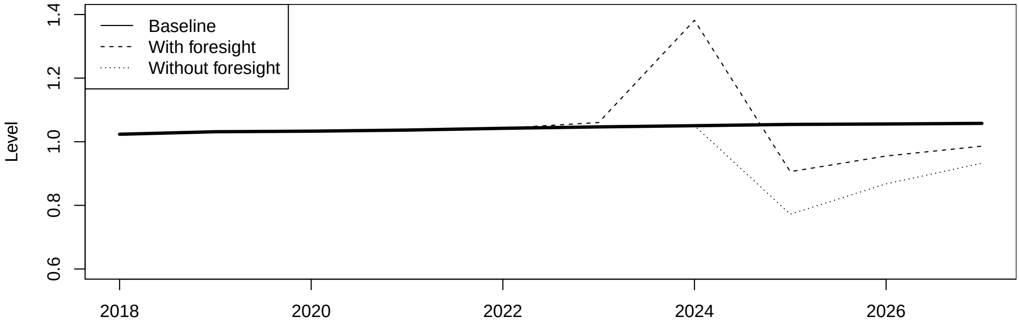

Scenario

- Baseline (same as before based on CEPII data)
- Scenario 1:
  - The EU reduces available agricultural land in 2025 by 10 percent
  - Backdrop of CEPII growth
- Scenario 2:
  - Same shock but unexpected (it occurs all of the sudden in 2025)
- Aggregation same as in the previous example (8x8)

Stockholding results—the EU wheat output



Stockholding results—the EU wheat stocks



Proper closure to support dynamic models

- Closure in GTAP is not tied to a specific time frame (short run = ? months)
- A lot of parameters used in the standard GTAP model are not estimated (ESUBT = 0, ETRAE = -1, etc.)
- Work at USDA/ERS to re-estimate all elasticities with time frames following (Ivanic et al, JGEA *forth.*)

Table 5. Proposed ESUBT values using our one-year, three-year, six-year and infinite year estimates

com	E1	E3	E6	EI	com	E1	E3	E6	EI
pdr	0.56	1.00	1.39	1.78	nmm	1.45	1.52	1.59	1.66
wht	0.19	0.47	0.60	0.72	i_s	1.65	1.88	2.07	2.26

Conclusions

- Including foresight into the GTAP model is not difficult
- We can keep the standard GTAP model as a function of motion with minimal modifications
- With the benefit of integrating tools of GEMPACK (e.g., https://github.com/mivanic/HARr) it is possible to solve super models that include GEMPACK models
- We can take advantage of modern methods (e.g., parallelism) to solve dynamic models efficiently
- Using foresight in dynamic models is likely to produce realistic results and explain a complex interplay of policy implementations and market reactions