Computable General Equilibrium Models:
International trade

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Partial and General Equilibrium Models
Summer Term 2020

Aims for today

- Learn how international trade is depicted in CGEs:
  - Armington and CET
  - New trade theory models
  - Details about implementation in GTAP (CGEBox)

International trade in single country CGEs

- Import / export prices before taxation (= world market prices)
  - are either fixed
  - or depicted as a function of import and export quantities
- In the latter case, often combined with CES and/or CET
- Typically no differentiation by trading partner (domestic against rest-of-the-world)

International trade in global CGEs

- Most often found:
  - Demand for domestic produce and total imports based on Armington assumption (= CES demand system, quality differences by origin)
  - Demand from different importers described by a second CES nest
- Next extension:
  - Similar structure on supply side with CET-Transformation function
- Finally:
  - New trade theory models (Krugmann, Melitz) with fixed cost and non-competitive markets

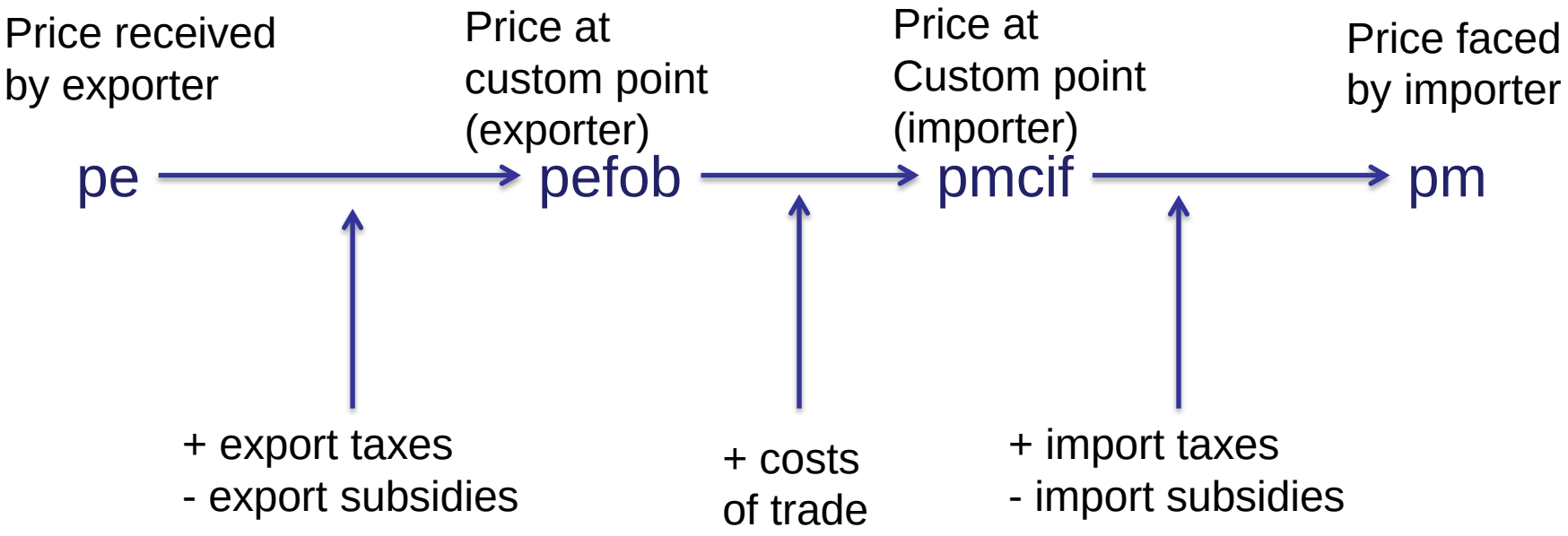
Armington approach

- Armington, Paul, 1969, "A Theory of Demand for Products Distinguished by Place of Production", International Monetary Fund Staff Papers, XVI (1969), 159-78, reflects
  - For aggregated product categories (“industrial goods”), law of one price makes no sense: aggregate composition differs between exporters / domestic sales (= quality differences)
  - Explains why counter-trade (countries trade with each other in both direction) is frequently observed
  - Armington proposes CES: easy to handle (homothetic), only substitution elasticity necessary

Armington and related data

- Using an Armington approach requires data on bi-lateral trade (trade matrices) and matching protection data (import duties, export subsidies)
- GTAP data comprises these data plus international trade margins to model:
  - f.o.b. price (free on board)
    = unit cost of production plus export taxes
    (latter could be negative = export subsidies)
  - c.i.f. price (cost, insurance and trade)
    = f.o.b. plus bi-lateral trade margin
    (=transport and transaction cost)
  - Import price before consumption taxes
    (c.i.f. plus import duties, later could be negative)

Armington and related data



f.o.b.: CGEBox (GTAP)

Exporter r

Importer rp

```
$$macro mm_pefob(r,i,rp,t) { \
        --- export taxes
        [(1 + exptx(r,i,rp,t) + etax(r,i,t)) \
    --- the following might substitutes out pe depending on the CETs
        between domestic sales and export resp. between exports
            * (  \
                --- use bilateral import prices if a CET between export destination is active
                pe(r,i,rp,t) $ psFlag(r,i,"pe") \
                --- use the export prices if there is only a CET between total exports and domestic use
              + pet(r,i,t)   $ psFlag(r,i,"pet") \
                --- otherwise, use supply price
              + ps(r,i,t)    $ psFlag(r,i,"ps")       )]
```

Taxes/subsidies on export
(collected by exporter)

c.i.f: CGEBox (GTAP)

f.o.b. price converted from exporter currency in international one

```
*
* --- costs, insurance and freight price (c.i.f): add transport margins to f.o.b. price
*
   $$macro m_pmcif(r,i,rp,t) { [ m_pefob(r,i,rp,t)/lcu(r,t) \
                               + (sum(m $ amgm(m,r,i,rp),     \
                                    amgm(m,r,i,rp)*ptmg(m,t)/lambdamg(m,r,i,rp,t))*tmarg(r,i,rp,t))\
                                                                                    $tmarg.l(r,i,rp,t)\
                               ]*lcu(rp,t) }
```

Price of transport mode (sea, air, other)

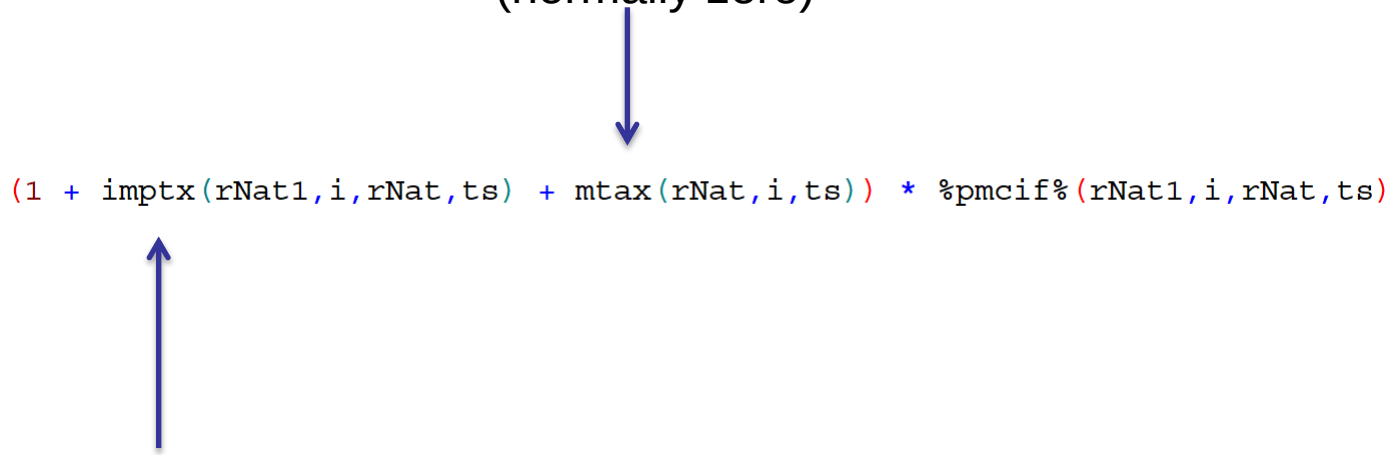
Per unit transport margin demand

Share of transport mode (sea, air, other) on cost

Tech. shifter

Import price CGEBox (GTAP)

Import tax shifter
(normally zero)



```
(1 + imptx(rNat1,i,rNat,ts) + mtax(rNat,i,ts)) * %pmcif%(rNat1,i,rNat,ts)
```

Ad-valorem equivalent
of bi-lateral border protection measures
(applied ad-valorem and specific tariffs,
tariff rate quota rents)

International prices: Transport margins

- In a CGE, all costs are explicit
  - i.e. differences between f.o.b. and c.i.f., represent intermediate and primary factor use (think of using a container on a vessel, related insurance …)
- In GTAP:
  - Different modes of transport *m* (land, sea, air) are differentiated

International prices: Transport margins

- Total global demand for transport services of type m depends on (Leontief):
  - Per unit demand for aggregated transport services for each product and bi-lateral link *tmarg*
  - The related current bi-laterally traded amount *xw*
  - The share parameters for the different transport services *amgm*
  - A technology shifter *lamdbamg* (normally equal to 1)

```
xtmgeq(m,ts(t)) ..
   xtmg(m,t)/xtmg.scale(m,t) =e= sum((r,i,rp) $ amgm(m,r,i,rp), amgm(m,r,i,rp)*tmarg(r,i,rp,t)
                                  * (  xw(r,i,rp,t)    $ rrComb(r,rp)
                                     + xw.l(r,i,rp,t) $ (not rrComb(r,rp)) )
                                     /lambdamg(m,r,i,rp,t))/xtmg.scale(m,t);
```

Total global demand e.g. for sea transport

International prices: Transport margins

- Total global demand for transport services of type m is supplied by the different regions (producers of transport services)
- CES cost minimal demand *xa*:

```
xatmgeq(rs(r),m,tmg,ts(t)) $ xaFlag(r,m,tmg) ..
   xa(r,m,tmg,t)/xa.scale(r,m,tmg,t)
    =e= alphaa(r,m,tmg,t)*xtmg(m,t)/xa.scale(r,m,tmg,t) *(ptmg(m,t)/(m_pa(r,m,tmg,t)/lcu(r,t)))**sigmamg(m) ;
```

Global demand

Global relative to regional price

Cost share of region r in total transport demand of type m for commodities tmg

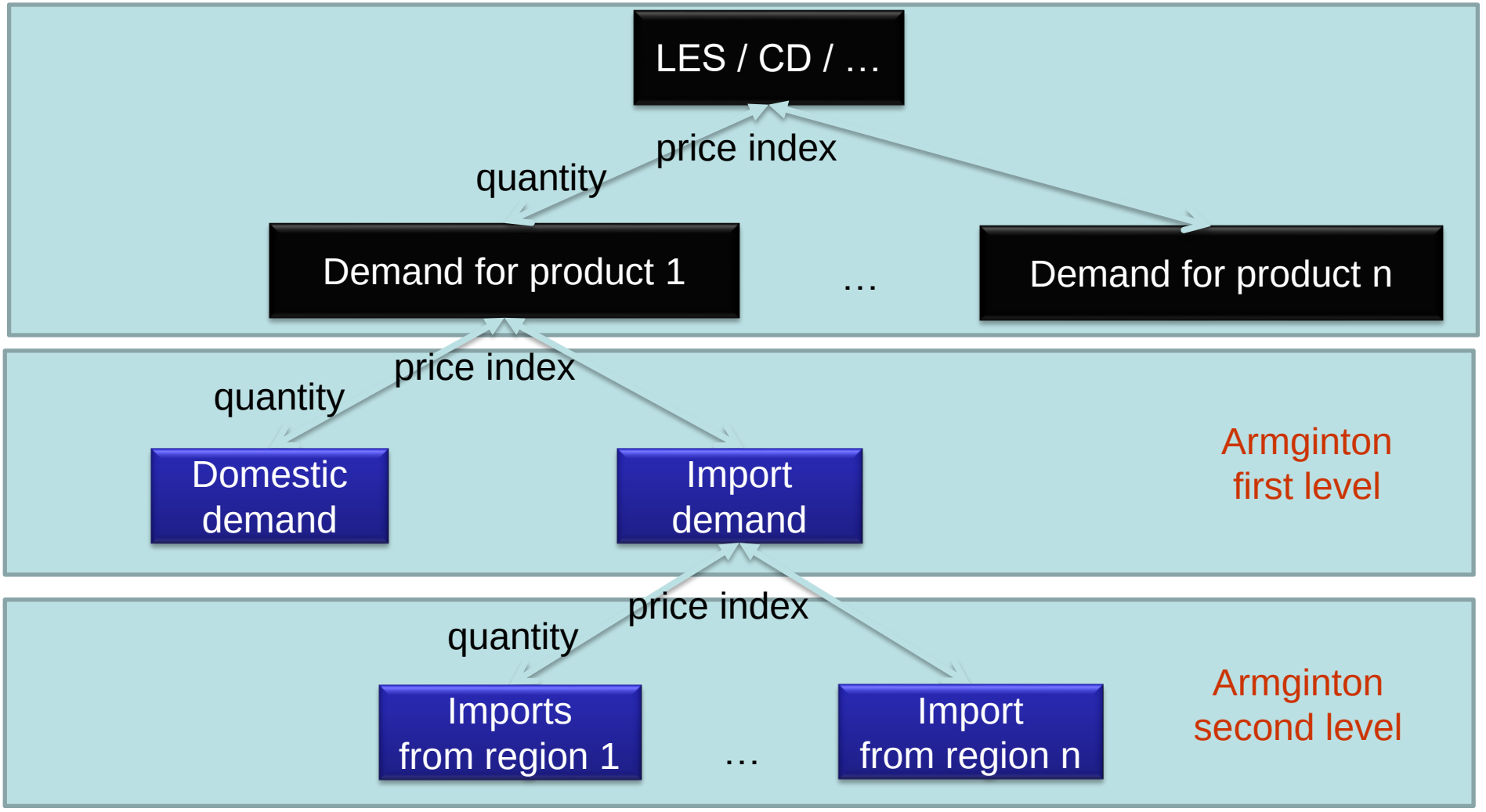
Matching dual price aggregator … unpleasant technical details

```
ptmgeq(m,ts(t)) ..

   ptmg(m,t) =e=
        (  (sum( (r,tmg) $ alphaa.l(r,m,tmg,t),
                      alphaa(r,m,tmg,t)*( (m_pa(r,m,tmg,t)/lcu(r,t))    $ rs(r)
                                        + (pa.l(r,m,tmg,t)/lcu.l(r,t))  $ (not rs(r)))**(1-sigmamg(m)) )**(1/(1-sigmamg(m))))/axmg(m,t) ) $ (sigmamg(m) ne 1)

      +  ( sum(tmg, prod(r $ alphaa.l(r,m,tmg,t), ((   (m_pa(r,m,tmg,t)/lcu(r,t))    $ rs(r)
                                                     + (pa.l(r,m,tmg,t)/lcu.l(r,t)) $ (not rs(r)))
                                                                /alphaa(r,m,tmg,t))**(alphaa(r,m,tmg,t))))/axmg(m,t) ) $(sigmamg(m) eq 1)
      ;
```

Armington as part of multi-stage demand system



Armington as part of multi-stage demand system

- Three levels:
  1. Top level distributes expenditure to different products given price index for that product (calculated in first level Armington)
  2. First level Armington:
     - Distributes expenditure by product to imports and domestic sales, used in second level
     - Calculates average price index of imports and domestic sales for that product, used in top level, using price index for imports from second level Armington
  3. Second level Armington:
     - Distributes expenditure from first level Armington for imports to different importers
     - Calculates average price index of imports for that commodity from the different import prices, used in first level Armington

CET for supply

- Mirrors the Armington approach on the supply side, i.e.:
  - Total domestic supply is distributed by CET to exports and domestic sales depending on prices received for exports and in the domestic market
  - Exports are distributed to different export destinations (= regions) based on price received at these destinations
  - Used e.g. in GLOBE, but not part of GTAP Standard. Option in CGEBox

New trade theory models

- Empirical observations:
  - Huge productivity differences between firms in same industry
  - Firms engaged as exporters more efficient than others

  $\Rightarrow$ Explanation:
    - Fixed costs of exports (find seller in other country, set-up subsidiary, translate sales and use manuals, comply with different standard in other countries …)
    - Only the more efficient firms are able to cover these additional costs

New trade theory models

- Fixed costs of exports => challenge for modeling:
  - Fixed cost imply increasing-returns-to-scale
  - Productivity differences can only prevail in the long-run (factors are mobile) in combination with some pricing power resulting from product differentiation (branding etc.)

New trade theory models

- Break-through for applied modeling when Krugmann and later Melitz suggest to model average firm over a distribution of productivity rather than trying to depict individual / group of firms differentiated by productivity
- Intuition: more productive firm “spent” their productivity advantage on covering fix costs of trade
- Pricing power from “love of variety”, similar to Armington: consumer prefer more differentiated bundles produced by many firms over less differentiated ones

New trade theory models

- Welfare gains from trade liberalization now:
  - As before: allocative gains by shifting production to more productive producers
  - New: fix costs of trade distributed over larger quantities: average production costs drop, efficiency gains
  - New: consumer benefit from entry of new exporting firms into export market due to love of variety (we can now also enjoy new wine varieties from Australia, not only the existing bundle …)

New trade theory models

- Currently, implemented in different CGEs:
  - GTAP-HET (2016), only one sector reported, higher aggregation
  - Jafari and Britz (2017) , CGEBox: >10 sector, highly detailed
  - Some further applications reported at GTAP conference