



# Workshop on Impact Analysis Toolkit

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ESCWA

## Session 6 : How to use global CGE models and analyze their results: illustrative studies

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# A few words to start with ...

❑ George Box (1978):

**« All models are wrong but some are useful »**

- ✓ The quality of the information that models provide is strongly related with the robustness of their theoretical foundations and the quality of the information that feeds them

❑ Dominique Van der Mensbrugge (2004):

**« Policy analysis can easily be discredited if various studies come to opposite conclusions and the reasons for these differences are not readily understood or explained »**

- ✓ Differences between analyses need to be understood (they could diverge for various reasons: differences in models employed, in data used, in assumptions made, in aggregation levels determined, etc.)

# A few words to start with ...

- ❑ **Still, when grounded on quality data and robust theoretical framework, global CGE models can be powerful tools that:**
  - Are capable to capture multiple interactions taking place within and between the different countries and sectors of the world economy
  - Provide a considerable amount of valuable information following policy shock (e.g. variations in exports, imports and production by country and sector, economic welfare, etc.)
  - Can influence policy formulation and decision making
- ❑ **But should be clear that this session will not enable you to use global CGE models (*unrealistic*)**
  - But rather to get a better understanding of how such models work and the type of results they generate

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# **Outline of the presentation**

- I. Main CGE modeling steps**
  - II. Using CGE modeling results to inform and guide policy decision**
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# I. Main CGE modeling steps

1. Define issue to be analyzed
  2. Build a rigorous theoretical model
  3. Collect/gather data inputs
  4. Code the model into a mathematical software
  5. Calibrate the model
  6. Check/Run the model
  7. Implement and simulate policy shock(s)
  8. Obtaining, extracting and interpreting results
-

# 1. Define issue to be analyzed

- ❑ Such as, assessing the expected economic impacts of the:
    - Establishment of the African Continental Free Trade Area (AfCFTA) on African countries
    - Effective implementation of the Arab Customs Union (ACU) on Arab countries
    - Formation of mega-regional trade agreements on third countries
    - Etc.
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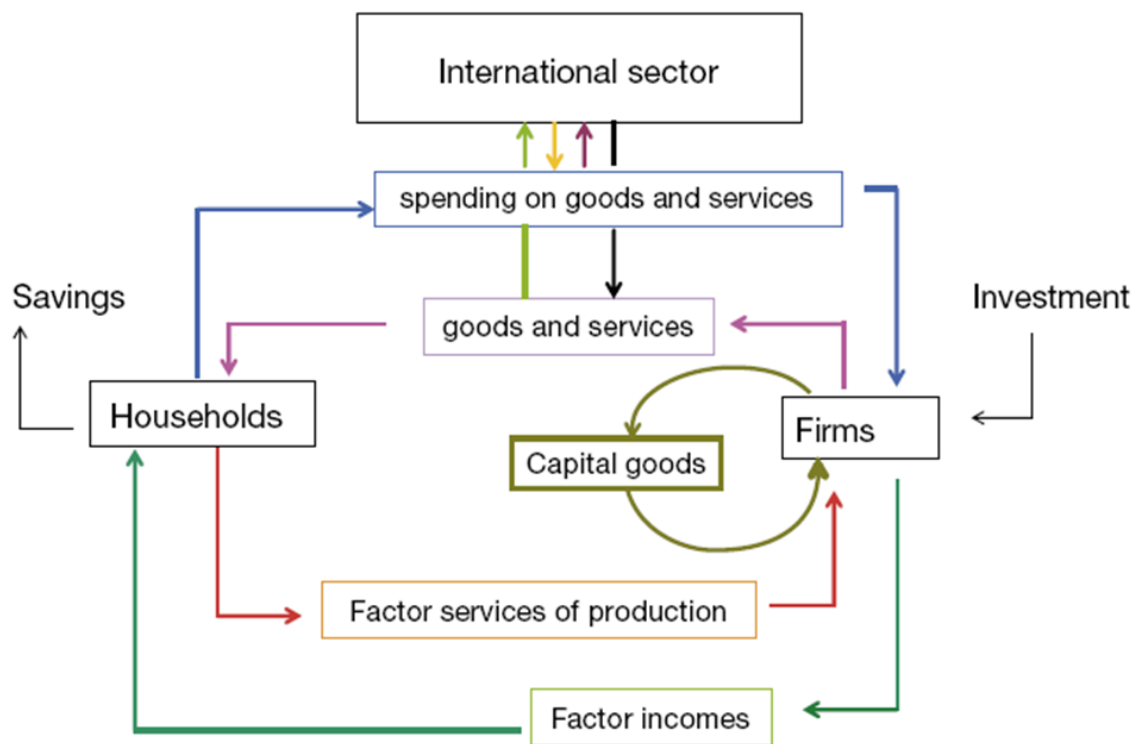
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# I. Main CGE modeling steps

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## 2. Build a rigorous theoretical model

- ❑ Describe all theoretical linkages and choosing functional forms to represent economic agents' behaviors
- Interactions between agents in an open economy:



Source: Piermartini R. and R. Teh, WTO Discussion Paper No. 10 (2005)

- Remark: it is possible to introduce the government such as: it collects taxes from the HHs and firms and duties from international transactions; it purchases goods and services as well as possibly making transfers to HHs



## 2. Build a rigorous theoretical model

- ❑ Interactions briefly illustrated on previous slide are modeled all together in a CGE framework
- ❑ Based on neoclassical economic assumptions such as:
  - Producers (*i.e. firms*) maximize their profits (*i.e. difference between revenues from sales and payments for factors of production and intermediate inputs*) or minimize production costs subject to a production technology constraint (supply-side)
  - Consumers (*i.e. households*) maximize their utility (*i.e. representing structure of preferences*) subject to a budget constraint (demand-side)
  - Equilibrium price for each good and factor of production is given when supply = demand

## 2. Build a rigorous theoretical model

- ❑ Examples of major existing multi-country multi-sector CGE models currently used for trade policy analysis:
  - Global Trade Analysis Project (**GTAP**) model
    - Developed by Purdue University (United States); Courses organized annually
    - Relatively friendly interface; programmed in GEMPACK (but also a version in GAMS)
    - More info at: <https://www.gtap.agecon.purdue.edu/>
  - Modeling International Relationships in Applied General Equilibrium (**MIRAGE**)
    - Developed by CEPII (Paris); Need to be a member of the MIRAGE consortium to use it (ECA and ESCWA are members along with CEPII, IFPRI, ITC, INRA, WTO, DG Trade of the European Commission, Trinity College, Universita del Molise)
    - Programmed in GAMS
    - More info at: <http://www.mirage-model.eu/miragewiki/index.php?title=Accueil>
  - **LINKAGE**
    - Developed and maintained by the World Bank; Programmed in GAMS and GEMPACK
    - More information at:  
<http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/0,,contentMDK:20357492~menuPK:681018~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html>

## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

#### ■ Supply-side of the Model (*nested structure*)

##### □ Production process

##### ■ (1<sup>st</sup> level) Production

$$\begin{array}{c} \text{Production} \\ = \\ \text{Intermediate Consumption} \\ + \\ \text{Value Added} \end{array}$$

##### ■ (2<sup>nd</sup> level) Intermediate Consumption & Value Added

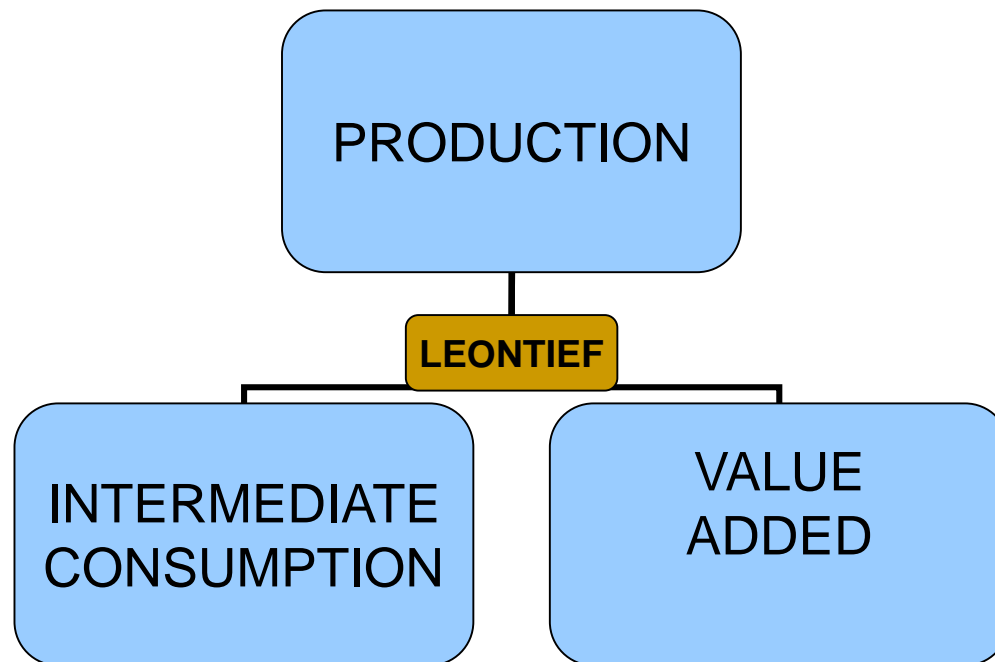
##### ■ (3<sup>rd</sup> level) Composite factor

##### □ Production factors and mobility

## 2. Build a rigorous theoretical model

- ***Basic structure of the MIRAGE model theoretical framework***

PRODUCTION (1<sup>st</sup> level)



***Perfect complementarity between Intermediate Consumption and Value Added***

## 2. Build a rigorous theoretical model

### ❑ Quick parenthesis about functional forms

- Most of the time, CGE models rely on Constant Elasticity of Substitution (CES) functions (to describe economic agents' behaviors) which can be declined into 3 commonly used functional forms depending on the value of the elasticity:

- **General case:**

$$Y = A[\alpha.K^{\frac{\sigma-1}{\sigma}} + (1-\alpha).L^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

Where:

A = factor productivity; K = Capital; L = Labor

$\alpha$  = share parameter;  $\sigma$  = elasticity of substitution between factors

- If  $\sigma \rightarrow 1$ ,  $(\sigma - 1/\sigma) = \rho \rightarrow 0$  :

$$Y = AK^{\alpha} L^{(1-\alpha)} \rightarrow \text{known as } \mathbf{Cobb-Douglas} \text{ function}$$

- If  $\sigma \rightarrow 0$ ,  $(\sigma - 1/\sigma) = \rho \rightarrow -\text{INF}$  :

$$Y = A \min\{L, K\} \rightarrow \text{known as } \mathbf{Leontief} \text{ function}$$

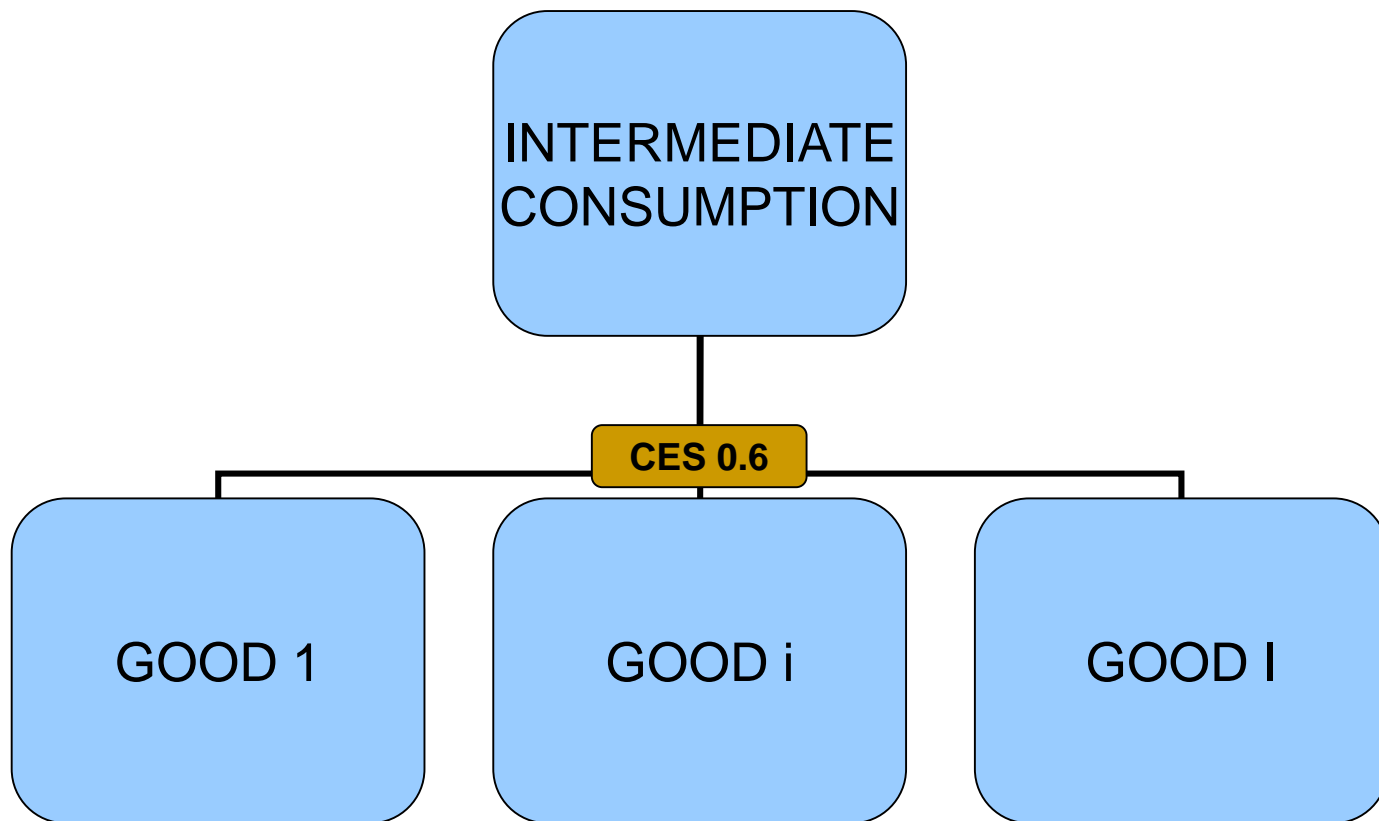
(i.e. factors of production to be used in fixed proportions; no substitutability between factors)

- Values of elasticities of substitutions are key as they determine how economic agents (e.g. producers and consumers) respond to relative price changes

## 2. Build a rigorous theoretical model

- ***Basic structure of the MIRAGE model theoretical framework***

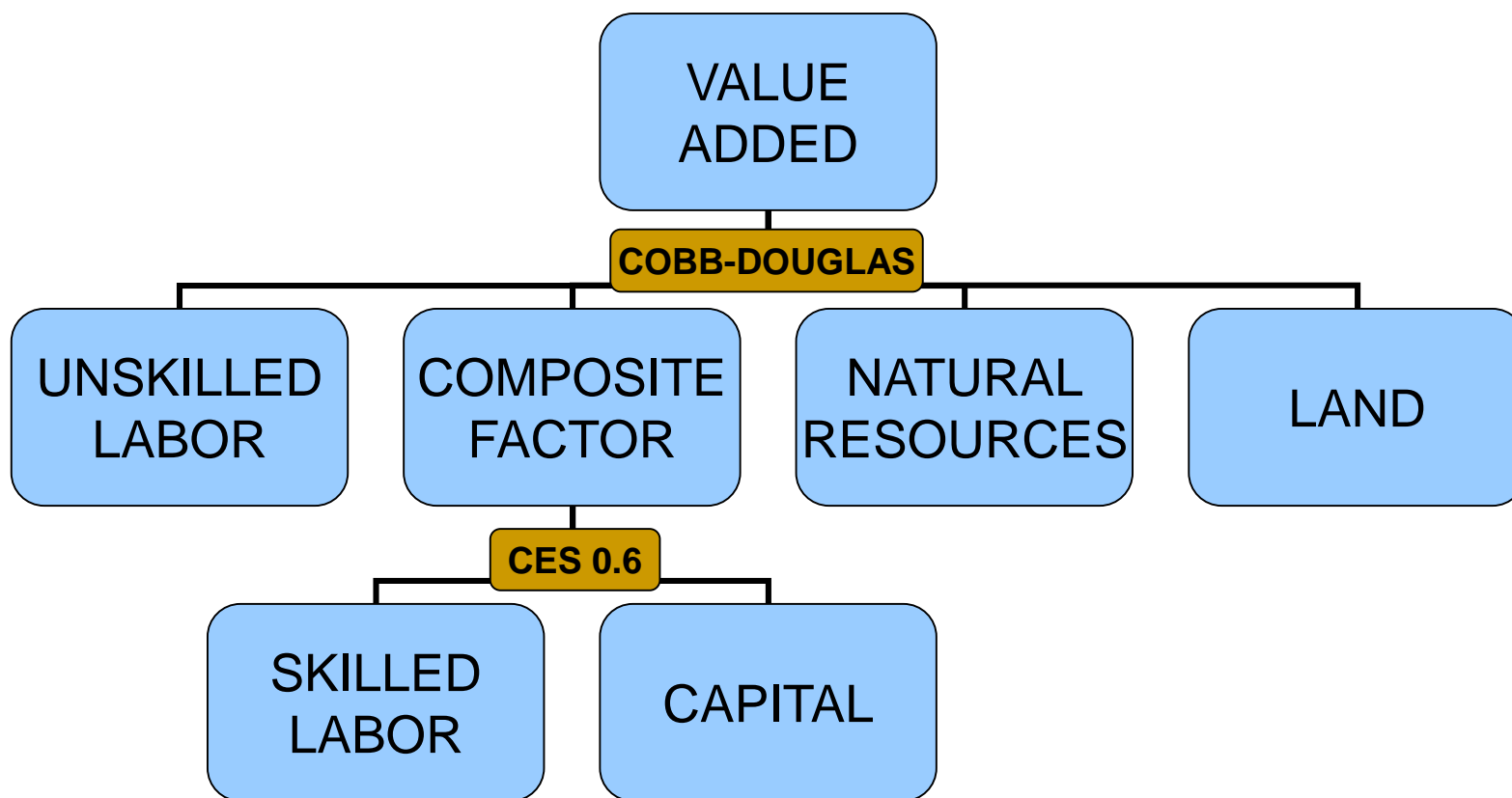
INTERMEDIATE CONSUMPTION (2<sup>nd</sup> level)



## 2. Build a rigorous theoretical model

- **Basic structure of the MIRAGE model theoretical framework**

VALUE ADDED (2<sup>nd</sup> & 3<sup>rd</sup> levels)



## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

#### ■ Production factors and mobility

- Skilled labor: perfect mobility between sectors
- Unskilled labor: imperfect mobility between agricultural and non agricultural sectors (perfect mobility among each group of sectors)
- Land: imperfectly mobile between sectors
- Natural resources: sector-specific and constant
- Capital: sector-specific and accumulative



## 2. Build a rigorous theoretical model

□ *Basic structure of the MIRAGE model theoretical framework*

### ■ Demand-side of the model (*nested structure*)

□ (1<sup>st</sup> level) Total Demand:

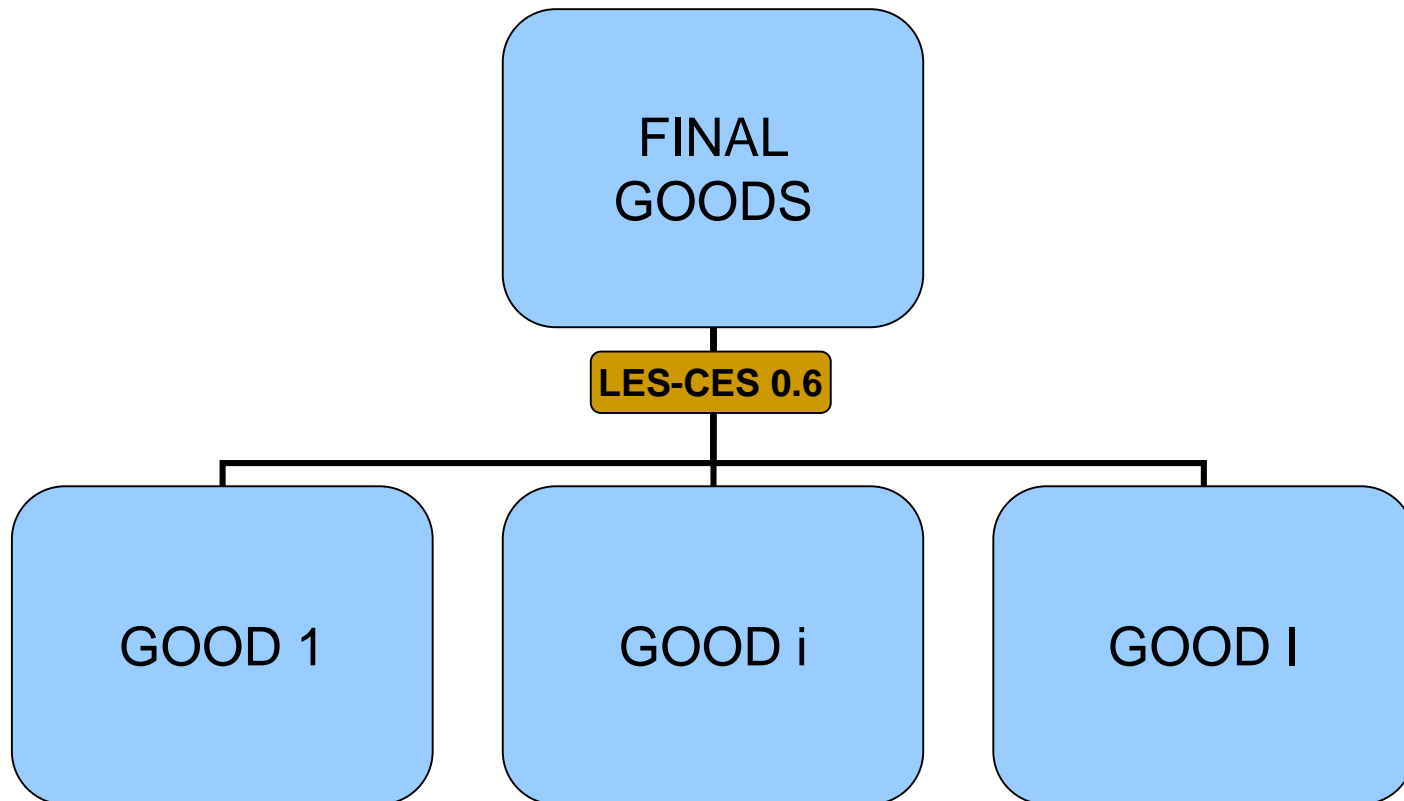
$$\begin{aligned} &\text{Total Demand} \\ &= \\ &\text{Demand for Final Goods} \\ &+ \\ &\text{Demand for Intermediate Goods} \\ &+ \\ &\text{Demand for Capital Goods} \end{aligned}$$

□ (2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> levels) Vertical differentiation of goods

## 2. Build a rigorous theoretical model

- *Basic structure of the MIRAGE model theoretical framework*

DEMAND FOR FINAL GOODS (1<sup>st</sup> level)



## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

**LES-CES** function

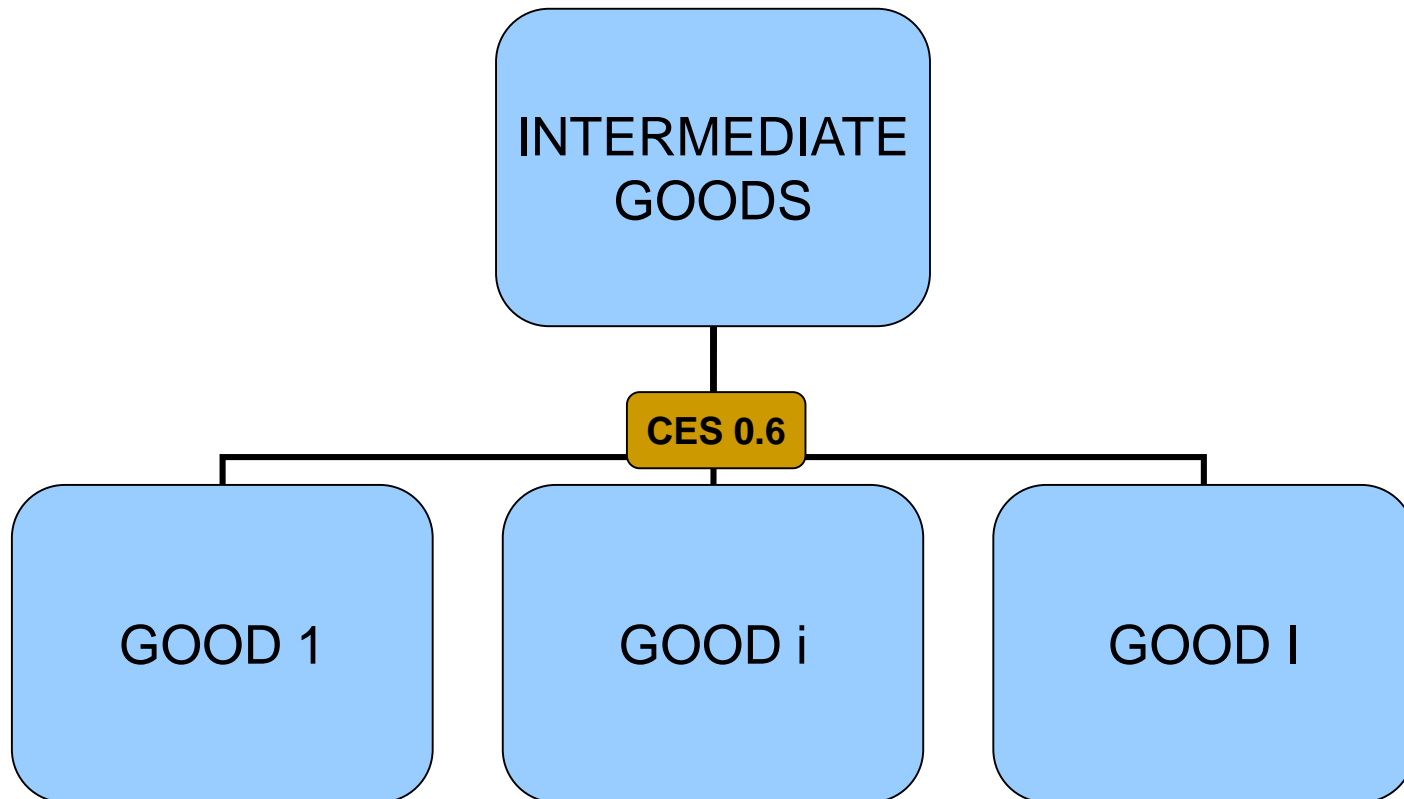
Linear Expenditure System - Constant Elasticity of Substitution

- The demand structure of each region depends on its income level (i.e.: a minimum level of the final consumption is assumed for each region according to the income level of which one the consumer is issued)
- In MIRAGE, minimum levels of consumption depend on level of development of countries (i.e. developed countries assumed to have lower minimum levels than developing countries)
- All other characteristics as a CES function

## 2. Build a rigorous theoretical model

- ***Basic structure of the MIRAGE model theoretical framework***

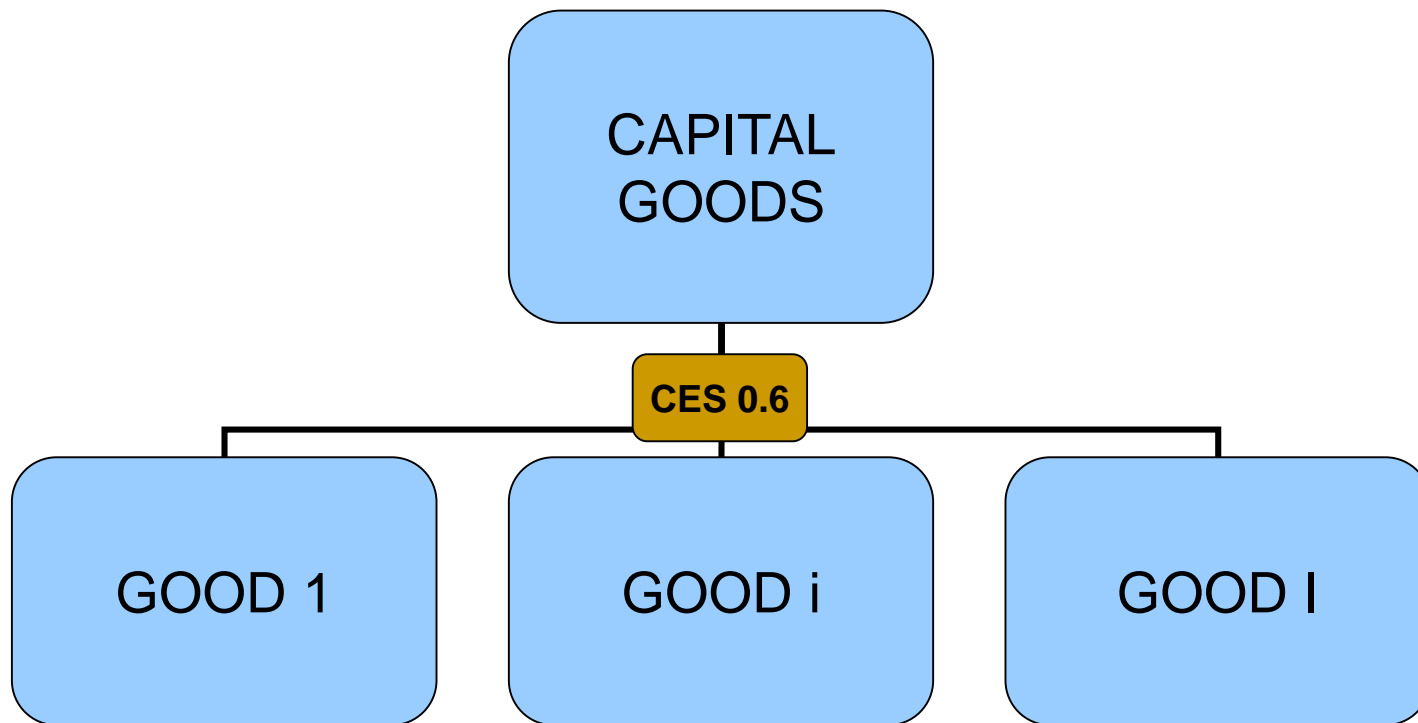
DEMAND FOR INTERMEDIATE GOODS (1<sup>st</sup> level)



## 2. Build a rigorous theoretical model

- *Basic structure of the MIRAGE model theoretical framework*

DEMAND FOR CAPITAL GOODS (1<sup>st</sup> level)



## 2. Build a rigorous theoretical model

### □ ***Basic structure of the MIRAGE model theoretical framework***

- Vertical differentiations (*3 levels by nested Armington*)

**Armington hypothesis: choice between products based on geographical origins** (*differentiations by geographical origins*)

- 2<sup>nd</sup> level : 2 quality ranges from geographical basis → 2 zones
  - Zone U = regions from the same quality of the region of the buyer
  - Zone V = regions from the other quality

*In MIRAGE, goods produced by developed countries are assumed to have a different quality than the ones produced by developing countries*

## 2. Build a rigorous theoretical model

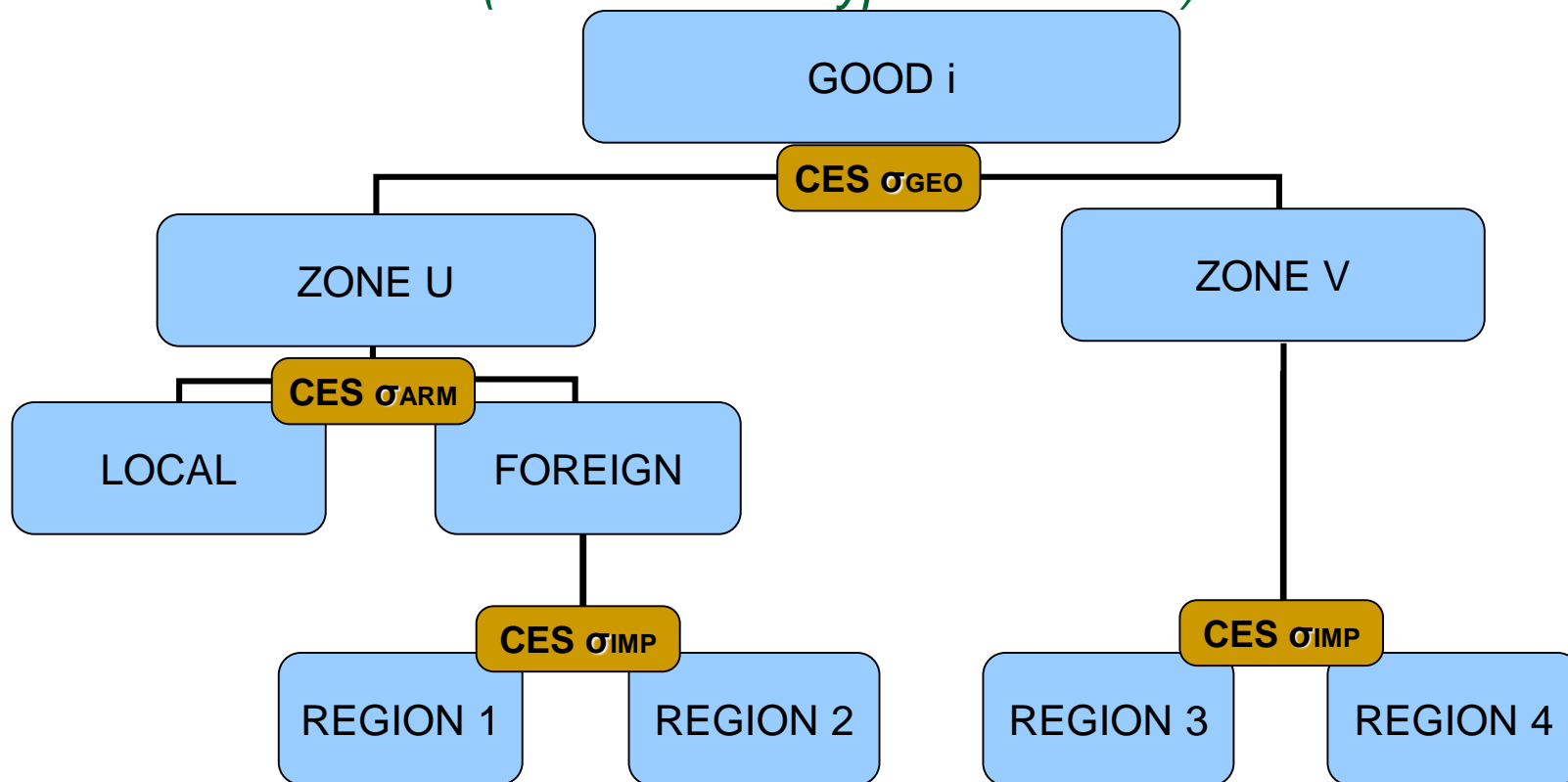
### □ ***Basic structure of the MIRAGE model theoretical framework***

- 3<sup>rd</sup> level: same hypothesis inside a same Zone of quality (i.e. local goods are assumed to be different than foreign ones)
  - Local region
  - Foreign regions
  
- 4<sup>th</sup> level: same hypothesis inside foreign regions (i.e. goods produced inside each foreign region are assumed to be different from the ones produced in all other foreign regions)
  - Foreign region 1
  - ...
  - Foreign region n
  - ...
  - Foreign region N

## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

VERTICAL DIFFERENTIATIONS (2<sup>nd</sup>, 3<sup>rd</sup> & 4<sup>th</sup> levels)  
(*valid for each type of demand*)



with,  $\sigma_{IMP(i)} = \epsilon_{l(i)}$ ,  $\sigma_{ARM(i)} = (\sigma_{IMP(i)} - 1)/2^{1/2} + 1$  and  $\sigma_{GEO(i)} = (\sigma_{ARM(i)} - 1)/2^{1/2} + 1$



## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

#### ■ Macroeconomic Closure

- The external balance of each region is maintained constant and fixed to its initial value
  - Any possible disequilibrium of the external balance is to be offset by an adjustment of the real exchange rate such as:
    - When trade is stimulated by a specific reforms (e.g. reduction in tariff barriers) then real exchange rate appreciate if exports increase more than imports or depreciate when exports increase less than imports

#### ■ Dynamic baseline

- Labor force supply based on demographic forecast from the World Bank (rate of population aged between 15 and 65 used for skilled and unskilled labor)
- GDP growth forecast provided by the World Bank until 2050

## 2. Build a rigorous theoretical model

### □ *Basic structure of the MIRAGE model theoretical framework*

#### ■ Modeling of Capital and Investment in MIRAGE

- Capital is sector-specific and immobile: the rate of return to capital may vary across sectors and regions
- Investment (domestic and foreign) is the only adjustment variable for capital stocks such as:

$$K_t = K_{t-1}(1 - \delta) + I_t$$

- Single formulation used to set both domestic and foreign investment: investment in sectors and regions is determined by the level of remuneration provided

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## **II. Main CGE modeling steps**

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  - 7. Implement and simulate policy shock(s)**
  - 8. Obtaining, extracting and interpreting results**
-

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### 3. Collect/gather data inputs

- ❑ For global SAM (GTAP database), detailed protection information (e.g. MAcMap-HS6 database), elasticities (from the literature, econometric estimates as well as GTAP database)

### 4. Code the model into a mathematical software

- ❑ Specify all variables and equations to represent theoretical framework of the model (i.e. model structure) in GAMS or GEMPACK
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## 5. Calibrate the model

- ❑ Assign values for all variables using data inputs and equations in order to solve the model for the base year (or benchmark)

## 6. Check/Run the model

- ❑ Make sure model does converge to its equilibrium following calibration/exercise:
  - If solution is not found, need to go back to the calibration step or the coding or even the theoretical definition of the model
  - If solution is found, go to the next step

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## 7. Implement and simulate policy shock(s)

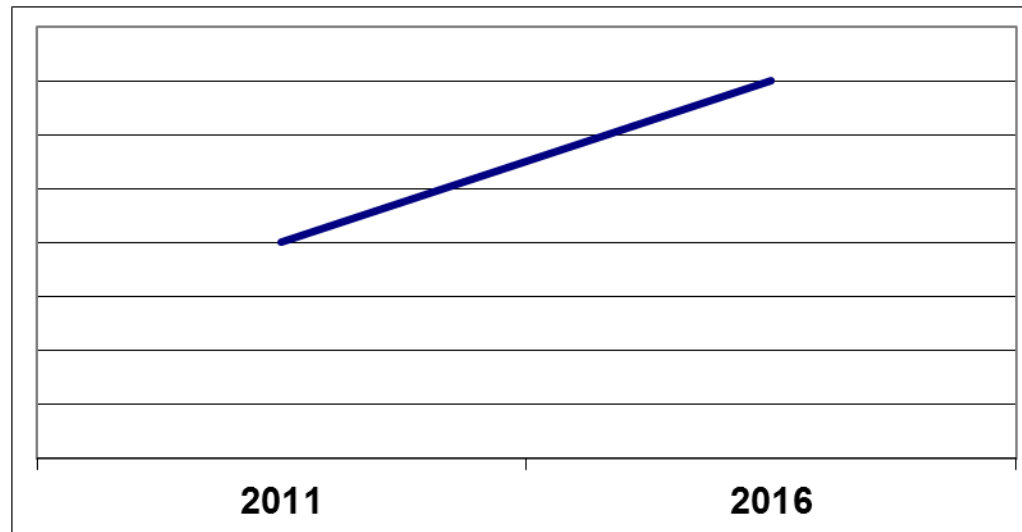
- ❑ Possible work outside the model (e.g. tariff scenario design using MAcMap-HS6)
- ❑ Coding of the shock(s) into the model
- ❑ Running the model to obtain new equilibriums and corresponding results:
  - a. Pre-experiment (updates between base year and current year)
  - b. Baseline (without shock)
  - c. Scenario(s) (inclusive of shock(s))



## 7. Implement and simulate policy shock(s)

### a. Pre-experiment

- To update value of certain exogenous variables between:
  - ✓ Base year of the SAM (e.g. GTAP database year for most CGE models)
  - ✓ And current year (or year before trade reforms will start being implemented)
  - ✓ Can be done in 1 iteration (for static CGE models) or several iterations (i.e. overtime for recursive dynamic CGE models)



- Examples: Yemen joining WTO in 2014, ECOWAS adopted its common external tariff (CET) in 2015, etc.

## 7. Implement and simulate policy shock(s)

### b. Baseline

- Also called “reference scenario”; based on prolongation of currently observed trends
- In a static CGE model:
  - ✓ Only one iteration between base year (or end of pre-experiment) and end of baseline
  - ✓ Does not consider any feedback related to the transition from current situation to end of baseline
- In a dynamic recursive CGE model:
  - ✓ As many iterations as number of years considered for the analysis
  - ✓ Capture changes associated with the transition from current situation to end of baseline; essentially driven by:
    - Key forecasts for exogenous variables : GDP, population, capital accumulation, etc.
    - Any other exogenous variable that you wish to adjust and include as part of the situation of reference (e.g. reflecting establishment of the TFTA in the baseline to capture only effects of further regional integration in Africa in a AfCFTA scenario)

## 7. Implement and simulate policy shock(s)

### c. Scenario(s)

- Implementation of policy reform(s) or shock(s) into the CGE model:
  - ✓ Example: implementing a CET for Arab countries
  - ✓ This will create a deviation from the baseline (i.e. convergence to a new equilibrium after shock)
- In a static CGE model:
  - ✓ Only one iteration between baseline and end of each scenario
- In a dynamic recursive CGE model:
  - ✓ As many iterations as number of years considered for the analysis
  - ✓ Run each scenario in parallel to the baseline

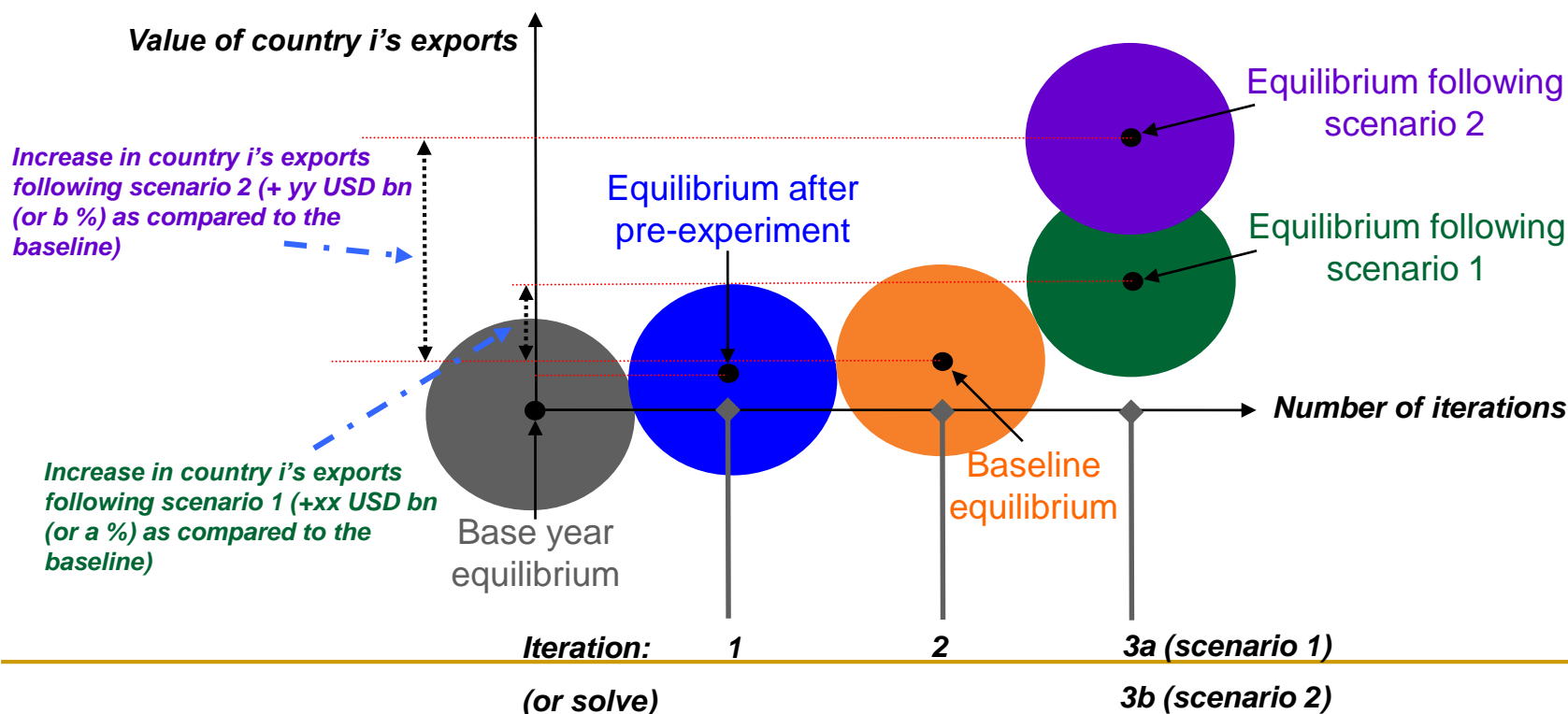
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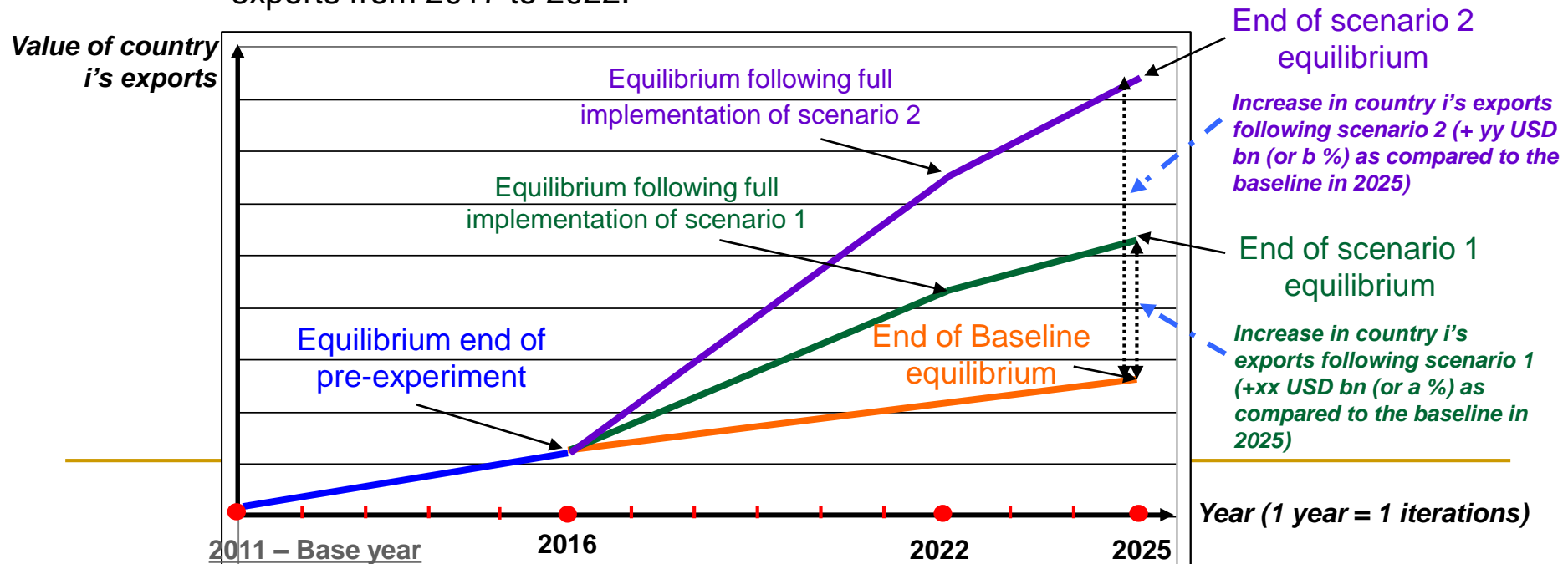
## 8. Obtaining, extracting and interpreting results

- ❑ In a **static** setting, effects/results from CGE models are **obtained** by difference between each scenario and the baseline (for each variable)
  - Example of positive effects on exports of country *i* following reduction of average tariffs ( $t_1$  in scenario 1;  $t_2$  in scenario 2;  $t_1 > t_2$ ) faced by country *i* on its exports:



## 8. Obtaining, extracting and interpreting results

- ❑ In a **dynamic** setting, effects/results (for each variable) are also obtained by comparison between the baseline and each scenario but in a particular year
  - Typically the year corresponding to the end of the simulation period (which is usually a few years after the shock has been fully implemented to give time for variables to fully adjust in the model)
  - Example of a positive effects on exports of country i following progressive reduction of average tariffs ( $t_1$  in scenario 1;  $t_2$  in scenario 2;  $t_1 > t_2$ ) faced by country i on its exports from 2017 to 2022:



## 8. Obtaining, extracting and interpreting results

- ❑ Convert results obtained into a friendly and easy to use format (e.g. from GAMS to Excel)
- ❑ Draw key messages (going back to the raw results as required and in order to justify messages)
  - Illustration of the types of key messages that can be drawn from CGE modeling work on next slides

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## **II. Using CGE modeling results to inform and guide policy decision**

- 1. Focus, motivation, objective and methodology**
  - 2. Key findings**
  - 3. Conclusion and influence**
-



# 1. Focus, motivation, objective and methodology

## Focus:

- *Industrializing through trade: from an African perspective*

## Motivation:

- Industrialization has been identified as one of the key pillars that will drive social and economic transformation of Africa in the next 50 years (African Union Agenda 2063)

## Objective:

- To examine whether and how trade arrangements/agreements can advance or hinder Africa's industrialization agenda

## Methodology:

- Using recent empirical evidence (mainly from CGE modelling; relying on MIRAGE model) in the area of trade arrangements/agreements, and focusing on their implications for Africa's industrialization

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## **II. Using CGE modeling results to inform and guide policy decision**

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**2. Key findings**

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## 2. Key findings

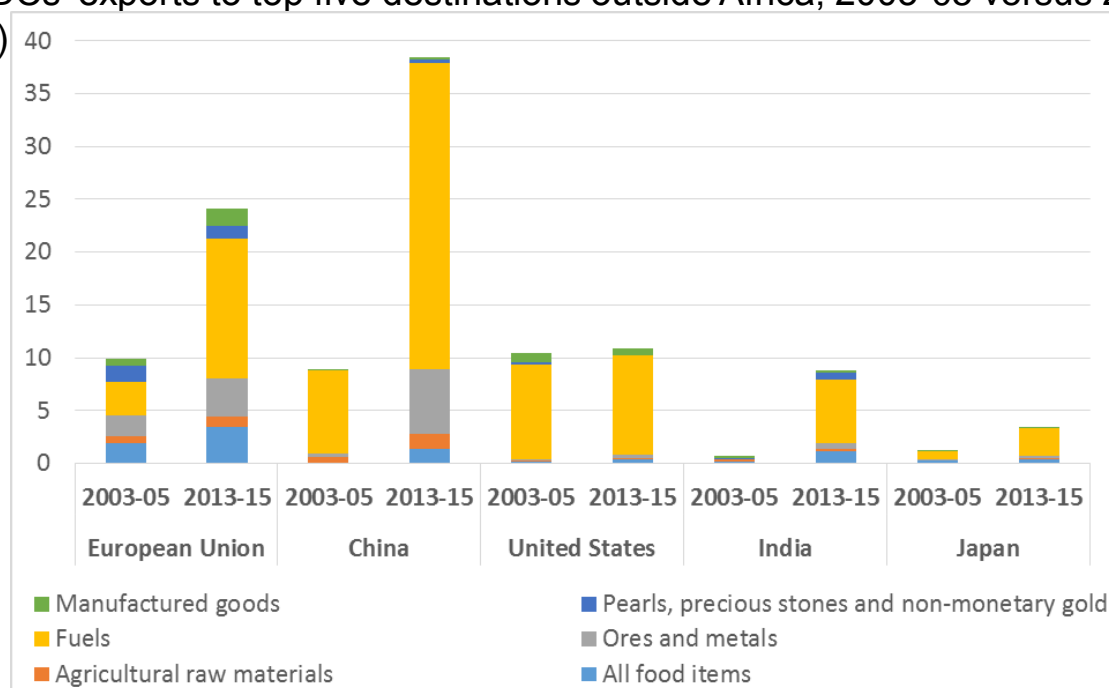
- ❑ ECA's research shows that trade arrangements and trade agreements can truly benefit African countries but not all trading configurations have the same impact; 3 key conclusions:
  - a. **Unilateral trade preferences** can certainly support Africa's trade but their unpredictability makes it difficult to develop the RVCs needed to sustain Africa's industrialization;
  - b. **Regional integration** offers a stronger basis for industrialization (e.g. boosting intra-African trade and its industrial content);
  - c. **Opening up Africa's market through reciprocal agreements** can also deliver benefits for African countries but their effect on industrialization tend to vary depending on the agreement (e.g. EPAs vs. South-South partnerships).
- ❑ Some insights to illustrate the above provided on next slides ...

## 2. Key findings

### a. Unilateral trade preferences

- If preferential schemes have been driving African LDCs' exports they have generally failed to support their industrialization

Evolution of African LDCs' exports to top five destinations outside Africa, 2003-05 versus 2013-15 averages (US\$ Billion)



Source: Author's calculations based on UNCTADstat

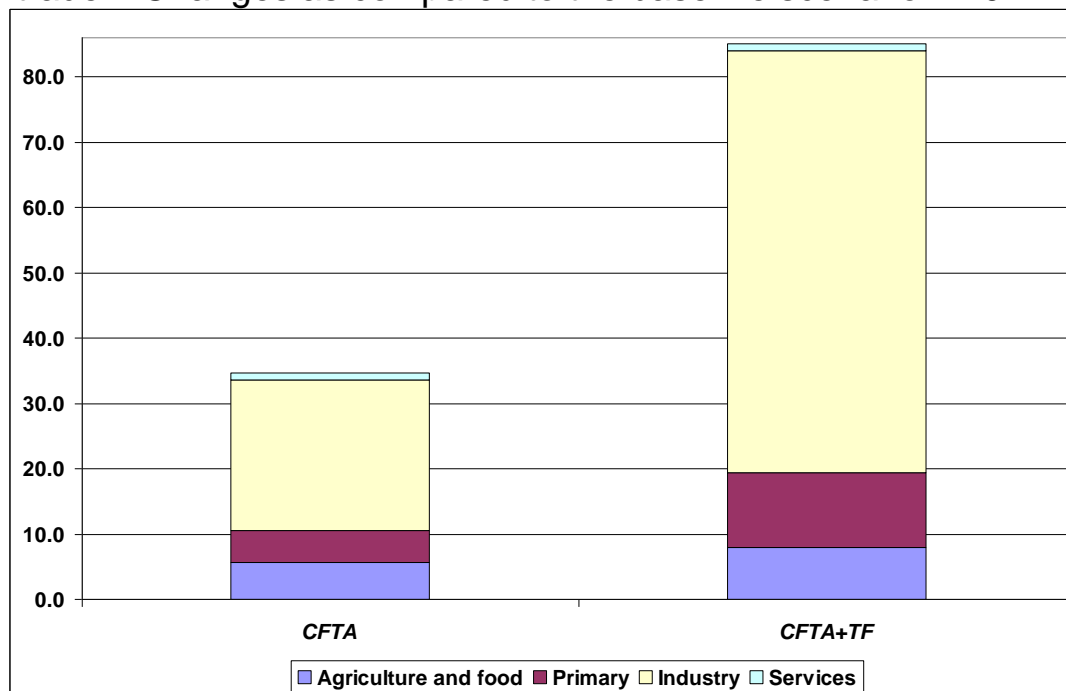
- Whether the destination is a traditional partner or an emerging market, African LDCs' exports are essentially concentrated in fuels and to a lesser extent ores and metals *(similar conclusions observed for non-LDCs benefiting from trade preferences)*

## 2. Key findings

### b. Regional integration

- As suggested by ECA's CGE modeling work, regional integration offers a stronger basis for Africa's industrialization; particularly the African Continental Free Trade Area (AfCFTA)

Intra-African trade – Changes as compared to the baseline scenario – 2022 – (US\$ Billion)



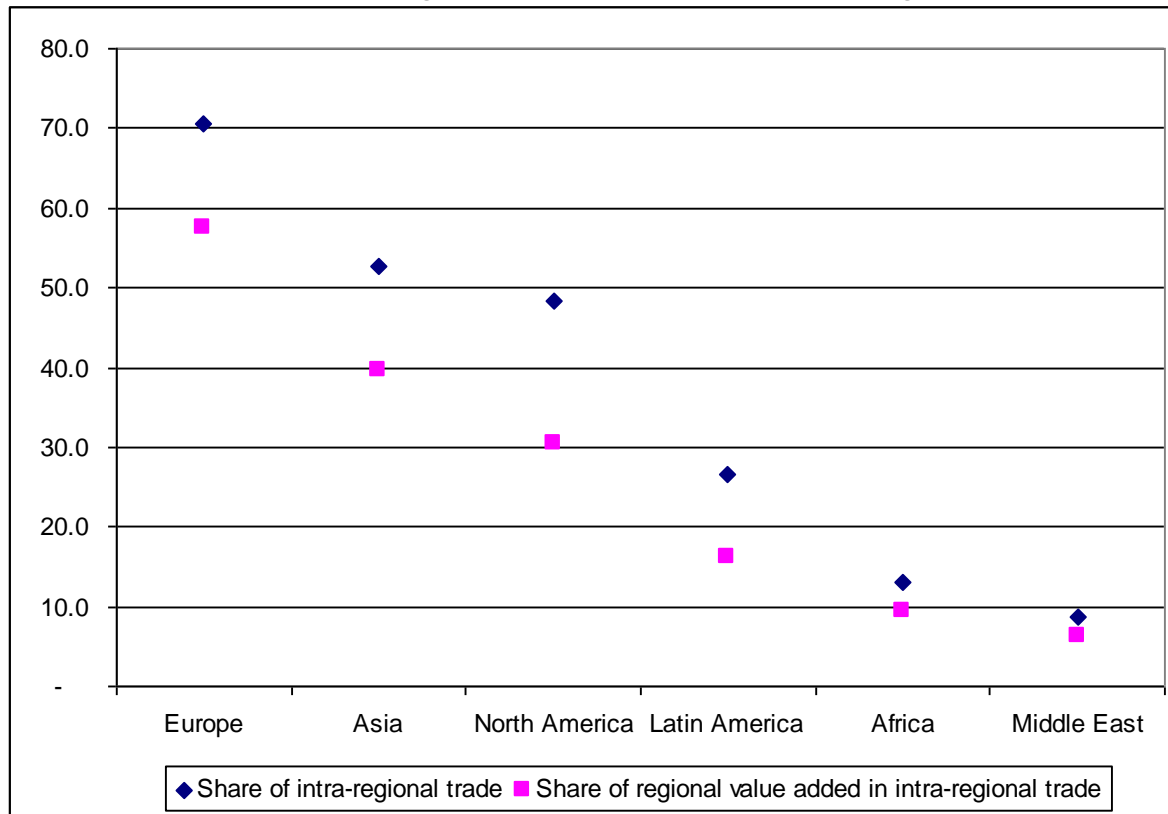
Source: based on MIRAGE CGE model (see Mevel & Karingi (2012 and 2013))

- Importance of trade facilitation (TF) measures to strongly enhance industrialization of intra-African trade (thanks to productivity gains); TF is one of the 7 priority clusters of BIAT action plan

## 2. Key findings

### b. Regional integration

Share of intra-regional trade versus share of regional value added in intra-regional trade, by main region, 2011 (%)



Source: WTO, *International Trade Statistics* (2012) and ECA computations

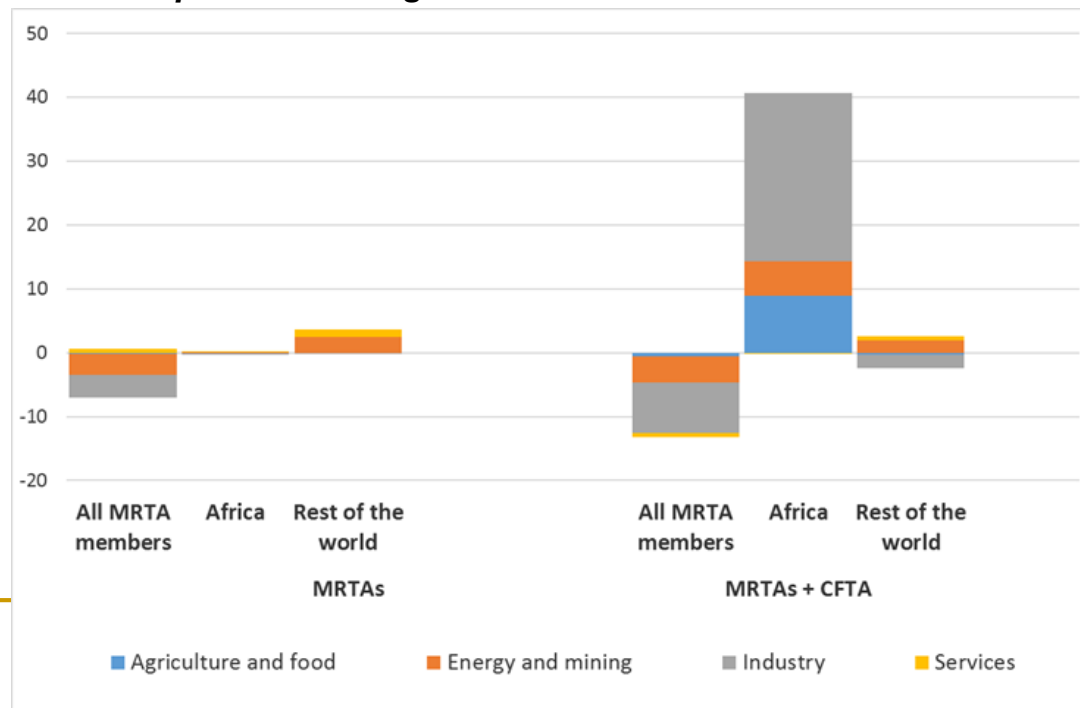
- The AfCFTA expected to enhance and diversify intra-African trade could increase output of value-added products issues from the regional market, thereby supporting regional value chains (RVCs)

## 2. Key findings

### b. Regional integration

- AfCFTA is also an imperative in the context of emergence of mega-regional trade agreements (i.e. TTIP ?, TPP (now CPTPP) and most importantly RCEP)
  - ✓ Preference erosion and increased competition for Africa on MRTA markets;
  - ✓ ECA's CGE modeling analysis finds RCEP to be most diverting for Africa's trade with considerable decrease of Africa's exports to India and China;
  - ✓ Outcomes to drastically change if AfCFTA established in parallel; thanks to strong increase in intra-African trade.

*Changes in **Africa's exports** following MRTAs alone vs. MRTAs+AfCFTA – 2040 – US\$ billion*



*Source: based on MIRAGE CGE model (see Mevel et Mathieu (2016))*

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## 2. Key findings

### b. Regional integration

- However, regional integration cannot be Africa's sole strategy:
    - ✓ Africa's share in global trade is less than 3%
    - ✓ Although full of potential, continental market is unlikely to provide trade opportunities that are ample enough to trigger a significant improvement of Africa's position in the world trade landscape
  - African economies need to open up with partners from outside the continent
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## 2. Key findings

### c. Opening up Africa's market through reciprocal agreements

- ***Example 1 - Economic Partnership Agreements (EPAs) with the EU; ECA's CGE modeling analysis indicating that:***
    - ✓ Africa would get trade gains with EPAs but mostly concentrated in non-industrial sectors (i.e. rice, milk, sugar and meat) and benefiting essentially African non-LDCs
    - ✓ However, increase in Africa's exports to the EU would come at the expense of intra-African trade
    - ✓ As for MRTAs, the CFTA is expected to mitigate any trade-related losses resulting from the EPAs on Africa
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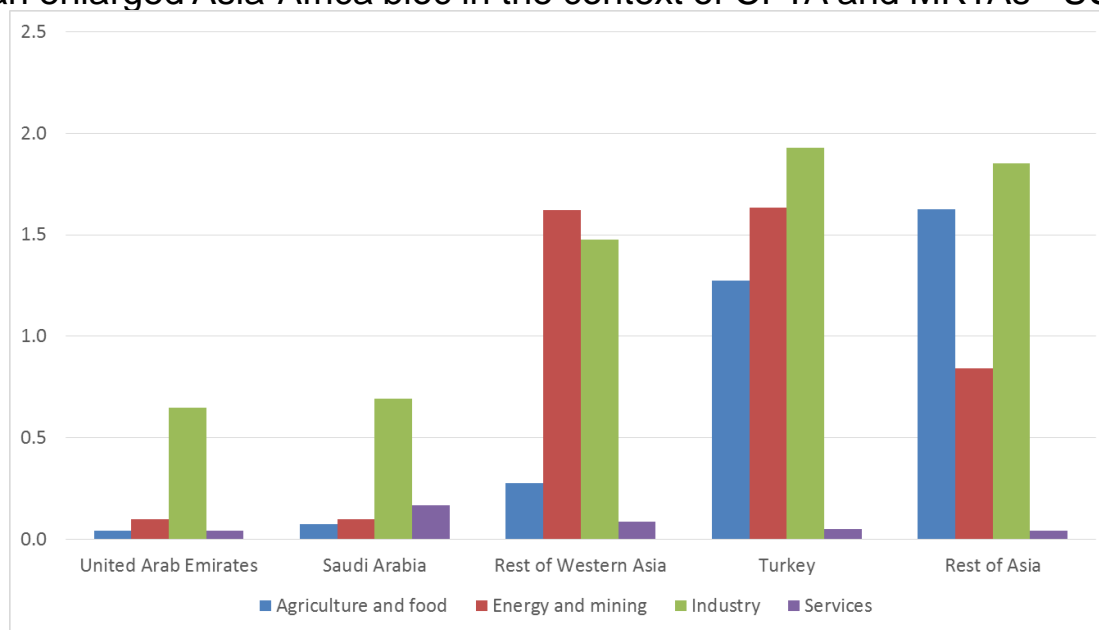
## 2. Key findings

### c. Opening up Africa's market through reciprocal agreements

#### ➤ ***Example 2 - Deepening integration between Africa and its South partners; ECA's CGE work demonstrates that:***

- ✓ It is when Africa enters into profound trade integration with Asian countries, beyond RCEP (particularly with countries from Western Asia) that the potential to support Africa's diversification and industrialization would be the greatest

Changes in Africa's exports to non-RCEP Asian countries/regions and main sectors following implementation of an enlarged Asia-Africa bloc in the context of CFTA and MRTAs– US\$ billion – 2022



Source: based on MIRAGE CGE model (see Mevel et Mathieu (2016))

- ✓ Depending integration between Africa and its South-South partners would not just be in Africa's interest; exports of Africa's counterparts would also be strongly stimulated

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## **II. Using CGE modeling results to inform and guide policy decision**

- 1. Focus, motivation, objective and methodology**
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### 3. Conclusion and influence

#### ❑ What did ECA's CGE modeling findings tell us about industrializing through trade in the African context?

- The right sequencing of trade policy reforms matters substantially:
  - ✓ **Africa's top priority should be to establish the AfCFTA along with complementary reforms (e.g. trade facilitation measures)**

*(For mitigating trade losses expected to be brought about by MRTAs, boosting intra-African trade, ensuring trade policy coherence, building the required RVCs to better go up the GVCs and enhancing Africa's competitiveness)*

- Then, Africa would be in better position to open up with outside partners (particularly with emerging partners from Asia and Western Asia) and improving its position in the global and rapidly evolving trade landscape

#### ❑ ECA's CGE modeling work has been instrumental in the AfCFTA process; and continues being highly demanded by member States and RECs

### 3. Conclusion and influence

- ❑ **On 21 March 2018, in Kigali, Rwanda:**
  - 44 African Union (AU) member States did sign the Agreement establishing the African Continental Free Trade Area (AfCFTA)
  - An additional 6 AU member States signed the Kigali Declaration by which they commit to sign the AfCFTA Agreement, after enough national consultations have taken place
  - Only 5 AU member States (i.e. Burundi, Eritrea, Guinea-Bissau, Nigeria and Sierra Leone) did not sign either of the 2 above legal documents as of today; but it is hoped they will all eventually sign
- ❑ **Ongoing technical work by ECA to shed light on pending issues and assisting member States with the development of their tariff offers**
- ❑ **ECA to undertake new CGE assessment of the AfCFTA based on latest modalities on goods, with attempt to look at RoO, liberalization of trade in services as well as improvements of NTBs/NTMs**

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# Thank you very much for your kind attention!

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