# Estimating Indirect Costs of Natural Disasters: effects of the rebuilding demand

S. Juhel[1,2], A. Delahais[2], V. Viguie[2]

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[1]LMD, [2]CIRED

# Introduction

# Indirect economic impacts definition

REUTERS

World Business Markets Breakingviews Video Mo

ENVIRONMENT OCTOBER 28, 2011 / 7:22 AM / UPDATED 10 YEARS AGO

**Thai floods batter global electronics, auto supply chains**

By Ploy Ten Kate, Chang-Ran Kim

6 MIN READ

BANGKOK/TOKYO (Reuters) - Manufacturers of car parts to computer hard

*Indirect economic impacts* generally arise due to the disruption of the flows of goods and services (and therefore economic activity) because of a disaster. (IPCC - SREX 2012)

# Diverse modeling methods[1]

**Computable General Equilibrium (CGE)**
Better adapted for long term analysis (substitution of factors and inputs)

e.g. Rose, Liao, and Bonneau, 2011

ARIO model

**IO-Model**
Better adapted for short term analysis (no substitution)

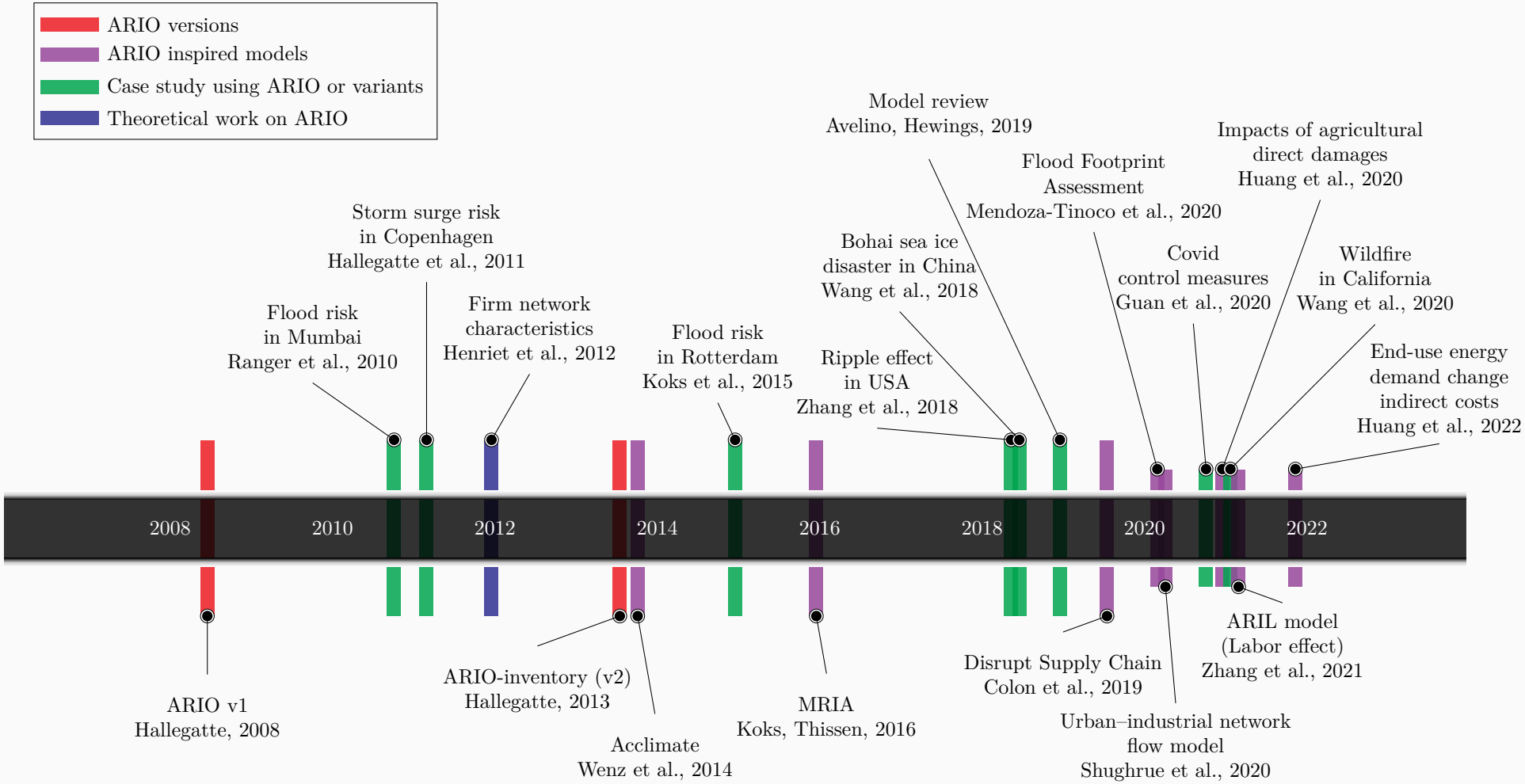
e.g. Hallegatte, 2013

**Agent based models**
More versatile, but require to calibrate many parameters

e.g. Otto et al., 2017

[1] A review of these: Botzen, Deschenes, and Sanders, 2019.

# ARIO


ARIO versions
ARIO inspired models
Case study using ARIO or variants
Theoretical work on ARIO
2008
2010
2012
2014
2016
2018
2020
2022
ARIO v1
Hallegatte, 2008
Flood risk
in Mumbai
Ranger et al., 2010
Storm surge risk
in Copenhagen
Hallegatte et al., 2011
Firm network
characteristics
Henriet et al., 2012
ARIO-inventory (v2)
Hallegatte, 2013
Acclimate
Wenz et al., 2014
Flood risk
in Rotterdam
Koks et al., 2015
MRIA
Koks, Thissen, 2016
Bohai sea ice
disaster in China
Wang et al., 2018
Ripple effect
in USA
Zhang et al., 2018
Model review
Avelino, Hewings, 2019
Flood Footprint
Assessment
Mendoza-Tinoco et al., 2020
Disrupt Supply Chain
Colon et al., 2019
Urban–industrial network
flow model
Shughrue et al., 2020
Covid
control measures
Guan et al., 2020
Impacts of agricultural
direct damages
Huang et al., 2020
ARIL model
(Labor effect)
Zhang et al., 2021
Wildfire
in California
Wang et al., 2020
End-use energy
demand change
indirect costs
Huang et al., 2022

# Research question

What is the robustness of the modelling of indirect economic impacts of natural disasters ?

# Main findings

- Modeling demand surge is key
- In this case:
  - Rebuilding process pace has the most implications
  - High sensitivity to economic data (MRIOT)
  - Higher sensitivity to model parameters (than without demand)

# Methodology

# Evaluation framework

**ARIO model**
Widely used model, basis for other indirect costs models.

BoARIO: Open -source -access Python implementation (generic, modular, efficient, documented)

**Economic data**
Three different Multi Regional Input Output Tables (MRIOTs) (year 2000 and 2010):

- EXIOBASE3 (163 sectors, 44 countries and 5 RoW regions)
- EORA26 (26 sectors, 189 countries)
- EUREGIO (14 sectors, 247 UE NUTS2 regions, 16 countries)

# Case study : July 2021 floods in Germany

Flash floods in Insul, Germany - July 2021 - AP Photo/Michael Probst

# Case study : July 2021 floods in Germany

- Direct impacts well evaluated (BMI, 2022; Trenczek et al., 2022; Munich RE, 2005)
- Large scale event: €33.4 billion direct damages
- In UE (matches EUREGIO MRIOT)

# ARIO model essentials

- Economy modeled as a set of *industries* (region,sector) and *final clients*, based on a MRIOT
- Shocks are a temporary *reduction in production* capacity and (possibly) a *rebuilding demand*
- Model outputs are time-series of the economy after the shock

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# Rebuilding/Recovery scenarios simulated

We consider two cases:

- No rebuilding demand, but a gradual recovery of production capacity
- A rebuilding demand corresponding to the direct damages, production capacity restored as demand is answered

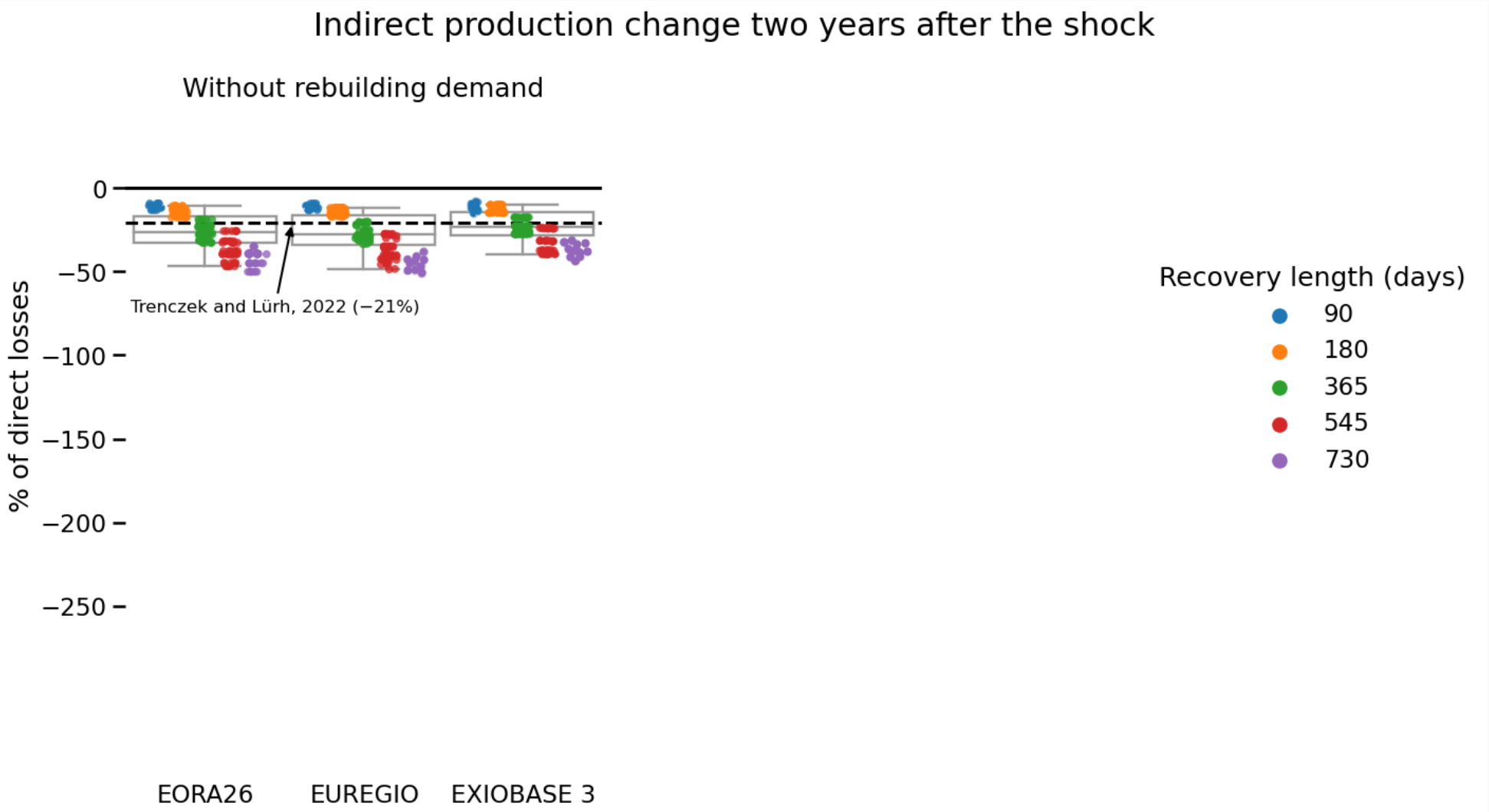
And different rebuilding/recovery duration:

- 3 months
- 6 months
- 12 months
- 18 months
- 24 months

(We also run simulations for a wide range of values for other parameters of the model)

# Results

# Effects of considering rebuilding demand : local results



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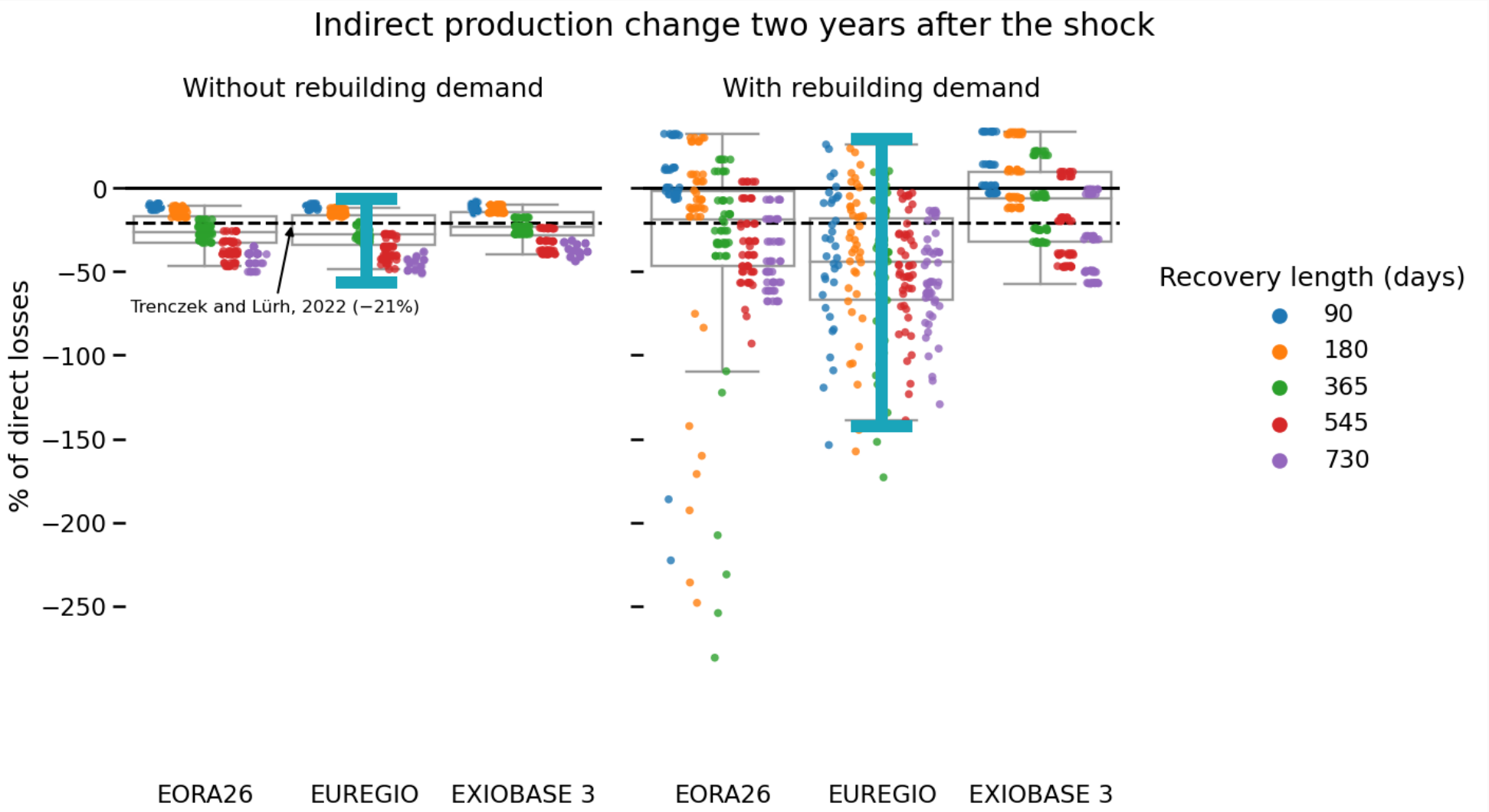

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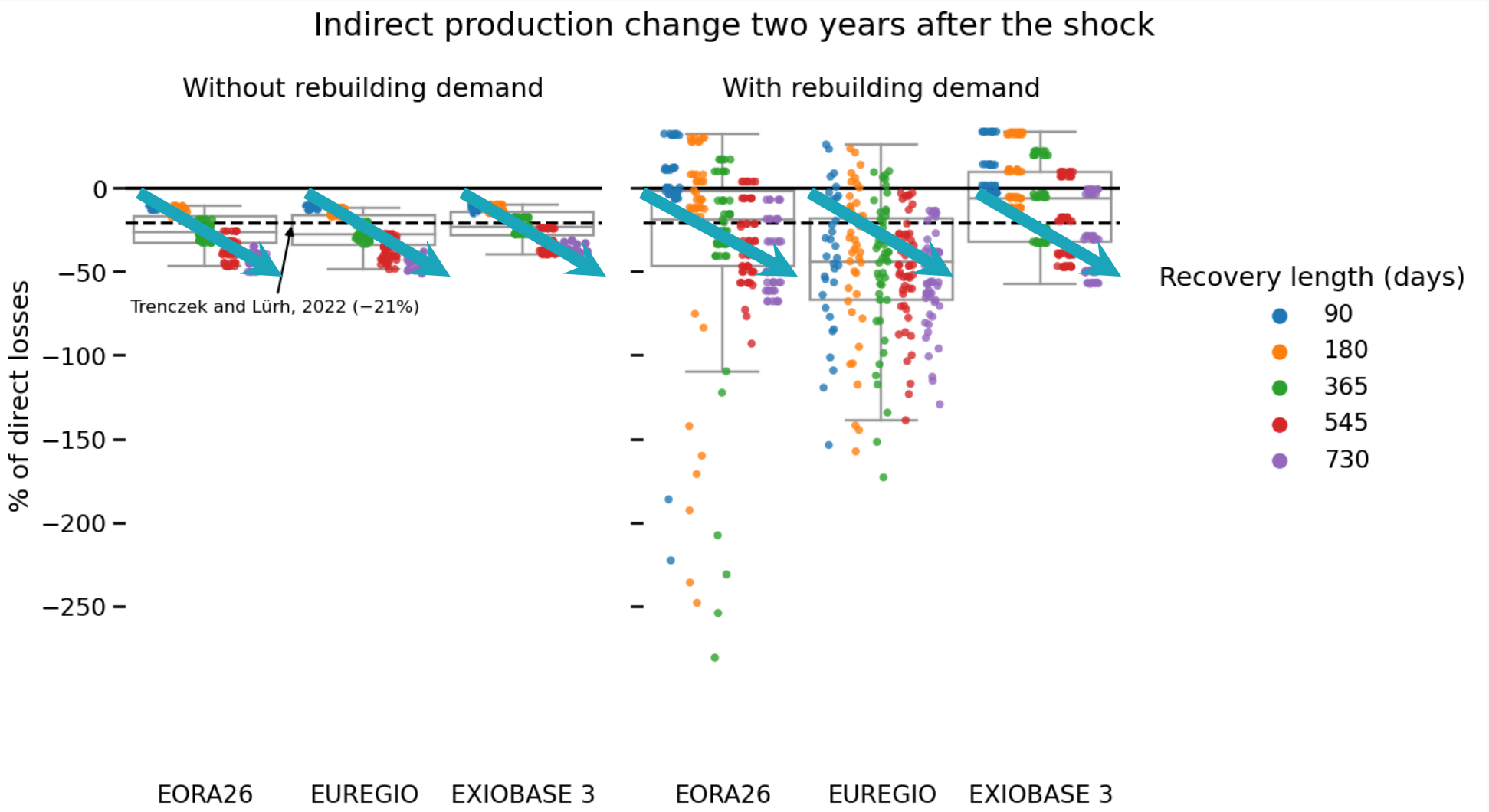

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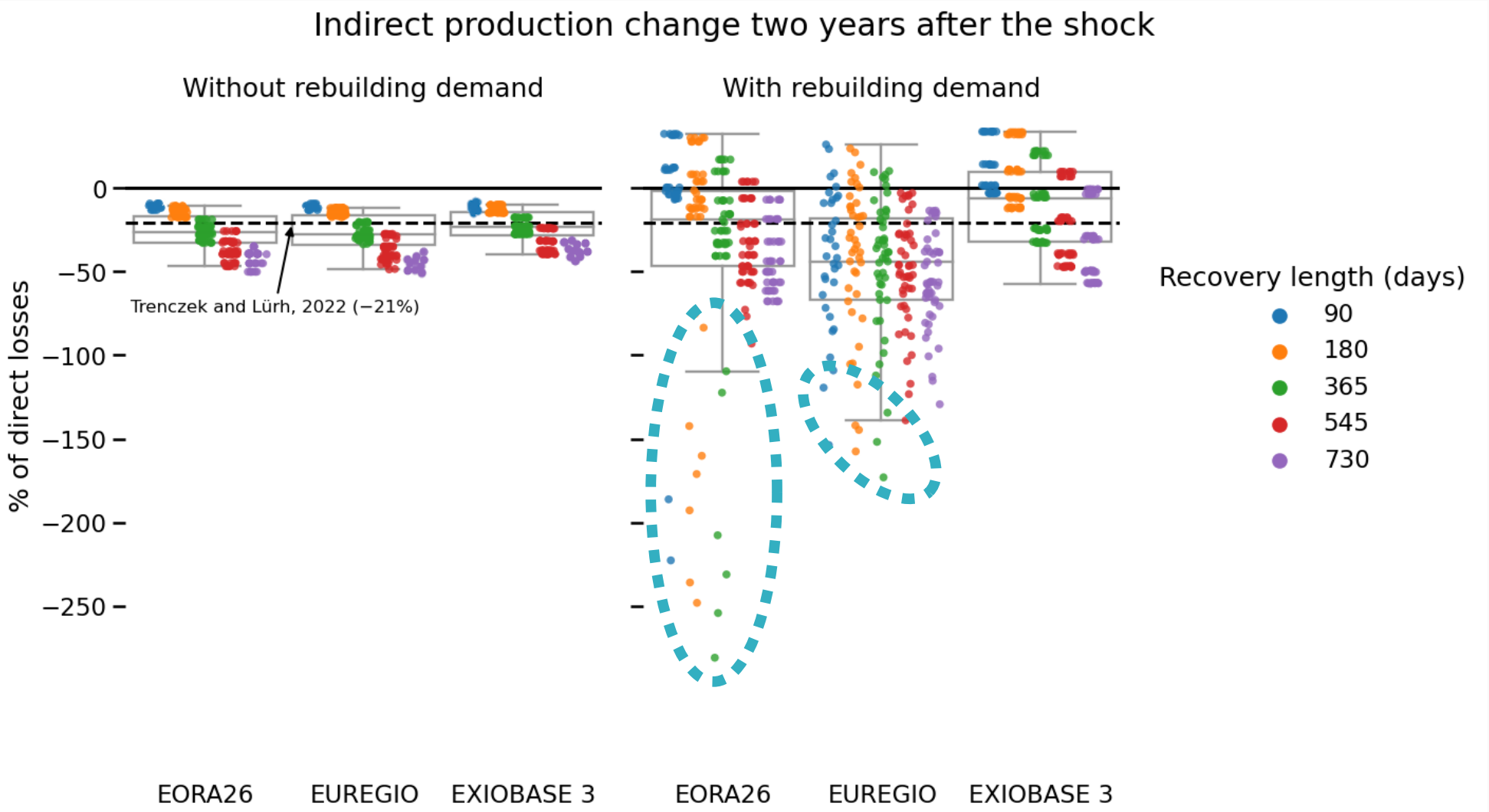
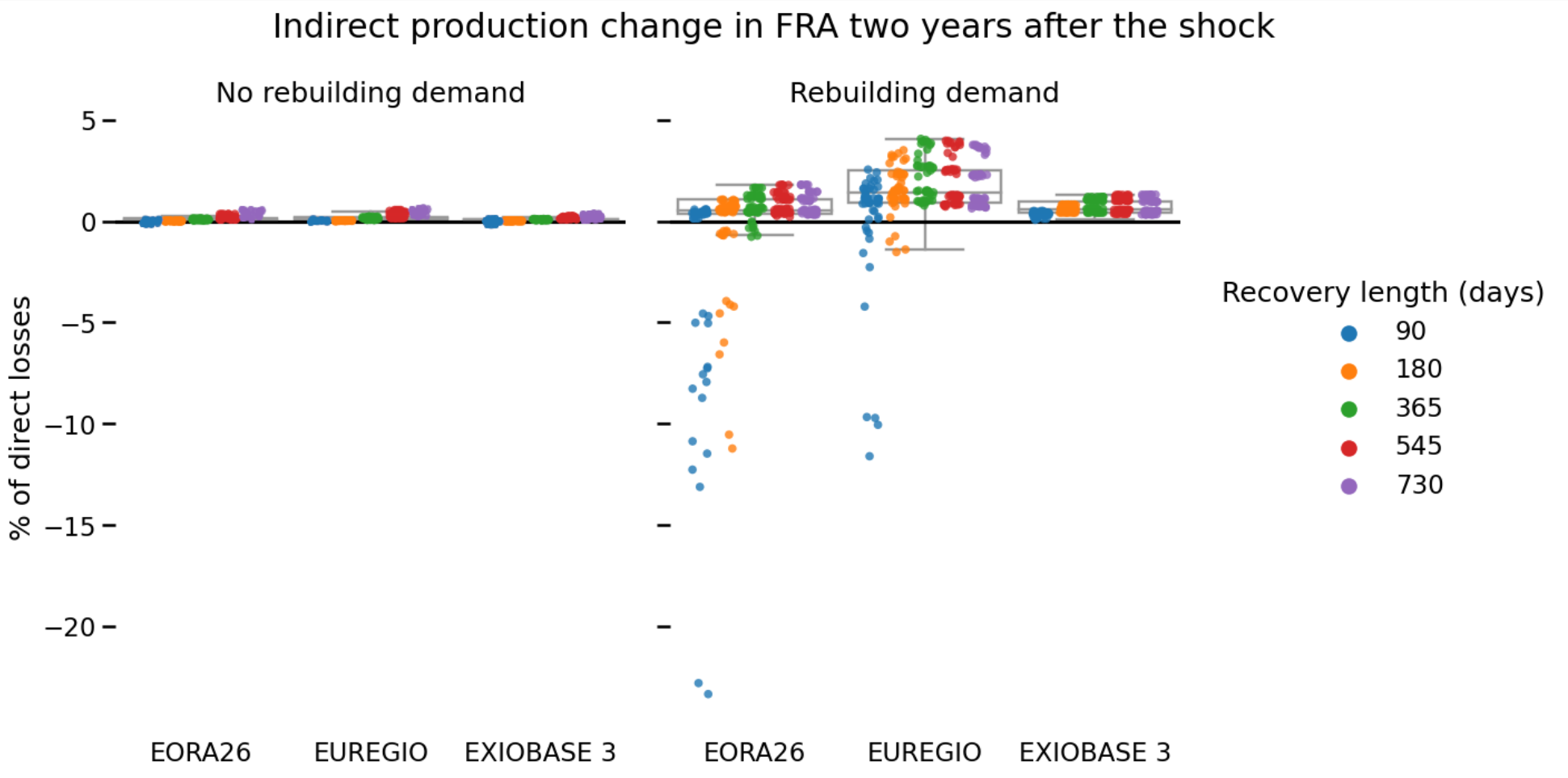


# Effects of considering rebuilding demand : in France



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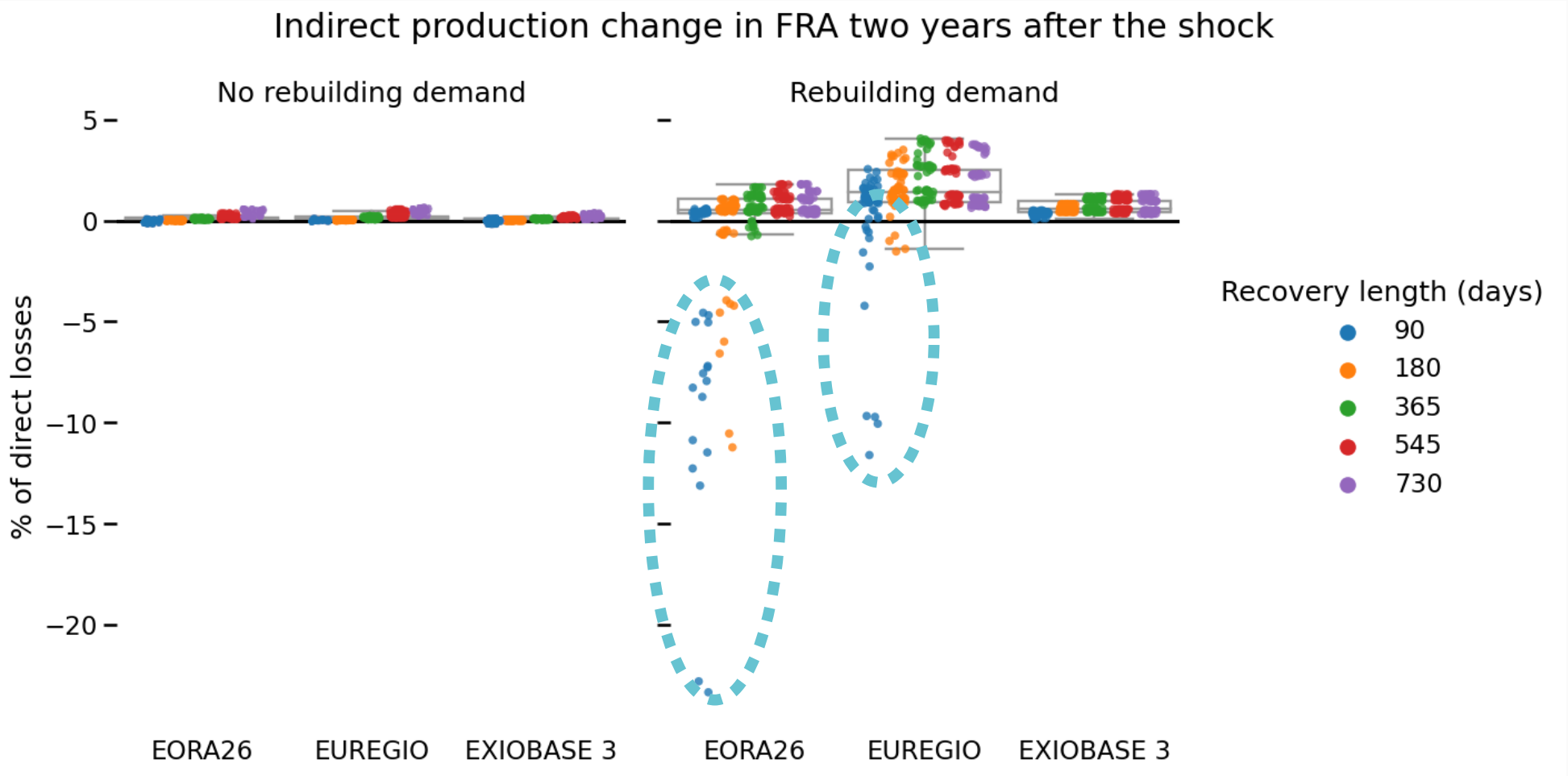

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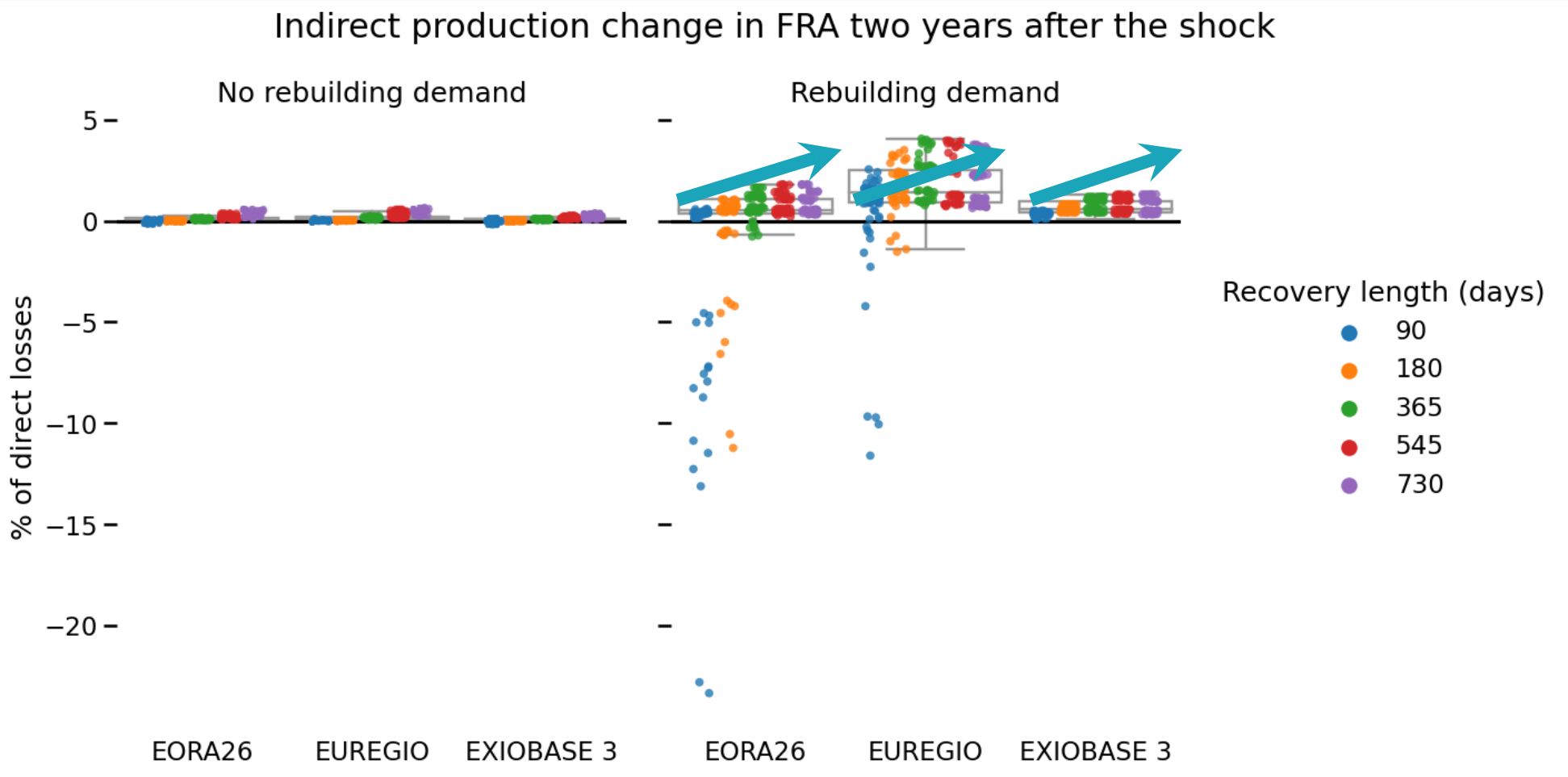

# Conclusions

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- Parameters and MRIOT choices can also influence the results, but mostly when demand surge is considered
- Negative outcomes are mainly local, and foreign production tends to benefit from local losses

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# Limits and further research

- Prices are considered constant
  $\implies$ real impact on welfare is uncertain
- Demand surged is entirely insured
  $\implies$ losses and recovery are underestimated
- Critical chains are unlikely accounted for
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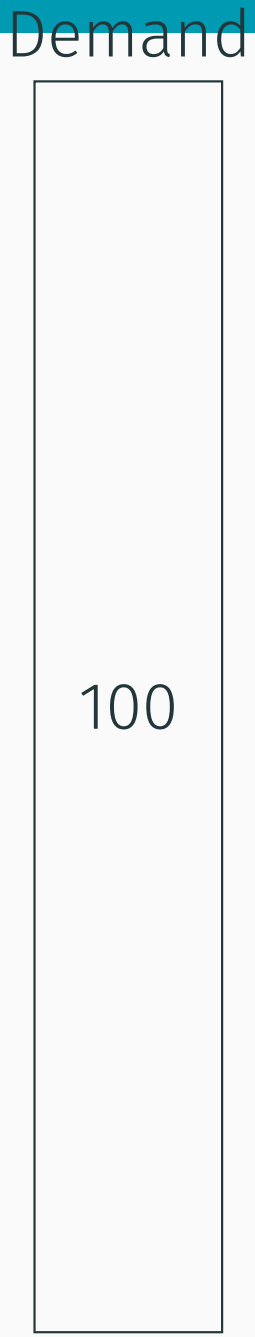
Thank you for your attention !

# Appendices

- Rationing scheme
- Model diagram
- Formalism
- Production
- Inventories
- Distribution scheme
- Orders
- Damages
- Recovery

# Proportional rationing scheme



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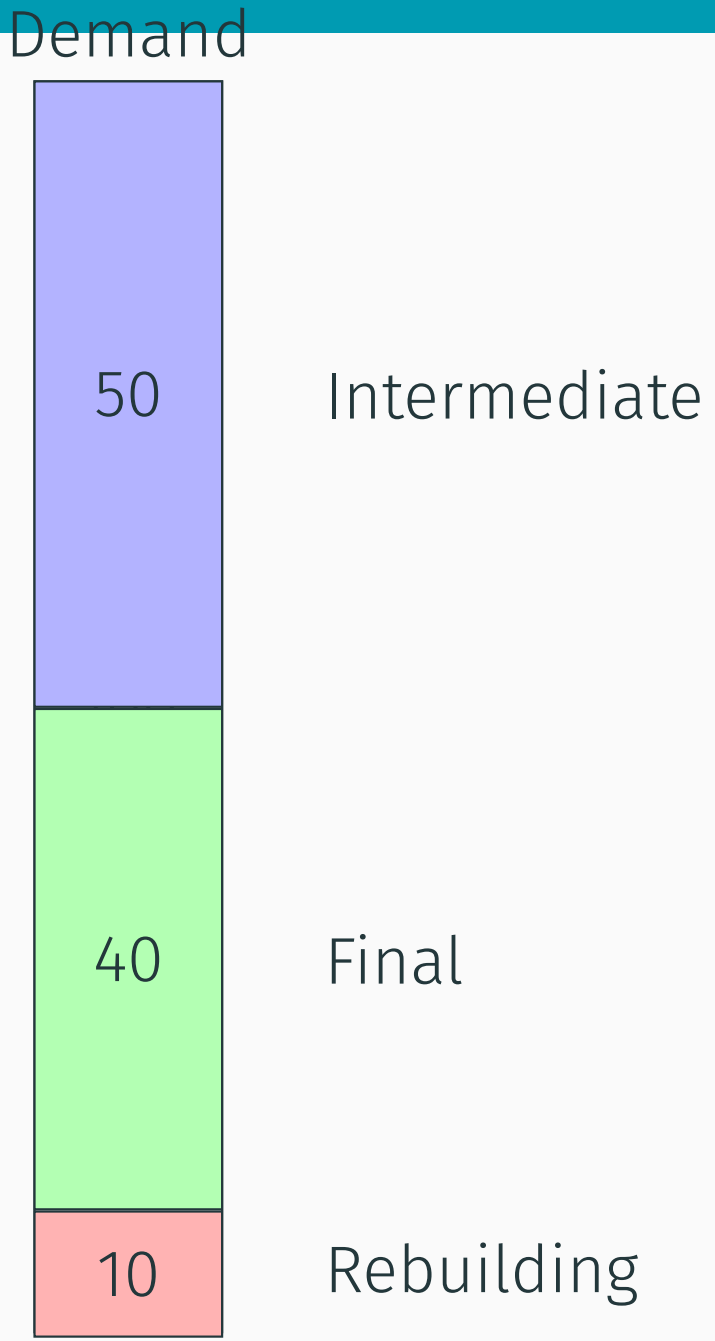

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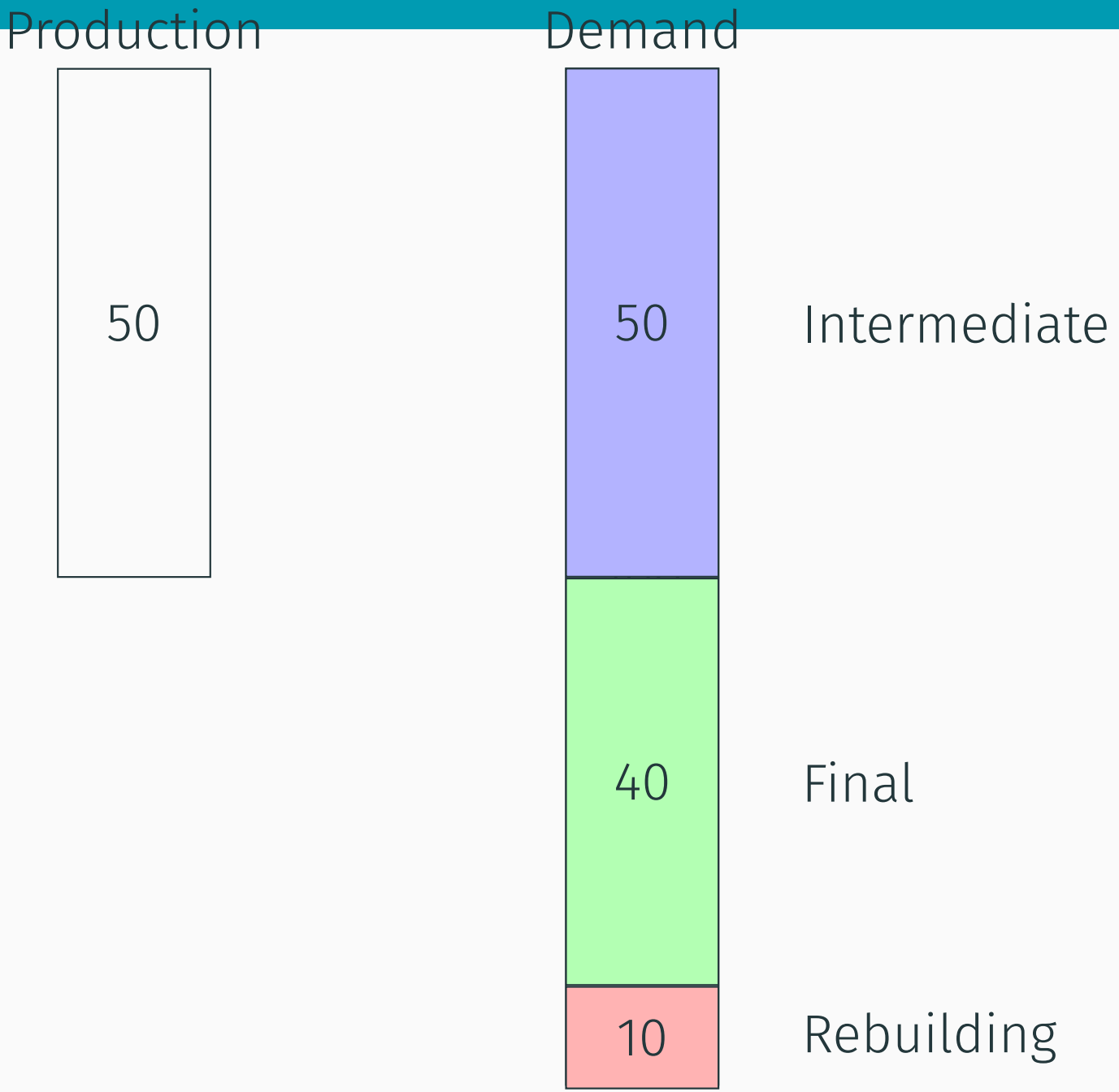

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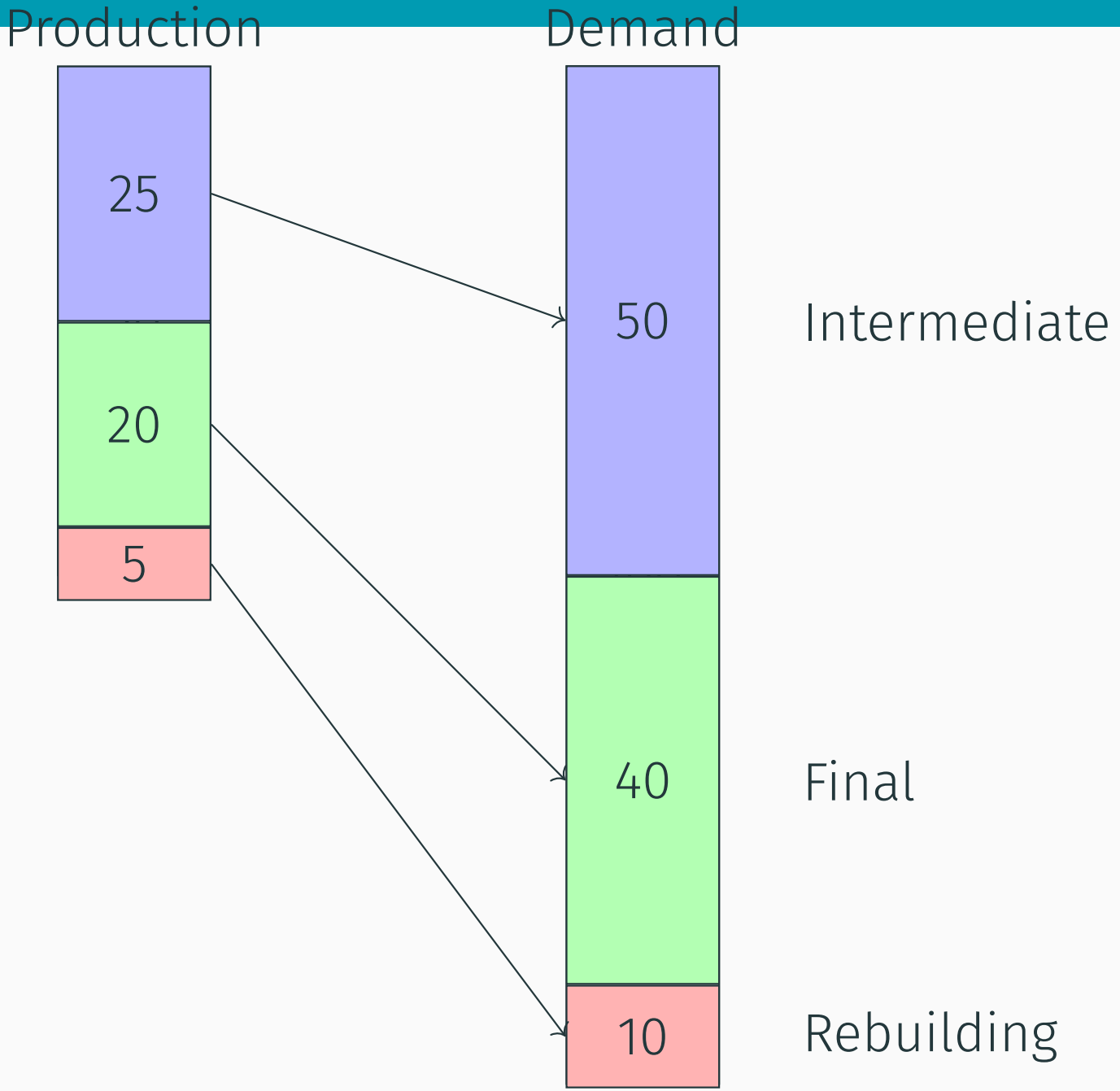

# Model diagram


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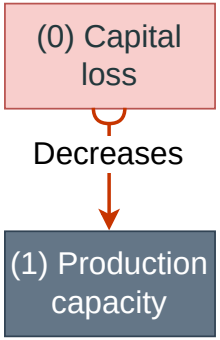


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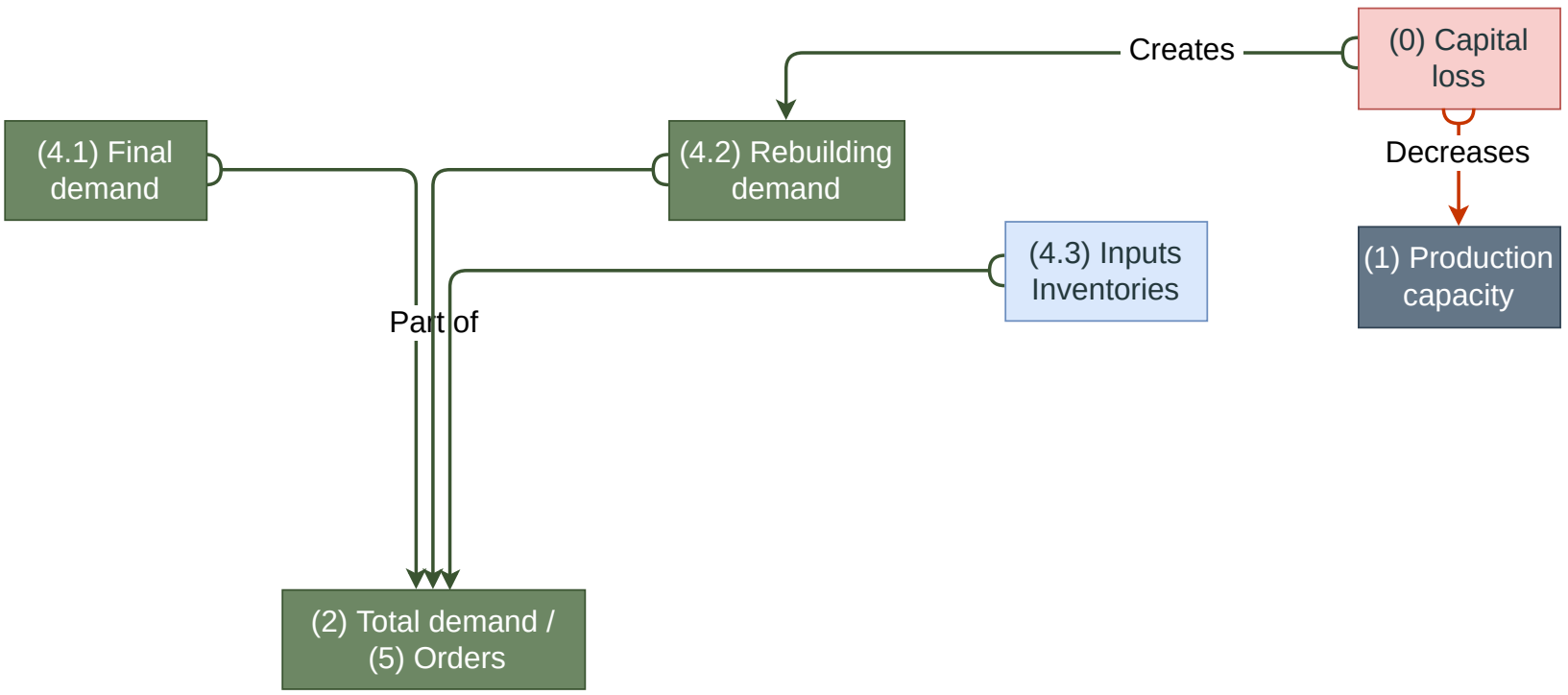


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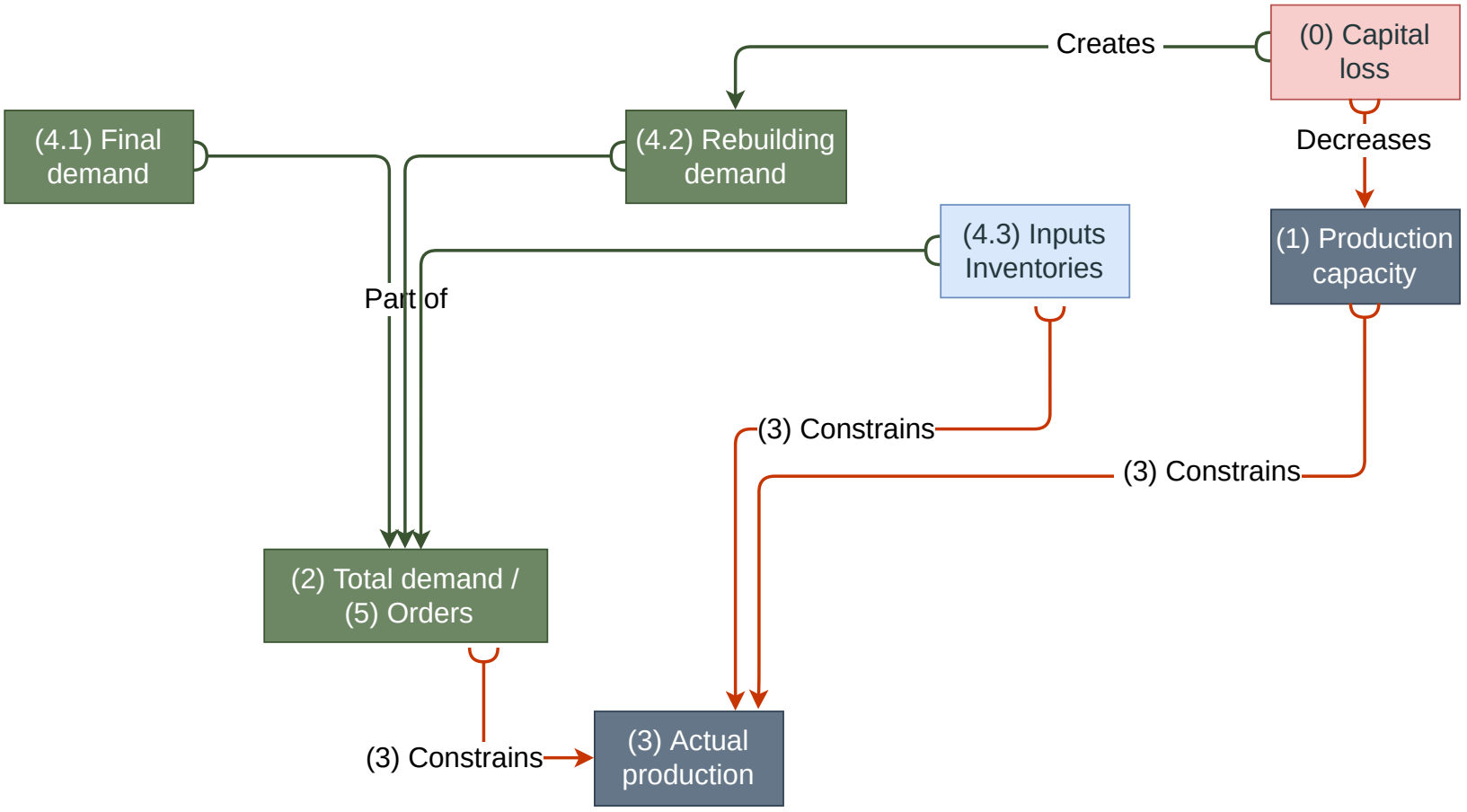


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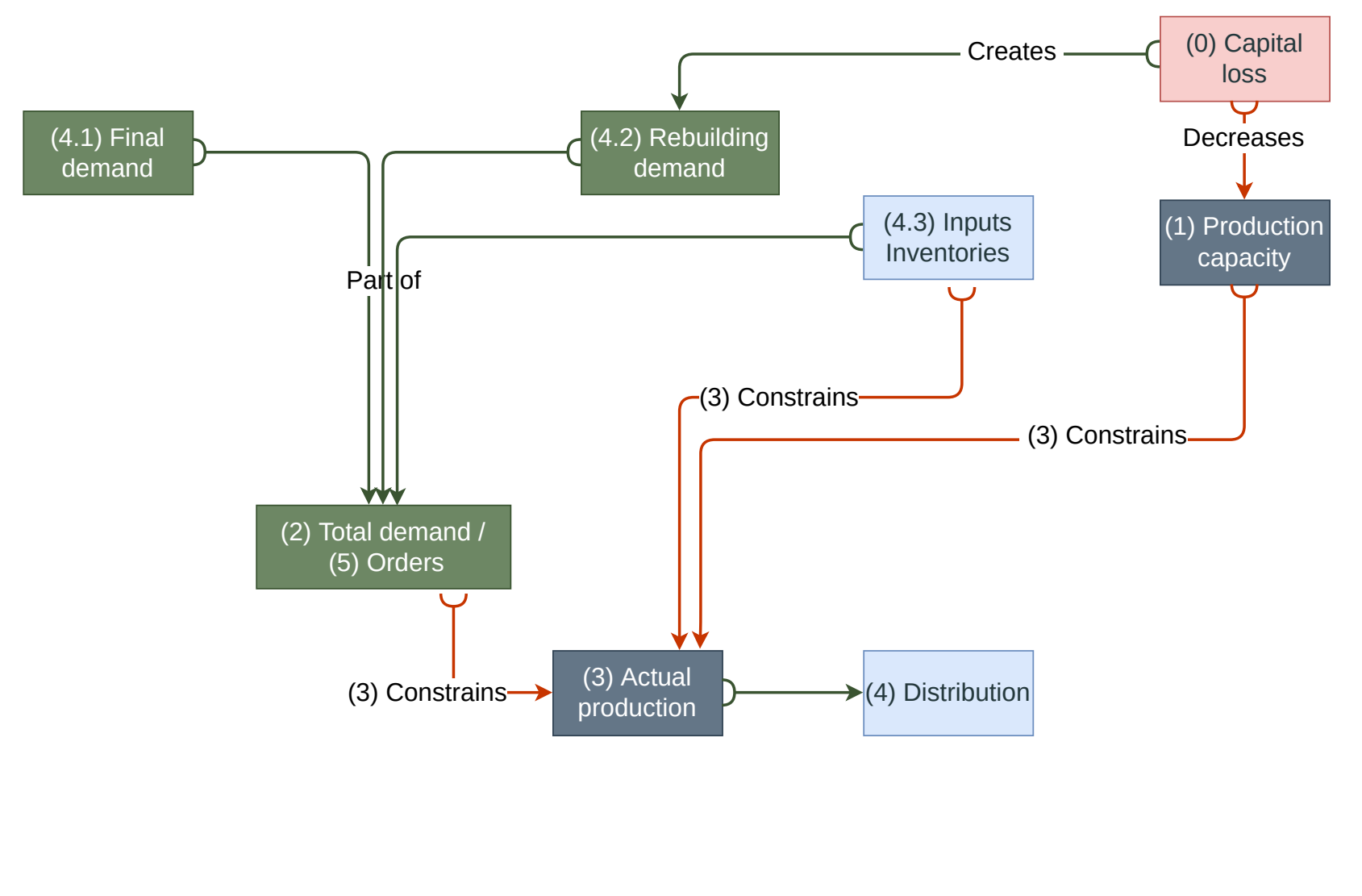


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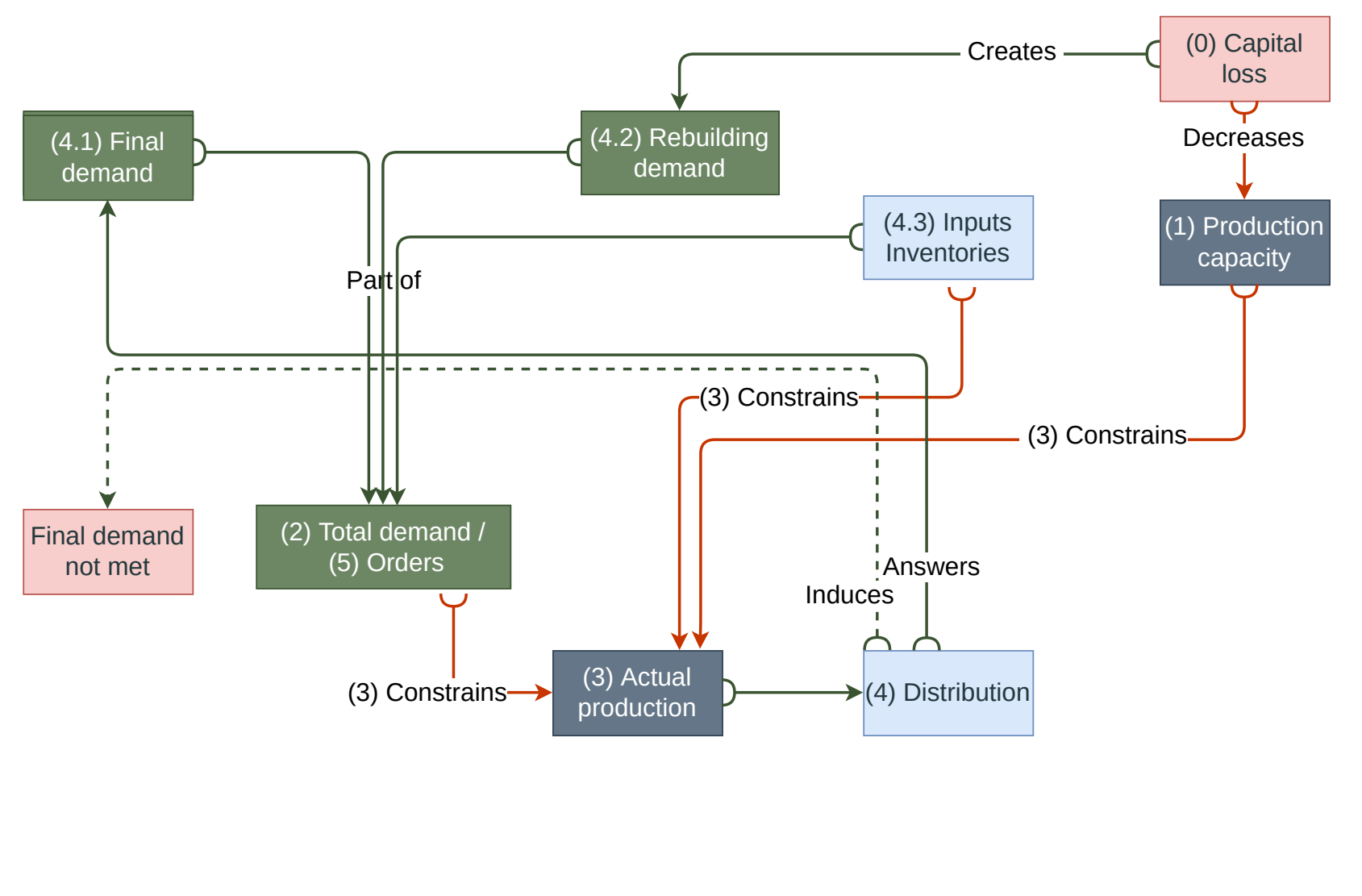


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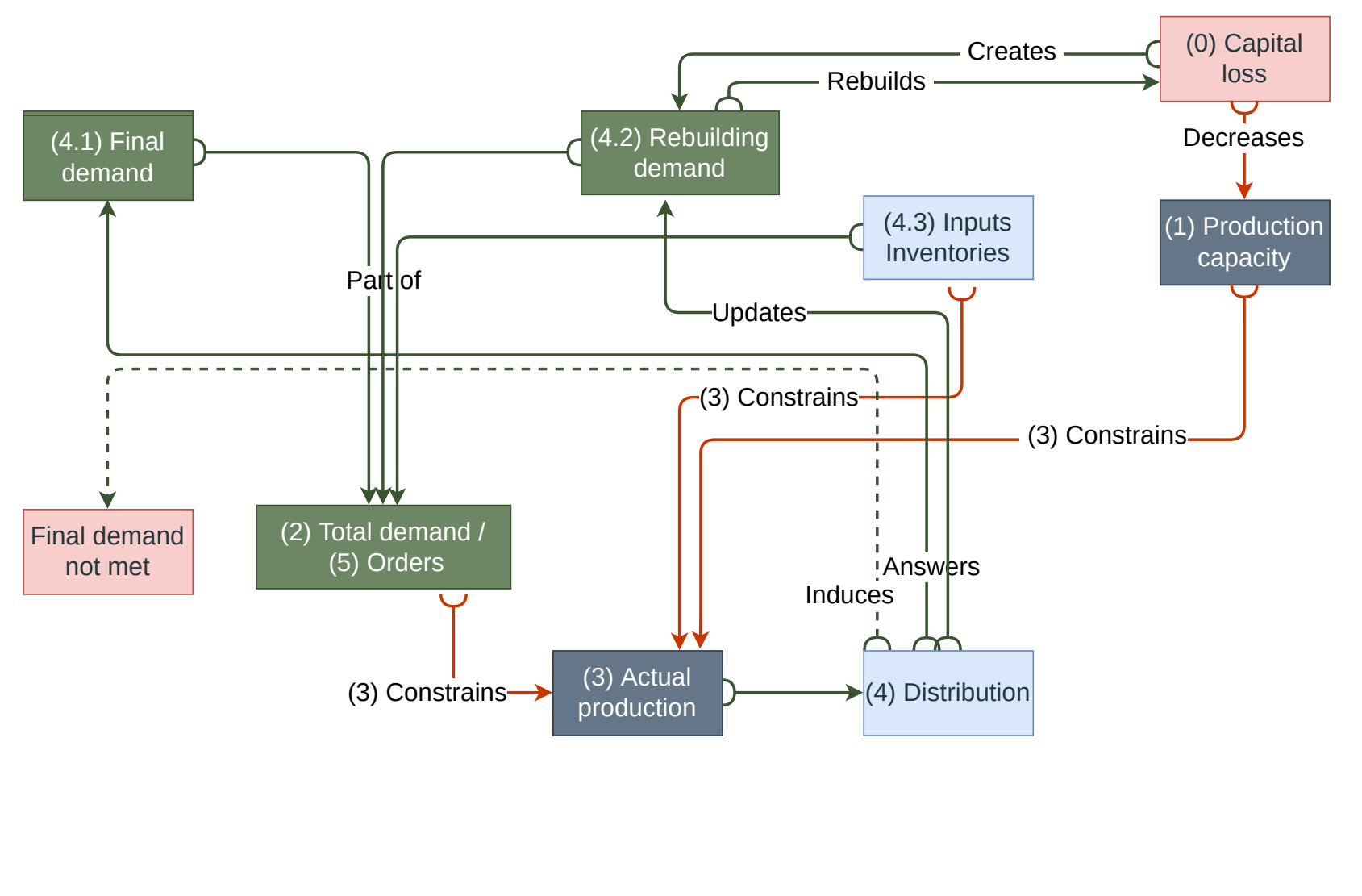


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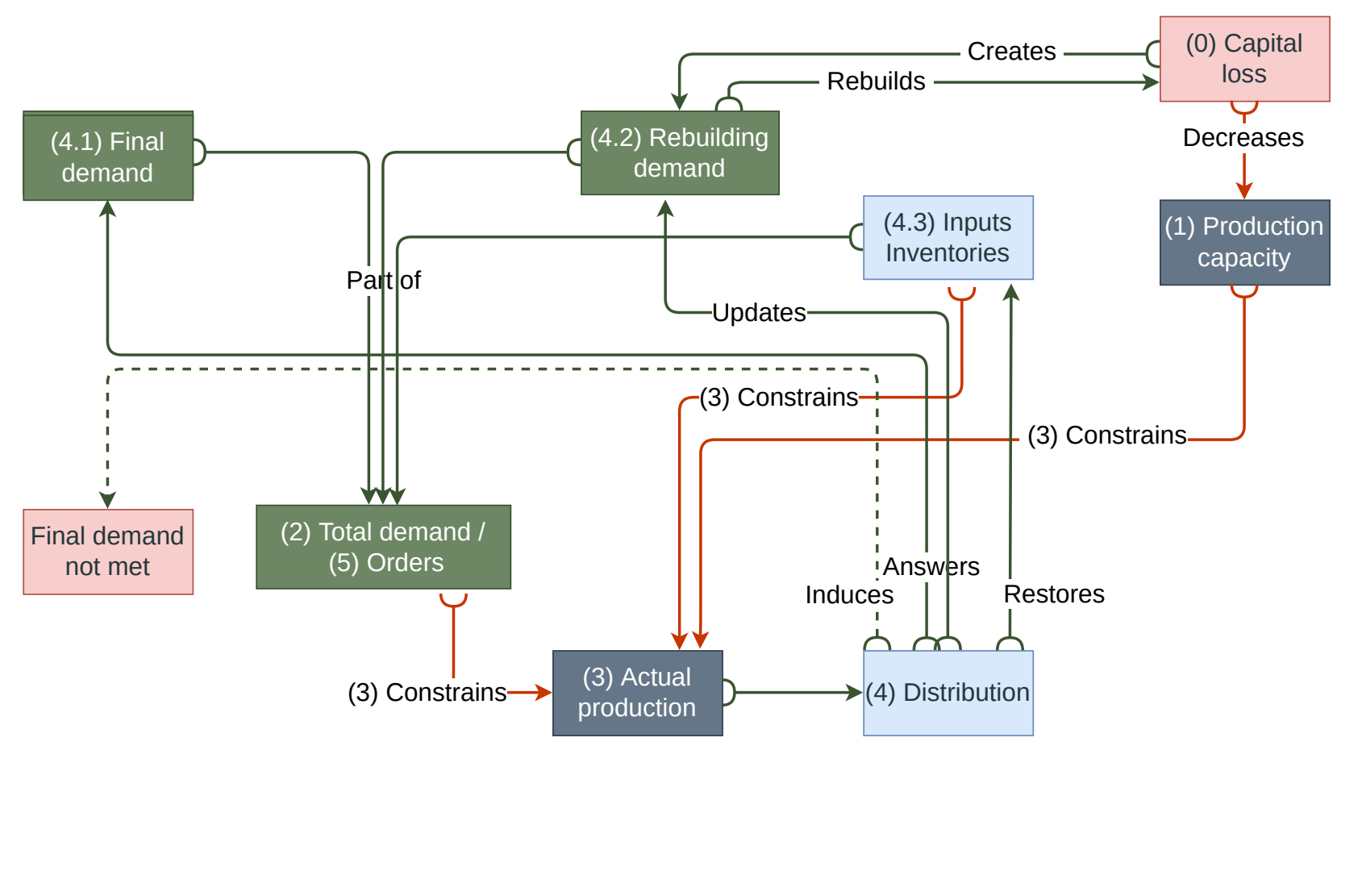


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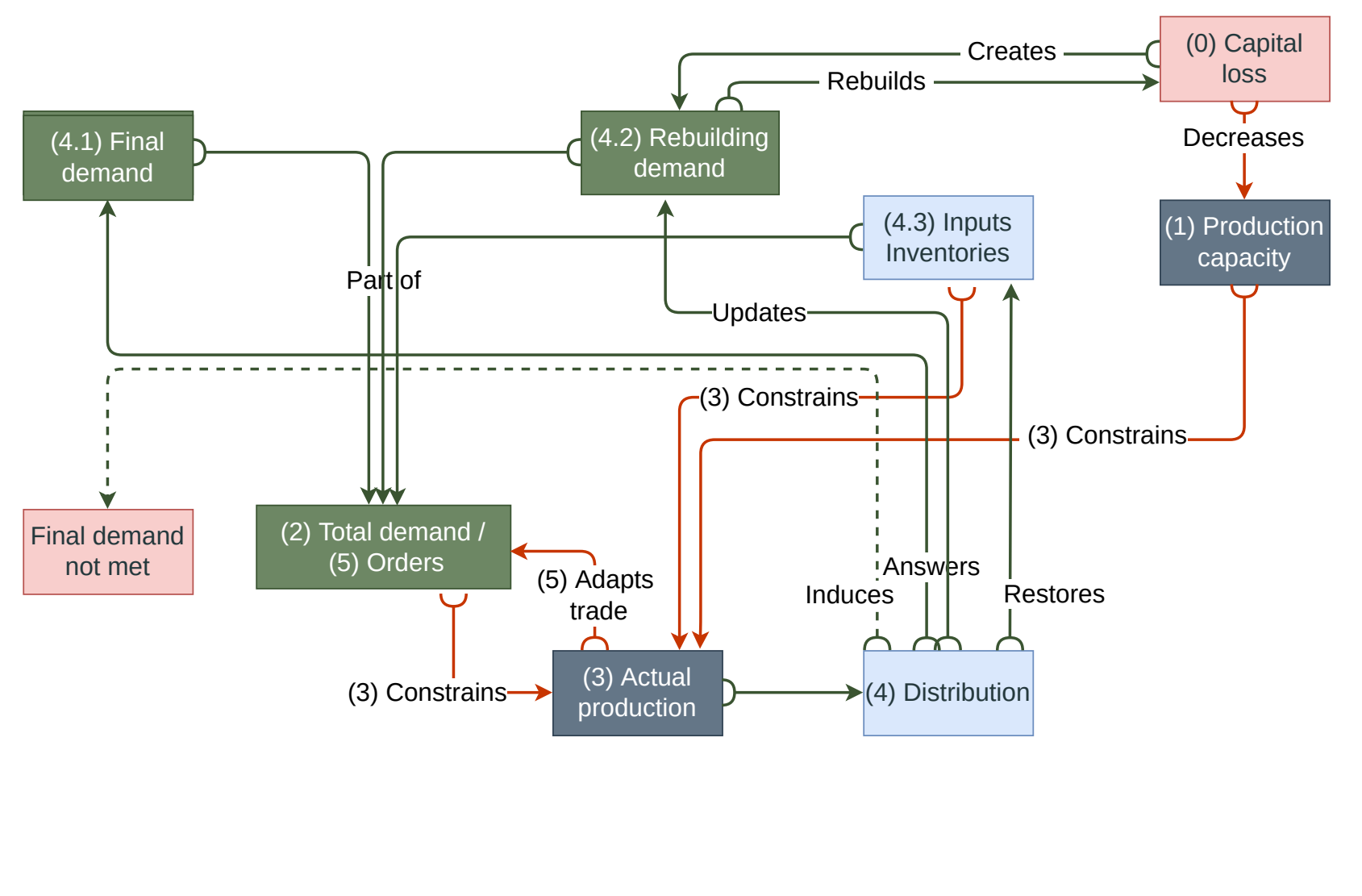


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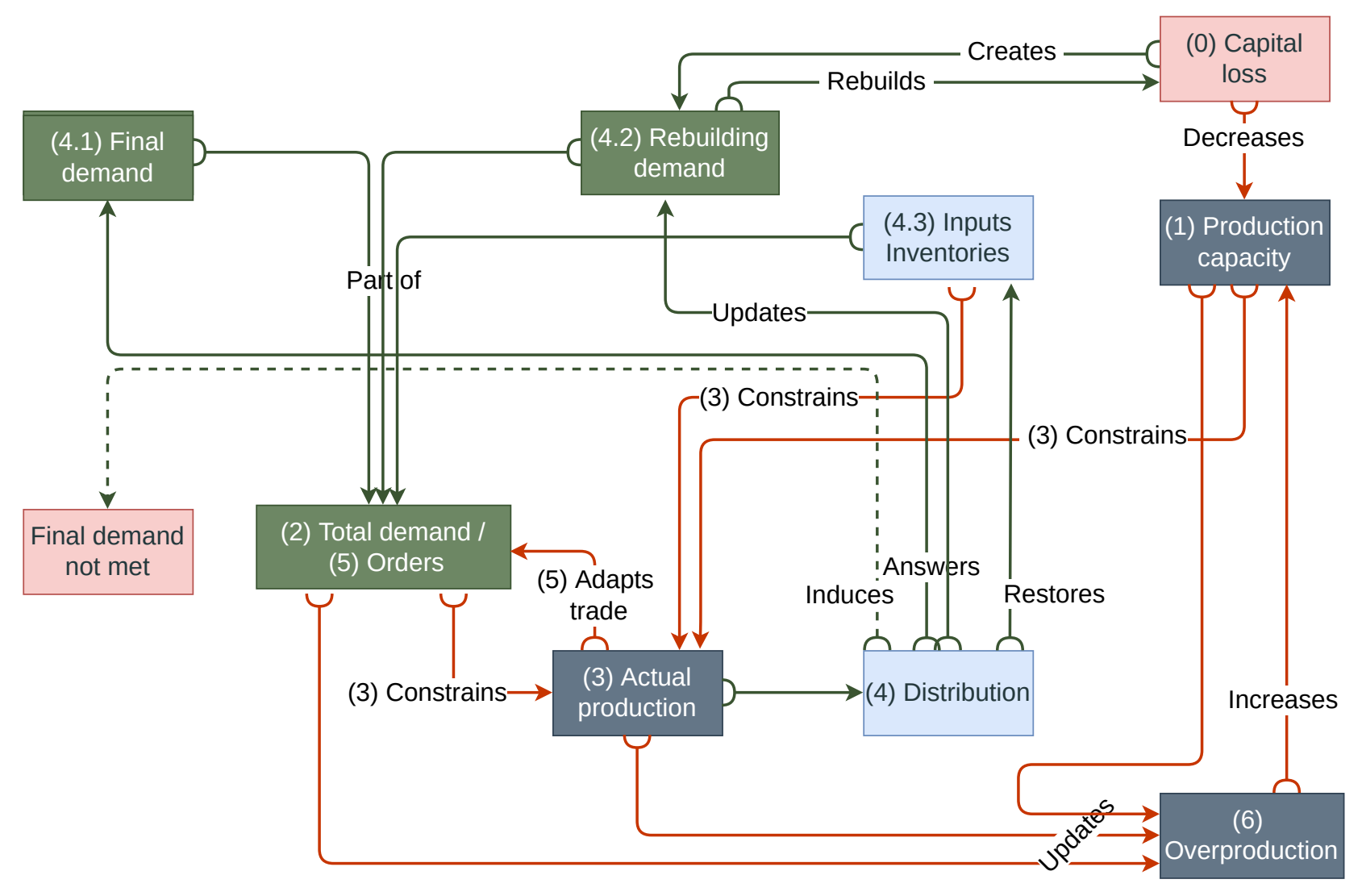



menu

# Formalism presentation

1. Production
2. Inventories
3. Distribution scheme
4. Orders
5. Damages
6. Recovery

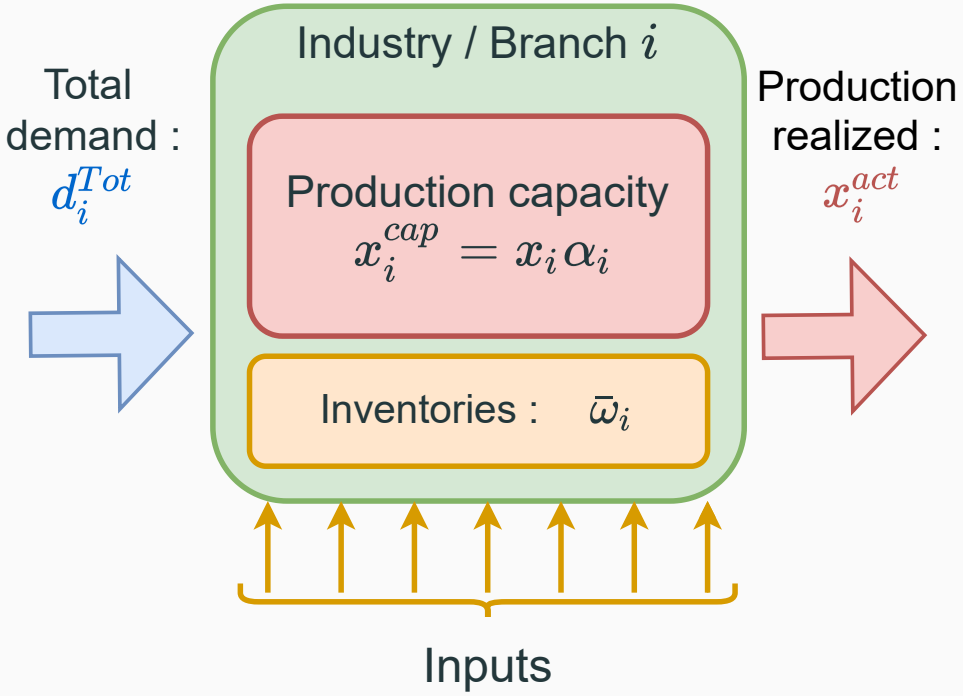
Point of view of an *industry*,

(i.e a sector in a region)

# Production

Base production $x$ from IO table.

$\alpha_i$: overproduction factor.




Constraints on actual/realized production:

1. $x_i^{act} \leq d_i^{tot}$
2. $x_i^{act} \leq x_i^{cap}$
3. $x_i^{act} \leq$ production *allowedby inventories constraints.*

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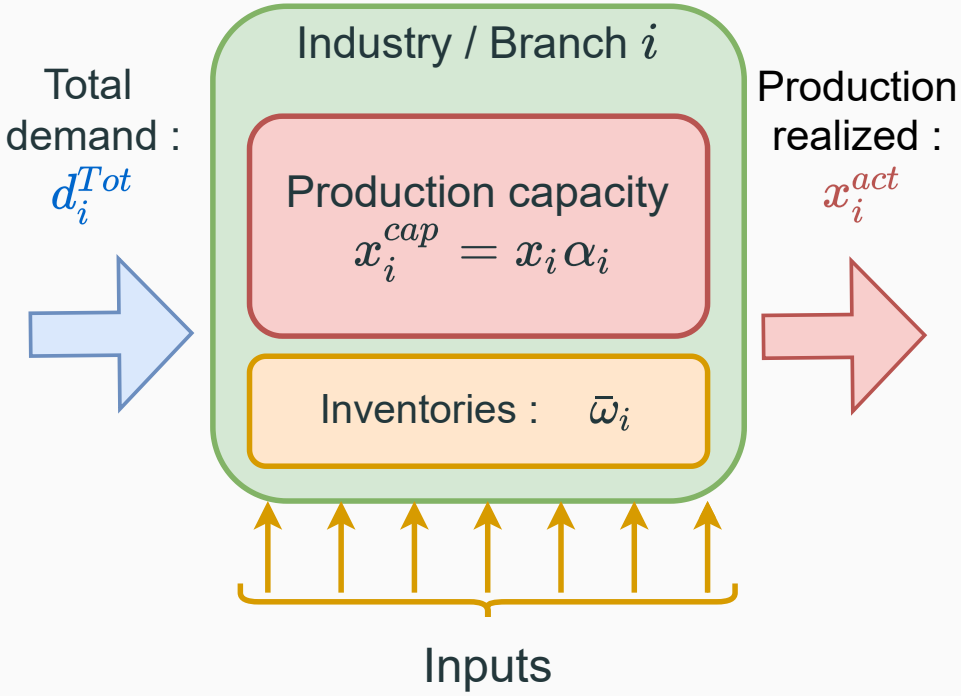


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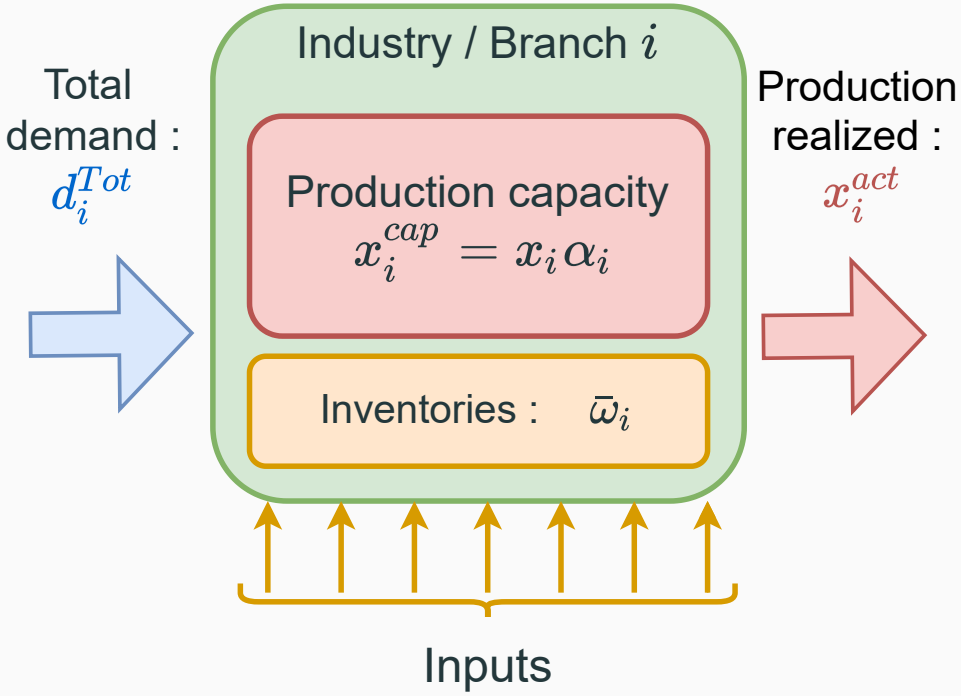


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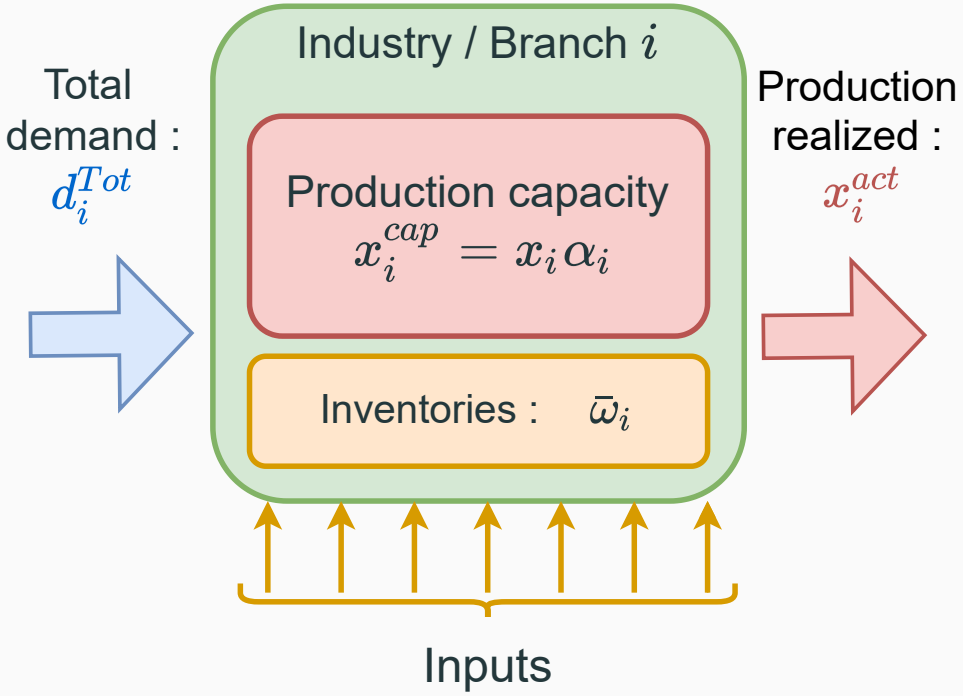


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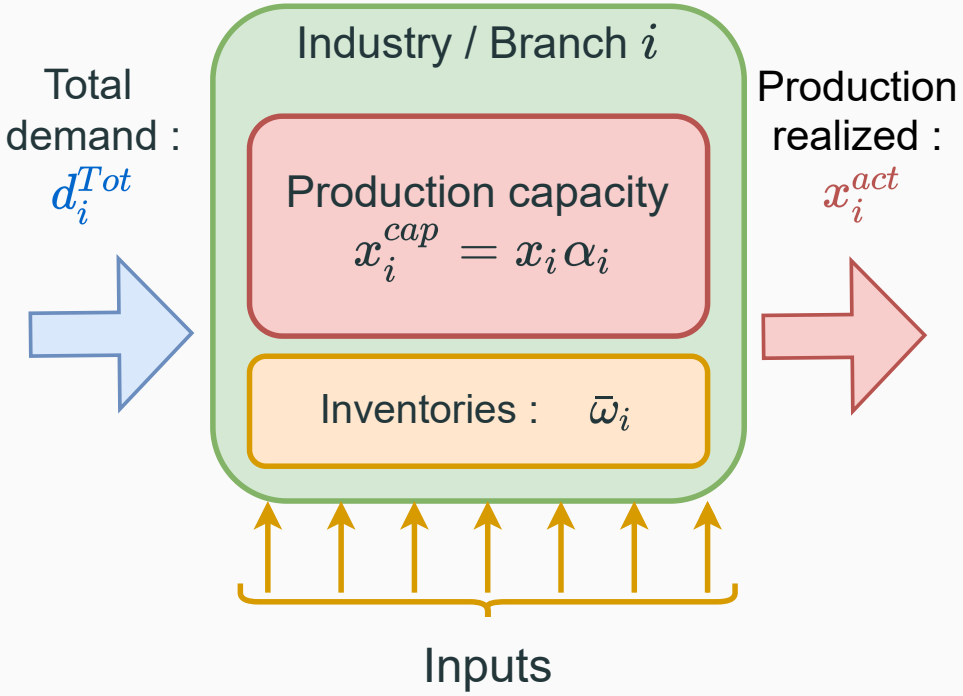


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# Inventories constraints

For every input : have at least $\psi$ % of the amount required to produce $x_i^{opt}$ during $\tau$ steps.

If not, shift from $x_i^{opt}$ to the maximum production satisfying this condition : $x_i^{cons}$. menu

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# Production distribution

Proportional rationing : if production of $i$ is $n\%$ of $d_i^{tot}$, then each "client" (intermediate and final) receive $n\%$ of its demand. Inventory begin to deplete.

Final demand not met is not reported but recorded as a loss. menu

# Demand / Orders

1. Fixed final demand $y^{final}$
2. Intermediate demand for realized production : $Z^{act} = x^{act} A^{\mathbf{S}}$ columns-sum.
3. Intermediate demand for inventories *restocking* : inventory gap times a characteristic time $\frac{1}{\tau^{inv}}$.
4. Rebuilding demand $y^{rebuild}$.

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# Damages effect

On production:

1. Direct damages distributed along a selected set of *impacted* sectors
2. Distribution proportional to GDP share of sector (in IO table)
3. Production reduction equal to ratio of damages over sector capital stock estimate.

On demand:

1. Rebuilding demand equal to direct damages
2. Distributed towards a selected set of *rebuilding sectors*

# Recovery process

Huge shift in production distribution in one day appears unrealistic
$\rightarrow$ Smooth production allocation towards rebuilding.

$$\gamma(t+1) = \gamma(t) + (\gamma^{max} - \gamma(t)) \frac{d^{rebuild} - x^{rebuild}}{d^{rebuild}} \cdot \frac{1}{\tau^{rebuild}}$$

menu