UNIVERSITÄT DUISBURG ESSEN

MERCATOR School of Management

Considering Sequence-Dependent Stochasticity in Production Schedules

Michael Manitz

Tel.: (+49 203) 3 79 - 14 43
E-Mail: michael.manitz@uni-due.de

Duisburg/Essen University
Faculty of Business Administration (Mercator School of Management)
Department of Technology and Operations Management
Professor for Production & Supply Chain Management
Lotharstr. 65
47057 Duisburg
GERMANY

http://www.msm.uni-due.de/pui

Joint work with:

- **Frank Herrmann** (OTH Regensburg)
- **Maximilian Munninger** (Duisburg/Essen University)

A (simpliest) example **2 Stages**

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Index Sets

$\mathcal{K}$ ... 3 products: $k =$ A1 and $k =$ B1 and $k =$ C1

$\mathcal{N}_k$ ... the components k that are needed for the final production process;
$\mathcal{N}_{\text{A2}} = \{\text{A1}\}$, $\mathcal{N}_{\text{B2}} = \{\text{B1}\}$, $\mathcal{N}_{\text{C2}} = \{\text{C1}\}$, $\mathcal{N}_{\text{A1}} = \mathcal{N}_{\text{B1}} = \mathcal{N}_{\text{C1}} = \emptyset$

$\mathcal{J}$ ... 2 bottleneck machines whose limited capacity concerns

Parameters

d_{kt} ... demand for product k in period t

s_k ... setup costs for product k

h_k ... holding costs for product k

tb_{jk} ... processing time per unit for product k on machine j

tr_{jk} ... setup time for product k on machine j

b_{jt} ... available capacity of machine j in period t

z_k ... pre-specified lead time for product k

MLCLSP

Minimize costs $$Z = \sum_{k \in \mathcal{K}} \sum_{t=1}^{T} (h_k \cdot y_{kt} + s_k \cdot \gamma_{kt})$$

subject to:

Initial inventory y_{k0} given due to a rolling planning horizon. $(k \in \mathcal{K})$

Demand in period t (inventory balance):

$$y_{k,t-1} + q_{k,t-z_k} - \sum_{i \in \mathcal{N}_k} a_{ki} \cdot q_{it} - y_{kt} = d_{kt} \qquad (k \in \mathcal{K};\ t = 1, 2, \ldots, T)$$

Capacities in period t:

$$\sum_{k \in \mathcal{K}} \left(\mathsf{tb}_{kj} \cdot q_{kt} + \mathsf{tr}_{kj} \cdot \gamma_{kt} \right) \leq b_{jt} \qquad (j \in \mathcal{J};\ t = 1, 2, \ldots, T$$

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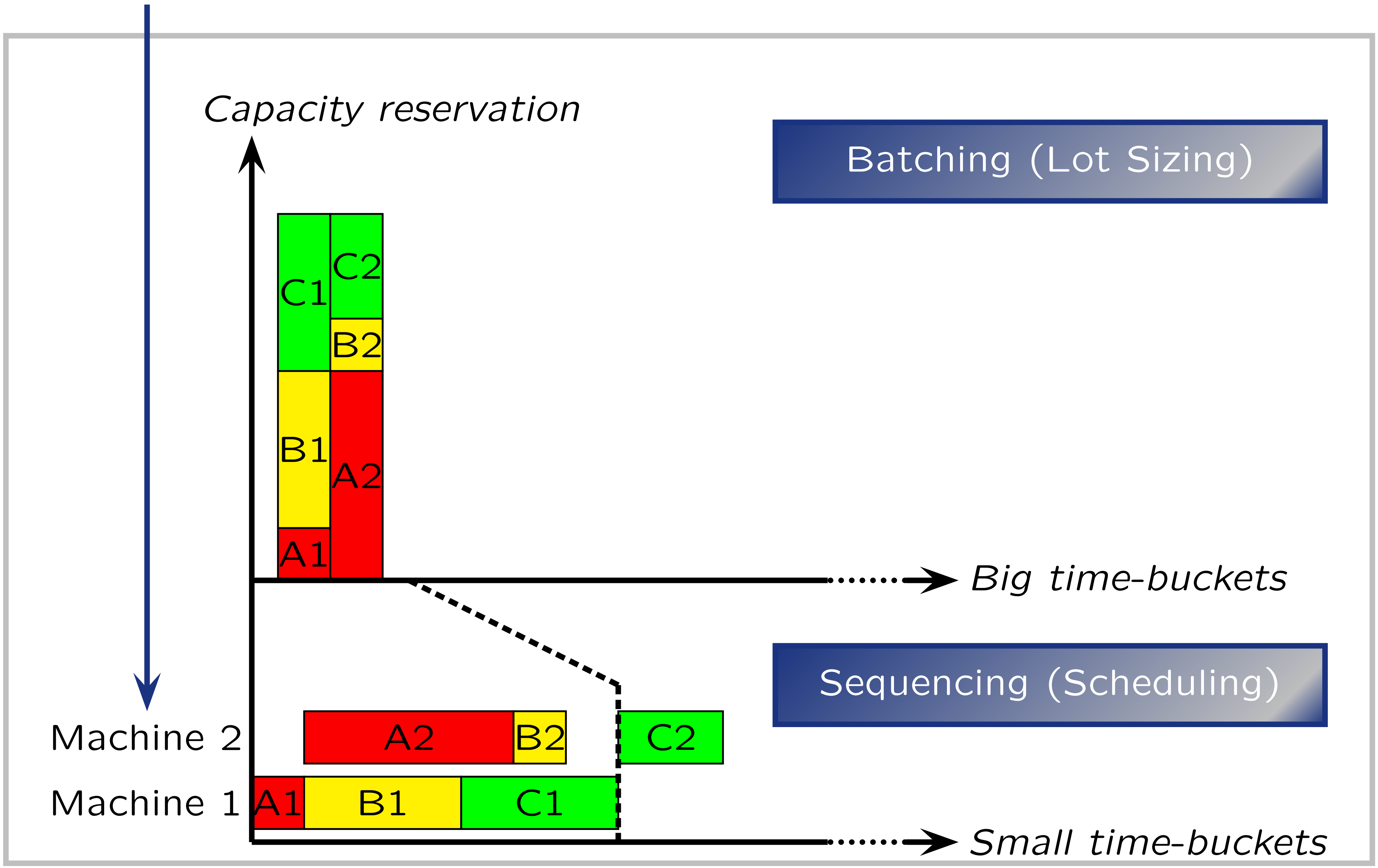
The situation in production planning & control:



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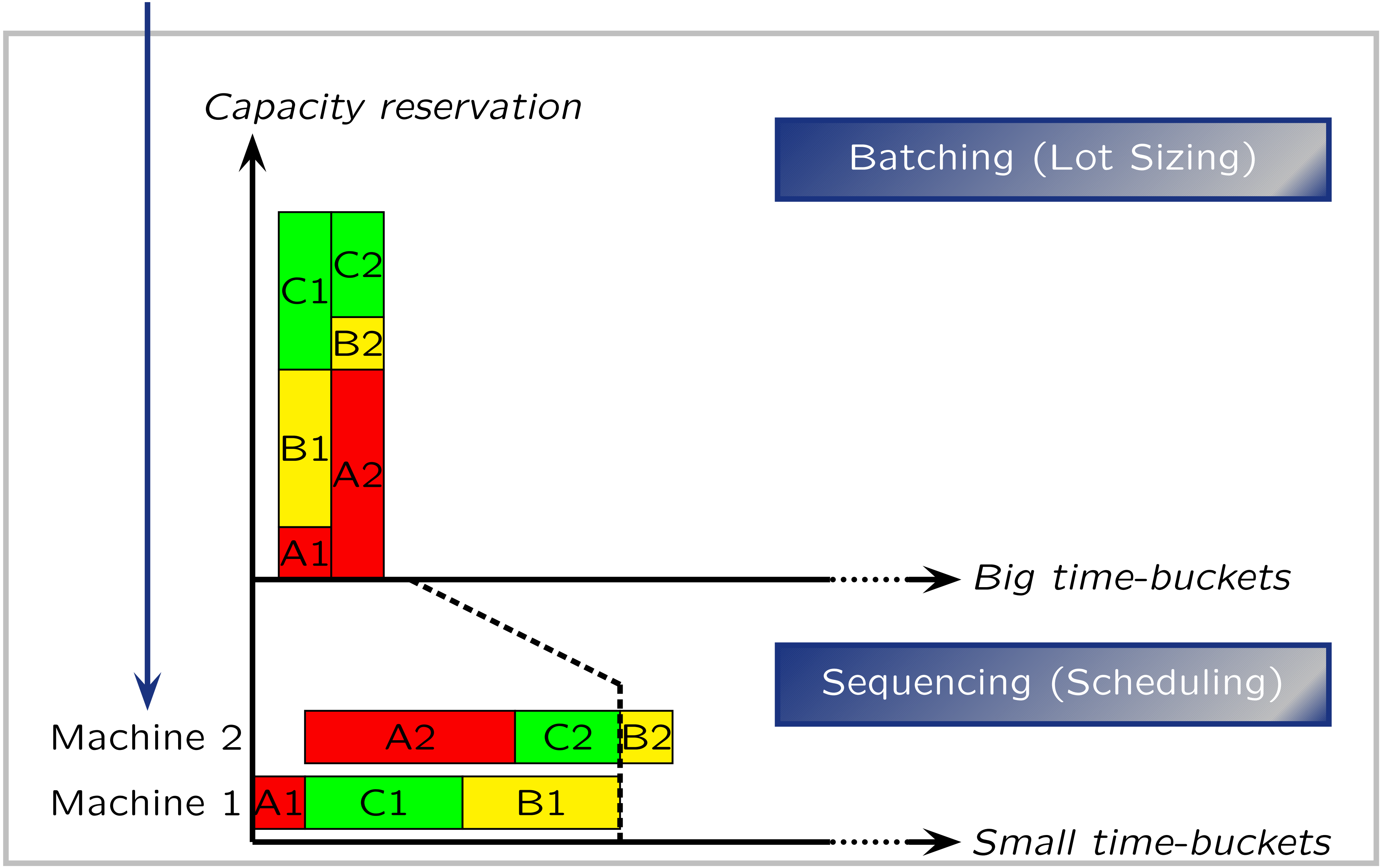

Tardinesses cannot be avoided.

Why the implementation of the production schedules from a deterministic optimization model leads to stochastic results ?

[Even if all the parameters are assumed to be deterministic !]

...

- sequencing rules
- sequencing constraints

The results of their application later on are not known during the rough-cut capacity planning (big-bucket model) and, hence, are unpredictable and—finally—stochastic.

The Backlog matters.

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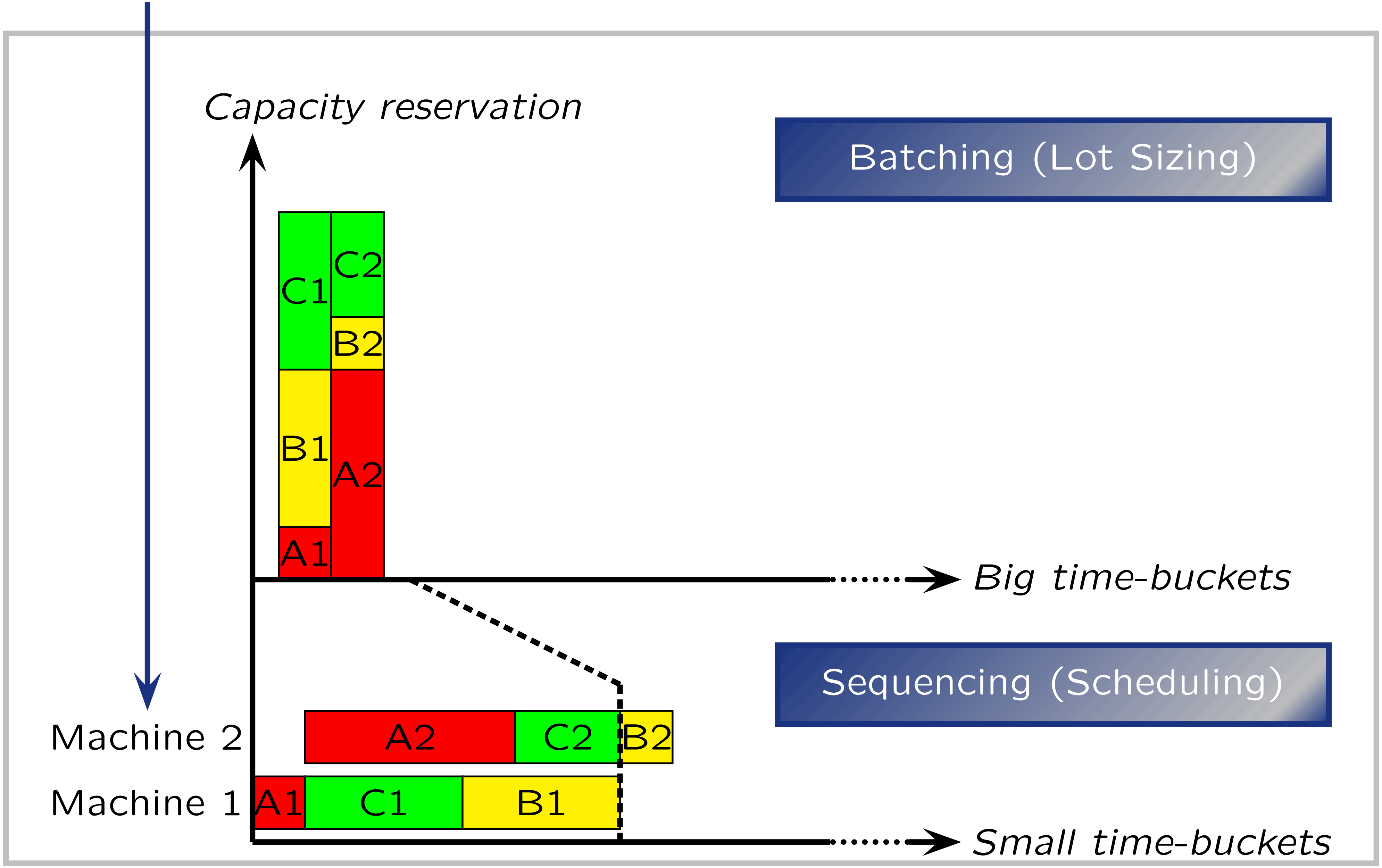
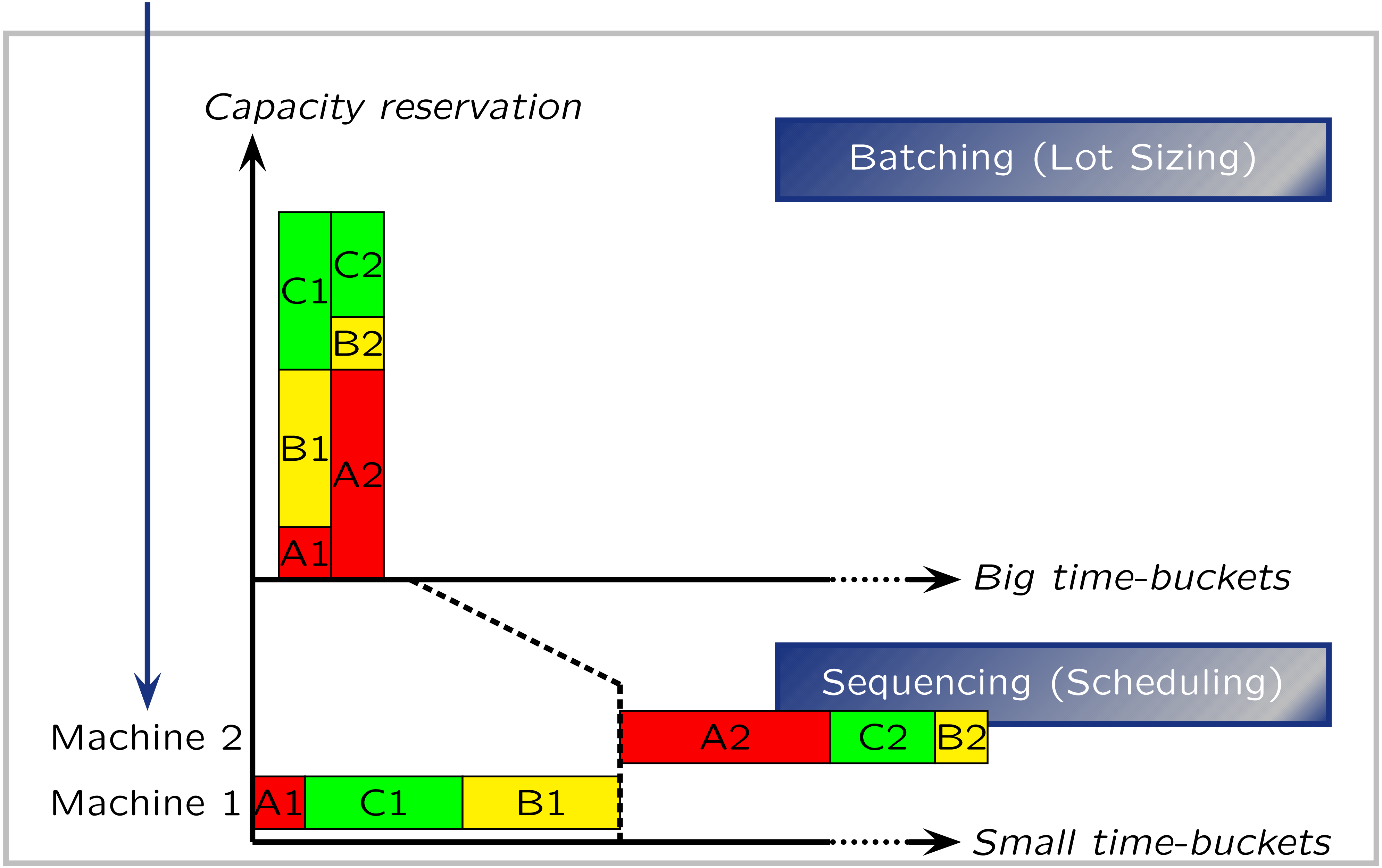
Augmenting the planned lead times—with or without doing anything—is the wrong answer.

Increasing the planned lead times:




Capacity reservation
Batching (Lot Sizing)
C1
C2
B2
B1
A2
A1
Big time-buckets
Sequencing (Scheduling)
Machine 2
A2
C2
B2
Machine 1
A1
C1
B1
Small time-buckets

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How to estimate the (expected) amount of backlog ?

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$$D_k = \sum_{t=1}^{T} d_{kt} \quad . \qquad (k \in \mathcal{K})$$

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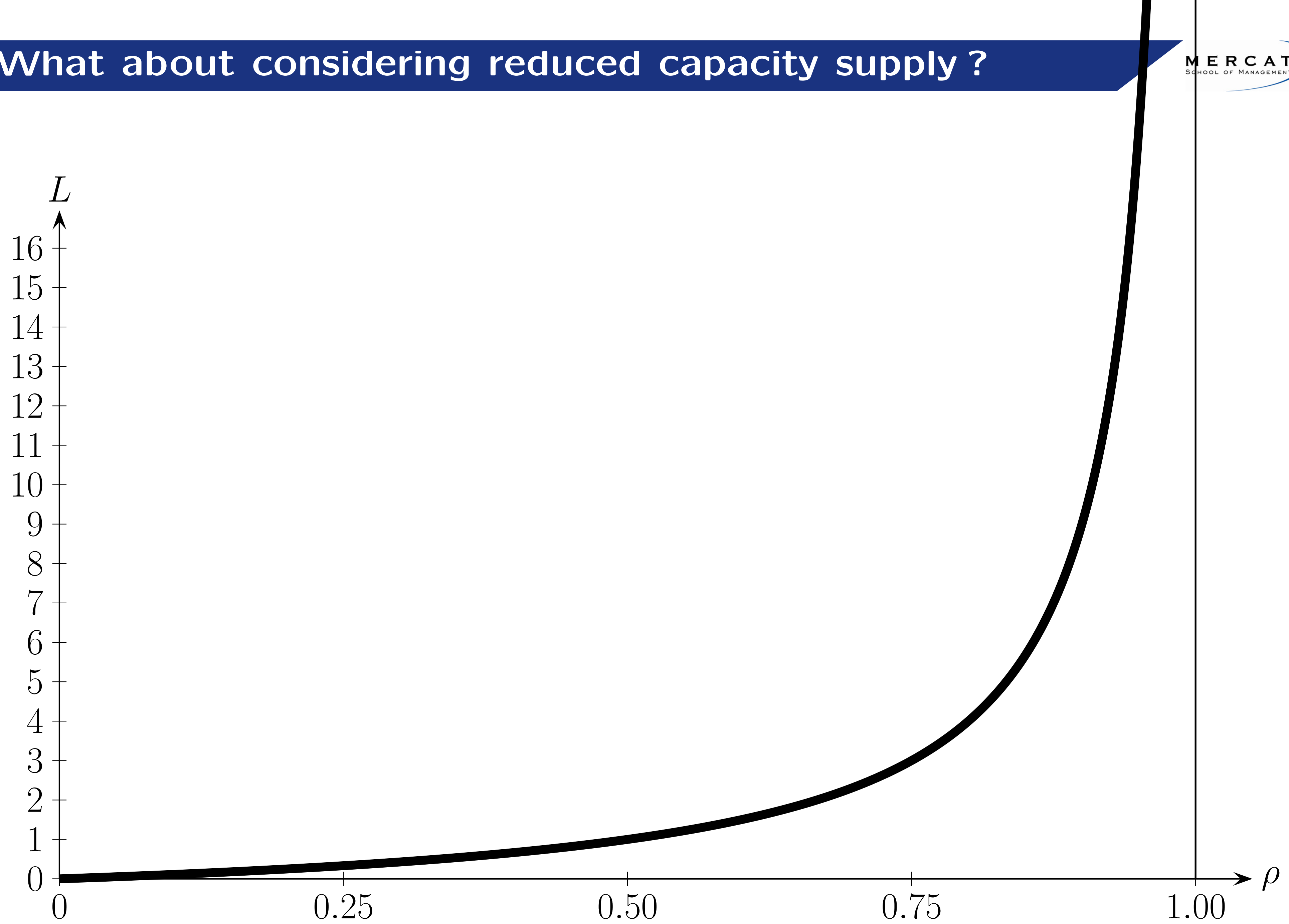

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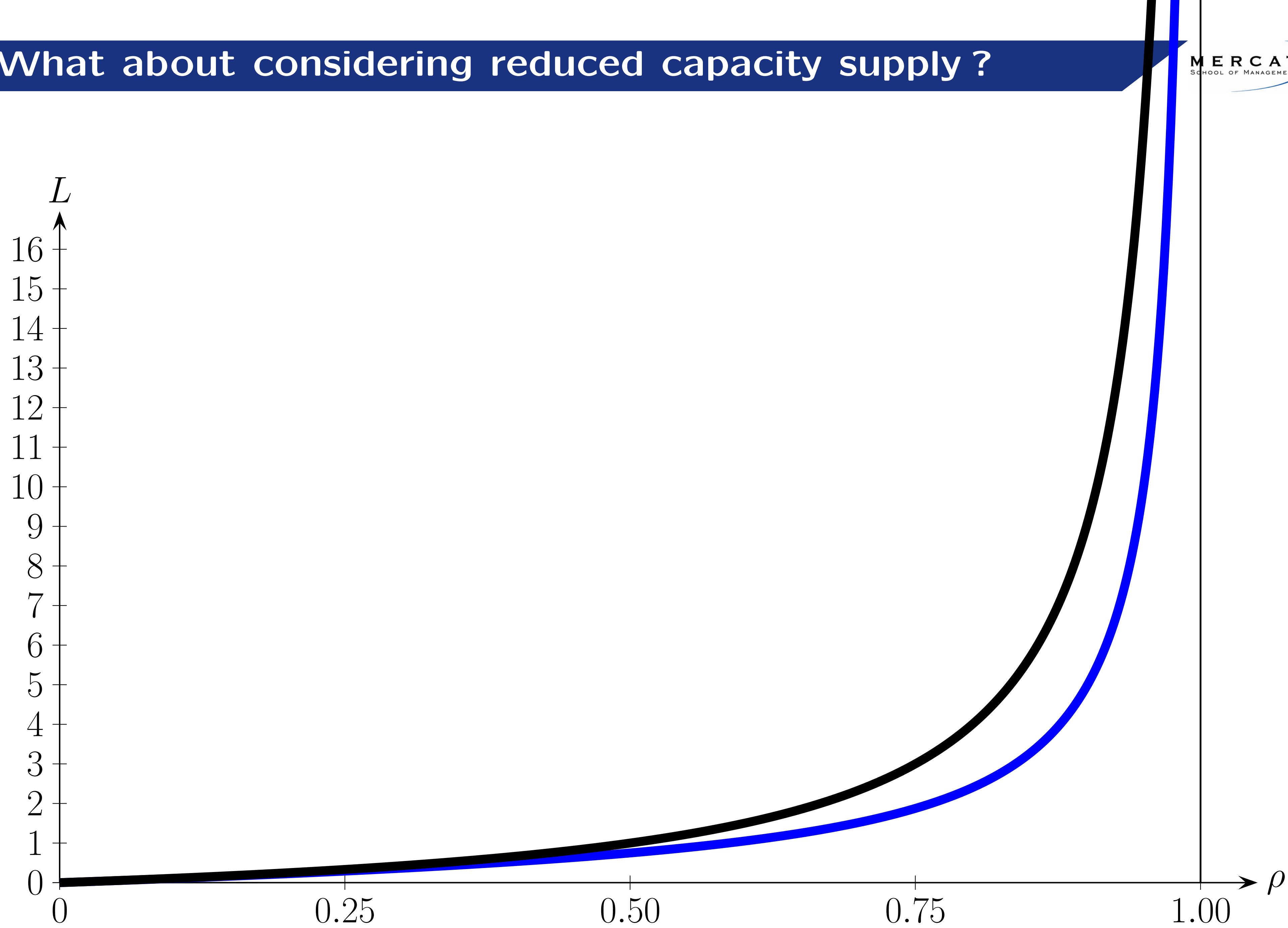

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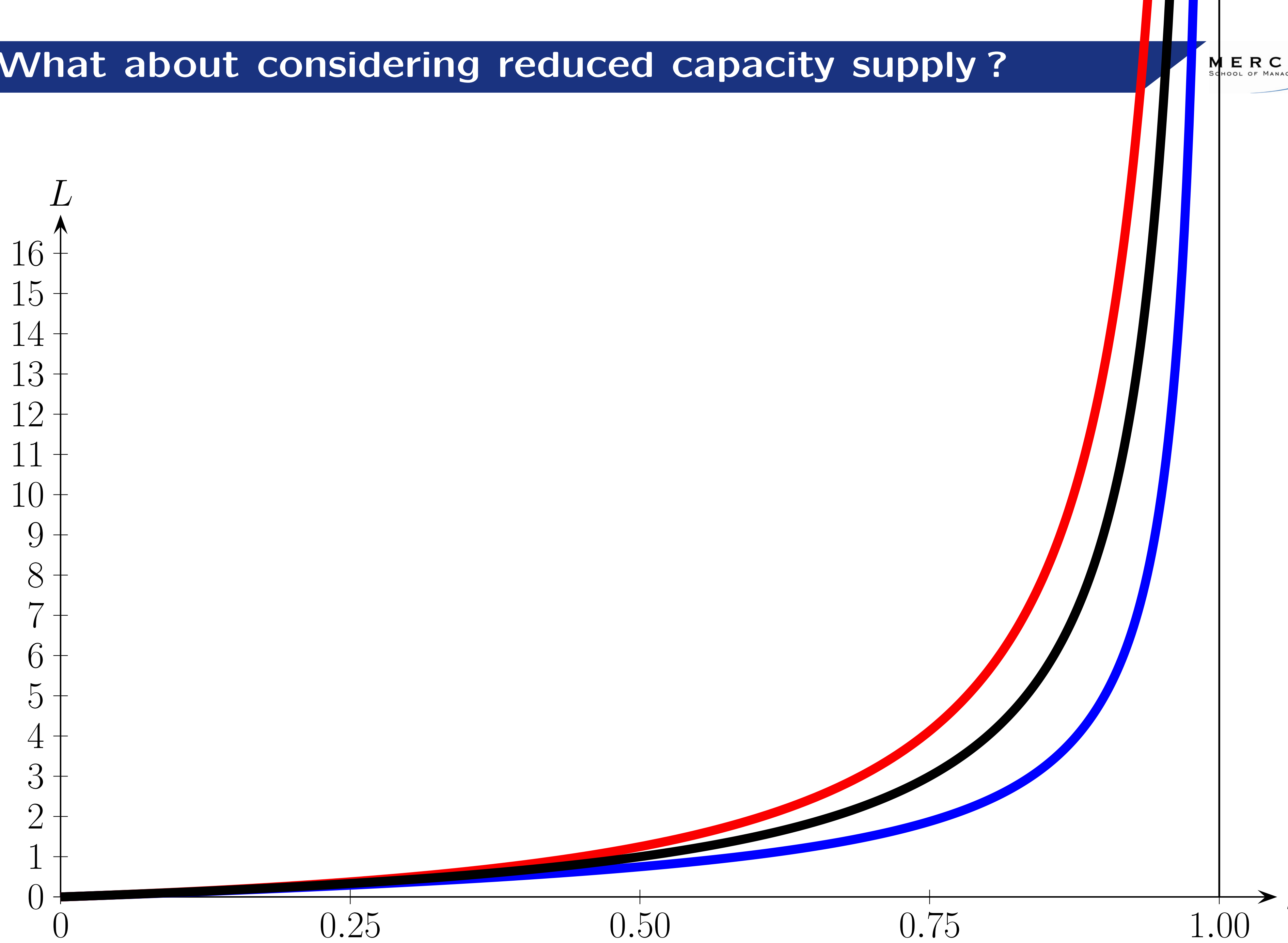

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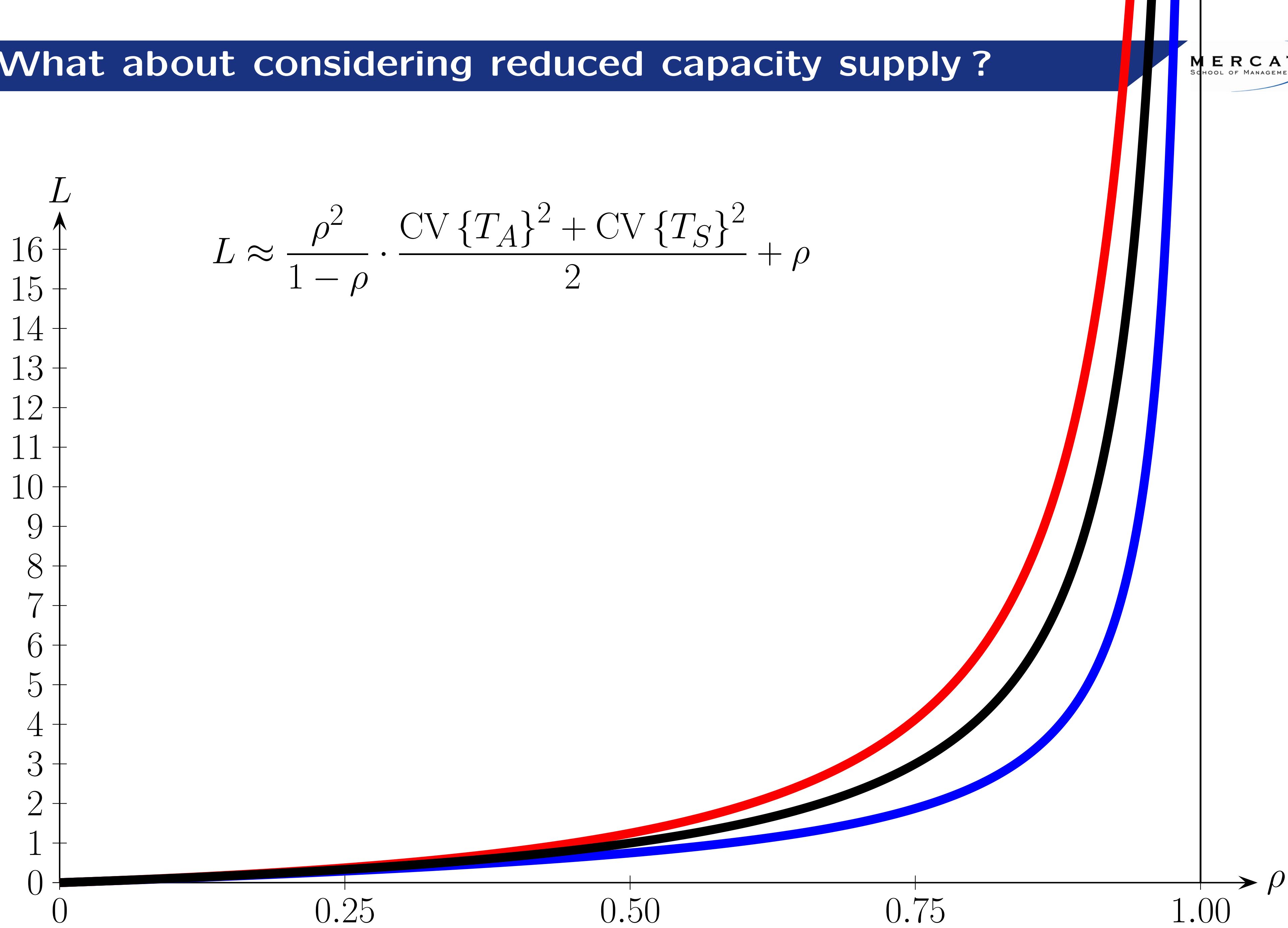

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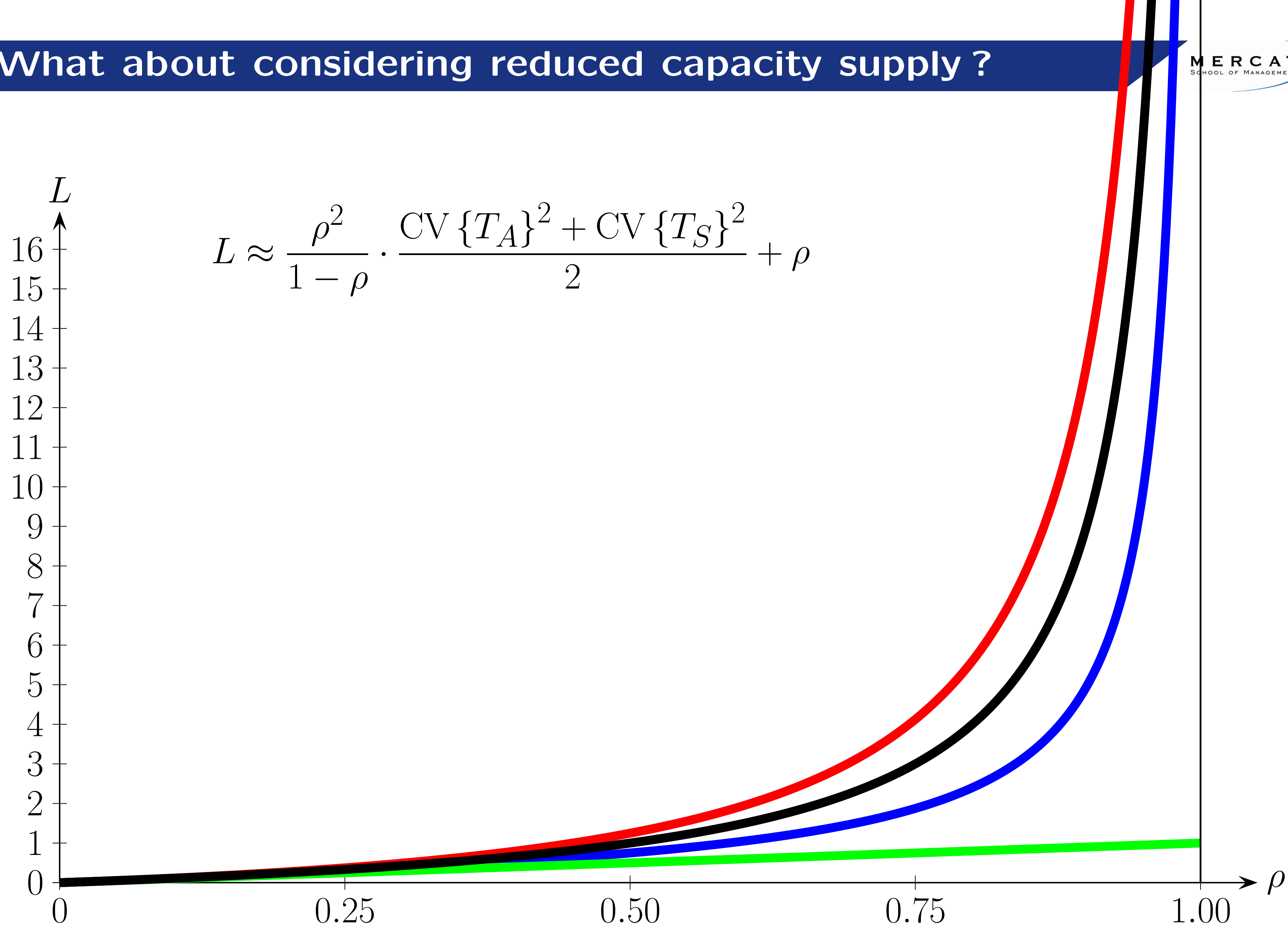

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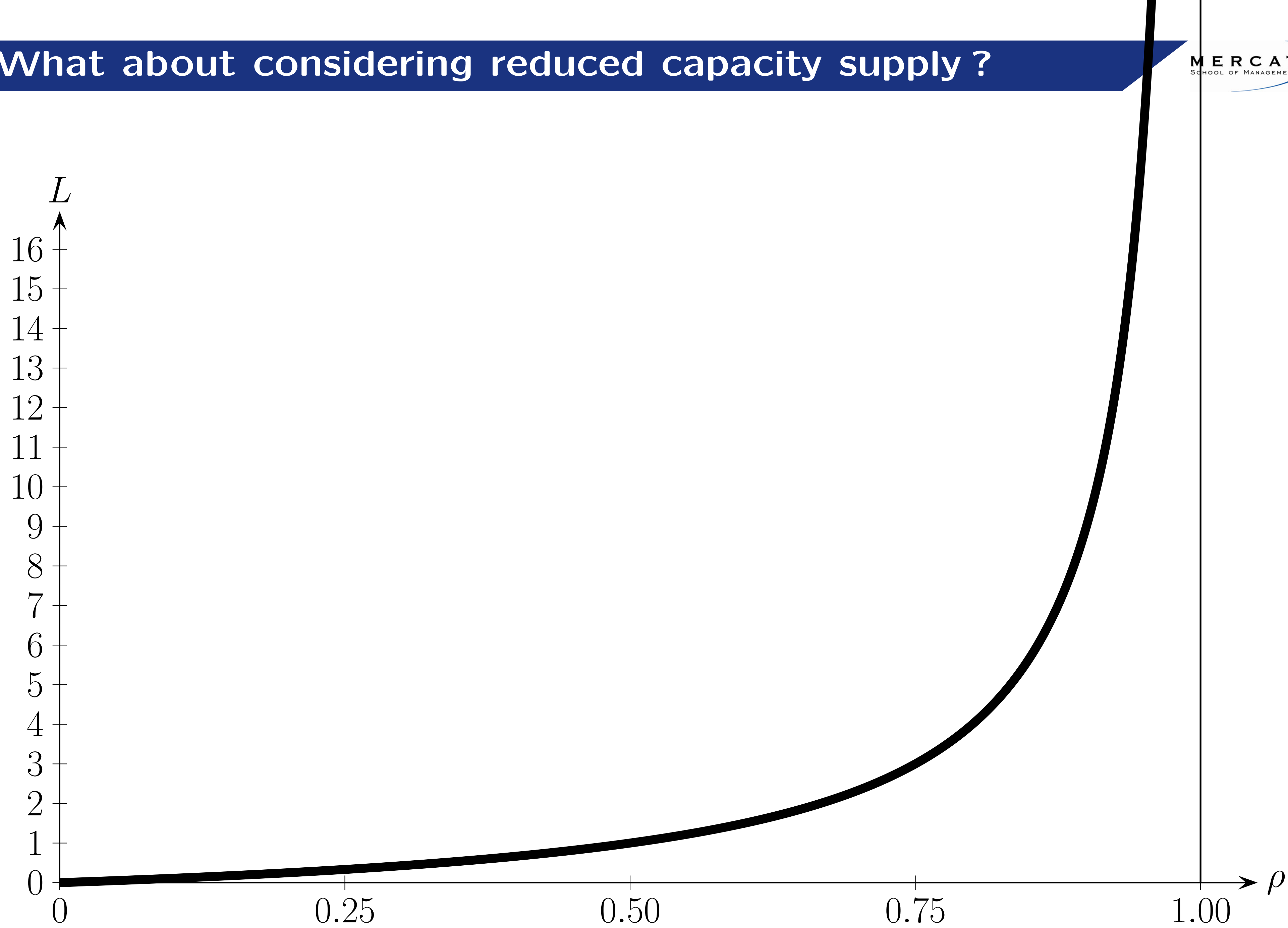

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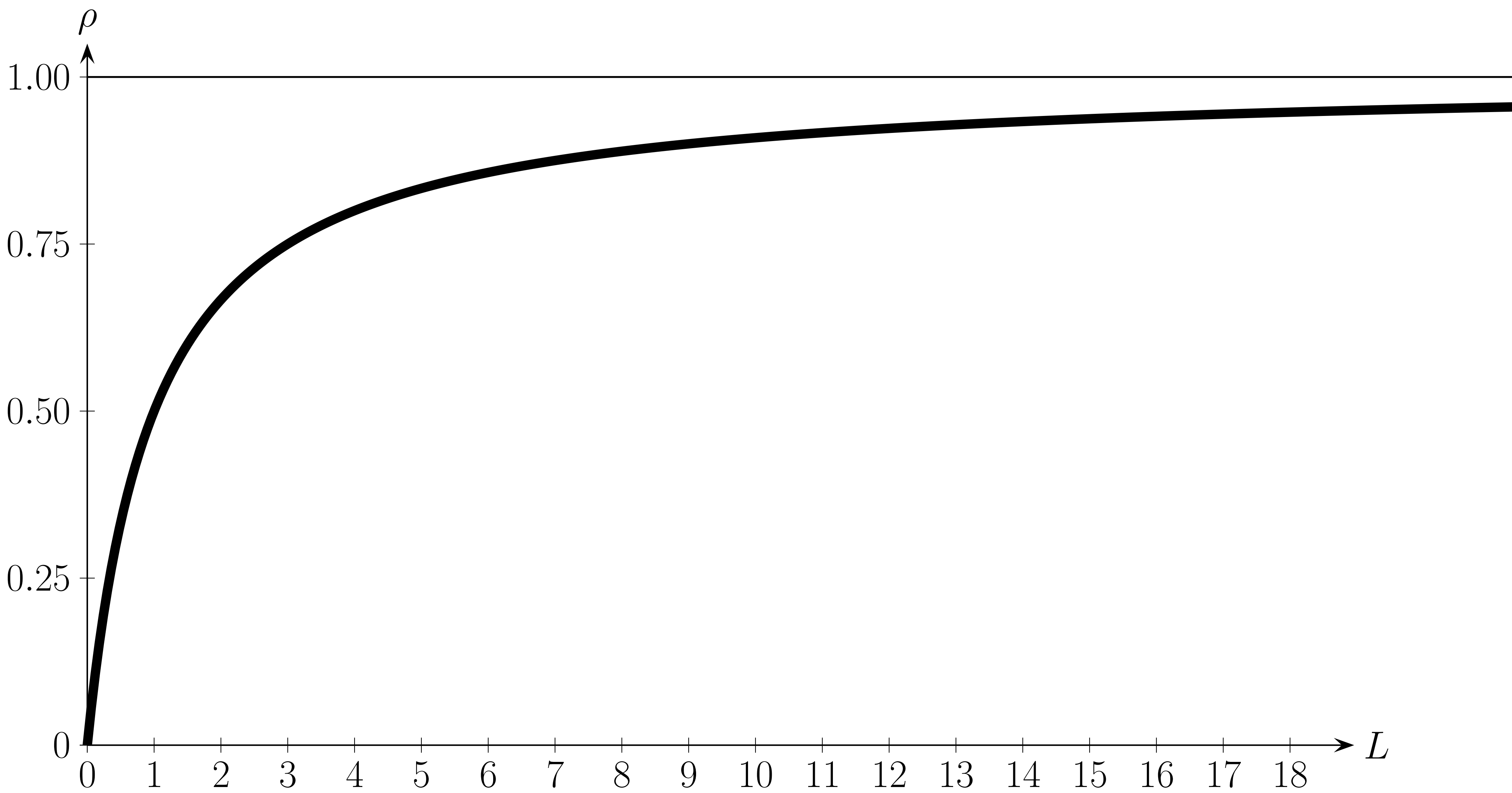

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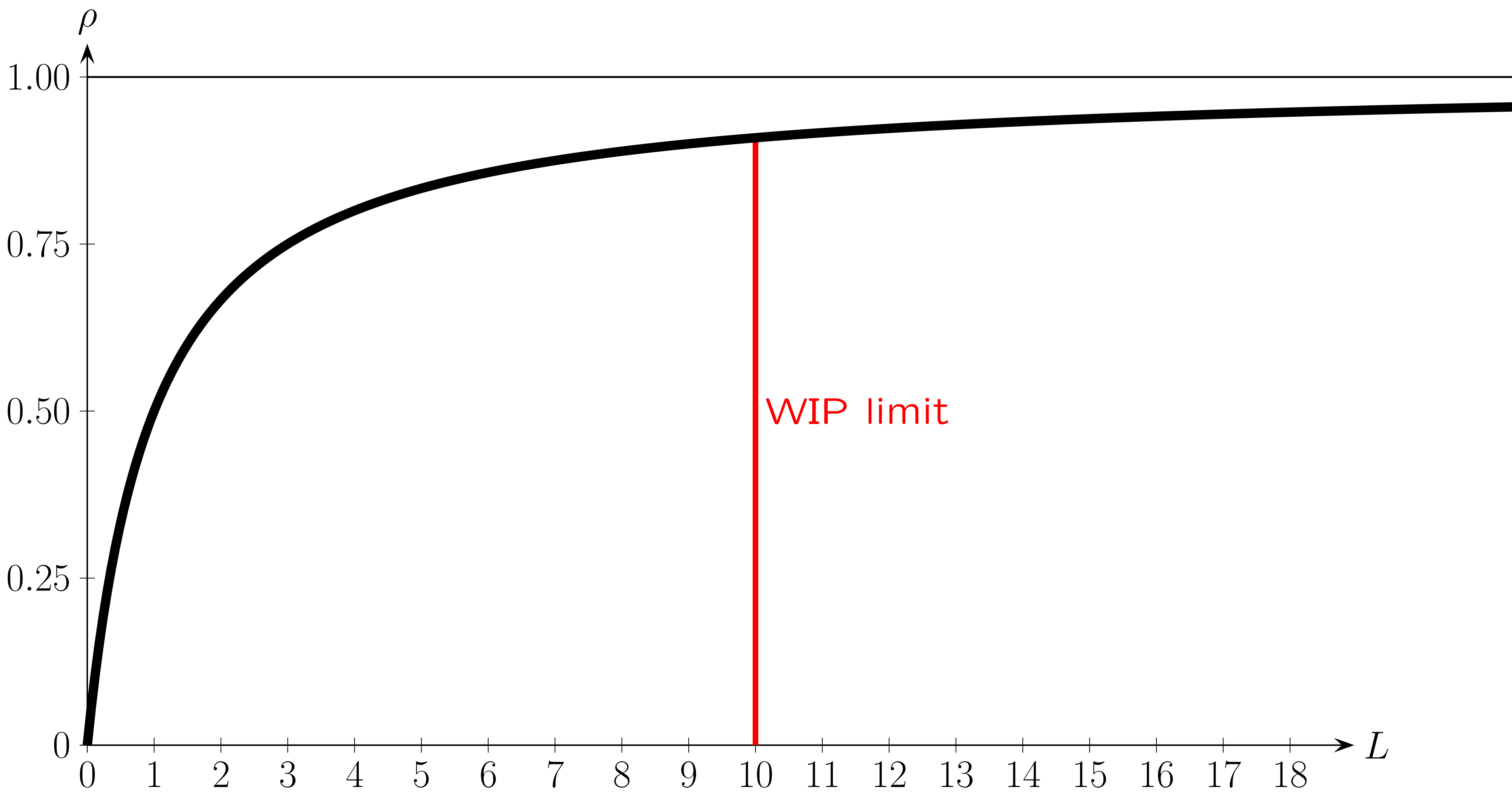

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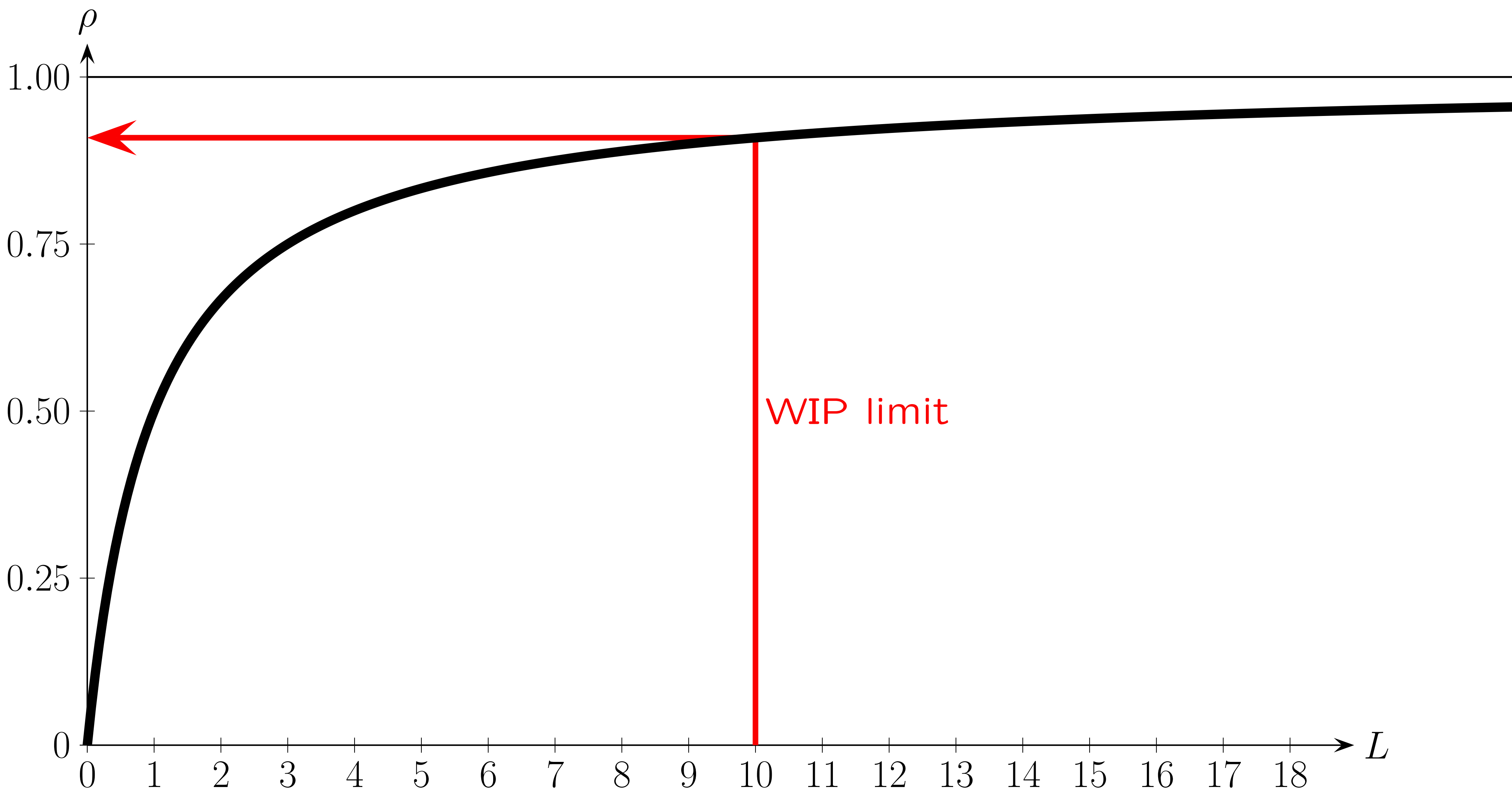

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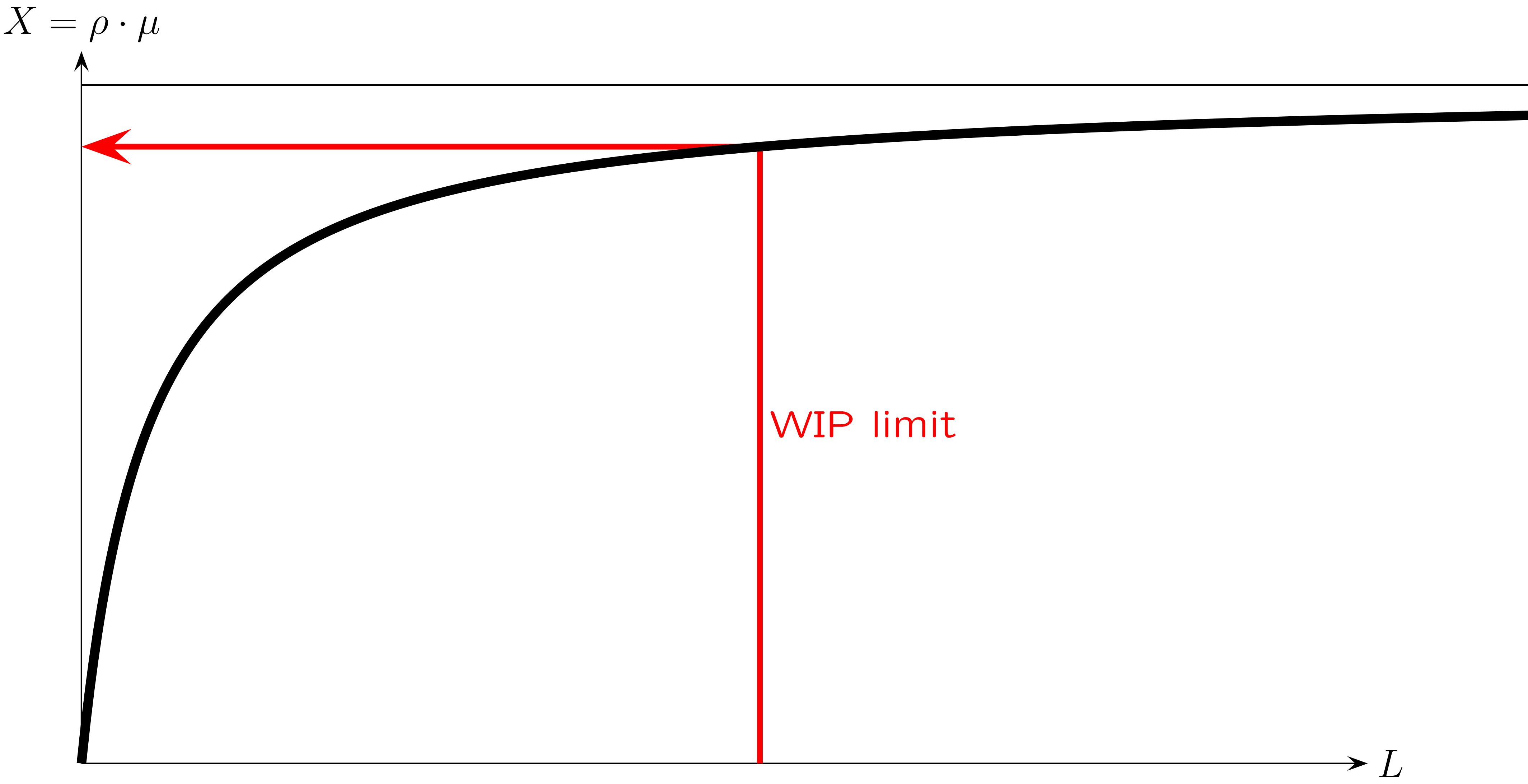

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Production-quantity limit:

$$w_{kt} = q_{kt} - X(q_{kt}) \qquad (k \in \mathcal{K};\ t = 1, 2, \ldots, T)$$

Effective capacity loss:

$$V_{jt} = \sum_{k \in \mathcal{K}} w_{kt} \cdot \mathsf{tb}_{jk} \qquad (j \in \mathcal{J};\ t = 1, 2, \ldots, T)$$

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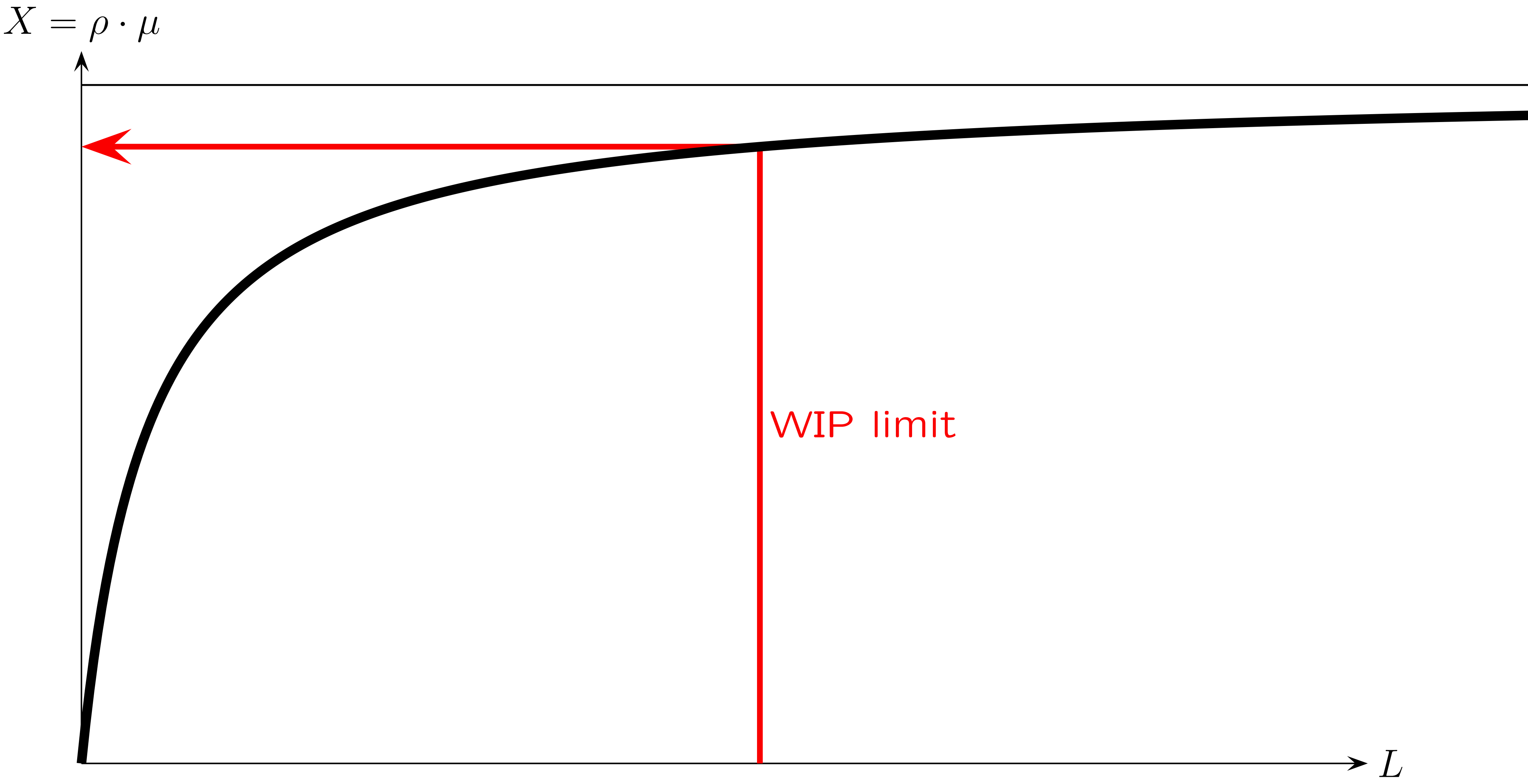
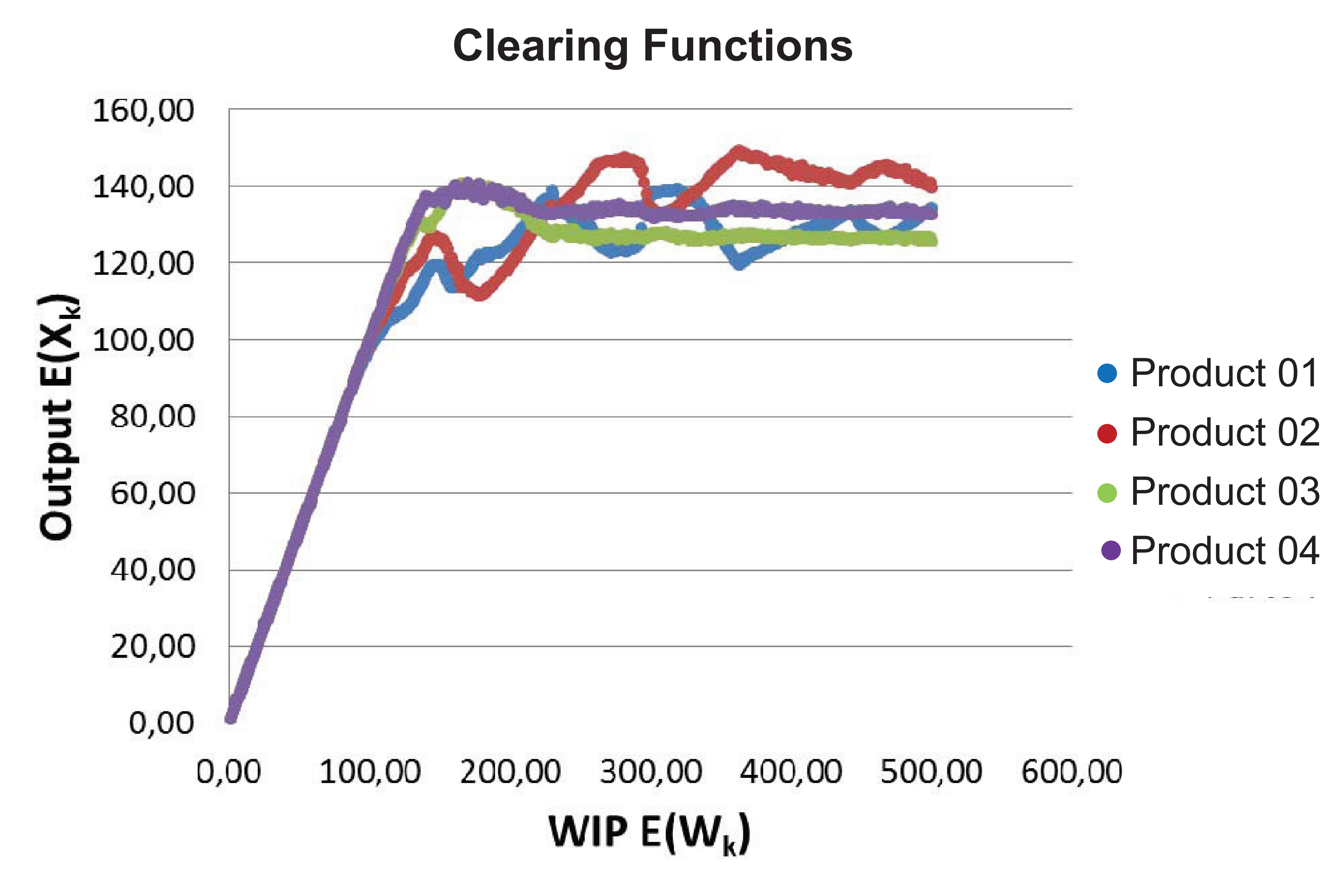
Ranges:

$$q_{kt} \geq 0;\ y_{kt} \geq 0;\ y_{kT} = 0;\ \gamma_{kt} \in \{0, 1\} \qquad (k \in \mathcal{K};\ t = 1, 2, \ldots, T)$$


$X = \rho \cdot \mu$
WIP limit
L


Clearing Functions
160,00
140,00
120,00
100,00
80,00
60,00
40,00
20,00
0,00
0,00
100,00
200,00
300,00
400,00
500,00
600,00
Output E(X_k)
WIP E(W_k)
Product 01
Product 02
Product 03
Product 04

What about doing integrated lot-sizing and scheduling ?

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MLPLSP

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Too complicated !

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- computational times

MLPLSP

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- practical application

Conclusion

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We cannot guarantee a feasible solution for the scheduling problem.