Research article

Fair profit distribution in global supply chains under demand uncertainty

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Appendix

Notations

Indices

g	product group
n	primary products
i	final products
j	factories
k	market
t	time period
s	scenarios
l	transfer price level

Sets

$\bar{G}_i$	set of the product group that final product i belongs to
G_j	set of groups that can be processed at factories j
$\bar{I}_g$	set of products in group g
I_k	set of final products that can be sold at market k
K_i	set of market selling final product i

Parameters

$ACap_h^S$	total capacity of supplier h
$ACap_j^F$	total capacity of factory j
AD_{jk}	total demands of final product i at market k
Cap_h^S	capacity of supplier h
Cap_j^F	capacity of factory j
CC_h^S	unit capacity expansion cost at supplier h
CC_j^F	unit capacity expansion cost at factory j
crf	the factor of capital recovery
D_{ikts}	demand of final product i at market k during time period t under scenario s
DC_{rhj}^S	unit primary product r's duties between supplier h and factory j
DC_{ijk}^P	unit final product i's duties between factory j and market k
FFC_{ij}^P	fixed final product i's formulation cost i at factory j
FPC_{rh}^S	fixed primary product r's production cost at supplier h
FTC_{rhj}^S	fixed primary product r's transportation cost from supplier h to factory j
FTC_{ijk}^P	fixed final product i's transportation cost from factories j to market k
IC_{rh}^{PS}	unit primary product r's inventory cost at supplier h
IC_{rj}^{PP}	unit primary product r's inventory cost at factory j
IC_{ij}^{FP}	unit final product i's inventory cost at factory j
IC_{ik}^{FM}	unit final product i's inventory cost at market k

$MaxAF_{rhj}^S$	maximum primary product r's flow from supplier h to factory j
$MaxAF_{ijk}^F$	maximum final product i's flow from factory j to market k
$MaxAP_{rh}^S$	maximum primary product r's production at supplier h
$MaxAP_{ij}^F$	maximum final product i's production at factory j
$MaxF_{rhj}^S$	maximum primary product r's flow from supplier h to factory j
$MaxF_{ijk}^F$	maximum final product i's flow from factory j to market k
$MaxIV_{rh}^{PS}$	maximum primary product r's inventory at supplier h
$MaxIV_{rj}^{PP}$	maximum primary product r's inventory at factory j
$MaxIV_{ij}^{FP}$	maximum final product i's inventory at factory j
$MaxIV_{ik}^{FM}$	maximum final product i's inventory at market k
$MaxP_{rh}^S$	maximum primary product r's production at supplier h
$MaxP_{ij}^F$	maximum final product i's production at factory j
$MaxPr_m$	the supply chain member m's maximum profit
$MinAF_{rhj}^S$	minimum total of primary product r flow from supplier h to factory j
$MinAF_{ijk}^F$	minimum flow of final product i from factory j to market k
$MinAP_{rh}^S$	minimum product of primary product r at supplier h
$MinAP_{ij}^F$	minimum product of final product i at factory j
$MinF_{rhj}^S$	minimum product flow of primary product r from supplier h to factory j
$MinF_{ijk}^F$	minimum flow of product i from factory j to market k
$MinIV_{rh}^{PS}$	minimum primary product r's inventory at supplier h
$MinIV_{rj}^{PP}$	minimum primary product r's inventory at factory j
$MinIV_{ij}^{FP}$	minimum final product i's inventory at factory j
$MinIV_{ik}^{FM}$	minimum final product i's inventory at market k
$MinP_{rh}^S$	minimum primary product r's production at supplier h
$MinP_{ij}^F$	minimum final product i's production at factory j
$MinPr_m$	minimum supply chain member m's profit
MC_{rh}^S	unit primary product r's material cost at supplier h

MC_{ij}^P	unit final product i's material cost at factory j
PC_{ik}	final product i's lost transaction penalty at market k
TPL_{rhl}^S	the level of transfer price of primary product r at supplier h
TPL_{ijl}^P	the level of transfer price of final product i at factory j
V_{ik}	final product i's selling price at market k
VFC_{ij}^P	unit variable formulation cost of final product i at factory j
VPC_{rh}^S	unit cost of variable production of the primary product r at supplier h
VTC_{rhj}^S	unit cost of variable transportation of the primary product r from supplier h to factory j
VTC_{ijk}^P	unit unit cost of variable transportation of final product i from factory j to market k
α_m	supply chain member m's bargaining power
β_{ij}	unit product consumption of final product i in factory j
τ_{jk}	transportation time between factory j and market k
$\bar{\tau}_{hj}$	transportation time between supplier h and factory j

Continuous Variables

AF_{rhj}^S	primary product r's total flow from supplier h to factory j
AF_{ijk}^P	final product i's total flow from factory j to market k
ALS_{ik}	final product i's total lost sales at market k
AP_{rh}^S	primary product r's total production at supplier h
AP_{ij}^F	final product i's total production at factory j
AS_{ik}	final product i's total sales at market k
CIC_h^S	cost of capital investment of supplier h
CIC_j^F	cost of capital investment of factory j
DUC_j^F	duties of final product incurred by factory j
DUC_k^M	duties of final product incurred by market k
F_{rhjt}^S	flow of primary product r from supplier h to factory j in time period t under scenario s

F^p_{ijkts}	flow of final product i from factory j to market k in time period t under scenario s
FOC^F_j	formulation cost of factory j
IV^{PS}_{rht}	inventory of the primary product r at supplier h in time period t under scenario s
IV^{PP}_{rjts}	inventory of the primary product r at factory j in time period t under scenario s
IV^{FP}_{ijts}	inventory of final product i at factory j in time period t under scenario s
IV^{FM}_{ikts}	inventory of final product i at market k in time period t under scenario s
IVC^S_h	supplier h's inventory cost
IVC^F_j	factory j's inventory cost
IVC^M_k	market k's inventory cost
LS_{ikts}	final product i's lost sales at market k in time period t under scenario s
LSC^M_k	final product's lost sales cost at market k
$\overline{OAF}^S_{najl}$	auxiliary variable, $\equiv O^S_{nal} \cdot AF^S_{naj}$
$\overline{OAF}^P_{ijkl}$	auxiliary variable, $\equiv O^P_{ijl} \cdot AF^P_{ijk}$
$\overline{OF}^S_{najlt}$	auxiliary variable, $\equiv O^S_{nal} \cdot AF^S_{najts}$
$\overline{OAF}^P_{ijklts}$	auxiliary variable, $\equiv O^P_{ijl} \cdot F^P_{ijkts}$
P^S_{rht}	production of the primary product r at supplier h in time period t under scenario s
P^P_{ijts}	production of final product i at factory j in time period t under scenario s
PC^S_h	production cost of supplier h
Pr_m	supply chain member m's profit
Pr_{mq}	profit of supply chain member m in segment q
Pr^S_h	supplier h's profit
Pr^F_j	factory j's profit
Pr^M_k	market k's profit

Re_h^S	supplier h's revenue
Re_j^F	factory j's revenue
Re_k^M	market k's revenue
RMC_h^S	supplier h's raw materials cost
RMC_j^F	factory j's raw materials cost
SA_{ikts}	sales of final product i at market k in time period t under scenario s
TP_{rh}^S	primary product r's transfer price from supplier h
TP_{ij}^p	final product i's transfer price from factory j
TPC_j^F	factory j's transfer payment cost
TPC_k^M	market k's transfer payment cost
TRC_j^F	cost of transportation incurred by factory j
TRC_k^M	cost of transportation incurred by market k
$TotPr$	the supply chain's total profit
$\Delta ACap_h^S$	total capacity increment of supplier h
$\Delta ACap_j^F$	total capacity increment of factory j
ΔCap_h^S	supplier h's capacity increment
ΔCap_j^F	factory j's capacity increment

Binary Variables

E_{rh}^S	1 if primary product r is produced at supplier h; 0 otherwise
E_{ij}^P	1 if final product i is produced at factory j; 0 otherwise
O_{rhl}^S	1 if level of transfer price l is chosen for primary product r at supplier h; 0 otherwise
O_{ijl}^P	1 if level of transfer price l is chosen for final product i at factory j; 0 otherwise
W_{rhts}^S	1 if primary product r is produced at supplier h in time period t under scenario s; 0 otherwise
W_{ijts}^P	1 if final product i is produced at factory j in time period t under scenario s; 0 otherwise

X_{rhj}^{S}	1 if the primary product r is transported from supplier h to factory j; 0 otherwise.
X_{ijk}^{P}	1 if final product i is transported from factory j to market k; 0 otherwise
Y_{rhjts}^{S}	1 if primary product r is transported from supplier h to factory j in time period t under scenario s; 0 otherwise
Y_{ijkts}^{P}	1 if final product i is transported from factory j to market k in time period t under scenario s; 0 otherwise