System Dynamics Model Equations

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1. SD Equations for “No Distributor” Model

Stock equations:

(1) Customs= INTEG (Shipment-Customs Clearance, 0) [Unit]
(2) Inventory for Shipments in HQ Region= INTEG (Production-Shipment, 1500) [Unit]
(3) Production Total Volume= INTEG (Production, 0) [Unit]
(4) Profit= INTEG (Revenue-Cost, 5000) [Dollar]
(5) Sales Total Volume= INTEG (Customs Clearance, 0) [Unit]

Flow equations:

(1) Cost=Unit Production Cost*Production + Fixed Cost for HQ + Shipment Cost + Sales Cost +HQ Export tax [Dollar/Month]
(2) Customs Clearance=DELAY1(IF THEN ELSE(Customs>0, Customs/Period B,0), Declaration Lead Time) [Unit/Month]
(3) Production=DELAY1(IF THEN ELSE(Target Production Volume>=Production Capacity, Production Capacity, Target Production Volume) , Production Lead Time) [Unit/Month]
(4) Revenue="Sales Price w/o Tariff"*Customs Clearance [Dollar/Month]
(5) Shipment=DELAY1(IF THEN ELSE((Inventory for Shipments in HQ Region/Period A)>=Order Quantity, Order Quantity, Inventory for Shipments in HQ Region/Period A),Shipment Lead Time) [Unit/Month]

Converters:

(1) Demand Reverse Effect on Price=(Unit Adjustment*500/Inventory for Shipments in HQ Region)^(1/6)*100 [Dmnl]
(2) HQ Export tax="Sales Price w/o Tariff"*Shipment*HQ Export tax Rate
Units: dollar/Month
(3) Order Quantity=(Unit Adjustment II*100/Sales Price w Tariff)^6*500*Sales Effort*Volume Coefficient [Unit/Month]
(4) Price Value=Demand Reverse Effect on Price [Dmnl]
(5) Sales Effort=Sales Cost/Sales Coefficient [Dmnl]
(6) Sales Price w Tariff=Price Value*Price Unit Reference [Dollar/Unit]
(7) "Sales Price w/o Tariff"=Sales Price w Tariff/(1+Tariff Rate) [Dollar/Unit]
(8) Shipment Cost=Order Quantity*Shipment Cost per Order [Dollar/Month]
(9) Target Production Volume= (((1-HQ Export tax Rate)*(1-1/Elasticity Coefficient)/(1+Tariff Rate)/(Unit Production Cost + Shipment Cost per Order)/Unit Coefficient)^Elasticity Coefficient)*Nonlinear Demand Coefficient*Volume Coefficient [Unit/Month]

Constants:

(1) Declaration Lead Time=0.5 [Month]
(2) Elasticity Coefficient=6 [Dmnl]
(3) FINAL TIME = 100 [Month]
The final time for the simulation.
(4) Fixed Cost for HQ=10000 [Dollar/Month]
(5) HQ Export tax Rate=-0.02 [Dmnl]
(6) INITIAL TIME = 0 [Month]
The initial time for the simulation.
(7) Nonlinear Demand Coefficient=100^6*500 [Dmnl]
(8) Period A=1 [Month]
(9) Period B=1 [Month]
(10) Price Unit Reference=1 [Dollar/Unit]
(11) Production Capacity=1e+09 [Unit/Month]
(12) Production Lead Time=0.5 [Month]
(13) Sales Coefficient=10000 [Dollar/Month]
(14) Sales Cost=8000 [Dollar/Month]
(15) SAVEPER = TIME STEP [Month]
The frequency with which output is stored.
(16 Shipment Cost per Order=10 [Dollar/Unit]
(17) Shipment Lead Time=0.5 [Month]
(18) Tariff Rate=0.3 [Dmnl]
(19) TIME STEP = 1 [Month]
The time step for the simulation.
(20) Unit Adjustment=1 [Unit]
(21) Unit Adjustment II=1 [Dollar/Unit]
(22) Unit Coefficient=1 [Unit/Dollar]
(23) Unit Production Cost=13 [Dollar/Unit]

(24) Volume Coefficient=1 [Unit/Month]

2. SD Equations for "Commissionaire" Model

Stock equations:

(1) Bonded Inventory in Distributor Region= INTEG (Shipments-Customs Clearance, 1000) [Unit]
(2) Distributor Profit= INTEG (Distributor Revenue-Distributor Cost, 0) [Dollar]
(3) HQ Profit= INTEG (HQ Revenue-HQ Cost, 0) [Dollar]
(4) Inventory for Shipments in HQ Region= INTEG (Production-Shipments, 1500) [Unit]
(5) Production Total Volume= INTEG (Production, 0) [Unit]
(6) Profit= INTEG (Revenue-Cost, 5000) [Dollar]
(7) Sales Total Volume= INTEG (Sales, 0) [Unit]
(8) Unbonded Inventory in Distributor Region= INTEG (Customs Clearance-Sales, 1000) [Unit]

Flow equations:

(1) Cost=Unit Production Cost*Production + Fixed Cost for HQ + Shipment Cost + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory + Sales Labor Cost + HQ Export tax + Distributor Local Tax + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(2) Customs Clearance=DELAY1(IF THEN ELSE((Bonded Inventory in Distributor Region/Cover Time)>Target Customs Declaration Volume, Target Customs Declaration Volume, Bonded Inventory in Distributor Region/Cover Time) , Lead Time for Declaration) [Unit/Month]
(3) Distributor Cost=Shipments*Transfer Price + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory+ Distributor Local Tax + Sales Labor Cost + Shipment Cost + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(4) Distributor Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(5) HQ Cost=Unit Production Cost*Production + Fixed Cost for HQ + HQ Export tax [Dollar/Month]
(6) HQ Revenue=Transfer Price*Shipments [Dollar/Month]
(7) Production=DELAY1(IF THEN ELSE(Target Production Volume>=Production Capacity, Production Capacity, Target Production Volume) , Production Lead Time) [Unit/Month]
(8) Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(9) Sales=DELAY1((Unit Adjustment II*100/Sales Price w Tariff)^6*500*Distributor Sales Efforts*Volume Coefficient, Sales Lead Time) [Unit/Month]
(10) Shipments=DELAY1(IF THEN ELSE((Inventory for Shipments in HQ Region/Period)>=Shipment Capacity, Shipment Capacity, Inventory for Shipments in HQ Region/Period) , Shipment Lead Time) [Unit/Month]

Converters:

(1) Demand Reverse Effect on Price=(Unit Adjustment*500/(Bonded Inventory in Distributor Region + Inventory for Shipments in HQ Region + Unbonded Inventory in Distributor Region))^(1/6)*100 [Dmnl]
(2) Distributor Local Tax=Sales Price w Tariff*Sales*Distributor Local Tax Rate [Dollar/Month]
(3) Distributor Sales Efforts=Distributor Contract/Contract Coefficient [Dmnl]
(4) HQ Export tax=Transfer Price*Shipments*HQ Export tax Rate [Dollar/Month]

(5) Price Value=Demand Reverse Effect on Price [Dmnl]
(6) Sales Labor Cost=Distributor Contract [Dollar/Month]
(7) Sales Price w Tariff=Price Value*Price Unit Reference [Dollar/Unit]
(8) "Sales Price w/o Tariff"=Sales Price w Tariff/(1+Tariff Rate) [Dollar/Unit]
(9) Target Customs Declaration Volume=IF THEN ELSE((Unbonded Inventory in Distributor Region/Cover Time)>2*Sales, 0, 2*Sales-Unbonded Inventory in Distributor Region/Cover Time) [Unit/Month]
(10) Target Production Volume= (Unit coefficient*(1-Distributor Local Tax Rate)*(1-1/Elasticity Coefficient)/(Unit Production Cost + Sales Unit Cost + Transfer Price*HQ Export tax Rate + Transfer Price*Tariff Rate))^Elasticity Coefficient*Nonlinear Demand Coefficient*Volume Coefficient [Unit/Month]
(11) Tariff=Customs Clearance*Tariff Rate*Transfer Price [Dollar/Month]
(12) Transfer Price="Sales Price w/o Tariff"*Transfer Coefficient [Dollar/Unit]

Constants:
(1) Contract Coefficient=10000 [Dollar/Month]
(2) Cover Time=1 [Month]
(3) Distributor Contract=9000 [Dollar/Month]
(4) Distributor Local Tax Rate=0.18 [Dmnl]
(5) Elasticity Coefficient=6 [Dmnl]
(6) FINAL TIME = 100 [Month]
The final time for the simulation.
(7) Fixed Cost for Distributor=1000 [Dollar/Month]
(8) Fixed Cost for HQ=9000 [Dollar/Month]
(9) HQ Export tax Rate=-0.02 [Dmnl]
(10) INITIAL TIME=0 [Month]
The initial time for the simulation.
(11) Lead Time for Declaration=0.5 [Month]
(12) Nonlinear Demand Coefficient=100^6*500 [Dmnl]
(13) Operation Cost for Bonded Inventory=1000 [Dollar/Month]
(14) Operation Cost for Unbonded Inventory=800 [Dollar/Month]
(15) Period=2 [Month]
(16) Price Unit Reference=1 [Dollar/Unit]
(17) Production Capacity=1e+09 [Unit/Month]
(18) Production Lead Time=0.5 [Month]
(19) Sales Lead Time=0.5 [Month]
(20) Sales Unit Cost=3 [Dollar/Unit]
(21) SAVEPER = TIME STEP [Month]
The frequency with which output is stored.
(22) Shipment Capacity=1e+09 [Unit/Month]
(23) Shipment Cost=1000 [Dollar/Month]
(24) Shipment Lead Time=0.5 [Month]
(25) Tariff Rate=0.3 [Dmnl]
(26) TIME STEP=1 [Month]

The time step for the simulation.

(27) Transfer Coefficient=0.6 [Dmnl]
(28) Unit Adjustment=1 [Unit]
(29) Unit Adjustment II=1 [Dollar/Unit]
(30) Unit coefficient=1 [Dollar/Unit]
(31) Unit Production Cost=13 [Dollar/Unit]
(32) Volume Coefficient=1 [Unit/Month]

3. SD Equations for "Fully-Fledged Distributor with Fixed Transfer Coefficient" Model

Stock equations:

(1) Bonded Inventory in Distributor Region= INTEG (Shipments-Customs Clearance, 1000) [Unit]
(2) Distributor Profit= INTEG (Distributor Revenue-Distributor Cost, 0) [Dollar]
(3) HQ Profit= INTEG (HQ Revenue-HQ Cost, 0) [Dollar]
(4) Inventory for Shipments in HQ Region= INTEG (Production-Shipments, 1500) [Unit]
(5) Production Total Volume= INTEG (Production, 0) [Unit]
(6) Profit= INTEG (Revenue-Cost, 5000) [Dollar]
(7) Sales Total Volume= INTEG (Sales, 0) [Unit]
(8) Unbonded Inventory in Distributor Region= INTEG (Customs Clearance-Sales, 1000) [Unit]

Flow equations:

(1) Cost=Unit Production Cost*Sales + Fixed Cost for HQ + Shipment Cost + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory +Sales Labor Cost + HQ Export tax + Distributor Local Tax + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(2) Customs Clearance=DELAY1(IF THEN ELSE((Bonded Inventory in Distributor Region/Cover Time)>Target Customs Declaration Volume, Target Customs Declaration Volume, Bonded Inventory in Distributor Region/Cover Time) , Lead Time for Declaration) [Unit/Month]
(3) Distributor Cost=Shipments*Transfter Price + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory + Distributor Local Tax + Sales Labour Cost+Shipment Cost + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(4) Distributor Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(5) HQ Cost=Unit Production Cost*Shipments + Fixed Cost for HQ + HQ Export tax [Dollar/Month]
(6) Production=DELAY1(IF THEN ELSE(Target Production Volume>=Production Capacity, Production Capacity, Target Production Volume) , Production Lead Time) [Unit/Month]
(7) Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(8) Sales=DELAY1((Unit Adjustment II*100/Sales Price w Tariff)^6*500*Distributor Sales Efforts*Volume Coefficient, Sales Lead Time) [Unit/Month]
(9) Shipments=DELAY1(IF THEN ELSE((Inventory for Shipments in HQ Region/Period)>=Shipment Capacity, Shipment Capacity , Inventory for Shipments in HQ Region/Period) , Shipment Lead Time) [Unit/Month]

Converters:

(1) Demand Reverse Effect on Price=(Unit Adjustment*500/(Bonded Inventory in Distributor

Region + Inventory for Shipments in HQ Region + Unbonded Inventory in Distributor Region))^(1/6)*100 [Dmnl]

(2) Distributor Local Tax=Sales Price w Tariff*Sales*Distributor Local Tax Rate [Dollar/Month]
(3) Distributor Sales Efforts=Distributor Contract/Contract Coefficient [Dmnl]
(4) HQ Export tax=Transfer Price*Shipments*HQ Export tax Rate [Dollar/Month]
(5) HQ Revenue=Transfer Price*Shipments [Dollar/Month]
(6) Order Volume=(Unit coefficient*(1-Distributor Local Tax Rate)*(1-1/Elasticity Coefficient)/(Sales Unit Cost + Transfer Price + Transfer Price*Tariff Rate))^Elasticity Coefficient*Nonlinear Demand Coefficient*Volume Coefficient [Unit/Month]
(7) Price Value=Demand Reverse Effect on Price [Dmnl]
(8) Sales Labor Cost=Distributor Contract [Dollar/Month]
(9) Sales Price w Tariff=Price Value*Price Unit Reference [Dollar/Unit]
(10) "Sales Price w/o Tariff"=Sales Price w Tariff/(1+Tariff Rate) [Dollar/Unit]
(11) Target Customs Declaration Volume=IF THEN ELSE(Unbonded Inventory in Distributor Region/Cover Time>2*Sales, 0, 2*Sales-Unbonded Inventory in Distributor Region/Cover Time) [Unit/Month]
(12) Target Production Volume=Order Volume [Unit/Month]
(13) Tariff=Customs Clearance*Tariff Rate*Transfer Price [Dollar/Month]
(14) Transfer Price="Sales Price w/o Tariff"*Transfer Coefficient [Dollar/Unit]

Constants:

(1) Contract Coefficient=10000 [Dollar/Month]
(2) Cover Time=1 [Month]
(3) Distributor Contract=10000 [Dollar/Month]
(4) Distributor Local Tax Rate=0.18 [Dmnl]
(5) Elasticity Coefficient=6 [Dmnl]
(6) FINAL TIME=100 [Month]
The final time for the simulation.
(7) Fixed Cost for Distributor=1000, [Dollar/Month]
(8) Fixed Cost for HQ=9000 [Dollar/Month]
(9) HQ Export tax Rate=-0.02 [Dmnl]
(10) INITIAL TIME=0 [Month]
The initial time for the simulation.
(11) Lead Time for Declaration=0.5 [Month]
(12) Nonlinear Demand Coefficient=100^6*500 [Dmnl]
(13) Operation Cost for Bonded Inventory=1000 [Dollar/Month]
(14) Operation Cost for Unbonded Inventory=800 [Dollar/Month]
(15) Period=1 [Month]
(16) Price Unit Reference=1 [Dollar/Unit]
(17) Production Capacity=1e+09 [Unit/Month]
(18) Production Lead Time=0.5 [Month]
(19) Sales Lead Time=0.5 [Month]
(20) Sales Unit Cost=3 [Dollar/Unit]
(21) SAVEPER = TIME STEP [Month]

The frequency with which output is stored.

(22) Shipment Capacity=1e+09 [Unit/Month]
(23) Shipment Cost=1000 [Dollar/Month]
(24) Shipment Lead Time=0.5 [Month]
(25) Tariff Rate=0.3 [Dmnl]
(26) TIME STEP =1 [Month]
The time step for the simulation.
(27) Transfer Coefficient=0.6 [Dmnl]
(28) Unit Adjustment=1 [Unit]
(29) Unit Adjustment II=1 [Dollar/Unit]
(30) Unit coefficient=1 [Dollar/Unit]
(31) Unit Production Cost=13 [Dollar/Unit]
(32) Volume Coefficient=1 [Unit/Month]

4. SD Equations for "Fully-Fledged Distributor with Fixed Transfer Price" Model

Stock equations:

(1) Bonded Inventory in Distributor Region= INTEG (Shipments-Customs Clearance, 1000) [Unit]
(2) Distributor Profit= INTEG (Distributor Revenue-Distributor Cost, 0) [Dollar]
(3) HQ Profit= INTEG (HQ Revenue-HQ Cost, 0) [Dollar]
(4) Inventory for Shipments in HQ Region= INTEG (Production-Shipments, 1500) [Unit]
(5) Production Total Volume= INTEG (Production, 0) [Unit]
(6) Profit= INTEG (Revenue-Cost, 5000) [Dollar]
(7) Sales Total Volume= INTEG (Sales, 0) [Unit]
(8) Unbonded Inventory in Distributor Region= INTEG (Customs Clearance-Sales, 1000) [Unit]

Flow equations:

(1) Cost=Unit Production Cost*Sales + Fixed Cost for HQ + Shipment Cost + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory + Sales Labor Cost + HQ Export tax + Distributor Local Tax + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(2) Customs Clearance=DELAY1(IF THEN ELSE((Bonded Inventory in Distributor Region/Cover Time)>Target Customs Declaration Volume, Target Customs Declaration Volume, Bonded Inventory in Distributor Region/Cover Time) , Lead Time for Declaration) [Unit/Month]
(3) Distributor Cost=Shipments*Transfer Price + Operation Cost for Bonded Inventory + Operation Cost for Unbonded Inventory + Distributor Local Tax + Sales Labor Cost + Shipment Cost + Tariff + Sales Unit Cost*Sales [Dollar/Month]
(4) Distributor Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(5) HQ Cost=Unit Production Cost*Shipments + Fixed Cost for HQ + HQ Export tax [Dollar/Month]
(6) HQ Revenue=Transfer Price*Shipments [Dollar/Month]
(7) Production=DELAY1(IF THEN ELSE(Target Production Volume>=Production Capacity, Production Capacity, Target Production Volume), Production Lead Time) [Unit/Month]
(8) Revenue=Sales*Sales Price w Tariff [Dollar/Month]
(9) Sales=DELAY1((Unit Adjustment II*100/Sales Price w Tariff)^6*500*Distributor Sales

Efforts*Volume Coefficient, Sales Lead Time) [Unit/Month]

(10) Shipments=DELAY1(IF THEN ELSE((Inventory for Shipments in HQ Region/Period)>=Shipment Capacity, Shipment Capacity , Inventory for Shipments in HQ Region/Period) , Shipment Lead Time) [Unit/Month]

Converters:

(1) Demand Reverse Effect on Price=(Unit Adjustment*500/(Bonded Inventory in Distributor Region + Inventory for Shipments in HQ Region + Unbonded Inventory in Distributor Region))^(1/6)*100 [Dmnl]
(2) Distributor Local Tax=Sales Price w Tariff*Sales*Distributor Local Tax Rate [dollar/Month]
(3) Distributor Sales Efforts=Distributor Contract/Contract Coefficient [Dmnl]
(4) HQ Export tax=Transfer Price*Shipments*HQ Export tax Rate [Dollar/Month]
(5) Order Volume=(Unit coefficient*(1-Distributor Local Tax Rate)*(1-1/Elasticity Coefficient)/(Sales Unit Cost + Transfer Price + Transfer Price*Tariff Rate))^Elasticity Coefficient*Nonlinear Demand Coefficient*Volume Coefficient [Unit/Month]
(6) Price Value=Demand Reverse Effect on Price [Dmnl]
(7) Sales Labor Cost=Distributor Contract [Dollar/Month]
(8) Sales Price w Tariff=Price Value*Price Unit Reference [Dollar/Unit]
(9) "Sales Price w/o Tariff"=Sales Price w Tariff/(1+Tariff Rate) [Dollar/Unit]
(10) Target Customs Declaration Volume=IF THEN ELSE(Unbonded Inventory in Distributor Region/Cover Time>2*Sales, 0, 2*Sales-Unbonded Inventory in Distributor Region/Cover Time) [Unit/Month]
(11) Target Production Volume=Order Volume [Unit/Month]
(12) Tariff=Customs Clearance*Tariff Rate*Transfer Price [Dollar/Month]

Constants:

(1) Contract Coefficient=10000 [Dollar/Month]
(2) Cover Time=1 [Month]
(3) Distributor Contract=10000 [Dollar/Month]
(4) Distributor Local Tax Rate=0.18 [Dmnl]
(5) Elasticity Coefficient=6 [Dmnl]
(6) FINAL TIME=100 [Month]
The final time for the simulation.
(7) Fixed Cost for Distributor=1000 [Dollar/Month]
(8) Fixed Cost for HQ=9000 [Dollar/Month]
(9) HQ Export tax Rate=-0.02 [Dmnl]
(10) INITIAL TIME=0 [Month]
The initial time for the simulation.
(11) Lead Time for Declaration=0.5 [Month]
(12) Nonlinear Demand Coefficient=100^6*500 [Dmnl]
(13) Operation Cost for Bonded Inventory=1000 [Dollar/Month]
(14) Operation Cost for Unbonded Inventory=800 [Dollar/Month]
(15) Period=1 [Month]
(16) Price Unit Reference=1 [Dollar/Unit]

(17) Production Capacity=1e+09 [Unit/Month]
(18) Production Lead Time=0.5 [Month]
(19) Sales Lead Time=0.5 [Month]
(20) Sales Unit Cost=3 [Dollar/Unit]
(21) SAVEPER=TIME STEP [Month]
The frequency with which output is stored.
(22) Shipment Capacity=1e+09 [Unit/Month]
(23) Shipment Cost=1000 [Dollar/Month]
(24) Shipment Lead Time=0.5 [Month]
(25) Tariff Rate=0.3 [Dmnl]
(26) TIME STEP=1 [Month]
The time step for the simulation.
(27) Transfer Price=18 [Dollar/Unit]
(28) Unit Adjustment=1 [Unit]
(29) Unit Adjustment II=1 [Dollar/Unit]
(30) Unit coefficient=1 [Dollar/Unit]
(31) Unit Production Cost=13 [Dollar/Unit]
(32) Volume Coefficient=1 [Unit/Month]