The collaborative optimization of uncertain supply chain network under multi-generation co-existence

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Abstract

This paper studies the collaborative optimization of multi-generation co-existence supply chain network of single manufacturer, multi-distribution centre and market. Firstly, we considered the effects of prices, time and substitutability on the market demand of both new and old products and the whole production and marketing decision, and then subdivide the products demand of each generation. Secondly, considering that as the lifecycle stage of each generation differs, there exist differences in demand characteristics, which make the structure of supply chain network obviously different, we built WCVaR risk optimization model of production-distribution network under co-existence, which subjects to scattering distribution constraints and solve the model by Lingo11.0 and then made simulation analysis. Lastly, we verified the validity of the model with the optimization results of numerical simulation.

Keywords: multi-generation co-existence, supply chain network, collaborative optimization, WCVaR

1 Introduction

With the development of science and technology, globalizing market competition and complicated and variable demand, the lifecycle of innovative perishable goods like mobile phones, computers, toys, etc. has been shorter and shorter, and the short lifecycle of perishable goods quickens the replacement of products, so the situation of co-existence in market of multi-generation products is normal to see. About the researches on multi-generation co-existence, domestic and foreign scholars have obtained abundant achievements, and their research contents mainly focus on the market prediction of new products, the decision of new products entering a market, price decision, production decision and products innovation and benefit coordination, (Kurawarwala, 1998; Hu Zhineng, 2013) etc. However, the structural design of supply chain under multi-generation co-existence hasn't received due attention. The design optimization of supply chain network is one of the most important strategic problems in enterprises and related research achievements which mainly focus on the design, analysis, coordination, management, optimization, and recombinant of supply chain has been quite abundant, involving production and purchase game model, production-plan model, inventory model, distribution system model, logistics distribution model, network optimization model, facility location model, etc. (Carlos J Vidal, 1997; ChenJian, 2001; Marc Goetschalckx, 2002; Haralambos Sarimveis, 2008; Melo M T, 2009).

However, the existing achievements on network design optimization cannot be completely applied to the supply chain network of multi-generation co-existence. What leads to this is that the existing researches on supply chain mainly aim at single product or unrelated multiple products, ignoring the diversity of periodical characteristics of products. Generally, in order to maintain a sound operational situation, enterprises need to conduct continuous researches to develop new products, the most satisfying picture to see is when the decline stage of the first generation products is still on the go, the second generation products have entered the growth stage of market and the third generation products have accessed to the introductory stage namely to start conceiving the latest generation products. Not only can it give full play to investment efficiency of the first generation, but also the following new products can occupy the market in succession, which can meet the demand of market and make the sales revenue and profit of enterprises grow stably as well. Some scholars held the idea that the measures taken by the supply chain should be different as the lifecycle stage of products differ, thereby, when facing the periodical demand characteristics of the lifecycle stage of the perishable goods are in the highly dynamic change, the operational strategies of the single supply chain are not compatible with the market competition any more, as a result, different operational strategies should be integrated and reconstructed fast and dynamically according to the change of periodical characteristics. However, the researches on single- product or the unrelated multiple products in most existing documents are based on the static demand characteristics while in the circumstance of multi-generation co-existence, the new and the old are

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closely associated with each other. Meanwhile, there exists differences in demand characteristics because the lifecycle stage of each generation differs, which makes their structures of supply chain network obviously different and there is much remarkable difference with the co-existence of single product and multiple independent products. So the network optimization of double channel in co-existence should be the collaborative optimization with different supply chain patterns rather than the independent optimization with single pattern.

In view of this, this paper introduces WCVaR on the basis of the researches that have done by other scholars to measure the risk of production-distribution network which is with risk preference in the co-existence of new and old products. By making risk assessment, predicting the exposure degree of risk and the loss magnitude, we can take risk aversion measures in advance. This paper builds network optimization model which aims to minimize the risk of production-distribution network in the co-existence of new and old products and meets certain service level. The model takes the situation in which the uncertain demand information is discrete points into consideration in order to explore the production-distribution strategy with minimal risk under the worst situational network.

2 Problems description and explanation

2.1 PROBLEMS DESCRIPTION

When the perishable goods of new generation hit the market, firstly, their quality, function, and appearance design are always of higher level compared to the old products. More often than not the new products can take the place of the old but the old can't in turn, in other words, the demand is of unidirectional substitution. Secondly, in the aspect of pricing, the price of the new products is much higher as they appear on the market. Some consumers will be immediately in demand of the new products, but some consumers will hesitate because of their higher sensitivity to price than to function and they won't afford to buy before the price is goes down. So the demand elasticity of consumers in hesitation is large. For the old products, we can retain the customers and hold the market share by reducing the price and taking promotion measures , and we must take the sales potential of old products into full consideration when pricing the new products. Also, the price reduction of old products should decrease the customer loss of new products as much as possible so that the enterprises can gain more profits. Therefore, in the circumstance of co-existence, the prices of both new and old products have great influence on the demand. Moreover, with more market competitors, the competition is increasingly fierce. Only by making quick response to market can the enterprises satisfy the consumers' individualized demand, improve consumer satisfaction and then attract and retain the consumers and finally win the market. So the response time would also affect the demand of new and old products.

In conclusion, the actual market demand of new and old products could be quite complicated because of the unidirectional substitution of new products, the interaction between the prices of new and old products and the effects of response time. In addition, the lifecycle stages of new and old products differ, so do their production-distribution patterns, modes of transportation and inventory locations, which makes their network design more complicated. But in reality, it's quite difficult to obtain the initial distribution information of demand through the historical data because of the specificity of products and sometimes the data we got are just some scattering points, which, as a result, greatly restrict the solutions to the existing models. So, in the circumstance of co-existence of multi-generations, in order to realize the risk minimization of the whole network with certain service level, enterprises need to exercise the optimal design of production- distribution network of two generations in the case of high uncertainty and complication of demand, and simultaneously to determine the price, lead time, production quantity, locations of distribution centres, integrated optimization of storage and the transportation problems.

2.2 MODEL ASSUMPTIONS AND PARAMETERS

1) Assumptions are made as follows in order to simplify the complication of models.

Assumption 1. The perishable goods of two generations are of the same brands, the new generation is in growth stage while the old generation is in mature stage.

Assumption 2. The demand variables in each market are mutually independent, the initial demand subjects to the discrete distribution of point set only.

Assumption 3. The actual demand in each market is negatively linear with the lead time and price.

Assumption 4. The demand of products is in unidirectional substitution, and the substitution rate is negatively linear with the price gap between the new and old products.

Assumption 5. The price is identical in the same market stage .

Assumption 6. The order cycles of both new and old products are identical and known, and both of them adopt the (t,s) ordering policy.

Assumption 7. The raw material suppliers and manufacturers adopt JIT distribution policy, and the manufacturers do not have raw material in stock.

Assumption 8. Not taking the restriction of production capacity and transport capacity of the factory into consideration.

Assumption 9. To get closer to reality and keep the generality, the transport of both new and old products adopt the PTP&HUB distribution modes.

2) Parameter determination.

Superscripts and subscripts:

i is the sales market;
j is the distribution centre;
k is the classifications of products;
s is the sample size.

Time parameters:

g_1 is the unit production time of new semi-finished products;
l_1 is the unit reprocessing time of new semi-finished products;
t_k is the production time of unit product k;
t_o is the time interval for ordering;
$tm_{(*)}$ is the transport time between facilities.

Cost parameters:

v_k is the variable production cost of unit product k;
q_1 is the unit variable production cost of new semi-finished product;
e_1 is the unit variable processing cost of new semi-finished product;
r_i is the regular freight from factory to market i;
v_{ki} is the unit variable freight of product k from factory to market i;
r_j is the regular freight from factory to distribution centre j;
v_{kj} is the unit variable freight of product k from market to distribution center j;
r_{ji} is the regular freight from distribution center j to market i;
v_{kji} is the unit variable freight of product k from distribution center j to market i;
cs_k is the unit shortage cost of product k.

Related parameters about price demand:
a_k is the price elasticity of demand of product k;
b_k is the time elasticity of demand of product k;
c is the conversion rate of demand the old products to the new products;
Δpc is the price gap between new and old products when c=0;
D_{ki}^{0s} is the initial demand of product k in market i;
$D_{ki}^{'s}$ is the core demand of product k in market i;
D_{ki}^{s} is the actual demand of product k in market i;
p_s is the appearance probability of the sth sample.

0-1 variables:

Y_i is a 0-1 variable for whether to transport from factory to market i;
Z_j is a 0-1 variable for whether to transport from factory to distribution center j;
F_{ji} is a 0-1 variable for whether to transport from distribution center j to market i.

Decision variables:

pc_k is the price of product k;
t_{ik} is the due date for product k in market i;
x_k is the production of product k;
m_1 is the production of new semi-finished products;
w_1 is the reprocessing amount of new semi-finished products;
ζ_{ki} is the shortage amount of product k in market i;
y_{ki} is the traffic volume for product k from factory to market i;
z_{kj} is the traffic volume for product k from factory to distribution centre j;
f_{kji} is the traffic volume for product k from distribution center to market.

3 Model building and solving

3.1 MODEL BUILDING

As the lifecycle stage of both new and old generation differs, there exist differences in production-distribution patterns, storage locations and response time, which concretely represented in the differences of loss function composition, time constraint, flow conservation and demand relationship. For new products in growth stage, we adopt the production mode of ordering-assembling of which the loss function mainly consider the income loss, production and processing cost of semi-finished goods, freight and shortage loss. While for the old products, we produce according the inventory, and it's loss function mainly includes the income loss, production cost, freight and the shortage loss. In this paper, we build WCVaR risk optimization model of the whole production-distribution network in the circumstance of co-existence, which subjects to the box discrete distribution. On the basis of providing the customers of new and old products with satisfying service level, the objective function is to minimize the worst-case conditional value-at-risk of the whole production-distribution network to the least. The WCVaR risk optimization model of production-distribution network in co-existence is built as follows.

$$MinT = \sum_{k=1}^{2}\theta_k + \sum_{k=1}^{2} v_k x_k + q_1 m_1 + e_1 w_1 + \sum_{i=1}^{I}\left(r_i Y_i + \sum_{k=1}^{2} v_{ki} y_{ki} \right) + \sum_{j=1}^{J}\left(r_j Z_j + \sum_{k=1}^{2} v_{kj} z_{kj} \right) + \sum_{j=1}^{J}\sum_{i=1}^{I}\left(r_{ji} F_{ji} + \sum_{k=1}^{2} v_{kji} f_{kji} \right) + \sum_{k=1}^{2}\sum_{i=1}^{I} cs_k \zeta_{ki} \quad (1)$$

$$s.t.\ \alpha_k + \frac{1}{1-\beta}\pi^T u_{ks} \le \theta_k, k = 1,2 , \quad (2)$$

$$u_{ks} \ge -\sum_{i=1}^{I} pc_k D_{ki}^{s} - \alpha_k, \forall k, s , \quad (3)$$

$$u_{ks} \ge 0, \forall k, s , \quad (4)$$

$$x_1 + w_1 = \sum_{i=1}^{I} y_{1i} + \sum_{j=1}^{J} z_{1j} , \quad (5)$$

$$x_2 = \sum_{i=1}^{I} y_{2i} + \sum_{j=1}^{J} z_{2j} , \quad (6)$$

$$w_1 = m_1 , \quad (7)$$

$$z_{kj} = \sum_{i=1}^{I} f_{ijk} , \forall k, j, \quad (8)$$

$$E\{D_{ki}^s\} - \zeta_{ki} \le y_{ki} + \sum_{j=1}^{J} f_{ijk} \le \max\{D_{ki}^s\} - \zeta_{ki}, \forall k, i , \quad (9)$$

$$\sum_{i=1}^{I} \zeta_{ki} \le \max\{\sum_{i=1}^{I} D_{ki}^s\} - x_k - w_k , \quad (10)$$

$$g_1 m_1 + t_{i1} \le to, \forall i , \quad (11)$$

$$t_1 x_1 + l_1 w_1 + Y_i tm_i \le t_{i1}, \forall i , \quad (12)$$

$$t_1 x_1 + l_1 w_1 + Z_j tm_j + F_{ji} tm_{ji} \le t_{i1}, \forall i , \quad (13)$$

$$t_2 x_2 + Z_j tm_j + t_{i2} \le to, \forall j, i , \quad (14)$$

$$F_{ji} tm_{ji} \le t_{i2}, \forall j, i , \quad (15)$$

$$t_2 x_2 + Y_i tm_i \le to, \forall i , \quad (17)$$

$$D_{ki}^{'s} = D_{ki}^{0s} - a_k pc_k - b_k t_{ik}, \forall i, k , \quad (18)$$

$$D_{1i}^s = D_{1i}^{'s} + c D_{1i}^{'s}, \forall i , \quad (19)$$

$$D_{2i}^s = D_{2i}^{'s} - c D_{2i}^{'s}, \forall i , \quad (20)$$

$$c = 1 + (pc_2 - pc_1) / \Delta pc , \quad (21)$$

$$x_k, m_1, w_1, y_{ki}, z_{kj}, f_{kji} \ge 0 . \quad (22)$$

The Equation (1) represents the minimal worst-case conditional value-at-risk of production - distribution network in the co-existence of two generations, mainly considering the income loss, production, assembling, transport and shortage cost. Equation (2) represents the income risk in the worst case, Equations (3) and (4) represent the discrete constraints; Equation (5) represents the conservation of production and transport volume of the new products; Equation (6) represents the conservation of production and transport volume of the old products; Equation (7) represents that the production of new semi-finished products is equal to the processing capacity; Equation (8) represents the conservation of the entering and exiting amount in distribution centres; Equation (9) represents the conservation of demand and traffic volume of two generations; Equation (10) represents the constraint of shortage amount; Equations (11) to (13) express the composition of actual response and constraints of new products; Equations (14) to (17) express the composition of actual response and constraints of old products; Equation (18) represents the price and time have effects on the demand; Equations (19) and (20) express the substitution rate has effect on actual demand; Equation (21) represents the relationship between substitution rate and price gap of two generations; Equation (22) is to make constraints that each variable isn't less than zero.

3.2 MODEL TRANSFORMATION

In Equation (2), π^T represents discrete points, Zhu and Fukushima (2009) defined the discrete points of box set. When π subjects to box set distribution, then the probabilities of discrete points satisfy:

$$\pi \in \mathrm{P_D^B} = \{\pi : \pi = \pi^0 + \eta, e^T \eta = 0, \underline{\eta} \le \eta \le \overline{\eta}\} . \quad (23)$$

In Equation (23), π^0 is a known distribution, η is a constant, $e^T\eta$ is to guarantee that π is a probability distribution, e is a unit vector, then P_D^B is called as box discrete distribution.

So, the constraint (2) can be equivalently transformed to:

$$\alpha_k + \frac{1}{1-\beta}\sum_{s=1}^{S} p_s u_{ks} + \frac{1}{1-\beta}\sum_{s=1}^{S} (\bar{\eta}_{ks}\xi_{ks} + \underline{\eta}_{ks}\omega_{ks}) \le \theta_k , \quad (24)$$
$$k = 1, 2$$

$$e_{ks} zz_k + \xi_{ks} + \omega_{ks} = u_{ks}, \forall k, s , \quad (25)$$

$$\xi_{ks} \ge 0, \omega_{ks} \le 0, \forall k, s . \quad (26)$$

Now, the model has transformed to mixed integer programming model which can be solved with some related methods and software.

3.3 MODEL SOLVING

The mixed integer programming model which can be solved with branch and bound method, cutting plane approach and Lagrangian algorithm has the features of multi variables, many constrained formulas with respond time composition and constraints, and moreover great amount of data of samples need to be processed in the solving process. Compared to the general models of logistics network design, this model is much more complicated so that it's difficult to obtain the accurate solution with common methods. For optimization model solving, Lingo is considered as a professional software package which is a perfect choice to solve combinational optimization with the characteristics of efficient running and easy operation. This paper will solve the model by programming with Lingo11.0.

4 Numerical simulation

A certain manufacturer of perishable products with high-tech plans to construct a production-distribution integration network of co-existence of new and old products, and now there exists a manufactory, three markets and three distribution centres. For the new products in growth stage, the unit production cost is 700 yuan, the production efficiency is 0.012 hour per piece. For semi-finished products, the variable production cost is 450 yuan per piece, the production efficiency is 0.008 hour per piece, the variable reprocessing cost is 230 yuan per piece and the reprocessing efficiency is 0.006 hour per piece; While for the old products in mature stage, the unit production cost is 430 yuan, the production efficiency is 0.01 hour per piece. The freight from manufactory to each market is respectively 12.5 yuan, 9.5 yuan and 10 yuan. The freight from manufactory to each distribution centre is respectively 3.6 yuan, 3 yuan and 4.2 yuan. The transport time form manufactory to each market is respectively 4 hours, 3 hours and 6 hours, while the transport time from market to each distribution centre is respectively 2.5 hours, 4 hours and 3.5 hours. The delivery lead time for new products is from 30 to 50 hours in each market and the price range is [1500,2000]; While the delivery lead time for old products is from 15 to 25 hours and the price range is[1000,1200]; Δpc =1000 and the interval time of ordering is stipulated to be 200 hours; $a_1 = 0.01$, $a_2 = 0.03$, $b_1 = 2.5$, $b_2 = 1$, data of other related parameters is shown in Table 1 and Table 2.

TABLE 1 The unit variable transport cost from distribution centre to market (yuan per piece)

distribution centre \ market	I_1	I_2	I_3
J_1	7	6	6.5
J_2	9	4	5
J_3	5.5	2.5	8

TABLE 2 The transport time from distribution centre to market (hour)

distribution centre \ market	I_1	I_2	I_3
J_1	3	5	4
J_2	2	8	6
J_3	4.5	7.5	3

4.1 SIMULATION RESULTS

Take 500 points as the historical data sample of initial demand with Monte Carlo Method., and the points correspond with D_{ki}^{s} in Equation (3), namely s=500; let $\beta_1 = \beta_2 = 0.95$; $0.0001 \le \eta \le 0.0008$, solving the model by programming with lingo 11.0, it takes 39 min 19 s to get the global optimal solution, and the calculation results are as follows: the target risk value T=-3019568 yuan, and the optimal operation strategy of production-distribution network is shown Table 3 and Table 4.

TABLE 3 The optimal solution of the price of both new and old products and lead time

pc_1	pc_2	t_{11}	t_{12}	t_{21}	t_{22}	t_{31}	t_{32}
1832	1200	30	15	30	15	30	15

TABLE 4 The optimal solution of the production of new and old products

x_2	xp_1	xrp_1
2953	1972	1972

TABLE 5 The logistics distribution of both new and old products and the optimal solution of 0-1 transport variables

z_{12}	z_{13}	z_{22}	z_{23}	f_{123}	f_{223}	f_{131}	f_{231}
614	1358	1092	1861	614	1092	878	973
f_{132}	f_{232}	Z_2	Z_3	F_{23}	F_{31}	F_{32}	**else**
480	888	1	1	1	1	1	0

As is shown in Table 3, when the new and old products coexist, in order to obtain the maximal profit, the price of old products is 1200 yuan, which is the maximum of permitted price, but its price is still far lower than the 1832 yuan of new products. To attract consumers as many as possible with lower price and then increase the sales volume, we don't price the new products at their highest, but considering the huge sales potential of old products, the price of new products shouldn't be too low for fear that the consumers of old products would turn to the new. Only in this way can the enterprises get more profits. From Table 4, we can see that the optimal production of old products is 2953 pieces which is far more than the 1972 pieces of new products, what leads to this is that the old products are in mature stage and its demand is maximal and stable while the new products are in the grow and the demand is still increasing, from which we also can conclude that the old products are in great demand at present. Meanwhile, the new products are produced only by ordering-assembling mode, because the category of products in growth is numerous and the customers have high personalized requirement, the production without delay costs high and it's difficult to satisfy the changeable demand in short time. By adopting ordering-assembling, not only can the scale production for semi-finished goods reduce the cost and improve the accuracy of prediction, but also can shorten the response time and assemble the products with diversity to adapt to the changeable demand. Furthermore, the optimal lead time of both new and old products is the minimum, the reason is that whatever stage they are in, growth stage or mature stage, the response time is the key factor to improve the service level, to enhance the competition ability and to win the market.

From Table 5, we can know that both new and old products which are distributed through J2 and J3 choose the HUB only as the centralized distribution, this is because that the manufacturer is far away from the markets. In spite of the guaranteed timeliness of nonstop transportation, the freight is quite high when directly distributed from manufacturer to 3 markets, which is respectively 12.5 yuan, 9.5 yuan and 10 yuan per piece while the highest and the lowest unit freight from distribution centers to market is just respectively 12.2 yuan and 7 yuan, so we don't adopt the PTP direct distribution. Similarly, the unit transportation cost from distribution centers J1 to 3 markets respectively reaches to 23.1 yuan, 22.1 yuan and 22.5 yuan per piece, which makes the total freight much higher than the freight from J1 and J2, while the freight to 3 markets in the optimal scheme is respectively 20, 17,17.5 yuan per piece, so we don't choose J1.For old products, it's likely to reduce the logistics cost with the scale advantages of centralized distribution and the new products can be assembled in distribution centres as well in order to make response to the market demand in short time. On the other hand, the storage and transportation of both new and old products can be integrated by choosing the same distribution centres and distribution modes, cutting down the cost of storage, transportation and management to the maximal extend. From the logistics assignment of each node, we can see that the model takes the choice of routes and logistics assignment into consideration from the optimal view of the whole production-distribution network.

In conclusion, the strategies of production and sale in present market list as follows: the old products are still in great demand, so we adopt the low price strategy and maximal price level to stabilize the market and increase the sales; The new products should be priced rationally to find a balance between its own profit and the profit reduction of old products so as to realize the maximal profit of the two products. As for the production, the short term demand of old products is steady, so we should take the effects of price, time and demand substitution into full consideration according to the existing demand information, and then arrange the production reasonably; While the new products should also attach much importance to the demand of old products and pay due attention to the effects of its own price, time and substitution rate, and then price and make production plan for semi-finished goods reasonably. In terms of the choices of distribution modes and distribution centres, both new and old products should follow the principle that cost is to keep optimal in a certain period of time, thus reducing the transportation cost to the maximal extend. In terms of the logistics assignment, the scale benefit brought by the integrated transportation of the two products should receive due attention to minimize the cost of logistics and management. So, effective and reasonable production-distribution network can provide powerful guidance for decision making in the market where the new and old products coexist, and the correct decision not only can effectively weight various costs, reasonably arrange the logistics assignment for the two products, minimize the risk of supply chain and win much more profits, but also can incent various strategies to optimize and improve constantly.

4.2 SENSITIVITY ANALYSIS

By analysing the sensitivity of some parameters in model can the decision maker choose appropriate optimization strategy of production-distribution network according to the actual situation.

To analyse the effects of the risk preference of decision maker on the WCVaR risk value of the whole production-distribution network, now analyse the sensitivity respectively for the confidence levels of both new and old products (β_1 and β_2). Taking the parameters in examples as reference value, we scale down the ratio between β_1, β_2 and the reference value by 5% and then explore the relationship between the WCVaR risk value and the lessoned ratio. The result is shown in Figure 1.

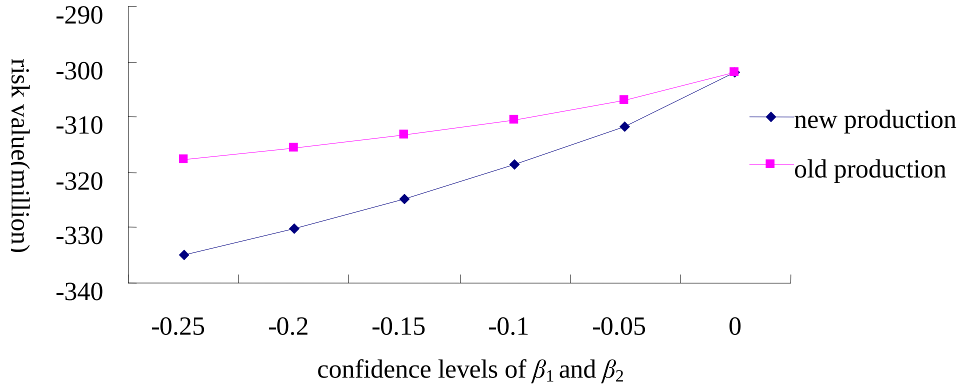

FIGURE 1 Relationship between the change of β_1 and β_2 and target value

As is shown in Figure 1, when other conditions are fixed, respectively change the confidence levels of both new and old products (β_1 and β_2), the target value is much more sensitive to the confidence level of new products than to that of the old products, which indicates that the decision maker's attitude to the risk of new products can arouse greater fluctuation for the whole production-distribution network, reflecting the new products market has stronger sensitivity. So, the decision maker could take different measures in different markets according to the actual operation to reduce the risk loss.

The alteration of confidence level β_1 and β_2 do not have effects on the production, distribution modes, option of distribution centres and low assignment, but it does affect the price strategies of both new and old products. The Table 6 shows the optimal price of the two products at different confidence levels.

TABLE 6 The optimal price of new and old products at different confidence levels

Confidence level	β_1	0.95			0.90			0.85		
	β_2	0.95	0.90	0.85	0.95	0.90	0.85	0.95	0.90	0.85
New product		1832	1847	1857	1839	1854	1864	1842	1855	1865
Old product		1200	1200	1200	1200	1200	1200	1200	1200	1200

From Table 6, we can see that however the confidence level β_1 and β_2 changes, the price of old products remains at 1200, which means that the decision maker's risk attitude can't affect the price of old products. When the values of β_1 and β_2 shrink simultaneously, the price of old products rises, which indicates that when the risk preference decreases, the decision maker tends to adopt conservative marketing strategy, namely to sustain the market share to the most at low risk level. While when β_1 is fixed and only β_2 is reduced, the price of new products also increase, the width of which, however, is over the effects of its own confidence level. This is because the risk value is much more sensitive to the confidence level of new products than to that of the old products, the risk reduction brought by the reduction of unit β_2 is less than what brought by unit β_1, which, as a result, makes the integral risk level increase relatively and finally price high for new products so as to maintain the high profits. So, in the market where the new and old products coexist, the decision maker's risk preference to different products market would affect mutually and the decision should be made after integral trade off and consideration according the actual situation. Under the box discrete distribution, the disturbance value of probability distribution of the random variable D_{ki}^{s} is between $\bar{\eta}_{ks}$ and $\underline{\eta}_{ks}$. In order to acquire the effects of demand fluctuation extend on the WCVaR risk value of network, now we analyze how the WCVaR risk value of production-distribution network changes under different disturbance. As shown in Figure 2.

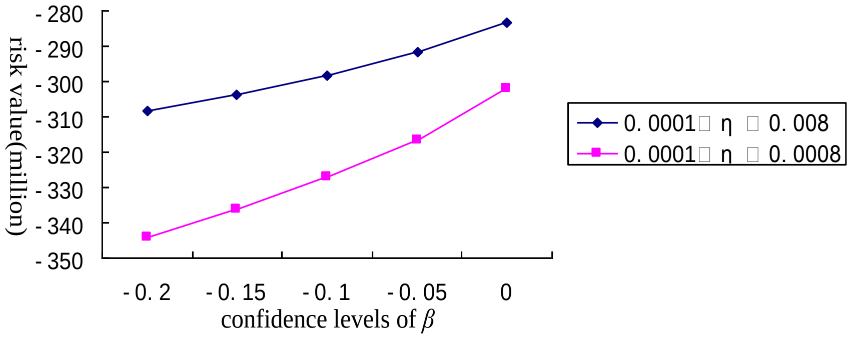

FIGURE 2 The relationship between disturbance value and target value at different confidence levels

From Figure 2, the corresponding decision value and WCVaR risk values would change as the disturbance value varies. At the same confidence level, the WCVaR risk value would increases as the disturbance value of demand probability distribution increases, which indicates that the larger fluctuation extend, the higher network risk. Furthermore, when widen the variation range of disturbance value, the WCVaR risk value tends to be stable. It means that the model is with good robustness in the disturbance which is brought by uncertain random distribution. Thus, it can been seen that the WCVaR method can effectively measure the risk of production-distribution network when the demand of products market is with different fluctuation extend, and the larger the fluctuation extend is , the more robust the model is. It provides beneficial guidance, reference and help for the decision makers of supply chain to analyse, measure and manage the actual risk of production-distribution network.

5 Conclusion

What attracts customers to perishable products most is the uniqueness in technology, performance and value. The uniqueness of products is always perishable because once a product is in good graces of customers, the competitors would produce similar goods with strong substitutability as soon as possible, which force the enterprise to utilize newer technology and update the products constantly to ensure the stable income in the long term. According to the co-existence of multi-generations, this paper builds risk optimization model which considers the substitution of new products to old products, the effects of price and lead time on demand and generate discrete data sample of demand with Monte Carlo Method. We explore the optimal strategy which meets the minimal WCVaR risk value of the whole production-distribution network, namely simultaneously determine the production scale of both new and old products, price, lead time, locations of distribution centres and the optimal transport route which are verified through numerical simulation.

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