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Research Paper

A optimal pricing and inventory model for perishable agricultural products

XiuxiuLi[1],YuquanCui*[2]WentianZhang[1]
[1] *School of mathematics,Shandonguniversity,Jinan,China*
[2] *School of mathematics,Shandong university,Jinan,China,(corresponding author)*

ABSTRACT
The researchobject of thispaper was theinventorysystemof asingleperishableagriculturalproduct.Inthisinventorysystem,thedemand rateof theproduct wasaffectedbythesalespriceandalsotherandomnessofthedemanddescribedbytheBrownianmotion.Atthesametime,thispaper constructedtheattenuationcoefficientfunctionofperishableproducts.Thecoefficientconsistedoftwoparts.The firstpartwasfixed referredtothepreviousstudies.Thesecondwasthestochasticpartcausedbyexternalenvironmentorhumanfactors.Anditwasdescribedby theBrownianmotion.Differentfrompreviousstudies,thispaper introducedboththestochasticdemandand theattenuationcoefficientof stochastic factorsinto themodelingoftheinventorysystem.Withoutloss of generality,we studied a sales replenishment cycle of perishableagriculturalproductsfromzeroreplenishment totheoptimalinventorySandthecycleTwasdividedintoN stages.Therelativeanalytical solutions weregivenin thecasesof fixedinventoryandfixedprices.Andwepointedouttheimpactofuncertaintyfactorparametersonpricingandprofits. Thededuction that thephasedpricing resultedinalimitedprofitimprovementoverthesinglepricingwasobtainedbycomparativeanalyzing. Inaddition,Wealsoshowed thepracticalsignificanceofintroducingrandom factorsbytheexplorationofthe relationshipbetweenthecoefficients.
Keywords:Perishableagriculturalproduct,theBrownianmotion,theinventorysystem

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I. Introduction

With theimprovement of people'sliving standard,people's requirements onthequality ofagriculturalproductsarealsoimproving.However,thedeteriorationandlossofagriculturalproductswillinevitablyoccurineachprocessof thesupplychain. From theperspectiveof sellers'market,consideringtheinventorycontrolandthephasedpricingstrategyof perishableagriculturalproductswillbeconducivetoboostprofitability,reducethewasteof freshproductsinmanysupermarketsor retailersandpromote thedevelopmentoffreshagriculturalproductsindustrychain.
Manyscholarshavestudiedanddevelopedthe replenishmentstrategyofperishablegoods.Theresearchonperishableproductsbeganin1977[1]anditwasassumedthattheproductwasinexponentialdecayformandthedeteriorationcoefficientwasconstant in the literature. However,thedeterioration rateofperishablegoodsisnot constant in reallife. Scholarsat homeandabroadintroduced theconcept of non-immediatemetamorphismandstudied theproduct orderingandproductionstrategymodel.HongChenetal.[2]consideredtheproblemofoptimalinventoryandphasedpricinginaninventorysystemwith theuncertaindemand.Inthispaper,standardBrownianmotionwasusedinthedemand rate.NitaH.Shah[3]studiedintegratedinventorysystemandpricingandorderingstrategy forvendor-buyersupplychainsystem.Andwhendemand rateisincreasingfunctionofthetimeanddecreasing functionof the retail price,theydevelopedandvalidatedamathematicalmodel.

As for the freshproducesupplychainmanagement (FSCM),ManishShuklaandSanjay Jharkharia[4] collected andanalyzedtherelatedstudiesupto2011.Thefactorssuchastheglobalizationandtheconsumerawareness have attracted theattentionof researchersandpractitioners towards theFSCM.Theliteraturepointedthatmostofthe

supplychainproblemsare generally well studied and explored formanufacturing products,but have recently gainedattention for agri-freshproduce. In recent tenyears,withtheincreasingattentionpaidtoagriculturalproduction,moreandmorescholarshaveconductedin-depthstudiesonthe supply chain of agriculturalfresh products.In theaspect of coldchainlogisticsof agriculturalproducts,some scholars designedandoptimizedtheevaluationindexsystemmodelbasedon riskidentificationinorder tomanagepotential risks.Somescholars[5]alsoestablishedanevaluationmethodbasedonCVaRtoevaluateandcontrol risks.Intermsofsupplychaincoordination,scholars[6,7]have improvedtheexisting supply chain contracts andestablisheda supply chain coordinationmodelfor agriculturalandfreshproducts.Scholars[8,9]builtthemixedinteger linear programmingmodelsfordifferentagriculturalandfreshproductstooptimizedistributioncostsinthesupplychain .Attention,scholarsherehaveconsideredtheperishablecharacteristicsoffreshagricultural products.In addition,another scholars[10] considersthecustomerresponse factor into theshort-termfood supply chainproblem.Scholars[11] consideredtheinventorycontrolof freshagriculturalproductsunderWeibulldistribution,andintegratedinflationanddelaypayment. Therefore,the inventoryandpricingoptimizationmodel of agriculturalfreshproductsisestablishedbasedontheexistingstudies. In thispaper,standardBrownianmotionisusedtodescribetheuncertainfactorsofdemandrateandthequalitydecayoffreshagriculturalproductsover time.Atpresent,therearefewstudiesconsideringthe two factorscomprehensively.

2ProblemFormulation

2.1Problemdescription

Theresearchobject of thispaper istheseller ofsomeperishableagriculturalproductssuchasthelargesuper-marketsand thewholesalemarketsof agriculturalproducts.

Firstly,thedemandfunction,theinventoryfunctionand thepricing replenishment strategy weredescribedas follows.

Thedemand rate $\lambda(p)$ is thedecreasing functionof theprice p andpositive-valued.Also, $\lambda(p)$ istwicecontinuousdifferentiablein theinterior ofthedomainofthefunction.Manycommonly-useddemandfunctionssatisfytheabove assumption. B(t)represents the standardBrownianmotionanddescribedtherandomness.Notethatσ1isaconstant coefficientsatisfying $0 < \sigma_1 < 1$.Thedecaycoefficientofperishableproductsis $\theta(t) = \mu(t) + \sigma_2 B(t)$ where $B(t)$ isthestandardBrownianmotionand $0 < \sigma_2 < 1$.TheninventorylevelX(t)attimetsatisfy $X(t) = S - \theta(t)S - D(t)$.

In the followingmodel,wesuppose theperishableproduct isreplenishedimmediately.Thatis,thedemandisalwaysmetimmediately.Thetimeintervalbetweentwoconsecutivereplenishmentiscalledoneperiod T .Inventory replenishment quantityisset tobe S . As for agivenpositiveintegerNwhichstandsforthecyclestagesdividedinto,weassumethat $S = S_0 > S_1 > \cdots > S_{(N-1)} > S_N = 0$ andthecorrespondingstagepriceis $P = (p_1, p_2, \cdots, p_N)$ .Withoutgenerality,weassumesthatthecycleinventoryisaddedfromzerotooptimalinventory S .Inaccordancewiththedivided N stagesinacycle,let $T_0 = 0$ betheinitialstate.Let T_n bethetime for theinventorylevelfirstreaches S_n .That means $T_n = \inf\{t \geq 0 : D(t) + \theta(t)S = nS / N\}$,wherewetaketheattenuationof theperishablegoods intoconsideration.

Asimplegraphicofacycleisshownbelow.

$$S = S_0 \xrightarrow[\mu_1, p_1]{} S_1 \xrightarrow[\mu_2, p_2]{} \cdots \xrightarrow[\mu_n, p_n]{} \cdots \xrightarrow[\mu_N, p_N]{} S_N$$

The time interval of phase N is $\tau_n := T_n - T_{(n-1)}$,i.e.

$\tau_n = \inf\{t \geq 0 : \lambda(p_n)t + \sigma_1 B(t) + \mu(t)tS + \sigma_2 B(t) = S / N\}$ Convenient to discuss below, we assume that the first part of the perishable product's attenuation function in a fixedphase as fixed values,noting as $\mu_n = \int_{T_{(n-1)}}^{T_n} \mu(t)dt$ .Therefore, $\tau_n = \inf\{t \geq 0 : \lambda(p_n)t + \sigma_1 B(t) + \mu_n tS + \sigma_2 B(t) = S/n\}$.

2.2Thepreliminaryanalysis

Combinedwith thestrongMarkovpropertyofBrownianmotion,thefollowingcanbeobtained.

$$E(\tau_n) = \frac{S}{N(\lambda_n + \mu_n S)} \quad (1)$$

$$E(\tau_n^2) = \frac{(\sigma_1 + \sigma_2 S)^2}{(\lambda_n + \mu_n S)^2} \cdot E(\tau_n) + E^2(\tau_n) \quad (2)$$

According to thedivisionof thephasesin thecyclementionedabove,wecanget $X(T_{(n-1)}) = S_{(n-1)}$ and $X(T_n) = S_n$. Incombinationwith therelationshipbetween theinventoryleveland thedemand,thefollowingcan be obtained.

$$\begin{aligned}\int_{T_{n-1}}^{T_n} X(t)dt &= T_n S_n - T_{n-1}S_{n-1} - \int_{T_{n-1}}^{T_n} t dX(t) \\ &= T_n S_n - T_{n-1}S_{n-1} - \int_{T_{n-1}}^{T_n} T_{n-1} dX(t) + \int_{T_{n-1}}^{T_n} (t - T_{n-1}) dX(t) \\ &= \tau_n S_n + \int_{T_{n-1}}^{T_n} (t - T_{n-1}) dX(t - T_{n-1}) \\ &= \tau_n S_n - \int_{T_{n-1}}^{T_n} (t - T_{n-1})(\lambda(t) + S\mu(t))dt - (\sigma_1 + \sigma_2 S)dB(t)\end{aligned}$$

Since $E(\int_{T_{n-1}}^{T_n} (\sigma_1 + \sigma_2 S)dB(t)) = 0$,then

(3)

$$E[\int_{T_{n-1}}^{T_n} X(t)dt] = E[S_n \tau_n - \int_{T_{n-1}}^{T_n} (t - T_{n-1})(\lambda_n + \mu S)dt]$$

$$= S_n E[\tau_n] + \frac{1}{2}(\lambda_n + \mu S)E[\tau_n^2]$$

$$= \frac{S \cdot S_n}{N(\lambda_n + \mu S)} + \frac{S(\sigma_1 + \sigma_2 S)^2}{2N(\lambda_n + \mu S)^2} + \frac{S^2}{2N^2(\lambda_n + \mu S)}$$

Therefore,theexpectedprofit of phase N canbeexpressedasthefollowingequation.

$$\begin{aligned}v(S, p_n) &= E[p_n(\frac{S}{N} - \theta_n \frac{S}{N}) - h\int_{T_{n-1}}^{T_n} X(t)dt] \\ &= p_n(1 - \theta_n)\frac{S}{N} - h[\frac{S \cdot S_n}{N(\lambda_n + \mu_n S)} + \frac{S(\sigma_1 + \sigma_2 S)^2}{2N(\lambda_n + \mu_n S)^2} + \frac{S^2}{2N^2(\lambda_n + \mu_n S)}]\end{aligned}$$

(4)

Where $\theta_n=\int_{T_{n-1}}^{T_n} d\theta(t)=\int_{T_{n-1}}^{T_n}\mu(t)dt+\int_{T_{n-1}}^{T_n}\sigma_2 dB(t)=\mu_n+\int_{T_{n-1}}^{T_n}\sigma_2 dB(t)$, $S_n=\frac{(N-n)S}{N}$ .Inthispaper,whenthe replenishmentquantityis S ,weusetheequation $c(S)$ tostand for thecorrespondingcost. Then the totalprofit of thecycleis

$$\sum_{n=1}^{N}v_n(S,P)=\sum_{n=1}^{N}[p_n(1-\theta_n)\frac{S}{N}-\frac{hS\cdot S_n}{N(\lambda_n+\mu_n S)}-\frac{hS(\sigma_1+\sigma_2 S)^2}{2N(\lambda_n+\mu_n S)^2}-\frac{hS^2}{2N^2(\lambda_n+\mu_n S)}]-c(S) \quad (5)$$

$$=\sum_{n=1}^{N}[p_n(1-\theta_n)\frac{S}{N}-\frac{h(N-n+\frac{1}{2})}{N^2}\cdot\frac{S^2}{(\lambda_n+\mu_n S)}-\frac{hS(\sigma_1+\sigma_2 S)^2}{2N(\lambda_n+\mu_n S)^2}]-c(S)$$

Therefore,thedecisionvariablesof decisionmakersaretheinventory replenishmentquantity S andthepricevector $P=(p_1,p_2,\cdots,p_N)$. The rest of thepaper will mainly focuson thesolutionofthedecisionvariables.

3Modelconstructingandpreliminaryresults

3.1Theoptimalreplenishmentquantitymodelwhenthepriceisfixed

Firstly,notethat $\lambda_n(p_n)+\mu_n S=g_n(p_n)$ .And forconvenience,thelong-termaverageprofit functionisintroduced,notingas $V(S,P)$.

$$V(S,P)=\frac{\sum_{n=1}^{N}v_n(S,P)}{\frac{S}{N}\cdot\sum_{n=1}^{N}\frac{1}{\lambda_n+\mu_n S}}=\frac{\sum_{n=1}^{N}v_n(S,P)}{\frac{S}{N}\cdot\sum_{n=1}^{N}\frac{1}{g_n}}$$

$$=\frac{\sum_{n=1}^{N}[p_n(1-\theta_n)-\frac{hS(N-n+\frac{1}{2})}{N}\cdot\frac{1}{g_n}-\frac{h(\sigma_1+\sigma_2 S)^2}{2}\cdot\frac{1}{g_n}-a(S)]}{\sum_{n=1}^{N}\frac{1}{g_n}} \quad (6)$$

When thepricevector $P=(p_1,p_2,\cdots,p_N)$ isfixed,thesolutionof themodelis tosolve theoptimizationproblem $\max_{S>0}V(S,P)$ .Basedonthestrictconcavityoftheprofitfunctionforreplenishment S inthepreviouspaper,theoptimal replenishmentquantitycanbesolvedbythefirstordercondition.

$$\frac{\partial V(S,P)}{\partial S}=\sum_{n=1}^{N}[\frac{p_n(1-\theta_n)}{N}-\frac{h(N-n+1/2)}{N^2}\cdot\frac{2S\lambda_n+S^2\mu_n}{(\lambda_n+\mu_n S)^2}]-c'(S) \quad (7)$$

3.2Thesinglepricingmodelwhenthereplenishmentsisfixed

Firstly,wehave $V(S,P)=p_n(1-\theta_n)(\lambda_n+\mu_n S)-\frac{hS}{2}-\frac{h(\sigma_1+\sigma_2 S)^2}{2(\lambda_n+\mu_n S)}-a(S)(\lambda_n+\mu_n S)$ when $N=1$ .Further,itcanbesimplifyasthefollowing.

$$V(S,P)=p(1-\theta)g(p)-\frac{hS}{2}-\frac{h(\sigma_1+\sigma_2 S)^2}{2g(p)}-a(S)g(p)$$

$$=r(p)-\frac{hS}{2}-\frac{h(\sigma_1+\sigma_2 S)^2}{2g(p)}-a(S)g(p)$$

According to the strict concave assumption of the average profit function on the price in the previous paper,there exists a vector P that maximizes the average profit and satisfies the first-order condition.

$$p(1-\theta)+\frac{(1-\theta)g(p)}{g'(p)}+\frac{h(\sigma_1+\sigma_2 S)^2}{2g^2(p)}=a(S) \quad (8)$$

To analyze the expressions of the first-order conditions,the following propositions can be gotten.

Theorem 1.Based on the premise of this paper,considering the single pricing problem when the periodic replenishment quantity S is fixed,the optimal pricing p^* is determined by the above first-order conditions,and the following discussion can be made.

(i) The marginal revenue $r'(p)|_{p=p^*}$ at the optimal price p^* is no greater than the average replenishment cost $a(S)$.

(ii) The optimal price p^* decreases with respect to σ_1, σ_2 and h.

(iii)The optimal average profit $V(S,p^*)$ decreases with respect to σ_1, σ_2 and h.

Proof. Firstly,we recallthatthe revenuefunctionis $r(P)=p(1-\theta)g(p)$.Thenthemarginal revenue $r'(p)|_{p=p^*}$ attheoptimalprice $p*$ is $r'(p^*)=p^*(1-\theta)+\frac{(1-\theta)g(p^*)}{g'(p^*)}$. Combinedwith thefirstorder formulasatisfyby p^*,we can get $r'(p^*)\le a(S)$.Since $g(p)$ was defined as a decreasing function of p,i.e. $g'(p)<0$,the following inequalities can be derived.

$$\frac{\partial^2 V}{\partial p\partial\sigma_1}=\frac{2h(\sigma_1+\sigma_2 S)g'(p)}{2g^2(p)}<0,\ \frac{\partial^2 V}{\partial p\partial\sigma_2}=\frac{2Sh(\sigma_1+\sigma_2 S)g'(p)}{2g^2(p)}<0,$$

$$\frac{\partial^2 V}{\partial p\partial h}=\frac{(\sigma_1+\sigma_2 S)^2 g'(p)}{2g^2(p)}<0,\ \frac{\partial^2 V}{\partial p\partial a(S)}=-g'(p)>0.$$

So far,problems2and3havebeenproven.

Asfor problem4,withoutofgenerality,let $h_1\le h_2$ andtheoptimalsinglepricesarerespectively p_1^*, p_2^* .Correspondingly,wehave the revenue functions $V(S,p_1^*,h_1)$ and $V(S,p_2^*,h_2)$. Then, $V(S,p_1^*,h_1)\ge V(S,p_2^*,h_1)\ge V(S,p_2^*,h_2)$ canbeobtained. It shouldbepointed that thefirstinequalityisbasedonthebestof p_1^*,andthesecondinequality canbeestablishedby theobjectivefunction.

3.3Thephasedpricingmodelwhenthereplenishment S isfixed

For theconvenienceofanalysisanddiscussion,basedonthe originallong-term average profitrate formula(6),thefollowingarrangementismade.Notingthat $w_n=\frac{1}{(\lambda_n(p_n)+\mu_n S)}$,thedecisionvariableisconverted to $W=(w_1,w_2,\cdots,w_N)$.Then the problem can be described as the following.

$$\max_W V(S,W)=\frac{\sum_{n=1}^{N}[p(\frac{1}{w_n})-\frac{hS}{N}(N-n+\frac{1}{2})w_n-\frac{h(\sigma_1+\sigma_2 S)^2}{2}w_n^2-a(S)}{\sum_{n=1} Nw_n} \quad (9)$$

First of all,wepoint that $r(g)=p(g)g(1-\theta)$. Under theconditionofthereplenishmentquantityisfixed,

$$r''(g)=(1-\theta)[2p'(g)+gp''(g)] \text{ and } \frac{d^2 p(\frac{1}{w})}{dw}=\frac{1}{w^3}[2p'(\frac{1}{w})+\frac{1}{w}p''(\frac{1}{w})]$$

havethesamepositiveandnegativeproperties. Thenthestrictconcavityof $p(\frac{1}{w})$ with respectto w isobtainedfromthestrictconcavityof $r(g)$ with respectto g .SoinEquation(9),thestrict convexityof moleculeswithrespect to w canbeobtained.Basedonthedefinitionofpseudo-concave functionin theliterature[2],if theratioof positiveconcavefunctiontopositivelinear functionispseudo-concave,the above formula is pseudo-concave function. And thenwehave

$$\Delta_w V(S,w_1)(w_2-w_1)\le 0 \Rightarrow V(S,w_2)<V(S,w_1)$$

Therefore,the following theorem can be obtained.

Theorem2. In thecaseof thefixedinventory replenishment quantity,the optimalsolution exists and is unique.If theoptimal solutionconforms to thereallife,then the price components satisfy $p_1^*\le p_2^*\le p_3^*\le\cdots\le p_N^*$.

Proof. Theexistenceanduniquenessof theoptimalsolutionareknown. Andit isassumed that thesolutionsexistina reasonable range,thentheoptimal W canbeobtainedbysolving thefirst orderconditions. That is $\frac{\partial\tilde{v}_n(S,w_n)}{\partial w_n}=\frac{\sum_{k=1}^{N}\tilde{v}_k(S,w_k)-c(S)}{\sum_{k=1}^{N}w_k}$, $n=1,2,\cdots,N$,where $\tilde{v}_n(S,w_n)=v_n(S,p(\frac{1}{w_n}))$ .Noticethatthe right-handsideoftheaboveequationdoesnot dependonstage n . Andwecannotice that $p_n=p(\frac{1}{w_n})$ increaseswithrespectto w_n .Sothestatementcanbeconvertedtoprovethat w_n^* is non-negative.Observingthattheequation(9)containsterms $\sum_{n=1}^{N}nw_n$,consider thefollowing reasoningprocess.For any vector $W=(w_1,w_2,\cdots,w_n)$ that satisfytheconditions,rearrangeitscomponents fromsmallest tolargest. Bydoingthisrearrangement,wecanmakesurethat $\sum_{n=1}^{N}nw_n$ isthelargestwhileother valuesinequation (9)remainunchanged.Therefore,combinedwiththe optimization, the conclusion can be proved.

Meanwhile,similar to thediscussionintheorem1,therearethefollowing conclusions.

Theorem3. In the caseoftheinventoryreplenishmentquantity S isfixedandtheoptimalprice $P=(p_1,p_2,\cdots,p_N)$ exists,theoptimalaverageprofit $V(S,P^*)$ decreases with respect to σ_1 , σ_2 and h .

3.4Thecomparativeanalysisofsinglepricingandmultiplepricing

The followingpart willcompare theaverageprofitsof multi-stagepricingconditionandsinglepricingconditionwhentheinventory replenishmentquantity S isfixed.

Asfor equation (9),letsettheoptimalsolutionfor multi-stagepricingtobe $W^*=(w_1^*,w_2^*,\cdots,w_N^*)$,thenthecorrespondingpriceis $P^*=(p_1^*,p_2^*,\cdots p_N^*)$ .Letnote theoptimalprofit in thecase of multi-stage pricingby V_N^* . In thesinglepricingcase,thecorrespondingis V_1^* .For the convenienceofdiscussion,let $\overline{w}=\sum_{n=1}^{N}w_n$ and $V_1=V(S,\overline{w})$. It iseasy toknow that $V_1\le V_1^*$ .Then,wehave

$$V_N^*-V_1^*\le V_N^*-V_1$$

$$V_N^*-V_1=\frac{\sum_{n=1}^{N}[p(\frac{1}{w_n^*})-p(\frac{1}{w})]-\frac{hS}{N}\sum_{n=1}^{N}[(N-n+\frac{1}{2})w_n^*-\frac{N}{2}\overline{w}]-\frac{h(\sigma_1+\sigma_2 S)^2 N}{2}[\frac{1}{N}\sum_{n=1}^{N}w_n^{*2}-\overline{w}^2]}{\sum_{n=1}^{N}w_n^*}$$

Accordingtothepreviousassumption,thefirstmolecular termintheaboveequationisobviouslylessthanzero. Observing the thirdmolecular term, $\frac{1}{N}\sum_{n=1}^{N} w_n^{*2} - \overline{w}^2 \geq 0$ canbegottenbyapplyingtheCauchy-Schwartzinequality. Therefore,wehavethefollowing.

$$V_N^* - V_1^* \leq \frac{-\frac{hS}{N}\sum_{n=1}^{N}[(N-n+\frac{1}{2})w_n^* - \frac{N}{2}\overline{w}]}{\sum_{n=1}^{N} w_n^*}$$

$$= \frac{hS}{N}\left(\frac{\sum_{n=1}^{N} n w_n^*}{\sum_{n=1}^{N} w_n^*} - \frac{N+1}{2}\right)$$

$$= \frac{hS}{N} \cdot \frac{2w_1^* + 4w_2^* + \cdots + 2Nw_N^* - (N+1)(w_1^* + \cdots + w_N^*)}{2\sum_{n=1}^{N} w_n^*}$$

$$= \frac{hS}{N} \cdot \frac{(N-1)(w_N^* - w_1^*) + (N-3)(w_{N-1}^* - w_2^*) + \cdots}{2N\overline{w}}$$

Inthelastlineoftheaboveequation,wediscuss N intermsofparity.When N iseven,thelast item is $w_{(N/2)+1}^* - w_{N/2}^*$.When N is odd,the last item is $w_{(N+3)/2}^* - w_{(N-1)/2}^*$.So $V_N^* \geq V_1^*$ is easy to get.By analyzing the derivativeof theaverageprofits V_1^* and V_N^* ,it canbefoundthatthederivativehasanupperbound.Theupperbound isrelated to thedivisionofcyclestageandthe replenishmentamountofthefixedinventory.

4Numericalexamples

In thepreviousection,wecansee thatthe solutions ofourmodelare complex.Withoutloss ofgenerality,weuselinear functions tosimplify themodelandgivenumericalexamplestoillustratetheaboveconclusions.Thefollowingisthenexamplesofone-stage pricing theorem 2 in the model.

Inthenumericalexamples,wesetthesalescycletobe $[0,1]$.Thefirstpartofthedecaycoefficient of perishableagriculturalproductsisfixedinthesingleperiod $[0,1]$.Sincethe standardBrownianmotion satisfy $B(t)N(0,1)$,then $B(t)N(0,1)$ whenweset $t=1$. Recall that is $N(0,1)$ thestandardnormaldistribution. So thesecondpartofthedecaycoefficientdependsonthecoefficient σ_2 .Setting μ tobe0.08,thentheattenuationcoefficientis $\theta = \mu + \sigma_2 = 0.08 + \sigma_2$ .Thefunctionofdemand rateinfluencedbypriceis $\lambda(p) = 50 - p$ andtheorderingcostfunction is $c(S) = 500 + 2S$.

The following tables briefly show the impact ofthe coefficient of demand uncertainty σ_1 ,the quality decay coefficient σ_2 and theholdingcost per unit h ontheoptimalpriceandthecorrespondingprofits.Andthe replenishmentquantityhereisfixedandsetas1000.

Table1:The impact of σ_1 on the optimal price and the profits

σ_1	σ_2	h	p	$V(S,p)$
0.05	0.30	1.00	59.6756	1286.007
0.10	0.30	1.00	59.6736	1285.794
0.15	0.30	1.00	59.6716	1285.581
0.20	0.30	1.00	59.6695	1285.367
0.25	0.30	1.00	59.6675	1285.154
0.30	0.30	1.00	59.6650	1284.940
0.35	0.30	1.00	59.6635	1284.727

0.40	0.30	1.00	59.6614	1284.513

Table2:The impact of σ_2 on the optimal price and the profits

σ_1	σ_2	h	p	$V(S,p)$
0.20	0.05	1.00	66.2586	2995.251
0.20	0.10	1.00	65.7821	2725.282
0.20	0.15	1.00	64.8953	2417.220
0.20	0.20	1.00	63.5814	2072.782
0.20	0.25	1.00	61.8381	1694.446
0.20	0.30	1.00	59.6695	1285.367
0.20	0.35	1.00	57.0777	849.2741
0.20	0.40	1.00	54.0539	390.3976

From table1,we can see that when other conditions remain unchanged, the optimal price and the corresponding profits obtained by the model increase with the impact factor of demand uncertainty σ_1. Based on the settings, the decrement is not obvious in some ways.However,the decreasing trend is certain. In reality, the decreasing trend and magnitude are closely related to the actual demand rate of fresh agricultural products and the market conditions. This also indicates that the model in this paper has certain universality,which can be further extended and applied in specific real life situations.

Similarly, from table2,the conclusion that the optimal price decreases with respect to σ_2 can be seen. Also,the corresponding profits decreases with respect to σ_2.What's more, the decrement is more obvious than table1 in some ways.That means the quality decay coefficient of agricultural and fresh products should be paid more attention in the supply chain.

Table3:The impact of h on the optimal price and the profits

σ_1	σ_2	h	p	$V(S,p)$
0.20	0.30	0.75	61.2500	1572.342
0.20	0.30	1.00	59.6695	1285.367
0.20	0.30	1.25	58.2040	1001.860
0.20	0.30	1.50	56.8339	721.4510
0.20	0.30	1.75	54.5447	443.0312
0.20	0.30	2.00	54.3251	168.7774

5Summaryandprospect

Thispaper describesaninventorycontrolsystemfor perishableagriculturalfreshproducts distributors.Inthispaper,anoptimizationmodelof inventorycontrolandphasedpricingisestablished. Differentfromthepreviousstudies,theuncertainty ofdemandandthelawofquality decay offreshandagriculturalproducts are consideredinthemodel designingof thispaper. ThestandardBrownianmotionandthe relatedcoefficientareusedtodescribetheuncertainty.Inthispaper,themodelissolved respectivelyinthecaseofthefixedinventoryandthefixedprice. Theinfluenceof theparametersset in thismodelontheoverallprofits is analyzedandnumericalexamplesaredesignedfor demonstration.Byanalyzing,for perishablefreshagriculturalproducts,itisofgreatpracticalsignificancefor sellerstoconsider bothdemanduncertaintyandquality decay coefficientininventory control.Inaddition,theoptimizationmodelin thispaper hasuniversalityandcanbeusedtosettheattenuationcoefficientanddemandimpact coefficient for specific freshagriculturalproducts.Forexample,forthisarticle'sdemandratefunction,the $\lambda(p,\cdots)$ couldconsider adding theimpact factorsother thanprice,whichwouldbeabetterguidetothe reality. Thereisnospecificnumericalsolutionmethod for thejoint inventorypricingprobleminthispaper.Atpresent,wecanusemathematicalsoftwareto get heuristic solution ormore precise numerical solution forspecificmodel ofspecificgoods.In thealgorithmdesignandpracticalapplicationofthemodel,we can carry outfurtherexploration.

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*Corresponding Author: XiuxiuLi

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