JOINT REPLENISHMENT AND PRICING OF A SINGLE PRODUCT UNDER EXCHANGE RATE UNCERTAINTY

by

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ABSTRACT

JOINT REPLENISHMENT AND PRICING OF A SINGLE PRODUCT UNDER EXCHANGE RATE UNCERTAINTY

Purchasing cost uncertainty in the future subject to exchange rate fluctuation is modeled as a markov chain transition matrix, and it is combined with supply chain profit maximization problem. This problem is modeled as a multi-period stochastic inventory control problem on USD/TRY dataset. Replenishment problem is considered under the myopic and dynamic inventory policies. Excess demand is lost, and salvage cost is zero. The procedures to compute order up to inventory levels of both inventory policies are determined. It is verified that $(1-P)$ value, which is an indicator of myopic solution effectiveness, shows the closeness of the dynamic and myopic inventory policies. Average profit is computed with a simulation which includes multi-period purchasing and selling steps. Demand is taken as a random variable with gamma distribution, since it can take only positive values. Price dependent demand is also evaluated. Moreover, the effect of variance in demand on both of order up to inventory level and average profit is analyzed. It is seen that the variance in demand increases the volatility in order up to inventory levels with respect to purchasing costs, and average profits. Optimal inventory level and pricing are also assessed together after replenishment problem is evaluated. Two different pricing systems are used, namely best constant pricing and best pricing. Best constant pricing represents that price is announced before purchasing cost is determined and it cannot be changed period by period. Best pricing represents that price can be updated with respect to purchasing cost in each period. A procedure to find out optimal order up to inventory level and best price combination is formed to handle exchange rate uncertainty. It is observed that purchasing cost volatility promotes the best pricing to maximize profit.

ÖZET

DÖVİZ KURU BELİRSİZLİĞİ ALTINDA BİR ÜRÜNÜN STOK YENİLENMESİ VE FİYATLANDIRILMASI

Döviz kuru dalgalanması altında, gelecek dönemdeki satın alma belirsizliği bir markov zinciri geçiş matrisi olarak oluşturulmuştur ve oluşturulan geçiş matrisi ile tedarik zinciri kar maksimizasyon problemi beraber değerlendirilmiştir. Bu problem, USD/TRY dataseti üzerinde çok periyotlu stokastik envanter kontrol problemi olarak modellenmiştir. Stok yenilenme problemi, miyopik ve dinamik envanter politikaları altında değerlendirilmiştir. Eldeki stoğu aşan taleplere izin verilmemiştir ve kurtarma maliyeti sıfırdır. Her iki envanter politikası için envanter seviyelerini bulma prosedürleri belirlenmiştir. Miyopik çözüm etkinliğinin bir göstergesi olan $(1 - P)$ değerinin, dinamik ve miyopik envanter politikaları arasındaki yakınlığı gösterdiği doğrulanmıştır. Ortalama kar, çok periyotlu satın alma ve satış adımlarını içeren bir simülasyon ile hesaplanmıştır. Talep, sadece pozitif değerler alması sebebiyle gamma dağılımının bir rassal değişkeni olarak kabul edilmiştir. Fiyata bağlı talep de değerlendirilmiştir. Ayrıca, talepteki varyans arttıkça, envanter seviyesindeki ve ortalama kardaki değişkenliğin arttığı görülmüştür. Stok yenilenme probleminden sonra optimal envanter seviyesi ve fiyatlandırma birlikte değerlendirilmiştir. En iyi sabit fiyatlandırma ve en iyi dinamik fiyatlandırma olmak üzere iki farklı fiyatlandırma sistemi kullanılmıştır. En iyi sabit fiyatlandırma, fiyatın satın alma maliyeti belli olmadan önce açıklandığı ve periyottan periyoda değişmediği durumu temsil etmektedir. En iyi dinamik fiyatlandırma, fiyatın satın alma maliyetine göre her periyot değişebildiği durumu temsil etmektedir. Döviz kuru belirsizliği ile başa çıkabilmek için optimal envanter seviyesi ve en iyi fiyat kombinasyonunu bulmayı sağlayan bir prosedür oluşturulmuştur. Karı maksimize etmek amacıyla, satın alma maliyetindeki değişkenliğin en iyi dinamik fiyatlandırmayı önerdiği görülmüştür.

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c	Purchasing cost
c_i	Purchasing cost at state i
$\bar{c}_i$	Prediction of purchasing cost in the next period at state i
CI	Confidence interval
D	Demand
$D(p)$	Price dependent demand
E	Price elasticity of demand
h	Holding cost
h_i	Holding cost at state i
h_{rate}	Holding cost rate
k	Number of cost states
$L(y)$	Single period cost function when the inventory is y
p	Price
P_i	Single period profit at state i
q_i	Steady-state probability at state i
t	Random demand
t_i	Random demand at state i
$W_i(x)$	Derivative of profit function at state i
y	Order up to inventory level
y_i	Order up to inventory level at state i
π_{ij}	Probability that purchasing cost going from state i to state j
Π	Purchasing cost transition matrix
τ_ρ	Probability that the demand is ρ units
$\phi(x)$	Probability density function of random demand
$\Phi(x)$	Cumulative distribution function of random demand

LIST OF ACRONYMS/ABBREVIATIONS

AP	Average profit
CoV	Coefficient of variation
Df	Degrees of freedom
Exp	Exponentially distributed demand
BCP	The best constant pricing
BP	The best pricing
Sd	Standard deviation
T.Exp	Truncated exponentially distributed demand
Unif	Uniformly distributed demand

1. INTRODUCTION

Technological developments contribute the world to be more connected in terms of cultural and economic relations. These developments enable people and organizations to exchange goods, services, information and energy quickly. As competition of companies increases, globalization term gets more trendy. However, globalization includes some pros and cons together from the view of the companies.

In recent years, many companies have international supply chain networks to get more profit. In other words, companies prefer producing in countries which have low-cost labor and transporting the products to their markets. Managing this kind of huge systems is really difficult, since it has several constraints such as long lead times and uncertainty in cost due to exchange rate. Therefore, it is obvious that getting more profit depends on whether the supply chain system is managed well or not.

In Turkey, following up exchange rate is significant for import and export activities in business, since it is always fluctuating, and it has uptrend. Although trading is risky in Turkey, it also means that there is an opportunity to make more money. If companies foresee the increase in exchange rate (USD/TRY), they order more before exchange rate increases, so they will get cost advantage after exhange rate increases. Therefore, if they manage their supply chain system well, they will have a chance to get more profit in TRY currency with the same capital.

When we determine the scope of the thesis, we take into account businesses which engage in import activities. In this case, the currencies of purchasing cost and selling price are different. The main question of the thesis is how a seller controls its inventory and selling price of a product if the purchasing cost of the seller's product is subject to exchange rate.

In this thesis, we investigate an inventory control problem under exchange rate uncertainty. The main objectives are replenishment and pricing where the purchasing cost is subject to exchange rate uncertainty. Purchasing cost transition matrix is obtained using USD/TRY weekly exchange rate data including more than two years period. Using this transition matrix, replenishment with the dynamic and myopic inventory policies are considered. After replenishment study is evaluated, joint replenishment and pricing is examined using the dynamic inventory policy under exchange rate uncertainty.

The organization of the thesis is as follows : Literature review with respect to the scope of this research can be found in Chapter 2. In Chapter 3, replenishment procedure under the dynamic and myopic inventory policies are explained in detail. In Chapter 4, we consider replenishment with the myopic and dynamic inventory policies on USD/TRY dataset. In Chapter 5, pricing and replenishment are evaluated together under the dynamic inventory policy.

The myopic and dynamic inventory policies are used to evaluate replenishment problem, and compared with each other. While comparing inventory policies, the results of order up to inventory levels and average profits are considered. In addition, $(1 - P)$ value, which is an indicator of myopic solution effectiveness, is assessed. Also, holding cost rate and price sensitivity analyses are carried out, so the effect of the preference of the paramaters is analyzed. Another point of interest is joint pricing and replenishment under exchange rate uncertainty. After order up to inventory levels are computed, best price is evaluated with a search mechanism over possible price values. Moreover, the effects of variance in demand on order up to inventory level and average profit are examined.

In Chapter 3, the dynamic and myopic inventory policies are explained in detail. Also, we verify the methods of the dynamic and myopic inventory policies on a numerical example. In addition, the dynamic and myopic inventory policies are compared in terms of order up to inventory levels and average profits. Average profits are computed using a simulation procedure, which is explained in detail in this chapter. Moreover, the efficiency of $(1-P)$ value, which is an indicator of myopic solution effectiveness, is considered with respect to the difference between the average profits of the dynamic and myopic inventory policies. As a result, calculation methods of order up to inventory level and average profit are verified. Also, it is observed that $(1-P)$ value is a significant measure to show effectiveness of myopic solution.

In Chapter 4, we implement the model on USD/TRY weekly exchange rate data including the dates between 01-10-2018 and 03-12-2020. Using exchange rate data, the transition matrix of purchasing cost states is formed. The obtained transition matrix includes the probabilities of the transitions from purchasing costs to other ones. However, time series analysis or different markov chain transition matrices including the transitions of the change rates of purchasing costs could have been used as well.

There are some assumptions in our USD/TRY exchange rate study to ease computations. There are no setup costs, capacity restrictions or leadtimes. Unsatisfied demand is lost. Salvage cost is zero. Purchasing cost is constant in USD currency, but it changes in TRY currency period by period due to exchange rate fluctuations. Holding cost is a linear function depending on purchasing cost. There is no strategic customer who can strategically choose when or how much to buy. Demand is occuring randomly subject to Gamma Distribution.

Using gamma distribution as demand distribution is preferred, since it has always positive values, and it is also a flexible distribution model. We use two parameters of gamma distributions, namely shape and scale parameters. We implement four different gamma distribution models to eliminate the effect of preferences of parameter values. To analyze the effect of variance in demand, we keep the mean of demand distribution constant, and change the variance.

The study using USD/TRY data shows that the myopic and dynamic inventory policies are close in terms of order up to inventory levels and average profits. Also,

$(1 - P)$ values verify this conclusion for all demand distributions. In addition, it is seen that myopic solution effectiveness, $(1 - P)$, increases as the variance in demand decreases.

Holding cost rate and price sensitivity analyses are also applied in Chapter 4. When price sensitivity analysis is carried out, two different cases are considered. First case assumes that demand is not affected by the change in price. Second case assumes that demand is dependent on price. In second case, elasticity is 3, so it means that there is an elastic relation between demand and price. As a result, sensitivity analyses show that variance in demand negatively affects the results in average profit regardless of holding cost rate and price parameters. Moreover, whether price is dependent on demand significantly affects order up to inventory levels and average profits obtained with simulation.

In Chapter 5, joint pricing and replenishment are considered together on USD/TRY dataset. While considering pricing, a search mechanism is used over 91 different possible price values. While determining best price, two different systems are used, namely best constant pricing and best pricing. First one represents that price is announced before cost state is determined, so there is only one best constant price for all purchasing cost states. This case can be seen in the businesses which have long price update period. Second case represents that price can be updated subject to purchasing cost state after purchasing cost is determined in each period. Therefore, price might be different for each purchasing cost state in order to maximize profit. This case can be observed especially in e-commerce since it enables the sellers to update their prices at any time. The results of pricing systems are compared in terms of order up to inventory levels and average profits.

When joint replenishment and pricing under exchange rate uncertainty is considered, it is seen that the results of best constant pricing are more consistent. However, the difference between mean values of average profits is high, so it can compensate for the volatility in average profit of best pricing. Therefore, it is seen that cost volatility promotes best pricing which enables to update price with respect to purchasing cost in each period. Also, as coefficient of variation of demand decreases, the performance of best pricing increases since mean of its average profits increases, and standard deviation of its average profits decreases.

2. LITERATURE REVIEW

Canyakmaz et al. investigate optimal inventory operations under exogenous price uncertainty. When they study on this problem, they also consider customer arrivals which are dependent on price. They use stochastic input prices, which affect purchasing cost and selling price, to compute optimal order up to inventory level. In this thesis, we investigate inventory control problem similar to their study. However, our main problem is based on purchasing cost uncertainty, but they also evaluate selling price uncertainty in their paper. Also, we evaluate pricing, but this point is not one of their areas of interest. Moreover, they apply sensitivity analyses for price volatility and customer sensivity to price changes, but we do not interest these areas. However, we carry out sensitivity analyses for holding cost rate and price parameters in this thesis [1].

Chen et al. study a periodic-review pricing and inventory control problem with stochastic price-dependent demand. The cost function that they use includes holding, shortage, and fixed ordering costs. Optimal inventory level and price are considered to maximize expected profit over the selling horizon each period. They show that (s,S) policy is optimal for replenishment at the beginning of each period with additive demand function. They decide replenishment at first, and then they use this input to determine optimal price. The main problem that they interest is similar to this paper. We evaluate periodic-review replenishment and pricing problem together under cost uncertainty. Similarly, price-sensitive demand is used and unsatisfied demand is lost. Also, holding cost affects profit, but shortage and fixed ordering costs are ignored in this study. Re-order point is not evaluated in contrast to their study, and cost uncertainty is not considered in their study [2].

Chen et al. consider a single-product, periodic review, non-stationary inventory system under total maximum capacity constraint and fixed ordering costs. They use state-dependent (s, S) policy, whose parameters only depend on the sum of the net inventory and the remaining capacity, and various selling price values in their numerical studies. They investigate how parameters affect the buyer's optimal performance. Likewise, we use a stochastic system which includes single-product and multi-period. Also, sensitivity analysis of holding cost rate and price are done to consider the effects of these parameters, but it is not the main aim of the thesis. In addition, maximizing expected profit is one of the important components of this thesis and it is not considered in their study. The main difference is that they do not consider cost uncertainty in contrast to this study [3].

Price and demand are exogenous in the newsvendor problem, and the aim is finding how much of product to stock for a single period. Dada and Petruzzi extent newsvendor problem by setting selling price and replenishment quantity for each period. They evaluate the problem with single period and multi period modeling, and also additive and multiplicative demand models. Likewise, inventory control problem is evaluated under multi-period system in this thesis. However, the problem is extended with exchange rate uncertainty and myopic heuristic approach in the first part. In the second part, pricing is evaluated under exchange rate fluctuation. Another difference is using different statistical distributions such as gamma, exponential and uniform distributions for demand distribution while they use mathematical demand models [4].

Federgruen and Heching consider joint pricing and inventory replenishment problem under demand uncertainty. They use single item with price sensitive stochastic demand to analyze outputs with periodic-review model. They handle the problem with both finite and infinite time horizons. They form the structure of an optimal combined pricing and inventory strategy in similar to this thesis. However, some assumptions are different compared to our study. In this study, backlogs are not allowed in contrast to their paper. We use gamma distribution as a demand distribution with different parameters, so we also interest in the effect of variance in demand distribution. Moreover, cost uncertainty is the most challenging part of this study, but it is not considered in their paper [5].

Gao et al. investigate a dynamic inventory control and pricing optimization problem in a periodic-review inventory system with price adjustment cost. They assume that the ordering quantity is capacitated. They evaluate the problem with sequential decisions : firstly, they determine ordering quantity, and then they determine selling price to maximize total profit. They determine price with respect to inventory-on-hand after replenishment decision. Likewise, we investigate optimal inventory level and price together in this study, but these decisions are considered together. Also, capacity restriction and setup cost are ignored in this study in contrast to their research. Another difference is that cost uncertainty is one of the most important factor in this thesis, but it is not a concern for their research [6].

Gavirneni considers exchange rate in a Markovian fashion under the periodic review inventory control problem concept. Optimal inventory level is calculated from one period to the next. In addition, they create a new measure, myopic-optimality, which is an accurate indicator of the effectiveness of myopic heuristics. Random walk, mean reverting and momentum models are used as cost transition matrix in the paper. This study is extended with adding exchange rate uncertainty in this thesis. In other words, a transition matrix is created with time-based exchange rate (USD/TRY) data; therefore, the inventory system is evaluated under this stochastic approach. Also, they use exponential and uniform demand distributions, while we add also gamma demand distribution with four different models. Moreover, we also analyze the effect of variance in demand. In addition, pricing is also evaluated in this thesis in contrast to their research [7].

Gullu and Gurel consider inventory and pricing decisions under cost and demand uncertainties. They focus on secondary market customers who are relatively price sensitive compared to more loyal primary market customers. Similarly, pricing and inventory level are investigated in this thesis. Also, we use price sensitive demand as their study. However, variance in demand is one of the significant elements to be investigated in this thesis. Also, sensitivity analyses for price and holding cost rate are applied to analyze the effects of the preferences of parameters [8].

Kalish deals with pricing of a new product over time in a monopolistic environment. The objective function is to maximize profit. Cost per unit is assumed to be declining with increasing demand. Therefore, cost per unit is dependent on volume of demand which is a function of selling price and cumulative sales. That demand is dependent on cumulative sales represents the effects of word-of-mouth and saturation. In this thesis, pricing is also evaluated under monopolistic environment and using objective is to maximize profit in similar to [9]'s paper. Another similarity is that demand is dependent on price, but word-of-mouth is not one of concerns in this study. Cost uncertainty and optimal inventory level are not problems that they handle; however, these components consist the most significant parts of our motivation for this study [9].

Khmelnitsky and Singer evaluate the problem of determining optimal price for a product with price-sensitive demand in continuous time. The aim of the policy that they use is to maximize revenue. They consider sales campaign under two pricing systems: first one is weekly updating dynamic pricing, and second one is optimal constant pricing. Similarly, pricing is a concern for this thesis and it is evaluated with optimal pricing and optimal constant pricing concepts. However, it is evaluated together with optimal order up to inventory level in this study. Also, price-sensitive demand is used and they assume that it can be approximated by a Wiener process. Although price-sensitive demand is used in this paper, we assume that demand follows gamma distribution with four different shape parameters. Therefore, the effect of variance in demand distribution is another concern in this study [10].

Kocabıyıkoglu and Popescu mention elasticity of the lost-sales rate (LSR), which enables to measure elasticity of stochastic demand under newsvendor with pricing (NVP) problem. Therefore, they provide a new measure tool for stochastic price-sensitive demand. They evaluate the problem with expected profit maximization approach under a single product for different demand models which are price dependent. In addition, they also evaluate the relationship between the optimal NVP price and a riskless price benchmark. This study is similar to their study in that they consider the problem with a stochastic system including only one product. Also, expected profit maximization problem is used to compare the policies and demand distributions. On the other hand, there are some differences between this thesis and their study. Firstly, some statistical models are used for demand function in this thesis while they use mathematical models. Secondly, exchange rate uncertainty is also considered in this study. Finally, this study also evaluates the difference between myopic and dynamic inventory policies [11].

Lee and Ren consider a periodic review stochastic inventory model under exchange rate uncertainty and different fixed ordering costs. The aim of their paper is to examine the benefits of vendor-managed inventory (VMI) by achieving economies of scale in production and delivery. They also use transition matrices, which have been used in Gavirneni's paper [7]. Inventory control problem with a system which is multi-period and including single product under exchange rate uncertainty is also analyzed in this thesis as well. However, economies of scale is not one of concerns to be analyzed in this thesis and also pricing is not evaluated in their study [12].

3. DYNAMIC AND MYOPIC INVENTORY POLICIES

3.1. Dynamic Inventory Policy

Dynamic inventory policy determines optimal order up to level as it satisfies the demand and minimizes cost at each period. In deterministic cases, demand is known at the beginning of the period. If there is not enough inventory, needed inventory is ordered. However, demand is not known at the beginning of the period in stochastic cases. Therefore, to be ordered quantity must be determined before the demand is observed. Dynamic inventory policy tries to maximize the profit at each period independently of deterministic or stochastic demand.

Time periods are equal to each other. Lead time is assumed as zero, in other words ordering and delivering happen at the same time. Holding cost is dependent on the inventory on-hand after demand is observed at the end of the period and it is a linear function. Unsatisfied demand is lost.

In the single period problem, expected single period profit is given as

$$E[P] = \max_{y \geq x} \left\{ \int_0^y [pt - h(y-t)]d\Phi(t) + py \int_y^\infty d\Phi(t) - c(y-x) \right\}. \tag{3.1}$$

In Equation (3.1), x represents the inventory on hand at the beginning of the period. y represents the order up to inventory level. Therefore, amount of $(y - x)$ needs to be purchased, and also each sold item creates revenue p per unit. $\Phi(t)$ represents the cumulative distribution function of random demand.

The first part of the above equation represents the single period cost function when the inventory is y, $L(y)$. Therefore, we can ease the formulation as

$$E[P] = \max_{y \geq x} \Big\{ L(y) - c(y - x) \Big\}. \tag{3.2}$$

If demand is lower than y, there is no salvage value, but there is holding cost, h. Also, if demand exceeds y, backorder is not allowed, so excess demand is lost.

Purchasing cost can have several values depending on the exchange rate and it can be shown as $c_i = \{c_1, c_2, c_3, ..., c_k\}$. It is assumed that purchasing cost follows a Markovian transition with the probability transition matrix $\Pi = [\pi_{ij}]$ where π_{ij} is the probability of purchasing cost going from state i to state j.

Price is assumed as constant and exogenous. Also, demand is random and exogenous. Expected sales can be shown as $E[S]_i = y_i - \int\limits_0^{y_i} \Phi(t)dt$ for $i = \{1, 2, ..., k\}$. Expected single period profit, $E[P]_i$ when the purchasing cost is c_i, is

$$\begin{aligned} E[P]_i &= p\big(y_i - \int\limits_0^{y_i} \Phi(t)dt\big) - h\int\limits_0^{y_i} \Phi(t)dt + py_i\int\limits_{y_i}^{\infty} d\Phi(t) - c_i(y_i - x), \\ &= p\big(y_i - \int\limits_0^{y_i} \Phi(t)dt\big) - h\int\limits_0^{y_i} \Phi(t)dt - c_i(y_i - x). \end{aligned} \tag{3.3}$$

First order derivative of $E[P]_i$ is

$$\frac{\partial E[P]_i}{\partial y_i} = p(1 - \Phi(y_i)) - h\Phi(y_i) - c_i. \tag{3.4}$$

And then, it is obtained that

$$p - (p + h)\Phi(y_i^{\star}) = c_i, \quad i = \{1, 2, ..., k\}. \tag{3.5}$$

Gavirneni proves that $p - (p+h)\Phi(x) < c_i$ if $x > y_i^\star$ for the infinite horizon problem [7]. From this property, if the inventory level is lower than optimal level, it is known that the derivative of the infinite horizon cost function at that level can be set equal to the purchasing cost in that period; if not, it can be computed with $W_i(x) = L'(x) + \sum_{\rho=1}^{x} \tau_\rho \sum_{j=1}^{k} \Big[W_j(x-\rho)\Big]\pi_{ij}$. Here, $W_i(x)$ represents the derivative of expected profit function at state i. τ_ρ is the probability that the demand is ρ units. x represents the inventory on hand. π_{ij} is the corresponding transition probability in the purchasing cost transition matrix.

Gavirneni uses the demands that were discretized with a gap of one unit [7]. We implement this assumption with $\phi(x) = \Phi(x) - \Phi(x-1)$ equation in Section 3.4 and Chapters 4 and 5.

Gavirneni forms a procedure to compute the dynamic order up to level as well [7]. The procedure is based on recursively estimating the derivative of the infinite horizon cost function. He assumes that the demand in any period is non-zero and distributed discretely. Initial $W_i(0)$ values are equal to c_i for all i values. The procedure is basically explained step by step as follows :

(i) Set $W_i(0) = c_i$ for all i values.

(ii) Compute $L'(x) = p - (p+h)\Phi(x)$ by starting with $x = 1$ and repeating it by increasing x one by one.

(iii) Compute $W_i(x)$ values using

$$W_i(x) = L'(x) + \sum_{\rho=1}^{x} \tau_\rho \sum_{j=1}^{k} \Big[W_j(x-\rho)\Big]\pi_{ij}. \tag{3.6}$$

In Equation (3.6), it is significant to check whether $W_i(x)$ is greater than c_i values. If yes, $W_i(x)$ value needs to be set at c_i value since it means x is below the optimal solution.

(iv) Find optimal solution which follows $y_i^\star = \inf\{x | W_i(x) < c_i\}$ for all i states. $y_i^\star$ is the optimal order up to inventory level in state i.

It is significant to be aware of that order up to inventory level can take only integer values for the dynamic inventory policy with this procedure. We relax this assumption assuming that the gap between x values is 0.2 for USD/TRY case in Chapters 4 and 5. Therefore, it is aimed that the difference between the dynamic and myopic inventory policies can be compared in a fairer way, since y_i^{myopic} values can take non-integer values. The calculation of y_i^{myopic} values is going to be explained in detail in Section 3.2.

3.2. Myopic Inventory Policy (Heuristic)

Myopic policies give optimal or nearly optimal solutions for inventory control problems. Computation is relatively easy with a myopic policy. Therefore, if dynamic and myopic solutions are close, it can be said that choosing myopic policy may be more efficient, while considering to be spent time for implementing dynamic inventory policy. As a result, measuring effectiveness of myopic policy becomes a quite significant indicator to determine whether dynamic and myopic inventory policies are close to each other. Gavirneni has launched an indicator of myopic solution effectiveness for this purpose [7].

Gavirneni makes some changes into expected profit equation in terms of myopic assumptions. He sets the salvage value for inventory on hand at the end of the period, and it is called $\bar{c}_i$. This term is calculated with $\bar{c}_i = \sum \pi_{ij} c_j$ equation in which π_{ij} represents corresponding probability of transition matrix. $\bar{c}_i$ means prediction of purchasing cost in the next period while being on state i [7]. This variable is added into the expected single period profit equation as

$$E[P]_i = \max_{y_i \geq x} \left\{ \sum_{t=0}^{y_i} [pt + (\bar{c}_i - h)(y_i - t)]\Phi(t) + py_i \sum_{t=y_i}^{\infty} \Phi(t) - c_i(y_i - x) \right\}. \quad (3.7)$$

After this update of expected profit, taking the derivative respect to y gives myopic order up to level so that $y_i^{myopic} = \Phi^{-1}\left(\frac{p-c_i}{p+h-\bar{c}_i}\right)$. It is significant to be aware of inside formula of the paranthesis which is a probability value. Therefore, it must be between 0 and 1 values. So, if this value exceeds 1, it is set to a value which is so close to 1, when numerical study is implemented.

Gavirneni launches an indicator which measures effectiveness of myopic policy for inventory control problems, and it is called $(1-P)$ [7]. $(1-P)$ predicts, on the average, the probability that being at the myopic level in a period when myopic policy is used. Gavirneni proves $(1-P)$ is a good indicator by comparing the differences of myopic and optimal solutions to $(1-P)$ values. The formula is

$$(1-P) = \sum_{i=1}^{k} q_i \sum_{j=1}^{k} \pi_{ij} \left(1 - \Phi\left(\left(\Phi^{-1}\left(\frac{p-c_i}{p+h-\bar{c}_i}\right) - \Phi^{-1}\left(\frac{p-c_j}{p+h-\bar{c}_j}\right) \right)^{+} \right) \right). \quad (3.8)$$

In Equation (3.8), q_i represents the steady state probability of purchasing cost transition matrix at state i.

Since $(1-P)$ value represents a probability, it can be between 0 and 1 values. High probability means that the problem tends to be solved with myopic policy, on the contrary low probability represents that the problem cannot be solved with myopic policy. In other words, the results of myopic and dynamic inventory policies are close, if $(1-P)$ value is close to 1.

3.3. Simulation Procedure for Calculating the Average Profit

Expected profit is a good indicator for considering the effectiveness of $(1-P)$ value. As mentioned in Section 3.1, Gavirneni used a procedure to find the dynamic order up to inventory level [7]. While performing the procedure, if the inventory level is lower than the optimal level, the derivative of the infinite horizon cost function at that level is set equal to the purchasing cost in that period. Because of this deduction, infinite horizon expected profit formula cannot be computed. It is known that the simulated average profit approximates the expected profit, if length of simulation time is long enough. Therefore, a simulation is applied to calculate average profit over the finite horizon for both myopic and dynamic inventory policies.

Since the focus point of this thesis is the uncertainty in the USD/TRY value in the future, the order of events in a period is as follows. Firstly, purchasing cost with respect to USD/TRY value is determined, in other words i state is determined. Secondly, order up to inventory level is calculated using determined purchasing cost. Thirdly, an order is placed by comparing order up to inventory level and inventory on hand. And then, unknown demand occurs, and revenue is calculated. Also, inventory on hand at the end of the period is calculated, and excess demand is lost. Next cost state, j, is assigned using purchasing cost transition matrix probabilities for corresponding i state. This procedure is repeated for the next period, until simulation time horizon is reached.

While performing simulation, initial inventory is assumed to be zero. Before simulation is applied, optimal inventory levels must be computed for each state i. To find average profit, simulation procedure is basically explained step by step below.

(i) Assign initial cost state, i, randomly with equal occuring probabilities.

(ii) Select corresponding order up to levels of myopic and dynamic policies for cost state i.

(iii) Check whether an order is needed using the initial inventory and the optimal inventory level. If an order is needed, compute the difference between $y_i^\star$ and the initial inventory level.

(iv) Sample a value using $\phi(x)$ probabilities to assign t, as random demand realization. While assigning t, it is significant that t must be an integer value, so that $\phi(x)$ probabilities are computed as

$$\phi(x) = \Phi(x) - \Phi(x-1). \tag{3.9}$$

(v) Calculate profit for this simulation epoch with single period profit for each policy as follows :

$$P_i = \left\{ \begin{array}{ll} pt - h(y_i - t) - c_i(y_i - x), & \text{if } t < y_i \\ py_i - c_i(y_i - x), & \text{if } t \geq y_i \end{array} \right\}.$$

(vi) Assign next cost state, j, randomly using purchasing cost transition matrix probabilities, π_{ij}.

(vii) Repeat steps (ii-vi) until simulation epoch reaches time horizon.

(viii) Compute mean of the single period profits at the end of each simulation.

We use the simulation procedure to calculate average profit in sensitivity and scenario analyses in Section 3.4 and also, Chapters 4 and 5. While performing simulation to compare the average profits of myopic and dynamic inventory policies, we use the same assigned demand value for the same simulation epoch.

3.4. The Numerical Example of Gavirneni

Gavirneni performs a numerical study to prove that myopic inventory policy might be a good approximation to the optimal dynamic inventory policy under cost uncertainty [7]. The aim of this section is to verify the model of Gavirneni with comparing the outputs, and determining whether $(1 - P)$ is an efficient measure to compare dynamic and myopic inventory policies.

In this section, the results in Gavirneni's paper are illustrated by using the same inputs [7]. In the paper, they use different purchasing cost values, which are given as $c_i = \{16, 18, 20, 22, 24\}$. The sales price is constant and 40. Holding cost is also constant and 5. He uses three demand distributions, namely uniform[1,200], exp(100), and exp(100) truncated at 300. He uses three different probability transition matrices for purchasing cost, namely random walk, mean reverting and momentum models. These matrices are

$$\begin{bmatrix} 0.5 & 0.5 & 0.0 & 0.0 & 0.0 \\ 0.5 & 0.0 & 0.5 & 0.0 & 0.0 \\ 0.0 & 0.5 & 0.0 & 0.5 & 0.0 \\ 0.0 & 0.0 & 0.5 & 0.0 & 0.5 \\ 0.0 & 0.0 & 0.0 & 0.5 & 0.5 \end{bmatrix}, \begin{bmatrix} 0.2 & 0.8 & 0.0 & 0.0 & 0.0 \\ 0.1 & 0.3 & 0.6 & 0.0 & 0.0 \\ 0.0 & 0.1 & 0.8 & 0.1 & 0.0 \\ 0.0 & 0.0 & 0.6 & 0.3 & 0.1 \\ 0.0 & 0.0 & 0.0 & 0.8 & 0.2 \end{bmatrix}, \begin{bmatrix} 0.8 & 0.2 & 0.0 & 0.0 & 0.0 \\ 0.6 & 0.3 & 0.1 & 0.0 & 0.0 \\ 0.0 & 0.5 & 0.0 & 0.5 & 0.0 \\ 0.0 & 0.0 & 0.1 & 0.3 & 0.6 \\ 0.0 & 0.0 & 0.0 & 0.2 & 0.8 \end{bmatrix}.$$

When we compare purchasing cost transition matrices, it is seen that each one has its own property. For random walk transition matrix, any cost state does not have advantage over the other one, since occuring probabilities are equal to each other. Whereas there is a tendency moving toward inner cost state, c_3, for mean reverting transition matrix, it tends to move toward outer points, c_1 and c_5, for momentum transition matrix.

While implementing the Gavirneni's example, $(1-P)$ values are calculated for all demand distributions and cost transition matrices [7]. The obtained $(1-P)$ values are shown in Table 3.1. As a consequence, when demand distributions are compared with respect to $(1-P)$ values, uniformly distributed demand has the highest one, and then exponentially and truncated exponentially distributed demands respectively for all cost transition matrices.

Table 3.1. $(1-P)$ values of the numerical example.

	Unif(1,200)	**Exp(100)**	**Trunc.Exp(100)**
Random Walk	0.987	0.941	0.950
Mean Reverting	0.992	0.965	0.970
Momentum	0.991	0.959	0.965

Moreover, while using mean reverting as purchasing cost transition matrix, the highest $(1-P)$ value is obtained, and followed by the order is momentum and then random walk transition matrices respectively for all demand distributions. Therefore, it can be concluded that$(1-P)$ value increases as the tendency moving toward inner purchasing cost states increases.

We can also compare the order up to inventory levels, y_i's, of dynamic and myopic policies. The procedure to obtain the dynamic inventory level has been explained in detail in the Section 3.1. It is assumed that $y_i^\star$ values can take only integer values just as Gavirneni's study [7]. Also, myopic inventory level can be found using $y_i^{myopic} = \Phi^{-1}\left(\frac{p-c_i}{p+h-\bar{c}_i}\right)$ as mentioned in the Section 3.2.

The obtained results are shown for exponentially distributed demand function in Table 3.2, and the values are the same as the results in Gavirneni's paper [7]. It is observed those $y_i^\star$ and y_i^{myopic} values decrease and the difference between them decreases as purchasing cost increases for all transition cost matrices.

Table 3.2. The optimal $y_i^\star$ and myopic y_i^{myopic} optimal levels for exp(100).

	Random Walk		**Mean Reverting**		**Momentum**	
c_i	$y_i^\star$	y_i^{myopic}	$y_i^\star$	y_i^{myopic}	$y_i^\star$	y_i^{myopic}
16	193	194.6	207	208.7	182	182.7
18	169	168.6	186	187.2	155	154.0
20	161	160.9	161	160.9	161	160.9
22	152	152.6	139	138.6	168	170.5
24	130	129.9	124	123.1	138	137.7

Holding cost sensitivity analysis is applied as holding cost is changed between 3 and 7, increasing it by 0.2. $y_i^\star$ and y_i^{myopic} values are computed according to the procedure, which is defined in Chapter 3, with different demand distributions under both of myopic and dynamic inventory policies. Table 3.3 shows $y_i^\star$ and y_i^{myopic} values with respect to c_i are obtained with random walk transition matrix and uniformly distributed demand for holding cost rate sensitivity under both inventory policies.

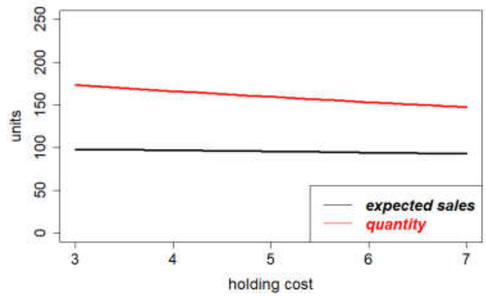
In Table 3.3, it is clear that the amount of $y_i^\star$ decreases as the value of c_i increases. Here, c_5 is the highest value, and c_1 is the lowest one. And also, $y_i^\star$ value decreases as holding cost rate increases. These results are valid for both inventory policies. In addition, it can be observed that $y_i^\star$ and y_i^{myopic} values are so close to each other, when the dynamic and myopic inventory policies are compared. Moreover, these results are valid for all obtained inventory level outputs which can be seen in Appendix A for other transition matrices and demand distributions.

Table 3.3. $y_i^\star$ and y_i^{myopic} values obtained from holding cost sensitivity with random walk transition matrix and uniformly distributed demand under different inventory policies.

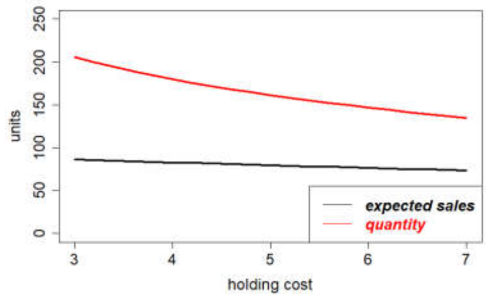
	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	184.6	176.0	173.9	171.4	160.0	185	176	174	172	160
3.2	183.2	174.6	172.4	169.8	158.4	184	175	173	170	159
3.4	181.8	173.2	170.9	168.2	156.9	182	174	171	169	157
3.6	180.5	171.9	169.5	166.7	155.3	181	172	170	167	156
3.8	179.1	170.5	168.1	165.1	153.8	180	171	169	166	154
4.0	177.8	169.2	166.7	163.6	152.4	178	170	167	164	153
4.2	176.5	167.9	165.3	162.2	150.9	177	168	166	163	151
4.4	175.2	166.7	163.9	160.7	149.5	176	167	164	161	150
4.6	173.9	165.4	162.6	159.3	148.1	174	166	163	160	149
4.8	172.7	164.2	161.3	157.9	146.8	173	165	162	158	147
5.0	171.4	163.0	160.0	156.5	145.5	172	163	160	157	146
5.2	170.2	161.8	158.7	155.2	144.1	171	162	159	156	145
5.4	169.0	160.6	157.5	153.8	142.9	169	161	158	154	143
5.6	167.8	159.4	156.2	152.5	141.6	168	160	157	153	142
5.8	166.7	158.3	155.0	151.3	140.4	167	159	156	152	141
6.0	165.5	157.1	153.8	150.0	139.1	166	158	154	150	140
6.2	164.4	156.0	152.7	148.8	137.9	165	157	153	149	138
6.4	163.3	154.9	151.5	147.5	136.8	164	155	152	148	137
6.6	162.2	153.8	150.4	146.3	135.6	163	154	151	147	136
6.8	161.1	152.8	149.3	145.2	134.5	162	153	150	146	135
7.0	160.0	151.7	148.1	144.0	133.3	160	152	149	144	134

Expected $y^\star$ can be calculated by multiplying $y_i^\star$ with corresponding steady state probability of the cost at state i, q_i, and then sum them up. Expected $y^\star$ values and expected sales can be seen in Figure 3.1 for holding cost sensitivity under myopic inventory policy and random walk transition matrix.

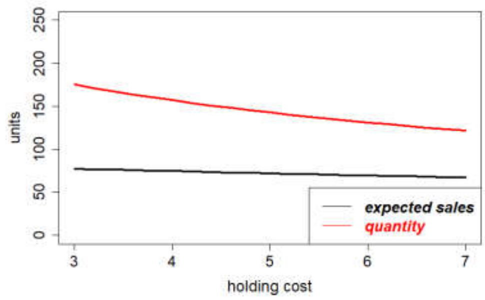
When Figure 3.1 is considered, it is obvious that order up to level decreases as holding cost increases. In addition, expected sales value also decreases as holding cost increases; however, the decrease in expected sales is not as much as in order up to inventory level. As a result, the inventory on hand decreases as holding cost increases. Also, if we compare the demand distributions, whereas exponentially distributed demand has the highest expected inventory on hand value, the difference between expected sales and order up to inventory level, uniformly distributed demand has the lowest one. Therefore, it can be concluded that expected inventory on hand increases as variance in demand increases. Moreover, expected inventory on hand values of different demand distributions get closer as holding cost increases.



(a) Demand ∼ Unif[1,200]



(b) Demand ∼ Exp(100)

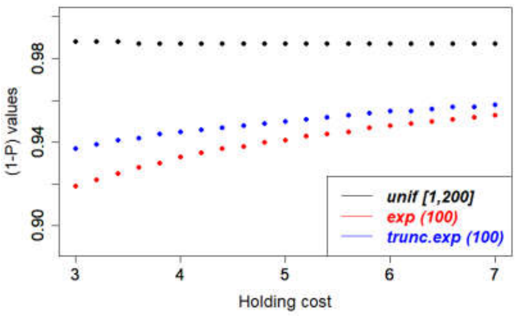


(c) Demand ∼ Trunc. Exp(100)

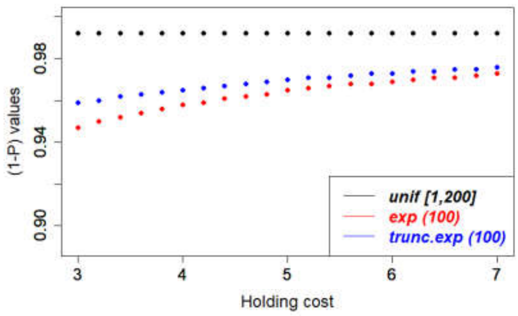
Figure 3.1. Expected $y_i^\star$ and Sales under Holding Cost Sensitivity with Random Walk and Myopic Inventory Policy for Different Demand Distributions.

Furthermore, holding cost sensitivity is also carried out under the dynamic inventory policy and the output is shown in Figure A.1 in Appendix A. The deductions obtained from Figure 3.1 are valid for the dynamic inventory policy as well. When we compare the results of dynamic and myopic inventory policies, there is not such a big difference between them, so we expect that $(1-P)$ values as holding cost changes. In addition, holding cost sensitivity is applied for all different cost transition matrices and it is observed that they have similar behavior for holding cost change.

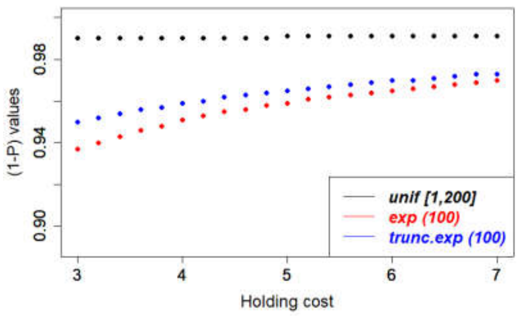
The graph including $(1-P)$ values with respect to h is shown in Figure 3.2. This graph indicates that $(1-P)$ values are so close to 1. While considering Figure 3.1 and Figure A.1, it is mentioned that $y_i^\star$ and y_i^{myopic} values are so close to each other, so it was expected that $(1-P)$ values keep close to 1 as holding cost changes. While considering Figure 3.2, it is seen that the expectation is satisfied.



(a) Random Walk



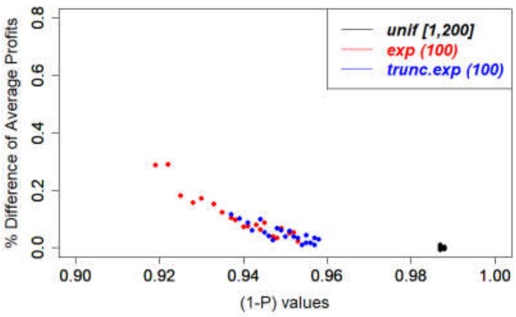
(b) Mean Reverting



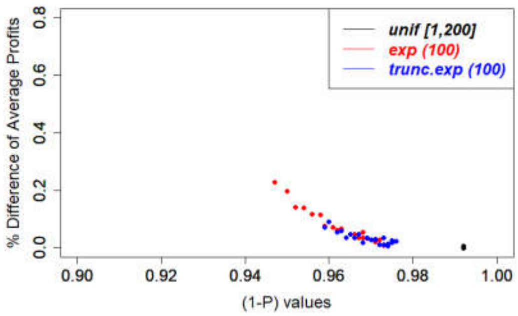
(c) Momentum

Figure 3.2. The Change of $(1-P)$ Values with respect to Holding Cost with Different Demand Distributions and Cost Transition Matrices.

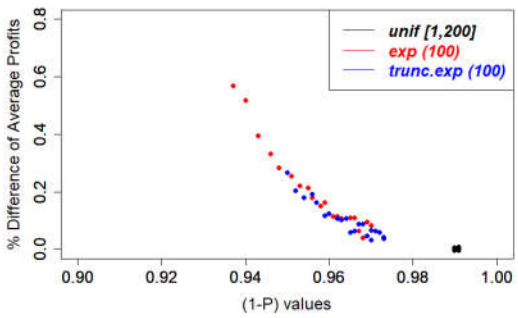
In Figure 3.2, it can be observed the same results which are obtained from Table 3.1. As holding cost increases, it is clear that $(1-P)$ values which are obtained with exponentially and truncated exponentially distributed demand increase as well. However, uniformly distributed demand does not have a dramatic change in $(1-P)$ value, when holding cost changes. Therefore, it can be concluded that myopic and dynamic inventory policies get closer as holding cost increases for exponentially and truncated exponentially distributed demand. When $(1-P)$ values of different demand distributions are compared, it is also observed that myopic and dynamic inventory policies get closer as variance in demand decreases.



(a) Random Walk



(b) Mean Reverting



(c) Momentum

Figure 3.3. Difference Percentage of Average Profits of Dynamic and Myopic Inventory Policies vs. $(1-P)$ Values for Different Demand Distributions and Cost Transition Matrices.

Simulation is applied to compute average profits for a finite horizon using order up to inventory levels which are obtained from holding cost sensitivity analysis for both of myopic and dynamic inventory policies. While the simulation procedure is carried out, it is assumed that time horizon is 1000, and the simulation is replicated 50 times. Average profits of dynamic and myopic inventory policies with respect to holding cost for different demand distributions and cost transition matrices are calculated using the procedure explained in the Chapter 3. Then, the difference percentage values between average profits of dynamic and myopic inventory policies are plotted with respect to $(1-P)$ values in Figure 3.3.

In Figure 3.3, it can be observed that mean reverting purchasing cost transition matrix has the highest $(1-P)$ values for all demand distributions, while random walk purchasing cost transition matrix has the lowest one. Also, $(1-P)$ values of uniformly distributed demand are not affected by holding cost change as much as others, whereas exponentially distributed demand is so sensitive for holding cost change. In addition, it is clear that $(1-P)$ value seems meaningful when we compare it with the difference of the average profits of myopic and dynamic inventory policies.

Table 3.4. The results obtained from t-test under different cost transition matrices.

	Random Walk			**Mean Reverting**			**Momentum**		
	Unif	Exp	T.Exp	Unif	Exp	T.Exp	Unif	Exp	T.Exp
$t_{statistic}$	0.003	0.29	0.14	0.01	0.2	0.095	0.01	0.44	0.24
CI_{lower}	-7.77	-7.95	-7.76	-7.43	-8.42	-7.83	-11.37	-8.98	-8.86
CI_{upper}	7.8	10.70	8.94	7.475	10.34	8.62	11.46	14.11	11.32

Moreover, independent t-test is applied to compare the average profits obtained from simulation of both inventory policies under different purchasing cost transition matrices and demand distributions. Here, the null hypothesis is that the average profits for both inventory policies are equal, alternative hypothesis is the average profits for both inventory policies are not equal. The results of t-test are shown in Table 3.4. It is obvious that all $t_{statistic}$ values are in between corresponding confidence intervals with 95% confidence level. Therefore, the average profits of both inventory policies are not statistically significantly different.

As a consequence, the model of Gavirneni is verified in this section using simulation [7]. In addition, it is observed that $(1 - P)$ is a good measure to compare myopic and dynamic inventory policies, when the inventory policies are compared with respect to average profit. We use these findings and methods in Chapters 4 and 5.

4. REPLENISHMENT UNDER THE MYOPIC AND DYNAMIC INVENTORY POLICIES

As purchasing cost changes, replenishment becomes a critical tool for organizations. If an increase in purchasing cost is predicted for the next period, and also the inventory is managed well, organizations can have a chance to increase their profits. Therefore, inventory management is one of the significant elements for organizations under exchange rate fluctuations.

The aim of this chapter is to implement the same methods, which are explained in Chapter 3, on USD/TRY dataset. Myopic and dynamic inventory policies are compared with respect to $(1-P)$, order up to inventory levels, and average profits computed using simulation. Moreover, holding cost rate and price sensitivity analysis are applied to consider the effect of the assumptions for these parameters.

4.1. Inventory Control Problem Under Exchange Rate Uncertainty

In real life, cost may change period by period because of exchange rate fluctuations. Therefore, we assume that purchasing cost can take several values shown as $c_i = \{c_1, c_2, ..., c_k\}$. It is assumed that holding cost is a linear function of the purchasing cost, so holding cost is a set and it can be shown as $h_i = \{h_1, h_2, ..., h_k\}$. Each state has a probability of occuring, so steady state probabilities which are calculated through transition probabilities can be shown as $q_i = \{q_1, q_2, ..., q_k\}$. Price is assumed as constant. As a result, single period expected profit equation is updated related to using h_i instead of h, and it is

$$E[P]_i = \max_{y_i \geq x} \left\{ \sum_{t=0}^{y_i} [pt - h_i(y_i - t)]\Phi(t) + py_i \sum_{t=y_i}^{\infty} \Phi(t) - c_i(y_i - x) \right\}. \tag{4.1}$$

Also, $(1-P)$ equation is updated in terms of the same change, and it is

$$(1-P)=\sum_{i=1}^{k} q_i \sum_{j=1}^{k} \pi_{ij}\left(1-\Phi\left(\left(\Phi^{-1}\left(\frac{p-c_i}{p+h_i-\bar{c}_i}\right)-\Phi^{-1}\left(\frac{p-c_j}{p+h_j-\bar{c}_j}\right)\right)^{+}\right)\right). \quad (4.2)$$

In this study, we use USD/TRY weekly exchange rate data including the dates between 01-10-2018 and 03-12-2020 to obtain purchasing cost transition matrix. The dataset is retrieved from Central Bank of the Republic of Turkey. It is assumed that purchasing cost is always 1000 USD, but its value in TRY changes period by period due to exchange rate fluctuations.

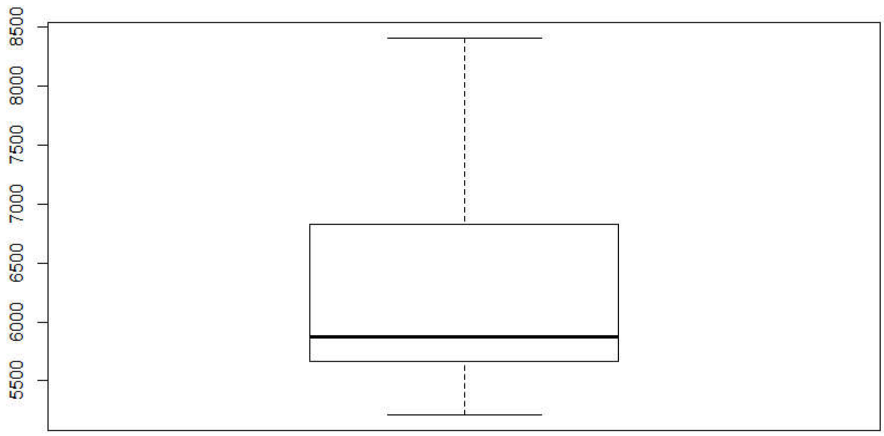


Figure 4.1. Boxplot of Purchasing Cost Values.

At first, the dataset is analyzed. Boxplot of the data is shown in Figure 4.1. It is observed that the cost is changed between 5210 and 8410 TRY. Median is 5875, lower quartile is 5660 and upper quartile is 6830. Also, the variance is higher for the values which are bigger than median, whereas the observation is opposite for the values which are lower than median. The change of cost depending of time is shown in Figure 4.2. Uptrend is clearly observed in this graph.

We decide to group cost values into bins to obtain purchasing cost transition matrix. Since minimum cost value is 5210 and maximum cost value is 8410, it is seen to be appropriate that width is determined as 200. Therefore, c_i states are found as

$c_i = \{5410, 5610, 5810, ..., 8410\}$. It can be said that there are 16 different states for purchasing cost.

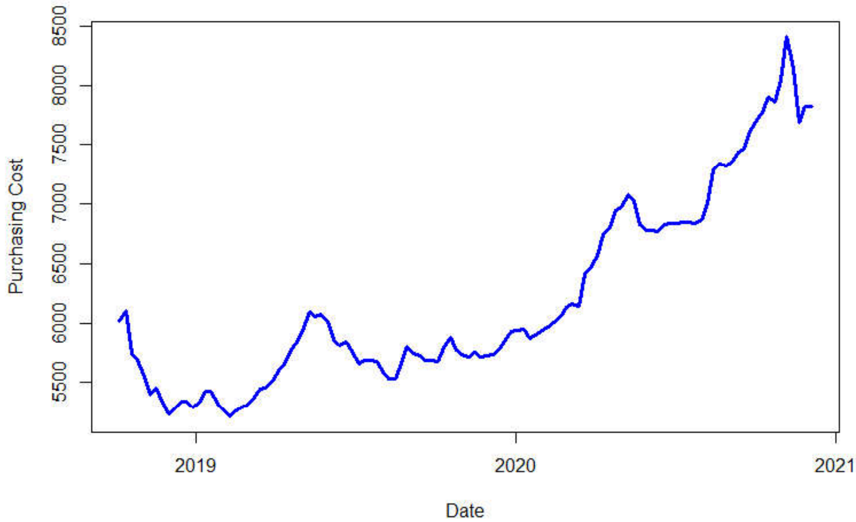


Figure 4.2. Time-Dependent Purchasing Cost Values.

After assigning bins, the transition probabilities are computed for each state for purchasing cost value by $createSequenceMatrix$ function from $markovchain$ package, launched by Spedicato, in R [13]. The logic of this function is as follows : it counts the transitions from state i to state j for all combinations of i and j values. A matrix is constituted with these count values. And then, each matrix element is divided by row sum, so it gives the probabilities of transitions from state i to state j as an approximation. Therefore, we obtain purchasing cost transition matrix.

After obtaining purchasing cost transition matrix, it is observed that there are zero probabilities for some transitions. We assign small α value instead of zero values to create a chance to occur these transitions. Here, α equals to 0.00001. Then, it is ensured that $RowSums$ equals to one for each row. The obtained transition matrix is

$$\begin{bmatrix}
0.76 & 0.23 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
0.27 & 0.54 & 0.18 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & 0.08 & 0.76 & 0.15 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & 0.21 & 0.63 & 0.14 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & 0.10 & 0.10 & 0.69 & 0.10 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.99 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.50 & 0.49 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.59 & 0.40 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.09 & 0.72 & 0.09 & 0.09 & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.50 & 0.49 & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.74 & 0.25 & \alpha & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.66 & 0.33 & \alpha & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.33 & 0.66 & \alpha & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.66 & 0.33 & \alpha \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.50 & \alpha & \alpha & 0.49 \\
\alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & \alpha & 0.99 & \alpha
\end{bmatrix}.$$

The obtained transition matrix is similar to none of random walk, mean reverting and momentum transition matrices. For the transition matrix obtained with USD/TRY dataset, purchasing cost tends to get higher values. In other words, there is a tendency moving toward right outer points, especially c_{13}, c_{14}, c_{15} and c_{16}.

When the obtained transition matrix is considered, it is clear that the probabilities of transitions are concentrated on the diagonal. As a result, a transition matrix including the increase or decrease rates in purchasing cost could have been used as well. However, we prefer using this version of the transition matrix to ease interpretation.

Discretized demand is used in this study as in Chapter 3. Since demand needs to be a positive value, we use gamma distribution for demand. While the mean value is kept constant, variance in demand is changed to analyze its effect. In this study, four different gamma distribution models are applied and the graph of their probability density functions is shown in Figure 4.3. Also, the properties of demand distributions are shown in Table 4.1.

Table 4.1. The properties of using gamma distribution models.

	Shape Parameter	**Scale Parameter**	**Mean**	**Sd**
Gamma Distribution 1	5	20	100	45
Gamma Distribution 2	4	25	100	50
Gamma Distribution 3	2	50	100	71
Gamma Distribution 4	1	100	100	100

It is assumed that holding cost has also different states and they are calculated with $h_i = h_{rate}c_i$. In this study, h_{rate} is assigned as 20 percentage. Price is constant and it is assigned as 9000. After these assumptions, $(1-P)$ values are calculated for each different gamma distributions and the results are shown in Table 4.2.

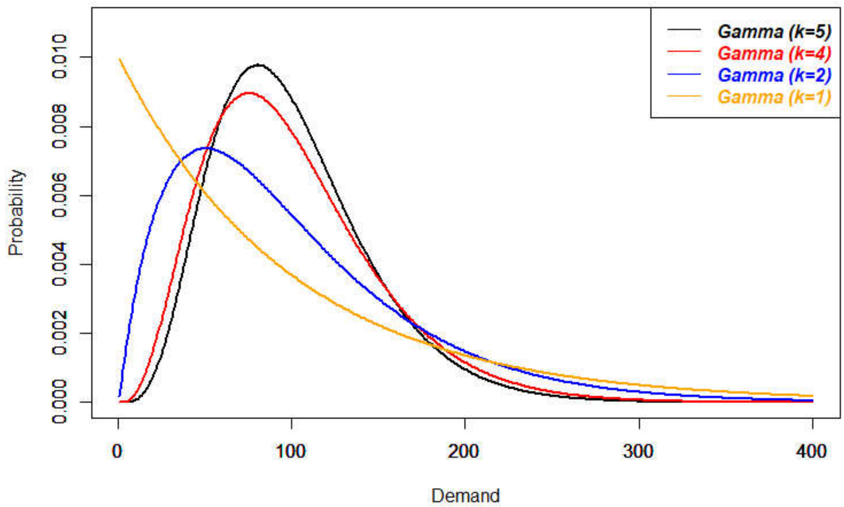


Figure 4.3. Probability Density Functions of Gamma Distributions.

In Table 4.2, it is observed that $(1-P)$ value decreases as variance in demand increases. Therefore, it can be said that myopic and dynamic inventory policies are getting closer as variance in demand decreases just as the results in Section 3.4.

Table 4.2. $(1-P)$ values obtained with different gamma distributions.

	$(1-P)$
Gamma Distribution (5,20)	0.99998
Gamma Distribution (4,25)	0.99985
Gamma Distribution (2,50)	0.99286
Gamma Distribution (1,100)	0.95816

After calculating $(1-P)$ values, order up to inventory levels of dynamic and myopic inventory policies are computed. While computing $y_i^\star$ according to the procedure in Chapter 3, the gap between searching inventory levels is taken as 0.2 instead of 1. The reason for this assumption is that y_i^{myopic} might be a decimal number, whereas $y_i^\star$ could not be with the procedure in Gavirneni's paper [7]. Therefore, the aim is to observe the difference of policies in a fair way. This assumption is going to be used for all analyses of USD/TRY case.

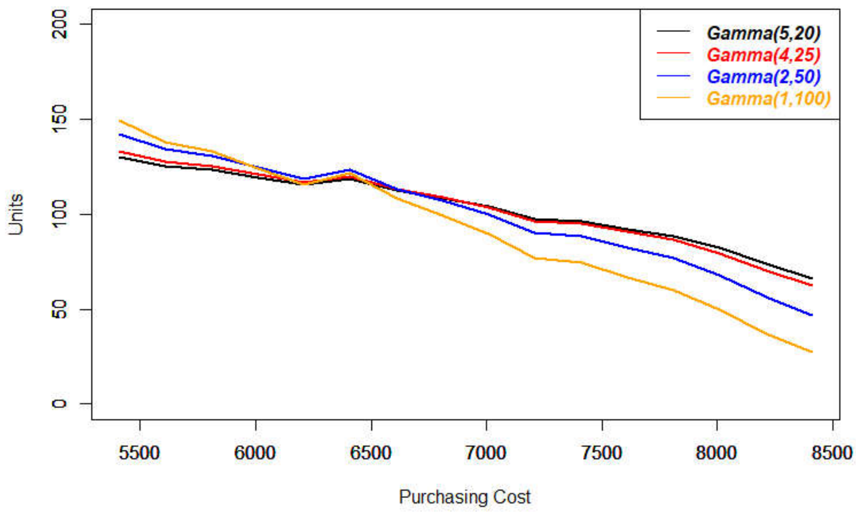


Figure 4.4. y* Values vs. Purchasing Cost States under Dynamic Inventory Policy.

Figure 4.4 shows $y^\star$ values subject to purchasing cost states under the dynamic inventory policy. Since $y^\star$ and y^{myopic} values are close to each other, the graph including results of the myopic inventory policy is not shown additionally. In Figure 4.4, it can be observed that $y^\star$ values, which are obtained with the dynamic inventory policy, decrease as purchasing cost increases in this graph. Also, higher variance in demand leads to higher change in $y^\star$ values. These results are also valid for the myopic inventory policy.

After computing order up to inventory levels, average profits are computed according to the simulation procedure which is explained in Chapter 3 for myopic and dynamic inventory policies. Time horizon is assumed as 5000, and simulation is replicated 50 times. Mean, standard deviation and coefficient of variation properties are computed using these 50 average profits for all demand distributions. The results can be seen in Table 4.3.

Table 4.3. Properties of average profits obtained with different demand distributions under the dynamic inventory policy.

	Mean	**Sd**	**CoV**
Gamma Distribution (5,20)	$60,776$	$4,806$	0.079
Gamma Distribution (4,25)	$57,620$	$5,705$	0.099
Gamma Distribution (2,50)	$43,460$	$5,432$	0.125
Gamma Distribution (1,100)	$25,240$	$5,313$	0.210

In Table 4.3, it is observed that average profit decreases significantly as variance in demand increases. Coefficient of variation is computed by standard deviation divided by mean. Therefore, it represents the variation according to mean value. In Table 4.3, it can be said that coefficient of variation of average profit obtained by simulation increases as variance in demand increases.

4.2. Sensitivity Analysis for Holding Cost Rate

Sensitivity analysis for holding cost rate is carried out in this section. While implementing holding cost rate sensitivity, the range is selected between 10-30 percentage incrementing it by 2.

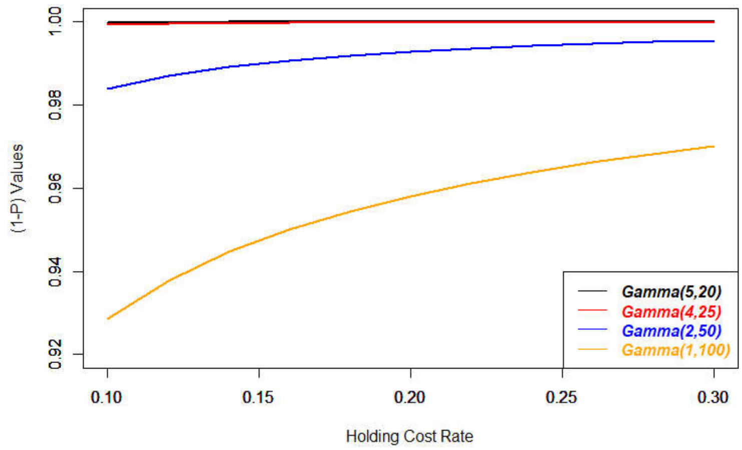


Figure 4.5. $(1-P)$ Values under Holding Cost Rate Sensitivity.

In Figure 4.5, it is obvious that $(1-P)$ value increases when holding cost rate increases, so myopic and dynamic inventory policies are getting closer as holding cost rate increases. However, there is not a dramatic change in $(1-P)$ values for Gamma Distribution with (5,20) and (4,25) parameters. Their performances are quite good since their variances are lower than others. Moreover, since $(1-P)$ values are higher than 0.90 for all demand distributions, the results of the myopic inventory policy must be close to the results of the dynamic inventory policy.

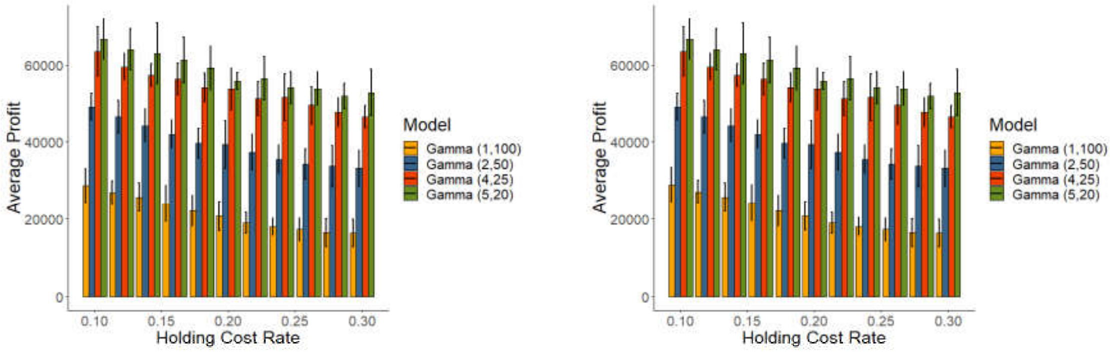
In Table 4.4, $y_i^\star$ and y_i^{myopic} values obtained from holding cost rate sensitivity under both inventory policies can be seen. $y_i^\star$ values with respect to c_i are calculated for other demand distributions and both of dynamic and myopic inventory policies as well, and they can be seen in the tables between B.1 and B.3 in Appendix B.

The results of holding cost sensitivity are consistent with the results in Section 3.4. In Table 4.4, it can be observed that $y^\star$ value decreases as holding cost rate increases for all c_i values and all demand distributions. Also, the change in $y^\star$ value increases as variance in demand distribution increases when holding cost rate increases. These results are valid for both of dynamic and myopic inventory policies.

Table 4.4. $y^{\star}$ values obtained from holding cost rate sensitivity with exchange rate transition matrix and demand with gamma distribution (k=5) under different inventory policies.

Myopic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	153.1	146.4	145.2	140.5	136.1	146.5	136.4	131.5	125.4	115.8	117.4	113.2	110.6	101.7	89.3	79.0
0.12	146.9	140.8	139.3	134.9	130.7	138.5	129.8	125.2	119.6	110.9	111.6	107.3	104.3	96.2	85.1	75.6
0.14	141.7	136.1	134.4	130.2	126.2	132.1	124.4	120.0	114.7	106.8	106.8	102.6	99.3	91.7	81.7	72.7
0.16	137.3	132	130.2	126.1	122.2	126.9	119.9	115.6	110.6	103.3	102.8	98.6	95.1	88.0	78.7	70.2
0.18	133.4	128.4	126.5	122.6	118.8	122.4	115.9	111.8	107.0	100.2	99.3	95.2	91.6	84.9	76.2	68.0
0.20	130.0	125.2	123.2	119.4	115.7	118.6	112.5	108.5	103.9	97.5	96.3	92.2	88.6	82.1	73.9	66.1
0.22	126.9	122.3	120.2	116.5	112.9	115.2	109.5	105.6	101.1	95.0	93.6	89.6	85.9	79.7	71.9	64.5
0.24	124.1	119.7	117.5	114.0	110.4	112.2	106.7	102.9	98.6	92.8	91.2	87.2	83.6	77.6	70.2	62.9
0.26	121.6	117.3	115.1	111.6	108.1	109.5	104.3	100.6	96.4	90.8	89.0	85.1	81.5	75.7	68.6	61.6
0.28	119.2	115.1	112.9	109.4	106.0	107.0	102.0	98.4	94.3	89.0	87.1	83.2	79.6	74.0	67.1	60.3
0.30	117.1	113.1	110.8	107.4	104.1	104.8	100.0	96.4	92.4	87.3	85.3	81.5	77.8	72.4	65.8	59.2
Dynamic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	153.2	146.4	145.4	140.6	136.2	146.6	136.4	131.6	125.6	115.8	117.4	113.2	110.8	101.8	89.4	79.2
0.12	147.0	141.0	139.4	135.0	130.8	138.6	129.8	125.2	119.6	111.0	111.6	107.4	104.4	96.2	85.2	75.6
0.14	141.8	136.2	134.6	130.4	126.2	132.2	124.4	120.0	114.8	107.0	106.8	102.6	99.4	91.8	81.8	72.8
0.16	137.4	132.2	130.2	126.2	122.4	127.0	120.0	115.8	110.6	103.4	102.8	98.6	95.2	88.2	78.8	70.2
0.18	133.4	128.6	126.6	122.6	118.8	122.6	116.0	112.0	107.2	100.4	99.4	95.2	91.8	85.0	76.2	68.2
0.20	130.0	125.4	123.2	119.4	115.8	118.6	112.6	108.6	104.0	97.6	96.4	92.2	88.6	82.2	74.0	66.2
0.22	127.0	122.4	120.4	116.6	113.0	115.4	109.6	105.6	101.2	95.2	93.6	89.6	86.0	79.8	72.0	64.6
0.24	124.2	119.8	117.6	114.0	110.6	112.2	106.8	103.0	98.8	93.0	91.2	87.4	83.6	77.8	70.2	63.0
0.26	121.6	117.4	115.2	111.6	108.2	109.6	104.4	100.6	96.4	91.0	89.2	85.2	81.6	75.8	68.6	61.6
0.28	119.4	115.2	113.0	109.6	106.2	107.2	102.2	98.4	94.4	89.0	87.2	83.4	79.6	74.0	67.2	60.4
0.30	117.2	113.2	111.0	107.6	104.2	104.8	100.0	96.4	92.6	87.4	85.4	81.6	78.0	72.6	66.0	59.4

Average profit values are computed according to the simulation procedure in Chapter 3 for holding cost sensitivity analysis. When average profit is computed, time horizon is assumed as 5000 and it is replicated 50 times. After replicated simulation computation, 50 average profits are obtained. Mean and standard deviation of average profits obtained with simulation replications can be seen in Figure 4.6.



(a) Myopic Inventory Policy (b) Dynamic Inventory Policy

Figure 4.6. Average Profits obtained with Holding Cost Sensitivity under Different Inventory Policies.

Figure 4.6 shows that average profit decreases, as holding cost rate increases. It was mentioned that average profit value increases as variance in demand decreases in Section 4.1. It is seen that this result does not change when holding cost rate changes. Also, when graphs of inventory policies are compared, it is clear that graphs are almost same.

The effects of increase in h_{rate} are explained in detail in this section. In Table 4.5, nominal values of changes in terms of $(1-P)$ and $y^{\star}$, and also the percentage change of average profits comparing with the average profit value, calculating with the default holding cost rate, can be observed for one percent increase in h_{rate}. It is observed that there is opposite relation between $(1-P)$ value and both of the order up to inventory level and average profit change comparing with the average profit, calculating with default holding cost rate parameter. Also, the change in $(1-P)$ value, in order up to inventory level and average profit percentage increases as variance in demand increases. Therefore, it can be said that variance in demand increases the sensitivity to the change in holding cost rate.

Table 4.5. The outputs of holding cost rate sensitivity analysis under dynamic inventory policy.

	$\frac{\Delta(1-P)}{\Delta h_{rate}}$	$\frac{\Delta E[y^{\star}]}{\Delta h_{rate}}$	$\frac{(\Delta AP/AP\|_{h=20\%})}{\Delta h_{rate}}$
Gamma Distribution (5,20)	< 0.001	-1.36	-1.28%
Gamma Distribution (4,25)	0.003	-1.49	-1.51%
Gamma Distribution (2,50)	0.058	-1.92	-2.29%
Gamma Distribution (1,100)	0.207	-2.23	-3.14%

4.3. Sensitivity Analysis for Price

In this section, sensitivity analysis for price is carried out. Price is assumed as constant and determined by market, so that it is assumed that the change in price does not change demand. We relax this assumption in Section 4.4. While implementing price sensitivity, the range is selected between 8500-9500 incrementing it by 100.

$(1-P)$ values are computed under price sensitivity, and the results can be seen in Figure 4.7. When price increases, it is obvious that $(1-P)$ value increases so that myopic and dynamic inventory policies are getting closer in Figure 4.7. However, there is not a dramatic change in $(1-P)$ values for Gamma Distribution with (5,20) and (4,25) parameters. Since their variances are lower than others, their performances are quite good again. As a result, it can be said that change in $(1-P)$ value decreases as variance in demand also decreases, when price increases. Moreover, since $(1-P)$ values are higher than 0.95 for all demand distributions and price values, it is known that the results of myopic and dynamic inventory policies are very similar.

Table 4.6. $y^{\star}$ values obtained from price sensitivity with exchange rate transition matrix and demand with gamma distribution (k=5) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	125.3	120.3	118	113.9	109.8	112.1	105.6	101.0	95.8	88.7	86.3	80.8	75.3	66.5	54.7	38.4
8600	126.3	121.4	119.1	115.1	111.1	113.5	107.1	102.7	97.6	90.7	88.5	83.5	78.5	70.3	59.8	47.3
8700	127.3	122.4	120.2	116.2	112.3	114.9	108.5	104.2	99.3	92.5	90.6	85.9	81.3	73.7	64.0	53.5
8800	128.2	123.3	121.2	117.3	113.5	116.2	109.9	105.7	100.9	94.2	92.6	88.1	83.9	76.8	67.7	58.4
8900	129.1	124.3	122.2	118.4	114.6	117.4	111.2	107.1	102.4	95.9	94.5	90.2	86.3	79.6	71.0	62.5
9000	130.0	125.2	123.2	119.4	115.7	118.6	112.5	108.5	103.9	97.5	96.3	92.2	88.6	82.1	73.9	66.1
9100	130.8	126.1	124.1	120.4	116.8	119.7	113.7	109.8	105.3	99.0	97.9	94.1	90.7	84.5	76.6	69.3
9200	131.6	127.0	125.0	121.4	117.8	120.8	114.9	111.1	106.7	100.4	99.5	95.8	92.7	86.7	79.1	72.2
9300	132.5	127.8	125.9	122.3	118.8	121.9	116.0	112.3	108.0	101.8	101.1	97.5	94.6	88.8	81.4	74.9
9400	133.2	128.7	126.8	123.2	119.8	123.0	117.2	113.5	109.2	103.2	102.5	99.1	96.3	90.8	83.6	77.3
9500	134.0	129.5	127.7	124.1	120.7	124.0	118.2	114.6	110.4	104.4	103.9	100.6	98.0	92.6	85.6	79.5
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	125.4	120.4	118.0	114.0	110.0	112.2	105.8	101.2	95.8	88.8	86.4	81.0	75.4	66.6	54.8	38.4
8600	126.4	121.4	119.2	115.2	111.2	113.6	107.2	102.8	97.6	90.8	88.6	83.6	78.6	70.4	59.8	47.4
8700	127.4	122.4	120.2	116.2	112.4	115.0	108.6	104.4	99.4	92.6	90.8	86.0	81.4	73.8	64.2	53.6
8800	128.2	123.4	121.2	117.4	113.6	116.2	110.0	105.8	101.0	94.4	92.8	88.2	84.0	76.8	67.8	58.6
8900	129.2	124.4	122.2	118.4	114.8	117.4	111.4	107.2	102.6	96.0	94.6	90.4	86.4	79.6	71.0	62.6
9000	130.0	125.4	123.2	119.4	115.8	118.6	112.6	108.6	104.0	97.6	96.4	92.2	88.6	82.2	74.0	66.2
9100	131.0	126.2	124.2	120.4	116.8	119.8	113.8	110.0	105.4	99.2	98.0	94.2	90.8	84.6	76.8	69.4
9200	131.8	127.0	125.2	121.4	117.8	121.0	115.0	111.2	106.8	100.6	99.6	96.0	92.8	86.8	79.2	72.4
9300	132.6	128.0	126	122.4	118.8	122.0	116.2	112.4	108	102.0	101.2	97.6	94.6	89.0	81.6	75.0
9400	133.4	128.8	127.0	123.4	119.8	123.0	117.2	113.6	109.4	103.2	102.6	99.2	96.4	90.8	83.6	77.4
9500	134.2	129.6	127.8	124.2	120.8	124.0	118.4	114.8	110.6	104.6	104.0	100.8	98.2	92.8	85.6	79.6

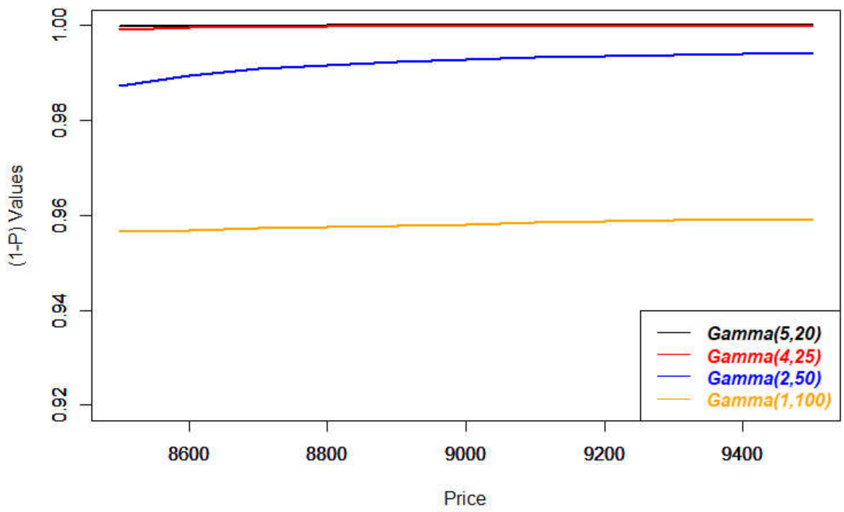
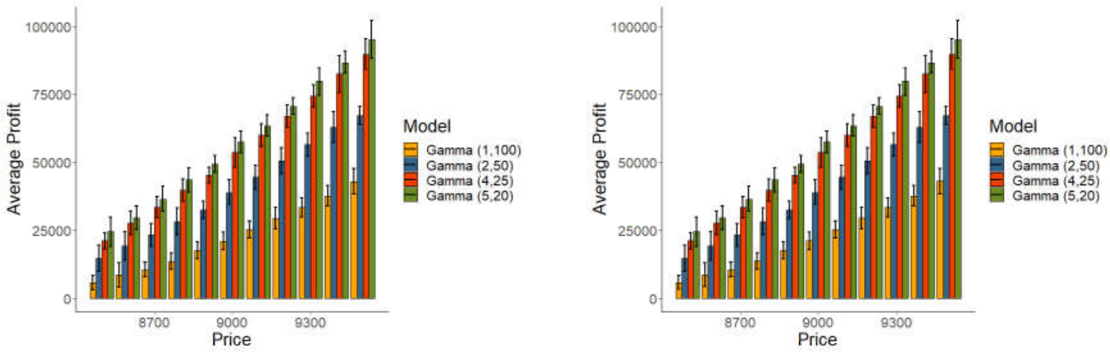


Figure 4.7. $(1-P)$ Values under Price Sensitivity.

$y_i^\star$ values with respect to c_i are computed according to the procedure in Chapter 3. Table 4.6 shows that $y^\star$ values are obtained from price sensitivity analysis for demand with gamma distribution (k=5) under both inventory policies. These values are computed for other assumptions as well, and they can be seen in the tables between B.4 and B.6 in Appendix B.

In Table 4.6, $y^\star$ value increases as price increases for all c_i values and all demand distributions under both of dynamic and myopic inventory policies. And also, the change in $y^\star$ value increases as variance in demand distribution increases, and price changes. Therefore, it is clear that $y^\star$ values are highly correlated with the variance in demand distribution for price sensitivity as well. These results are valid for both of myopic and dynamic inventory policies.

Average profits are computed with the same simulation procedure in Chapter 3 for price sensitivity analysis. Time horizon is assumed as 5000 and the simulation is replicated 50 times. Mean and standard deviation of average profits obtained with simulation can be seen in Figure 4.8. It is clear that average profit increases as price increases. There is an order among the demand distributions, if values are compared for all price values. As variance in demand decreases, average profit value increases and the order does not change as price changes.



(a) Myopic Inventory Policy

(b) Dynamic Inventory Policy

Figure 4.8. Average Profits Obtained with Price Sensitivity under Different Inventory Policies.

4.4. Sensitivity Analysis for Price with Price Dependent Demand

In this section, sensitivity analysis for price is carried out with price dependent demand. It is assumed that demand is multiplicative, and the mean demand is given as $D(p) = ap^{-E}$. Elasticity, E, is assumed as 3, so it means that there is an elastic relation between demand and price. In other words, demand increases as price decreases.

Since it is assumed that demand is dependent on price, expected single period profit equation is updated related to using $t(p)$ instead of t, and it is

$$E[P]_i = \max_{y_i \geq x} \left\{ \sum_{t=0}^{y_i} [pt(p) - h_i(y_i - t(p))] \Phi(t(p)) + py_i \sum_{t=y_i}^{\infty} \Phi(t(p)) - c_i(y_i - x) \right\}. \quad (4.3)$$

In Equation (4.3), i can take integer values between one and k.

While implementing price sensitivity, the range is selected between 8500-9500 incrementing it by 100 just as in the Section 4.3. In this section, elasticity refers to the relation between price and the mean of gamma demand distribution. Therefore, the mean of demand distribution increases as price decreases. Since we use various gamma distributions for demand, as mean changes with price, standard deviation changes as well. The relation between price and the mean of demand distribution can be seen in Figure 4.9. The reference point is assumed as $(p, D) = (9000, 100)$. Other mean points of demand distribution are computed with the mean demand function, $D(p) = ap^{-E}$, assuming that elasticity, E, is 3.

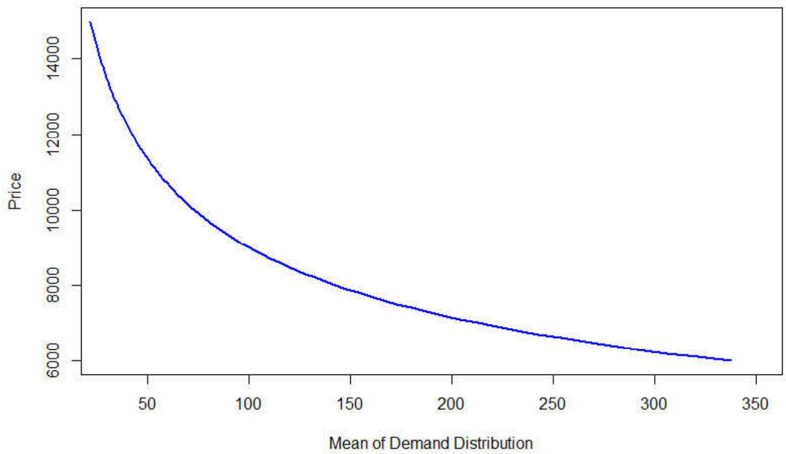


Figure 4.9. The Relation between Price and Mean of Demand Distribution.

In Figure 4.9, demand represents the mean value of demand distribution. In gamma distribution, we use shape and scale parameters. While adjusting mean, shape parameter is kept constant and only scale parameter is changed. The properties of gamma distribution with shape parameter being 5 can be seen in Table 4.7 as price changes. As price increases, mean of demand distribution decreases and also, variance in demand decreases as well.

It is mentioned that coefficient of variation, CoV, represents the variation according to mean value in Section 4.1. In Table 4.7, it is observed that coefficient of variation is constant as mean and variance in demand changes. The coefficient of variation values are shown in Table 4.8 for all demand distributions. It is observed that coefficient of variation increases as shape parameter of gamma distribution decreases.

Table 4.7. Properties of an using gamma distribution.

Price	Shape Par.	Scale Par.	Mean	Sd	CoV
8500	5	23.74	118.71	53.09	0.45
8600	5	22.92	114.61	51.26	0.45
8700	5	22.14	110.71	49.51	0.45
8800	5	21.39	106.97	47.84	0.45
8900	5	20.68	103.41	46.25	0.45
9000	5	20.00	100.00	44.72	0.45
9100	5	19.34	96.74	43.26	0.45
9200	5	18.72	93.62	41.87	0.45
9300	5	18.13	90.63	40.53	0.45
9400	5	17.55	87.77	39.25	0.45
9500	5	17.01	85.03	38.03	0.45

$y_i^\star$ and y_i^{myopic} values with respect to c_i are computed for price sensitivity according to the procedure in Chapter 3, while adjusting the mean of demand distribution according to price using elasticity parameter. Figure 4.10 indicates that there is a direct relation between $y_i^\star$ and purchasing costs under dynamic inventory policy.

Table 4.8. Coefficient of variation values of all gamma distributions with price dependent demand.

	Shape Par.	CoV
Gamma Distribution	5	0.45
Gamma Distribution	4	0.50
Gamma Distribution	2	0.71
Gamma Distribution	1	1.00

In Figure 4.10, it can be observed that slope of $y_i^\star$ with respect to c_i is different for different price values. Moreover, it is observed that the lines overlap around 8000 for purchasing cost. Here, order up to inventory level is almost constant regardless of the price value. In Table 4.6, this result is not observed, therefore it is clear that using price dependent demand causes the overlap of lines around 8000 for purchasing cost. Also, order up to inventory levels are computed for other demand distributions and inventory policies as well, and the results of all demand distributions can be seen in the tables between B.7 and B.10 in Appendix B.

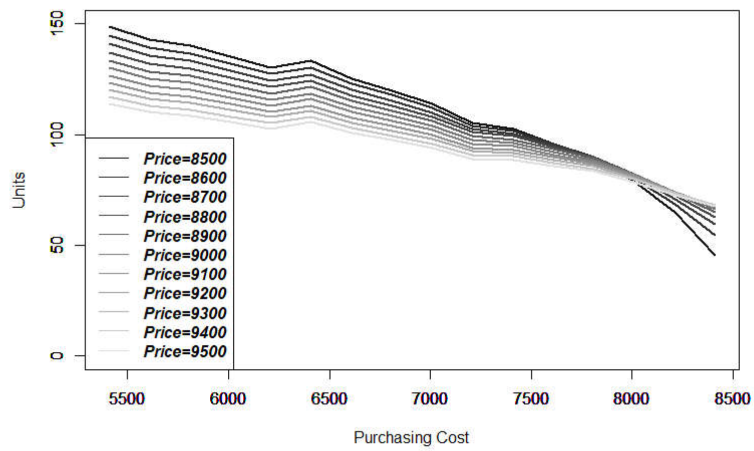
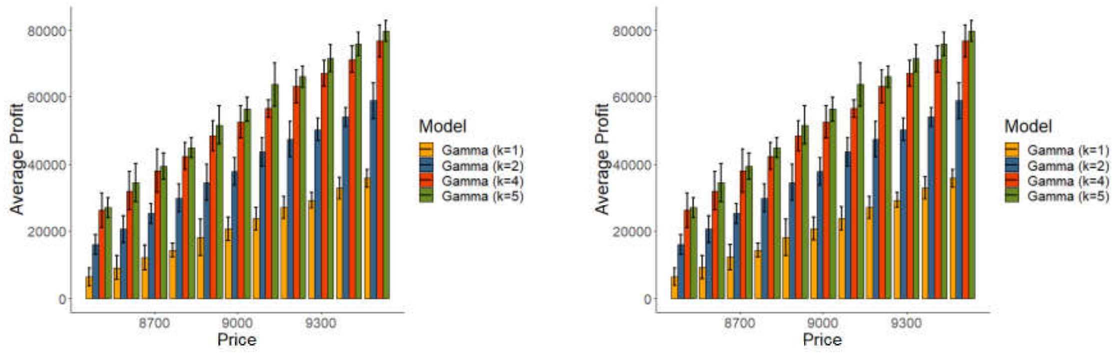


Figure 4.10. $y^\star$ Values Change with Gamma Dist. (k=5) under Dynamic Inventory Policy.

Simulation is performed to compute average profits for different demand distributions according to the procedure in Chapter 3 under both of the dynamic and myopic inventory policies. Assumptions are the same just as in Section 4.3. Time horizon is 5000 and the simulation is replicated 50 times. The results of average profit simulation is shown in Figure 4.11.

It is clear that average profit increases as price increases for all demand distributions in Figure 4.11 just as in Section 4.3, even though price sensitive demand is used. The reason of this result is that peak point of the revenue function is not reached under these circumstances. Also, there is an order among the demand distributions, if average profits are compared for all price values. Average profit value increases as variance in demand decreases, and the order does not change as price changes. In addition, graphs of inventory policies are compared, there is not such a big difference between the myopic and dynamic inventory policies.



(a) Myopic Inventory Policy

(b) Dynamic Inventory Policy

Figure 4.11. Average Profits obtained from Price Sensitivity with Price Dependent Demand under Different Inventory Policies.

If we compare the average profits under price sensitivity between Figure 4.8 and Figure 4.11, it is clear that the range of average profit values is lower in Figure 4.11. Therefore, the leverage effect of the increase in demand with respect to price can be seen as price decreases in Figure 4.8. And also, the opposite effect can be seen as price increases in the same graph. Moreover, the order among different demand distributions are the same for all price values in these graphs. Therefore, whether demand is dependent on price does not change the result that variance in demand is significant for average profit.

The effects of increase in price are explained in detail in this section. In Table 4.9, nominal values of changes in terms of $y^{\star}$ and average profit can be observed for one unit increase in price. It can be said that there is an opposite relation between the changes in order up to inventory level and average profit as coefficient of variation in demand increases.

Table 4.9. The outputs of price sensitivity analysis with price dependent demand under dynamic inventory policy.

	$\frac{\Delta E[y^{\star}]}{\Delta p}$	$\frac{\Delta AP}{\Delta p}$
Gamma Distribution (k=5)	0.003	70.3
Gamma Distribution (k=4)	0.007	64.6
Gamma Distribution (k=2)	0.018	53.7
Gamma Distribution (k=1)	0.026	37.1

5. JOINT REPLENISHMENT AND PRICING UNDER DYNAMIC INVENTORY POLICY

Pricing is one of significant strategic tools for organizations. Some brands get position at high prices, while some of them get position at low prices. Pricing strategy decision of companies dramatically affects how many they will sell. In this chapter, pricing is considered as a strategic tool to maximize profit under exhange rate uncertainty.

In Chapter 4, price is assumed as a constant value (p=9000) and the effects of price parameter change on $y^\star$ and average profit are analyzed. Besides these effects, purpose of this chapter is to determine the best price and $y^\star$ together. Since optimal order up to inventory level with respect to purchasing cost state is determined in Chapters 3 and 4, the main problem is to determine the corresponding best price in this chapter.

While determining best price, two different systems are used. First case assumes that price is announced before the purchasing cost state is determined, so there is only one best constant price for all cost states. This case can be observed in the businesses that have long price updating period or have long-term contract with their customers. The change in the purchasing cost does not affect the selling price. Second case assumes that price can be updated with respect to purchasing cost state at each period, so there are different best prices for all cost states. Second case can be observed especially in e-commerce. E-commerce allows the sellers to change the prices of the products at any time. We use simulation to carry out and compare these pricing systems.

In this chapter, dynamic inventory policy procedure, which is identified in Chapter 3, is used to determine $y^\star$. The procedure assumes that price is constant, so we ignore the effect of the change in price when we compute $y^\star$ values for best pricing case. Also, price dependent demand distribution is used for this chapter as in Section 4.4.

In addition, all assumptions are the same just as previous chapter, unless otherwise stated.

5.1. Joint Replenishment and Constant Pricing

In this section, we assume that price is announced before purchasing cost state is determined. The purpose of this section is to determine the best constant price and optimal order up to inventory levels with respect to purchasing cost states. A procedure is formed to find the best constant price and optimal order up to inventory levels together.

The first step of the procedure is to determine the range of possible prices. It is assumed that demand is dependent on price, so mean of demand distribution is determined with respect to each possible price. After getting p and D paired values, $y^\star$ values, which are dependent on them, are computed with dynamic inventory policy procedure as explained in Chapter 3. Therefore, we have (p, D, y) grouped values, and D and y values are dependent on p values. So, finding the best constant p is quite critical since it affects other inputs.

Average profit value can be computed using (p, D, y) grouped values for each price option. Simulation procedure is applied as explained in Chapter 3 to compute average profit values. After finding average profits obtained with simulation, the best constant price is selected with $p = \arg\max E[P]$ formula. We use a search mechanism over price.

The procedure to find best constant price and optimal order up to inventory levels is explained step by step below.

(i) Determining possible price values to be searched.
(ii) Mean of demand distribution is determined using $D(p) = ap^{-E}$ equation with respect to all possible prices. Elasticity, E, is assumed as 3.

(iii) $y_i^\star$ value for each cost state is computed as explained in Chapter 3 using possible prices and mean values of demand distribution, which are dependent on price.

(iv) Average profit simulation procedure is carried out separately as explained in Chapter 3 for each possible price. Therefore, we obtain average profit value for each possible price.

(v) Selecting the best constant price which maximizes average profit.

(vi) After finding the best constant price, corresponding mean value of demand distribution and optimal order up to inventory levels are selected among the values which are calculated in steps (ii-iii) in this procedure.

In conclusion, the best constant price regardless of purchasing cost state, and also optimal order up to inventory level subject to both of purchasing cost and price dependent demand are determined in this procedure. This procedure is going to be implemented on USD/TRY dataset in Section 5.3.

5.2. Joint Replenishment and Pricing

In this section, we assume that price can be updated related to cost state at each period. In real world, it is clear that selling price is not constant, when purchasing cost changes. Therefore, we form a procedure to find both of best price and optimal order up to inventory level for each cost state in this section. The best price and optimal order up to inventory level are determined after purchasing cost is observed. In addition, best pricing is not the same as dynamic pricing. Price only changes when purchasing cost changes for best pricing.

The procedure is similar to best constant pricing procedure. Until finding (p, D, y) grouped values, the steps are the same. While computing optimal order up to inventory level using the procedure in Chapter 3, we assume that price is constant. However, price is changed subject to purchasing cost in this chapter. Therefore, we ignore the effect of the change in price on optimal order up to inventory level.

The difference between pricing policies is in computation of average profits. Here, simulation procedure is carried out to compute average profit just as in the best constant pricing. However, the difference is that it is applied for each cost state separately. Therefore, there are different average profit values obtained with simulation for each purchasing cost state and price combination. The best price is determined by using $p_i = \arg\max E[P]_i$ formula for each cost state.

After finding best prices for each cost state, y_i and D_i parameters are also determined since these are dependent on p_i. As a result, we have $(c_i, h_i, y_i, p_i, D_i)$ for each cost state i. The procedure to find best prices and optimal order up to inventory levels for purchasing cost states is explained step by step below.

(i) Determining possible price values to be searched.

(ii) Mean of demand distribution is determined using $D(p) = ap^{-E}$ equation with respect to all possible prices. Elasticity, E, is assumed as 3.

(iii) $y_i^{\star}$ value for corresponding cost state is computed as explained in Chapter 3 using possible prices and mean of demand distribution values, which are dependent on price.

(iv) Purchasing cost state, i, equals to 1.

(v) Average profit simulation procedure is carried out separately as explained in Chapter 3 for each possible price and purchasing cost combination. Therefore, we obtain average profit value for each combination.

(vi) Selecting the best price which maximizes average profit for corresponding purchasing cost state.

(vii) Incrementing i by one.

(viii) Repeat steps (v-vii) until the best price is computed for each purchasing cost.

(ix) After finding the best prices, corresponding mean values of demand distribution and optimal order up to inventory levels are determined for all purchasing cost states.

In conclusion, the best price subject to purchasing cost state, and also optimal order up to inventory level subject to both of purchasing cost and price dependent demand are determined in this procedure. This procedure is going to be implemented on USD/TRY dataset and to be compared with best constant pricing procedure in Section 5.3.

5.3. Comparison of Best Constant Pricing and Best Pricing with Numerical Study

The aim of this section is to compare the systems including the best constant pricing and the best pricing. While implementing numerical study, the inputs are the same as Chapter 4. Here, we assume we search the price between 6000 and 15000 incrementing it by 100. Therefore, there are 91 different possible selling price values. Also, the relation between demand and price is assumed as multiplicative, and elasticity is assumed as 3 just as Section 4.4.

At first, best constant pricing system is performed. The best constant price and optimal order up to inventory levels are computed according to the procedure as explained in Section 5.1. When simulation procedure in step (iv) of the best constant pricing procedure is performed, time horizon is assumed as 3000, and the simulation is replicated 100 times. The results of the best constant prices and related demand distributions for different shape parameters can be seen in Table 5.1.

In Table 5.1, it can be observed that best constant price increases as shape parameter of demand distribution decreases. It was mentioned that coefficient of variation represents the variation according to mean value, and it is computed by standard deviation divided by mean in Section 4.1. According to the results of Table 5.1, the best constant price value increases as coefficient of variation in demand distribution increases. Moreover, the relation of mean and standard deviation of demand distribution is opposite according to the results.

Table 5.1. Results of best constant pricing with different shape parameters.

	Best Constant Price	Shape Par.	Scale Par.	Mean	Sd	CoV
Gamma Dist. 1	$12,900$	5	6.79	33.95	15.18	0.45
Gamma Dist. 2	$13,000$	4	8.30	33.20	16.60	0.50
Gamma Dist. 3	$14,300$	2	12.46	24.92	17.62	0.71
Gamma Dist. 4	$14,900$	1	22.04	22.04	22.04	1.00

Optimal order up to inventory levels with respect to determined the best constant prices for purchasing cost states under different demand models are shown in Figure 5.1. Here, it is clear that order up to inventory level decreases as purchasing cost increases in general. However, it can be observed that the change in optimal inventory levels with respect to purchasing cost states increases as coefficient of variation of demand distribution increases.

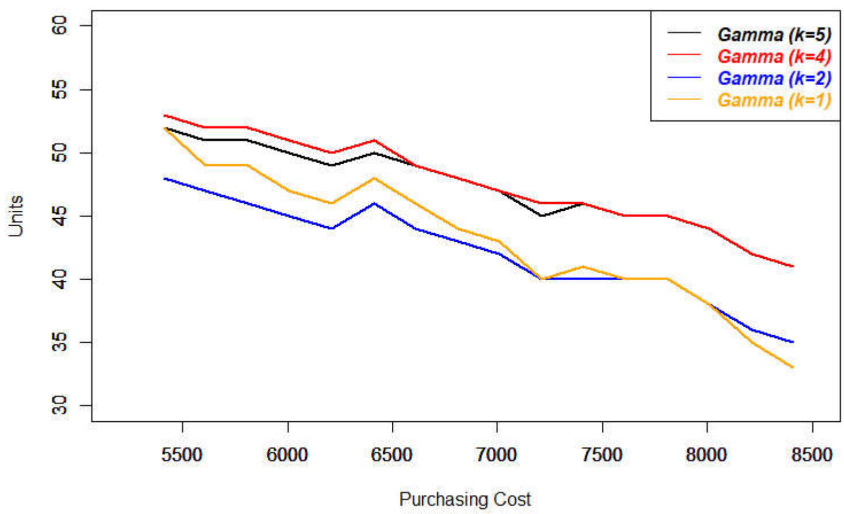


Figure 5.1. $y^\star$ Values for Each Cost State under Dynamic Inventory Policy and Different Demand Distributions for Best Constant Pricing.

After implementing the best constant pricing procedure, the best pricing procedure is carried out to determine best price for each cost state. The best prices and optimal order up to inventory levels are calculated as explained in Section 5.2. The assumptions of price elasticity and possible prices are the same. When simulation procedure in step (v) of the best pricing procedure is performed separately for each cost state, time horizon is assumed as 1000, and the simulation is replicated 100 times for each one.

The best prices with respect to purchasing cost states using different shape parameters of demand distribution are shown in Figure 5.2. It can be observed that best price and purchasing cost are directly related. Also, when demand distributions are compared, selling price increases for the same purchasing cost state in general as coefficient of variation of demand distribution increases.

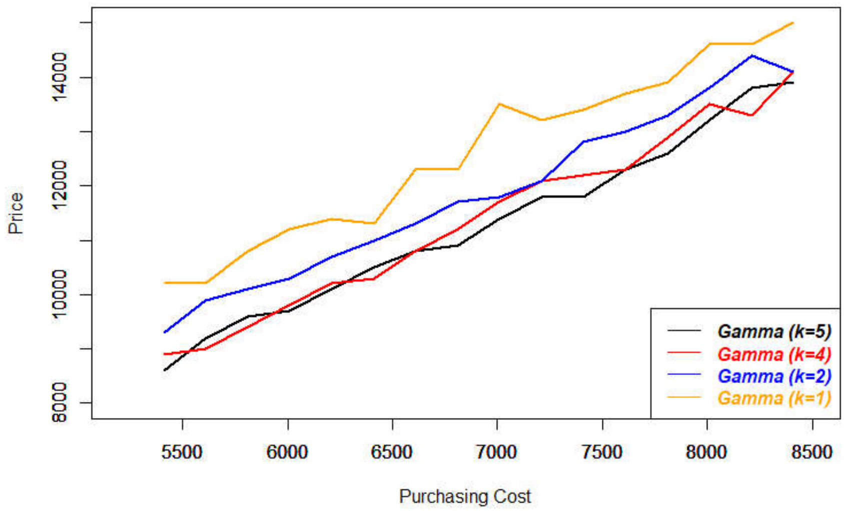


Figure 5.2. The Best Prices for Each Cost State under Dynamic Inventory Policy and Different Demand Distributions.

Optimal order up to inventory levels subject to purchasing cost states with respect to determined best prices under different demand models are computed. It is significant to remind that we ignore the effect of the change in price while computing $y_i^\star$. The results of optimal order up to inventory levels with respect to best prices and purchasing costs are shown in Figure 5.3. Here, it can be observed that the behavior is similar to best constant pricing case. It is clear that order up to inventory level decreases as purchasing cost increases in general. Also, the difference between optimal inventory levels of demand distributions decreases as purchasing cost increases. In addition, there is not such a significant difference among different demand models in Figure 5.3, in contrast to the results of Figure 5.1. Another difference is that optimal order up to inventory levels are between 33 and 143 in Figure 5.3, whereas they are between 33 and 54 in Figure 5.1. Therefore, it is clear that the range of optimal inventory levels and the volumes are higher for the best pricing case.

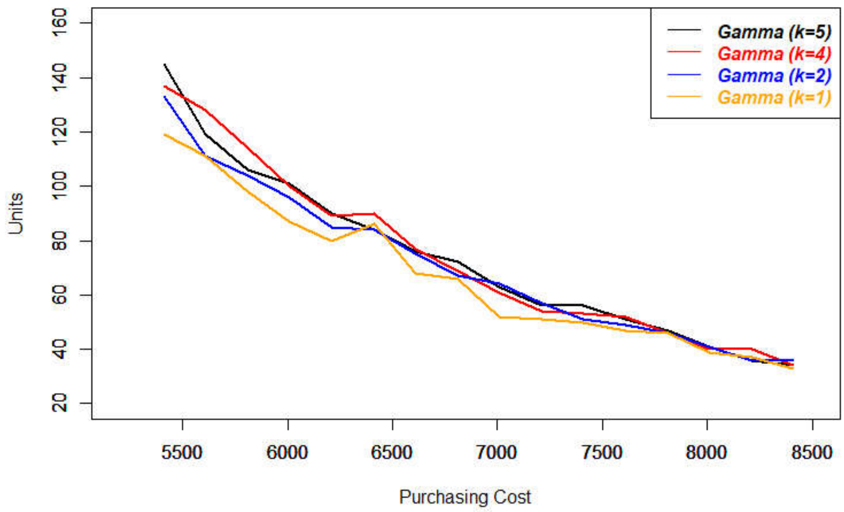


Figure 5.3. $y^{\star}$ Values for Each Cost State under Dynamic Inventory Policy and Different Demand Distributions for The Best Pricing.

After all computations, the systems including the best constant pricing and the best pricing are compared. It needs to be realized that price, properties of demand with respect to price, and $y_i^{\star}$ values are obtained in previous steps. For comparison, average profit simulation procedure is carried out as mentioned in Chapter 3. Time horizon is assumed as 4000 and it is replicated 100 times. Mean and standard deviation of average profits obtained from simulation are calculated for different demand distributions.

Using replicated simulation results, t-test is performed to check the means of average profits are equal or not. Here, hypothesis is that the average profits of the best constant pricing and the best pricing systems are equal, alternative hypothesis is that the average profits for both pricing systems are not equal. The results of t-test are shown in Table 5.2. It is obvious that all $t_{statistic}$ values are not in between corresponding confidence intervals with 95% confidence level. Therefore, average profits of both pricing policies are statistically significantly different for all demand distributions.

Table 5.2. T-test results of simulation for average profit under different demand distributions.

	$t_{statistic}$	CI_{lower}	CI_{upper}
Gamma Dist. (k=5)	135	$40,254$	$41,448$
Gamma Dist. (k=4)	71	$34,142$	$36,106$
Gamma Dist. (k=2)	69	$25,304$	$26,797$
Gamma Dist. (k=1)	27	$11,314$	$13,075$

Moreover, confidence interval levels, CI, represents the expected difference between average profits of the pricing systems in Table 5.2. It is observed that the expected difference value of average profit values decreases as shape parameter of the demand distribution decreases. In other words, expected difference value of average profits of the pricing systems decreases as coefficient of variation in demand distribution increases.

Table 5.3 shows the mean and standard deviation of average profits obtained from replicated simulation. It is clear that the best pricing has a significant advantage over the other one, when mean values are considered. Also, it is obvious that average profit decreases as shape parameter of demand distribution decreases. However, when standard deviation values are compared, best constant pricing has an advantage for all demand distributions. When demand distribution is used with shape parameter 5, best pricing can compensate for having higher standard deviation than best constant pricing due to the dramatic difference between mean of average profits.

Table 5.3. Properties of average profit values obtained with simulation under different demand distributions.

	Best Constant Pricing		**Best Pricing**	
	Mean	Sd	Mean	Sd
Gamma Dist. (k=5)	$93,880$	$1,763$	$134,731$	$2,459$
Gamma Dist. (k=4)	$96,495$	$2,183$	$131,619$	$4,463$
Gamma Dist. (k=2)	$89,924$	$2,099$	$115,975$	$3,146$
Gamma Dist. (k=1)	$84,103$	$2,453$	$96,298$	$3,727$

In conclusion, it is observed that the best price value increases as coefficient of variation in demand for both of the best constant pricing and the best pricing systems. Also, price value increases as purchasing cost increases for both of the pricing systems. Moreover, there is an opposite relation between purchasing cost and optimal order up to inventory levels for both of the pricing systems. While there are some similarities between the pricing systems, there are also differences, especially in the results of average profits. When standard deviation of average profit is analyzed, the best pricing might be seen as a bit risky, since its standard deviation values are higher than the other one's for all demand distributions. However, mean value of average profit is higher than the result of the best constant pricing for the best pricing system. Since the gap between mean of average profit values of the pricing systems is high, taking the risk of the deviation might be preferable to increase profit. Therefore, cost volatility promotes the best pricing which is an extreme pricing policy that changes every period.

6. CONCLUSION

In recent years, many companies face complex supply chain problems due to globalization. Because of competition among companies, their cost concerns get more significant. In Turkey, USD/TRY exchange rate is always fluctuating, so deciding and acting at the right moment is so crucial for financial sustainability. Therefore, we believe that this study will be useful for not only following academical studies related to exchange rate uncertainty, and also business problems.

We verify the methods to compute order up to inventory levels of the dynamic and myopic inventory policies using the same example of Gavirneni's paper at the beginning [7]. It is observed that $(1-P)$ value is a good measure to compare the dynamic and myopic inventory policies, because of the coherence between the $(1-P)$ values and average profits obtained with simulation under both dynamic and myopic inventory policies. Also, it is seen that the myopic and dynamic inventory policies get closer as variance in demand decreases. In addition, the change in purchasing cost transition matrix affects the closeness between the dynamic and myopic inventory policies. The myopic inventory policy may be used for the transition matrices, which have a tendency moving toward inner points, since myopic solution effectiveness increases. When holding cost sensitivity analysis is carried out, it is seen that order up to inventory level decreases as holding cost increases. Also, closeness of the dynamic and myopic inventory policies increases as holding cost increases.

We construct a Markovian transition matrix using USD/TRY exchange rate data. It is observed that there is a tendency moving toward higher purchasing cost values in the transition matrix. With using this transition matrix, we compare the myopic and dynamic inventory policies in terms of order up to inventory levels and average profit values under different demand distributions. We assume that there is no strategic customers, so we ignore speculative activities of customers such as changing strategically when or how much products they buy. As a result, it is seen that myopic inventory policy has a good performance on USD/TRY study, since $(1-P)$ value, which is an indicator of myopic solution effectiveness, is higher than 0.95 for all demand distributions. Also, $(1-P)$ value decreases as coefficient of variation of demand increases. In other words, myopic solution effectiveness decreases as coefficient of variation of demand increases. Moreover, it is observed that average profit obtained with simulation increases as coefficient of variation of demand decreases. The coefficient of variation of demand also affects the volatility in average profits.

Holding cost rate and price sensitivity analyses are also applied to analyze the effect of the change in parameter values on USD/TRY dataset. Price sensitivity is carried out with two different assumptions. First case assumes that demand is not affected by the change in price, and second one assumes that demand is dependent on price. Sensitivity analyses show that there is a clear pattern and order among demand distributions regardless of the holding cost rate and price parameters, when average profit graphs are considered. It is seen that the demand distribution, which has the lowest coefficient of variation, has the best performance according to the results of sensitivity analyses. Also, the order is not affected by the change of parameter values, but average profit and order up to inventory level values are affected by the change in holding cost rate and price parameters.

According to the results of holding cost rate sensitivity for gamma distribution using shape parameter 1, the one percent increase in holding cost rate causes 0.207 increase in $(1-P)$, and 2.23 decrease in expected order up to inventory level, and also 3.14% decrease in average profit. Therefore, average profit decreases as holding cost rate increases. Also, order up to inventory level decreases as holding cost rate increases. Moreover, effectiveness of the myopic inventory policy increases as holding cost rate increases. These results are valid for all demand distributions, but the change values are different. It is seen that the sensitivity to holding cost rate increases as coefficient of variation of demand increases in terms of $(1-P)$ value, expected order up to inventory level and average profit obtained with simulation.

It is observed that $(1-P)$ value increases as price increases in general, when price sensitivity analysis is carried out. However, there is not dramatic change in $(1-P)$ value in the results of price sensitivity analysis. The most significant difference between two different price sensitivity analyses is in order up to inventory levels. It is observed that using price dependent demand avoids dramatic change in order up to inventory levels, and also average profits.

According to the results of price sensitivity with price dependent demand, the one unit increase in price causes 0.026 increase in expected order up to inventory level, and 37.1 increase in average profit for gamma distribution using shape parameter 1. Therefore, expected order up to inventory level increases as price increases. Also, average profit increases as price increases. It is observed that the nominal change in expected order up to inventory level increases as coefficient of variation of demand increases. Moreover, nominal change in average profit decreases as coefficient of variation of demand increases.

After replenishment problem is evaluated on USD/TRY dataset, joint replenishment and pricing problem is considered. The aim is to compute best price and optimal order up to inventory level together. While determining best price, two different pricing systems are used, namely best constant pricing and best pricing. First one represents that price is announced before purchasing cost state is determined, so there is only one best constant price for all purchasing cost states. Second one represents that price can be updated with respect to purchasing cost state after purchasing cost is determined in each period, so price might be different for each cost state in order to maximize profit. While determining best price, average profit simulation is carried out. Then, price and order up to inventory level combination, which maximizes average profit value, are selected for both pricing systems.

It has been observed that best constant price increases as coefficient of variation of demand also increases. Also, best price with respect to purchasing cost increases as coefficient of variation of demand increases for best pricing system. It is seen that average profit obtained with simulation decreases as coefficient of variation of demand increases for both of pricing systems. However, volatility in average profit increases as coefficient of variation of demand increases.

T-test is carried out to determine whether there is a significant difference between average profits obtained with simulation from both pricing systems. According to the results, the pricing systems are significantly different, and the difference value decreases as coefficient of variation of demand increases. As a result, the best pricing system has an advantage over the best constant pricing system in terms of mean of average profits obtained with simulation.

When best constant pricing and best pricing systems are compared in terms of nominal values, the mean of average profits obtained with best constant pricing is 93,880 whereas it is 134,731 for best pricing for gamma distribution using shape parameter 5. The mean of average values are 84,103 and 96,298 respectively for gamma distribution using shape parameter 1. Moreover, standard deviation of average profits are 1,763 and 2,459 respectively for gamma distribution using shape parameter 5. Also, they are 2,453 and 3,727 respectively for gamma distribution using shape parameter 1. Therefore, it is seen that standard deviation of average profits obtained with simulation is higher for best pricing system. On the other hand, mean of average profits is also higher for best pricing system.

In conclusion, even though selecting best pricing seems risky, since it has higher volatility in average profits, the difference between average profits of both pricing systems is high. As a result, taking the risk of the volatility in average profit might be preferable to increase profit. In conclusion, cost volatility promotes best pricing, which enables to update price with respect to purchasing cost state in each period after purchasing cost is determined.

Beyond this research, some improvements for future work can be considered. Normalizing the purchasing cost with respect to inflation could be one of the meaningful points to be investigated. Also, speculative stocking activities of the sellers could be considered using the ratio of sales price to purchasing cost. The motivation behind this improvement is that a seller might not want to sell its product if its selling price is not high enough to persuade the seller to sell. Also, different transition matrices including the decrease or increase ratio of purchasing cost can be used in order not to limit the purchasing cost realizations.

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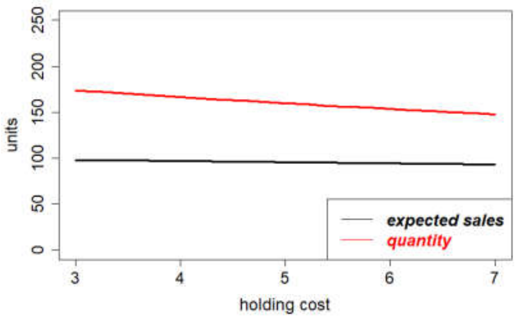
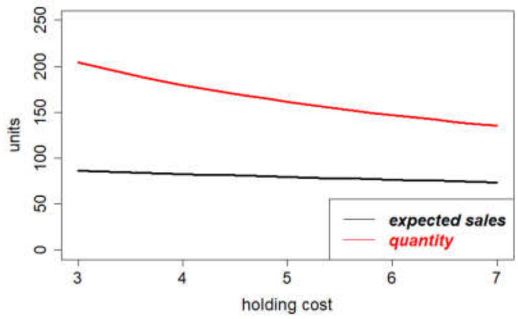
APPENDIX A: FIGURES AND TABLES OBTAINED FROM GAVIRNENI(2004)'S EXAMPLE

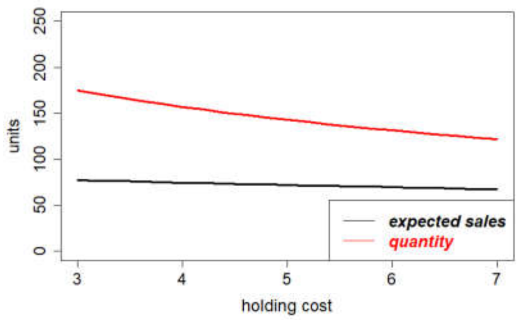
A figure which is related to holding cost sensitivity analysis under dynamic inventory policy, and $y^\star$ values which are obtained from sensitivity analyses with Gavirneni's example in Section 3.4 are attached this appendix [7]. order up to inventory values are shown separately according to using inventory policies, demand distributions, transition matrices, and the parameters which sensitivity analysis conducted.



(a) Demand $\sim$ Unif[1,200]



(b) Demand $\sim$ Exp(100)



(c) Demand $\sim$ Trunc. Exp(100)

Figure A.1. Expected $y_i^\star$ and Sales under Holding Cost Sensitivity with Random Walk and Dynamic Inventory Policy for Different Demand Distributions

Table A.1. $y^{\star}$ values obtained from holding cost rate sensitivity with random walk transition matrix and exponentially distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	256.5	212.0	203.7	194.6	160.9	252	212	204	192	161
3.2	247.7	206.4	198.1	189.1	157.1	244	207	198	187	158
3.4	239.8	201.1	192.9	184.0	153.4	237	201	193	182	154
3.6	232.5	196.2	188.0	179.2	149.9	230	197	188	178	150
3.8	225.9	191.5	183.5	174.7	146.6	223	192	184	173	147
4.0	219.7	187.2	179.2	170.5	143.5	218	188	179	169	144
4.2	214.0	183.1	175.1	166.5	140.5	212	183	175	165	141
4.4	208.7	179.2	171.3	162.7	137.7	207	180	172	162	138
4.6	203.7	175.5	167.7	159.2	135.0	202	176	168	158	135
4.8	199.0	172.0	164.2	155.8	132.4	198	172	165	155	133
5.0	194.6	168.6	160.9	152.6	129.9	193	169	161	152	130
5.2	190.4	165.5	157.8	149.5	127.6	189	166	158	149	128
5.4	186.5	162.4	154.8	146.6	125.3	186	163	155	146	126
5.6	182.7	159.5	152.0	143.8	123.1	182	160	152	143	124
5.8	179.2	156.7	149.3	141.2	121.0	178	157	150	141	121
6.0	175.8	154.0	146.6	138.6	119.0	175	154	147	138	119
6.2	172.6	151.5	144.1	136.2	117.0	172	152	144	136	118
6.4	169.5	149.0	141.7	133.8	115.1	169	149	142	134	116
6.6	166.5	146.6	139.4	131.6	113.3	166	147	140	131	114
6.8	163.7	144.3	137.1	129.4	111.6	163	145	137	129	112
7.0	160.9	142.1	135.0	127.3	109.9	161	143	135	127	110

Table A.2. $y^{\star}$ values obtained from holding cost rate sensitivity with random walk transition matrix and exponentially (truncated at 300) distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	209.7	180.9	175.0	168.5	142.8	208	181	175	167	143
3.2	204.3	176.9	171.0	164.4	139.7	203	177	171	163	140
3.4	199.4	173.2	167.2	160.6	136.8	198	174	168	160	137
3.6	194.7	169.6	163.6	156.9	134.0	194	170	164	156	134
3.8	190.3	166.2	160.2	153.5	131.3	189	167	161	153	132
4.0	186.2	163.0	156.9	150.3	128.7	185	163	157	150	129
4.2	182.3	159.9	153.9	147.2	126.3	182	160	154	147	127
4.4	178.6	156.9	150.9	144.2	123.9	178	157	151	144	124
4.6	175.0	154.1	148.1	141.4	121.7	174	155	148	141	122
4.8	171.7	151.4	145.4	138.7	119.5	171	152	146	138	120
5.0	168.5	148.8	142.8	136.1	117.5	168	149	143	136	118
5.2	165.4	146.3	140.3	133.6	115.5	165	147	141	133	116
5.4	162.5	143.9	137.9	131.3	113.5	162	144	138	131	114
5.6	159.6	141.6	135.6	129.0	111.7	159	142	136	129	112
5.8	156.9	139.4	133.4	126.8	109.9	157	140	134	127	110
6.0	154.4	137.3	131.3	124.7	108.2	154	138	132	125	109
6.2	151.9	135.2	129.2	122.7	106.5	152	136	130	123	107
6.4	149.5	133.2	127.2	120.7	104.9	149	134	128	121	105
6.6	147.2	131.3	125.3	118.8	103.3	147	132	126	119	104
6.8	144.9	129.4	123.5	117.0	101.8	145	130	124	117	102
7.0	142.8	127.6	121.7	115.2	100.4	143	128	122	115	101

Table A.3. $y^{\star}$ values obtained from holding cost rate sensitivity with mean reverting transition matrix and uniformly distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	189.0	183.3	173.9	163.6	155.3	189	184	174	164	156
3.2	187.5	181.8	172.4	162.2	153.8	188	182	173	163	154
3.4	186.0	180.3	170.9	160.7	152.4	186	181	171	161	153
3.6	184.6	178.9	169.5	159.3	150.9	185	179	170	160	151
3.8	183.2	177.4	168.1	157.9	149.5	184	178	169	158	150
4.0	181.8	176.0	166.7	156.5	148.1	182	176	167	157	149
4.2	180.5	174.6	165.3	155.2	146.8	181	175	166	156	147
4.4	179.1	173.2	163.9	153.8	145.5	180	174	164	154	146
4.6	177.8	171.9	162.6	152.5	144.1	178	172	163	153	145
4.8	176.5	170.5	161.3	151.3	142.9	177	171	162	152	143
5.0	175.2	169.2	160.0	150.0	141.6	176	170	160	150	142
5.2	173.9	167.9	158.7	148.8	140.4	174	168	159	149	141
5.4	172.7	166.7	157.5	147.5	139.1	173	167	158	148	140
5.6	171.4	165.4	156.2	146.3	137.9	172	166	157	147	138
5.8	170.2	164.2	155.0	145.2	136.8	171	165	156	146	137
6.0	169.0	163.0	153.8	144.0	135.6	169	163	154	144	136
6.2	167.8	161.8	152.7	142.9	134.5	168	162	153	143	135
6.4	166.7	160.6	151.5	141.7	133.3	167	161	152	142	134
6.6	165.5	159.4	150.4	140.6	132.2	166	160	151	141	133
6.8	164.4	158.3	149.3	139.5	131.1	165	159	150	140	132
7.0	163.3	157.1	148.1	138.5	130.1	164	158	149	139	131

Table A.4. $y^{\star}$ values obtained from holding cost rate sensitivity with mean reverting transition matrix and exponentially distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	289.8	248.5	203.7	170.5	149.9	281	243	204	171	150
3.2	277.3	239.8	198.1	166.5	146.6	270	235	198	167	147
3.4	266.3	231.9	192.9	162.7	143.5	261	228	193	163	144
3.6	256.5	224.7	188.0	159.2	140.5	252	221	188	160	141
3.8	247.7	218.1	183.5	155.8	137.7	244	215	184	156	138
4.0	239.8	212.0	179.2	152.6	135.0	236	209	179	153	135
4.2	232.5	206.4	175.1	149.5	132.4	230	204	175	150	133
4.4	225.9	201.1	171.3	146.6	129.9	223	199	171	147	130
4.6	219.7	196.2	167.7	143.8	127.6	218	194	168	144	128
4.8	214.0	191.5	164.2	141.2	125.3	212	190	164	142	126
5.0	208.7	187.2	160.9	138.6	123.1	207	186	161	139	124
5.2	203.7	183.1	157.8	136.2	121.0	202	182	158	137	121
5.4	199.0	179.2	154.8	133.8	119.0	198	178	155	134	119
5.6	194.6	175.5	152.0	131.6	117.0	193	174	152	132	118
5.8	190.4	172.0	149.3	129.4	115.1	189	171	150	130	116
6.0	186.5	168.6	146.6	127.3	113.3	186	168	147	128	114
6.2	182.7	165.5	144.1	125.3	111.6	182	165	144	126	112
6.4	179.2	162.4	141.7	123.3	109.9	178	162	142	124	110
6.6	175.8	159.5	139.4	121.4	108.2	175	159	140	122	109
6.8	172.6	156.7	137.1	119.6	106.6	172	156	137	120	107
7.0	169.5	154.0	135.0	117.9	105.1	169	154	135	118	106

Table A.5. $y^{\star}$ values obtained from holding cost rate sensitivity with mean reverting transition matrix and exponentially (truncated at 300) distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	228.1	204.8	175.0	150.3	134.0	226	203	175	151	134
3.2	221.5	199.4	171.0	147.2	131.3	219	197	171	148	132
3.4	215.3	194.3	167.2	144.2	128.7	214	193	167	145	129
3.6	209.7	189.6	163.6	141.4	126.3	208	188	164	142	127
3.8	204.3	185.1	160.2	138.7	123.9	203	184	160	139	124
4.0	199.4	180.9	156.9	136.1	121.7	198	180	157	137	122
4.2	194.7	176.9	153.9	133.6	119.5	194	176	154	134	120
4.4	190.3	173.2	150.9	131.3	117.5	189	172	151	132	118
4.6	186.2	169.6	148.1	129.0	115.5	185	169	148	129	116
4.8	182.3	166.2	145.4	126.8	113.5	182	165	146	127	114
5.0	178.6	163.0	142.8	124.7	111.7	178	162	143	125	112
5.2	175.0	159.9	140.3	122.7	109.9	174	159	141	123	110
5.4	171.7	156.9	137.9	120.7	108.2	171	156	138	121	109
5.6	168.5	154.1	135.6	118.8	106.5	168	154	136	119	107
5.8	165.4	151.4	133.4	117.0	104.9	165	151	134	117	105
6.0	162.5	148.8	131.3	115.2	103.3	162	148	132	116	104
6.2	159.6	146.3	129.2	113.5	101.8	159	146	130	114	102
6.4	156.9	143.9	127.2	111.9	100.4	157	144	128	112	101
6.6	154.4	141.6	125.3	110.3	99.0	154	141	126	111	99
6.8	151.9	139.4	123.5	108.7	97.6	152	139	124	109	98
7.0	149.5	137.3	121.7	107.2	96.2	149	137	122	108	97

Table A.6. $y^{\star}$ values obtained from holding cost rate sensitivity with momentum transition matrix and uniformly distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	180.5	169.2	173.9	180.0	164.9	181	170	174	180	165
3.2	179.1	167.9	172.4	178.2	163.3	180	168	173	178	164
3.4	177.8	166.7	170.9	176.5	161.6	178	167	171	177	162
3.6	176.5	165.4	169.5	174.8	160.0	177	166	170	175	160
3.8	175.2	164.2	168.1	173.1	158.4	176	165	169	173	159
4.0	173.9	163.0	166.7	171.4	156.9	174	163	167	172	157
4.2	172.7	161.8	165.3	169.8	155.3	173	162	166	170	156
4.4	171.4	160.6	163.9	168.2	153.8	172	161	164	168	154
4.6	170.2	159.4	162.6	166.7	152.4	171	160	163	167	153
4.8	169.0	158.3	161.3	165.1	150.9	169	159	162	165	151
5.0	167.8	157.1	160.0	163.6	149.5	168	158	160	164	150
5.2	166.7	156.0	158.7	162.2	148.1	167	157	159	162	149
5.4	165.5	154.9	157.5	160.7	146.8	166	155	158	161	147
5.6	164.4	153.8	156.2	159.3	145.5	165	154	157	160	146
5.8	163.3	152.8	155.0	157.9	144.1	164	153	156	158	145
6.0	162.2	151.7	153.8	156.5	142.9	163	152	154	157	143
6.2	161.1	150.7	152.7	155.2	141.6	162	151	153	155	142
6.4	160.0	149.7	151.5	153.8	140.4	160	150	152	154	141
6.6	158.9	148.6	150.4	152.5	139.1	159	149	151	153	140
6.8	157.9	147.7	149.3	151.3	137.9	158	148	150	152	138
7.0	156.9	146.7	148.1	150.0	136.8	157	147	149	150	137

Table A.7. $y^{\star}$ values obtained from holding cost rate sensitivity with momentum transition matrix and exponentially distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	232.5	187.2	203.7	230.3	174.1	231	188	203	222	175
3.2	225.9	183.1	198.1	221.7	169.5	224	184	198	214	170
3.4	219.7	179.2	192.9	214.0	165.1	218	180	193	208	166
3.6	214.0	175.5	188.0	20.07	160.9	213	176	188	201	161
3.8	208.7	172.0	183.5	200.5	157.1	208	172	184	196	158
4.0	203.7	168.6	179.2	194.6	153.4	203	169	179	190	154
4.2	199.0	165.5	175.1	189.1	149.9	198	166	175	185	150
4.4	194.6	162.4	171.3	184.0	146.6	194	163	172	180	147
4.6	190.4	159.5	167.7	179.2	143.5	190	160	168	176	144
4.8	186.5	156.7	164.2	174.7	140.5	186	157	165	172	141
5.0	182.7	154.0	160.9	170.5	137.7	182	155	161	168	138
5.2	179.2	151.5	157.8	166.5	135.0	179	152	158	164	135
5.4	175.8	149.0	154.8	162.7	132.4	176	150	155	161	133
5.6	172.6	146.6	152.0	159.2	129.9	172	147	152	157	130
5.8	169.5	144.3	149.3	155.8	127.6	169	145	150	154	128
6.0	166.5	142.1	146.6	152.6	125.3	166	143	147	151	126
6.2	163.7	140.0	144.1	149.5	123.1	164	141	145	148	124
6.4	160.9	138.0	141.7	146.6	121.0	161	138	142	145	121
6.6	158.3	136.0	139.4	143.8	119.0	158	136	140	143	119
6.8	155.8	134.0	137.1	141.2	117.0	156	135	138	140	118
7.0	153.4	132.2	135.0	138.6	115.1	153	133	135	138	116

Table A.8. $y^{\star}$ values obtained from holding cost rate sensitivity with momentum transition matrix and exponentially (truncated at 300) distributed demand under different inventory policies.

	Myopic Inventory Policy					**Dynamic Inventory Policy**				
h	c_1	c_2	c_3	c_4	c_5	c_1	c_2	c_3	c_4	c_5
3.0	194.7	163.0	175.0	193.2	153.1	194	163	175	189	154
3.2	190.3	159.9	171.0	187.6	149.5	190	160	171	184	150
3.4	186.2	156.9	167.2	182.3	146.0	186	157	167	179	147
3.6	182.3	154.1	163.6	177.4	142.8	182	155	164	174	143
3.8	178.6	151.4	160.2	172.8	139.7	178	152	160	170	140
4.0	175.0	148.8	156.9	168.5	136.8	175	149	157	166	137
4.2	171.7	146.3	153.9	164.4	134.0	171	147	154	162	134
4.4	168.5	143.9	150.9	160.6	131.3	168	144	151	159	132
4.6	165.4	141.6	148.1	156.9	128.7	165	142	148	155	129
4.8	162.5	139.4	145.4	153.5	126.3	162	140	146	152	127
5.0	159.6	137.3	142.8	150.3	123.9	160	138	143	149	124
5.2	156.9	135.2	140.3	147.2	121.7	157	136	141	146	122
5.4	154.4	133.2	137.9	144.2	119.5	154	134	138	143	120
5.6	151.9	131.3	135.6	141.4	117.5	152	132	136	140	118
5.8	149.5	129.4	133.4	138.7	115.5	150	130	134	138	116
6.0	147.2	127.6	131.3	136.1	113.5	147	128	132	135	114
6.2	144.9	125.8	129.2	133.6	111.7	145	126	130	133	112
6.4	142.8	124.1	127.2	131.3	109.9	143	125	128	130	110
6.6	140.7	122.5	125.3	129.0	108.2	141	123	126	128	109
6.8	138.7	120.9	123.5	126.8	106.5	139	121	124	126	107
7.0	136.8	119.3	121.7	124.7	104.9	137	120	122	124	105

APPENDIX B: TABLES OBTAINED FROM REPLENISHMENT STUDY

$y^\star$ values which are obtained from sensitivity analyses with exchange rate study in Section 3.4 are attached this appendix. These values are shown separately according to using inventory policies, demand distributions, and the parameters which sensitivity analysis conducted.

Table B.1. $y^\star$ values obtained from holding cost rate sensitivity with exchange rate transition matrix and demand with gamma distribution (k=4) under different inventory policies.

Myopic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	159.3	151.5	150.2	144.8	139.8	151.6	140.1	134.6	127.7	116.7	118.6	113.9	111.0	101.0	87.3	76.0
0.12	152.1	145.2	143.5	138.5	133.7	142.5	132.6	127.4	121.0	111.3	112	107.3	104	94.8	82.7	72.2
0.14	146.2	139.8	137.9	133.1	128.5	135.2	126.5	121.5	115.6	106.7	106.7	102.0	98.3	89.9	78.9	69.1
0.16	141.1	135.1	133.0	128.5	124.1	129.3	121.4	116.6	110.9	102.8	102.2	97.5	93.7	85.8	75.6	66.4
0.18	136.7	131.1	128.8	124.4	120.2	124.3	116.9	112.3	107.0	99.4	98.3	93.7	89.8	82.4	72.9	64.1
0.20	132.8	127.4	125.1	120.8	116.7	119.9	113.1	108.6	103.5	96.3	95.0	90.4	86.5	79.4	70.4	62.1
0.22	129.3	124.2	121.8	117.6	113.6	116.1	109.7	105.3	100.3	93.6	92.0	87.5	83.5	76.8	68.3	60.3
0.24	126.2	121.2	118.8	114.7	110.8	112.7	106.6	102.4	97.6	91.1	89.3	85.0	81.0	74.5	66.4	58.6
0.26	123.3	118.5	116	112.1	108.2	109.7	103.9	99.7	95.1	88.9	87.0	82.6	78.6	72.4	64.7	57.2
0.28	120.7	116	113.5	109.6	105.8	107.0	101.4	97.3	92.8	86.9	84.8	80.6	76.6	70.5	63.1	55.9
0.30	118.2	113.7	111.2	107.4	103.6	104.5	99.1	95.1	90.7	85.0	82.8	78.6	74.7	68.8	61.7	54.7
Dynamic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	159.4	151.6	150.2	145	139.8	151.8	140.2	134.6	127.8	116.8	118.6	114.0	111.2	101.0	87.4	76.0
0.12	152.2	145.2	143.6	138.6	133.8	142.6	132.8	127.4	121.2	111.4	112.2	107.4	104.0	95.0	82.8	72.4
0.14	146.2	139.8	138.0	133.2	128.6	135.4	126.6	121.6	115.6	106.8	106.8	102.0	98.4	90	79.0	69.2
0.16	141.2	135.2	133.2	128.6	124.2	129.4	121.4	116.6	111.0	103.0	102.2	97.6	93.8	86.0	75.8	66.6
0.18	136.8	131.2	129.0	124.6	120.2	124.4	117.0	112.4	107.0	99.4	98.4	93.8	90.0	82.4	73.0	64.2
0.20	133.0	127.6	125.2	121.0	116.8	120.0	113.2	108.8	103.6	96.4	95.0	90.6	86.6	79.4	70.6	62.2
0.22	129.4	124.2	121.8	117.8	113.6	116.2	109.8	105.4	100.4	93.6	92	87.6	83.6	76.8	68.4	60.4
0.24	126.2	121.4	118.8	114.8	110.8	112.8	106.8	102.4	97.6	91.2	89.4	85.0	81.0	74.6	66.4	58.8
0.26	123.4	118.6	116.2	112.2	108.2	109.8	104.0	99.8	95.2	89.0	87.0	82.8	78.8	72.4	64.8	57.2
0.28	120.8	116.2	113.6	109.8	106.0	107.0	101.4	97.4	92.8	87.0	84.8	80.6	76.6	70.6	63.2	56.0
0.30	118.4	113.8	111.2	107.4	103.8	104.6	99.2	95.2	90.8	85.2	83.0	78.8	74.8	69	61.8	54.8

Table B.2. $y^\star$ values obtained from holding cost rate sensitivity with exchange rate transition matrix and demand with gamma distribution (k=2) under different inventory policies.

Myopic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	182.4	170.4	168.4	160.2	152.6	170.6	153.1	144.8	134.5	118.6	121.3	114.5	110.4	96.4	77.9	63.4
0.12	171.4	160.7	158.2	150.6	143.4	156.6	141.9	134.1	124.8	110.9	111.9	105.2	1.5	88.0	71.9	58.7
0.14	162.3	152.6	149.7	142.6	135.8	145.8	132.8	125.5	116.9	104.4	104.3	97.8	92.8	81.4	67.0	54.8
0.16	154.6	145.6	142.5	135.7	129.2	136.9	125.3	118.4	110.3	98.9	98.1	91.7	86.5	76.0	62.9	51.6
0.18	148.0	139.5	136.3	129.8	123.6	129.5	118.9	112.3	104.7	94.2	92.7	86.5	81.3	71.5	59.5	48.9
0.20	142.1	134.2	130.8	124.6	118.5	123.2	113.4	107.0	99.8	90.0	88.2	82.1	76.8	67.7	56.5	46.5
0.22	137.0	129.4	125.9	119.9	114.1	117.7	108.6	102.4	95.5	86.3	84.2	78.3	73.0	64.4	53.9	44.4
0.24	132.3	125.1	121.5	115.7	110.1	112.9	104.3	98.3	91.7	83.0	80.6	74.9	69.7	61.5	51.6	42.6
0.26	128.1	121.2	117.6	111.9	106.4	108.6	1.4	94.7	88.3	80.1	77.5	71.9	66.7	58.9	49.6	41.0
0.28	124.3	117.6	114.0	108.5	103.1	104.7	96.9	91.4	85.2	77.4	74.7	69.2	64.1	56.6	47.8	39.5
0.30	120.8	114.3	110.7	105.3	100.1	101.2	93.8	88.4	82.4	74.9	72.1	66.7	61.8	54.5	46.1	38.2
Dynamic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	182.4	170.6	168.4	160.4	152.8	170.4	153.2	144.8	134.6	118.8	121.4	114.6	110.4	96.4	78.0	63.4
0.12	171.4	160.8	158.2	150.6	143.6	156.6	142.0	134.2	125.0	111.0	112.0	105.4	100.6	88.0	72.0	58.8
0.14	162.4	152.6	149.8	142.6	135.8	145.8	133	125.6	117.0	104.6	104.4	97.8	92.8	81.4	67.0	55.0
0.16	154.6	145.8	142.6	135.8	129.4	137.0	125.4	118.4	110.4	99.0	98.2	91.8	86.6	76.0	63.0	51.8
0.18	148.0	139.6	136.4	129.8	123.6	129.6	119.0	112.4	104.8	94.2	92.8	86.6	81.4	71.6	59.6	49.0
0.20	142.2	134.2	130.8	124.6	118.6	123.2	113.4	107.2	100.0	90.2	88.2	82.2	77.0	67.8	56.6	46.6
0.22	137.0	129.4	126.0	120.0	114.2	117.8	108.6	102.6	95.6	86.4	84.2	78.4	73.0	64.4	54.0	44.6
0.24	132.4	125.2	121.6	115.8	110.2	113.0	104.4	98.4	91.8	83.2	80.8	75.0	69.8	61.6	51.8	42.8
0.26	128.2	121.2	117.6	112.0	106.6	108.6	100.6	94.8	88.4	80.2	77.6	72.0	66.8	59.0	49.6	41.0
0.28	124.4	117.6	114.0	108.6	103.2	104.8	97.0	91.4	85.4	77.4	74.8	69.2	64.2	56.6	47.8	39.6
0.30	120.8	114.4	110.8	105.4	100.2	101.2	93.8	88.4	82.6	75	72.2	66.8	61.8	54.6	46.2	38.2

Table B.3. $y^{\star}$ values obtained from holding cost rate sensitivity with exchange rate transition matrix and demand with gamma distribution (k=1) under different inventory policies.

Myopic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	211.1	192.5	189.3	176.8	165.3	192.8	166	153.6	138.5	115.7	119.4	109.9	104.3	85.3	61.9	44.9
0.12	194.0	177.6	173.7	162.3	151.6	171.4	149.2	137.9	124.5	104.9	106.3	97.1	90.8	74.5	54.7	39.7
0.14	180.0	165.2	160.9	150.3	140.3	155.1	136	125.5	113.3	96.1	95.9	87.2	80.6	66.2	49.0	35.6
0.16	168.3	154.8	150.2	140.2	130.8	142.0	125.2	115.3	104.2	88.7	87.5	79.2	72.6	59.6	44.4	32.3
0.18	158.3	145.8	141.0	131.6	122.7	131.3	116.1	106.9	96.5	82.4	80.6	72.6	66.0	54.2	40.6	29.6
0.20	149.7	138.0	133.0	124.1	115.6	122.2	108.4	99.6	89.9	77.0	74.7	67.0	60.6	49.8	37.4	27.3
0.22	142.0	131.0	126.0	117.5	109.3	114.4	101.7	93.4	84.2	72.3	69.6	62.3	56.0	46.0	34.7	25.3
0.24	135.3	124.8	119.8	111.6	103.8	107.7	95.9	87.9	79.3	68.2	65.2	58.2	52.1	42.8	32.3	23.6
0.26	129.2	119.3	114.2	106.3	98.8	101.7	90.7	83.1	74.9	64.5	61.4	54.6	48.7	39.9	30.3	22.1
0.28	123.7	114.2	109.2	101.6	94.3	96.5	86.1	78.8	71.0	61.2	58.0	51.5	45.7	37.5	28.5	20.8
0.30	118.7	109.6	104.6	97.3	90.3	91.8	81.9	74.9	67.4	58.3	54.9	48.7	43.1	35.3	26.9	19.6
Dynamic Inventory Policy																
h_{rate}	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
0.10	210.8	192.6	189.4	176.8	165.4	189.4	165.6	153.2	138.2	115.8	119.4	110.0	103.0	84.4	61.4	45.0
0.12	193.8	177.6	173.6	162.2	151.6	169.0	149.0	137.6	124.2	105.0	106.2	97.2	90.0	73.8	54.2	39.8
0.14	179.8	165.4	161.0	150.4	140.4	153.4	135.8	125.2	113.2	96.2	96.0	87.2	80.0	65.8	48.6	35.8
0.16	168.2	154.8	150.2	140.2	131.0	140.6	125.0	115.2	104	88.8	87.6	79.2	72.0	59.2	44.2	32.4
0.18	158.2	146.0	141.0	131.6	122.8	130.2	116.0	106.8	96.4	82.6	80.6	72.6	65.6	54.0	40.4	29.6
0.20	149.6	138.0	133.0	124.2	115.6	121.4	108.2	99.6	89.8	77.2	74.8	67.0	60.2	49.6	37.2	27.4
0.22	142.0	131.2	126.0	117.6	109.4	113.8	101.6	93.4	84.2	72.4	69.6	62.4	55.8	45.8	34.6	25.4
0.24	135.2	125.0	119.8	111.6	103.8	107.0	95.8	87.8	79.2	68.4	65.2	58.2	51.8	42.6	32.2	23.6
0.26	129.2	119.4	114.2	106.4	99.0	101.2	90.6	83.0	74.8	64.6	61.4	54.6	48.6	39.8	30.2	22.2
0.28	123.6	114.2	109.2	101.6	94.4	96.0	86.0	78.8	71.0	61.4	58.0	51.6	45.6	37.4	28.4	20.8
0.30	118.6	109.8	104.6	97.4	90.4	91.4	82.0	75.0	67.4	58.4	55.0	48.8	43.0	35.2	26.8	19.8

Table B.4. $y^{\star}$ values obtained from price sensitivity with exchange rate transition matrix and demand with gamma distribution (k=4) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	127.5	121.9	119.2	114.6	110.1	112.7	105.4	100.3	94.4	86.6	83.9	78.0	72.0	62.4	50.0	33.1
8600	128.7	123.1	120.5	116.0	111.5	114.2	107.0	102.1	96.4	88.7	86.4	80.8	75.4	66.6	55.3	42.2
8700	129.7	124.2	121.7	117.2	112.9	115.7	108.6	103.8	98.3	90.8	88.7	83.5	78.5	70.2	59.8	48.7
8800	130.8	125.3	122.9	118.5	114.2	117.2	110.2	105.5	100.1	92.7	90.9	85.9	81.3	73.5	63.7	53.8
8900	131.8	126.4	124.0	119.7	115.5	118.6	111.7	107.1	101.8	94.6	93.0	88.3	84.0	76.6	67.2	58.2
9000	132.8	127.4	125.1	120.8	116.7	119.9	113.1	108.6	103.5	96.3	95.0	90.4	86.5	79.4	70.4	62.1
9100	133.8	128.4	126.2	122	117.9	121.2	114.5	110.1	105.0	98.0	96.8	92.5	88.8	82.0	73.4	65.5
9200	134.7	129.4	127.2	123.1	119.0	122.5	115.8	111.5	106.5	99.6	98.6	94.5	91.0	84.4	76.1	68.6
9300	135.6	130.4	128.2	124.1	120.2	123.7	117.1	112.9	108.0	101.1	100.3	96.3	93.1	86.7	78.6	71.5
9400	136.5	131.3	129.2	125.2	121.3	124.9	118.3	114.2	109.4	102.6	101.9	98.1	95.0	88.9	80.9	74.1
9500	137.4	132.3	130.2	126.2	122.3	126.0	119.5	115.5	110.8	104.1	103.5	99.8	96.9	90.9	83.2	76.6
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	127.6	122.0	119.4	114.8	110.2	112.8	105.4	100.4	94.6	86.6	84.0	78.0	72.0	62.6	50.0	33.2
8600	128.8	123.2	120.6	116.0	111.6	114.4	107.2	102.2	96.6	88.8	86.4	81.0	75.4	66.6	55.4	42.4
8700	129.8	124.4	121.8	117.4	113.0	115.8	108.8	104.0	98.4	90.8	88.8	83.6	78.6	70.4	59.8	48.8
8800	130.8	125.4	123.0	118.6	114.2	117.2	110.2	105.6	100.2	92.8	91.0	86.0	81.4	73.6	63.8	54.0
8900	132.0	126.4	124.2	119.8	115.6	118.6	111.8	107.2	102.0	94.6	93.0	88.4	84.0	76.6	67.4	58.4
9000	133.0	127.6	125.2	121.0	116.8	120.0	113.2	108.8	103.6	96.4	95.0	90.6	86.6	79.4	70.6	62.2
9100	133.8	128.6	126.2	122.0	118.0	121.4	114.6	110.2	105.2	98.0	97.0	92.6	88.8	82.0	73.4	65.6
9200	134.8	129.6	127.4	123.2	119.2	122.6	115.8	111.6	106.6	99.8	98.8	94.6	91.0	84.6	76.2	68.8
9300	135.8	130.4	128.4	124.2	120.2	123.8	117.2	113.0	108.0	101.2	100.4	96.4	93.2	86.8	78.6	71.6
9400	136.6	131.4	129.4	125.2	121.4	125.0	118.4	114.2	109.6	102.8	102.0	98.2	95.2	89.0	81.0	74.2
9500	137.6	132.4	130.2	126.2	122.4	126.2	119.6	115.6	110.8	104.2	103.6	99.8	97.0	91.0	83.2	76.6

Table B.5. $y^{\star}$ values obtained from price sensitivity with exchange rate transition matrix and demand with gamma distribution (k=2) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	134.4	126.1	122.2	115.6	109.1	112.8	102.5	95.4	87.4	77.0	73.5	65.9	58.4	47.0	33.1	16.9
8600	136.0	127.8	124.0	117.5	111.1	115.0	104.8	97.9	90.1	79.8	76.8	69.5	62.6	51.8	38.8	25.2
8700	137.6	129.5	125.8	119.3	113.1	117.2	107.1	100.3	92.7	82.6	79.8	72.9	66.5	56.2	43.9	31.7
8800	139.1	131.1	127.5	121.1	115.0	119.3	109.3	102.7	95.2	85.1	82.7	76.1	70.2	60.3	48.5	37.3
8900	140.7	132.6	129.2	122.9	116.8	121.3	111.4	104.9	97.5	87.6	85.5	79.2	73.6	64.1	52.6	42.1
9000	142.1	134.2	130.8	124.6	118.5	123.2	113.4	107.0	99.8	90.0	88.2	82.1	76.8	67.7	56.5	46.5
9100	143.6	135.7	132.4	126.2	120.3	125.1	115.4	109.1	102.0	92.3	90.7	84.9	79.9	71.0	60.1	50.5
9200	145.0	137.1	133.9	127.8	121.9	126.9	117.3	111.1	104.1	94.5	93.1	87.5	82.8	74.2	63.5	54.3
9300	146.4	138.6	135.4	129.4	123.6	128.7	119.1	113.1	106.2	96.6	95.5	90.0	85.6	77.2	66.7	57.7
9400	147.7	140.0	136.8	130.9	125.2	130.4	120.9	114.9	108.2	98.7	97.7	92.4	88.3	80.0	69.7	61.0
9500	149.0	141.3	138.3	132.4	126.7	132.1	122.6	116.8	110.1	100.7	99.9	94.8	90.8	82.7	72.5	64.1
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	134.4	126.2	122.4	115.6	109.2	112.8	102.6	95.6	87.6	77.2	73.6	66	58.4	47.0	33.2	17.0
8600	136.0	127.8	124.2	117.6	111.2	115.0	105.0	98.0	90.2	80.0	76.8	69.6	62.6	51.8	38.8	25.4
8700	137.6	129.6	125.8	119.4	113.2	117.2	107.2	100.4	92.8	82.6	80.0	73.0	66.6	56.4	44.0	31.8
8800	139.2	131.2	127.6	121.2	115.0	119.4	109.4	102.8	95.2	85.2	82.8	76.2	70.2	60.4	48.6	37.4
8900	140.8	132.8	129.2	123.0	116.8	121.4	111.4	105.0	97.6	87.8	85.6	79.2	73.6	64.2	52.8	42.2
9000	142.2	134.2	130.8	124.6	118.6	123.2	113.4	107.2	100.0	90.2	88.2	82.2	77.0	67.8	56.6	46.6
9100	143.6	135.8	132.4	126.2	120.4	125.2	115.4	109.2	102.2	92.4	90.8	85.0	80.0	71.0	60.2	50.6
9200	145.0	137.2	134.0	127.8	122.0	127.0	117.4	111.2	104.2	94.6	93.2	87.6	82.8	74.2	63.6	54.4
9300	146.4	138.6	135.4	129.4	123.6	128.8	119.2	113.2	106.2	96.8	95.6	90.2	85.6	77.2	66.8	57.8
9400	147.8	140.0	137.0	131.0	125.2	130.4	121.0	115.0	108.2	98.8	97.8	92.6	88.4	80.0	69.8	61.2
9500	149.2	141.4	138.4	132.4	126.8	132.2	122.8	116.8	110.2	100.8	100.0	94.8	90.8	82.8	72.6	64.2

Table B.6. $y^\star$ values obtained from price sensitivity with exchange rate transition matrix and demand with gamma distribution (k=1) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	138.2	126.3	120.8	111.4	102.5	107.6	93.5	84.1	73.8	60.8	56.6	47.7	39.4	27.7	15.4	4.7
8600	140.6	128.7	123.4	114.1	105.2	110.7	96.6	87.4	77.2	64.3	60.5	51.9	44.0	32.5	20.2	9.6
8700	143.0	131.1	125.9	116.7	107.9	113.7	99.7	90.6	80.5	67.6	64.2	55.9	48.4	37.1	24.8	14.3
8800	145.2	133.5	128.3	119.2	110.5	116.6	102.7	93.7	83.8	70.9	67.8	59.8	52.6	41.5	29.2	18.8
8900	147.5	135.7	130.7	121.7	113.1	119.4	105.6	96.7	86.9	74.0	71.3	63.5	56.7	45.7	33.4	23.1
9000	149.7	138.0	133.0	124.1	115.6	122.2	108.4	99.6	89.9	77.0	74.7	67.0	60.6	49.8	37.4	27.3
9100	151.8	140.2	135.3	126.4	118.0	124.9	111.1	102.5	92.8	80.0	77.9	70.5	64.3	53.6	41.3	31.2
9200	153.9	142.3	137.5	128.7	120.4	127.5	113.8	105.2	95.7	82.9	81.1	73.8	67.9	57.4	45.0	35.0
9300	155.9	144.4	139.7	131.	122.7	130.0	116.4	107.9	98.5	85.7	84.1	77.1	71.4	61	48.6	38.7
9400	158.0	146.4	141.9	133.2	124.9	132.5	118.9	110.5	101.2	88.4	87.1	80.2	74.8	64.5	52.1	42.3
9500	159.9	148.4	144.0	135.3	127.2	135.0	121.3	113.1	103.8	91.0	90.0	83.2	78.1	67.8	55.4	45.7
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	138.2	126.4	120.8	111.4	102.6	106.6	93.4	84.0	73.6	60.8	56.6	47.6	39.0	27.6	15.2	4.8
8600	140.6	128.8	123.4	114.2	105.4	109.8	96.6	87.2	77.2	64.4	60.4	51.8	43.6	32.4	20.0	9.8
8700	142.8	131.2	126.0	116.8	108.0	112.8	99.6	90.4	80.4	67.8	64.2	55.8	48.0	37.0	24.6	14.4
8800	145.2	133.6	128.4	119.2	110.6	115.8	102.6	93.6	83.6	71.0	67.8	59.8	52.4	41.4	29.0	19.0
8900	147.4	135.8	130.8	121.8	113.2	118.6	105.4	96.6	86.8	74.2	71.4	63.4	56.4	45.6	33.2	23.2
9000	149.6	138.0	133.0	124.2	115.6	121.4	108.2	99.6	89.8	77.2	74.8	67.0	60.2	49.6	37.2	27.4
9100	151.8	140.2	135.4	126.4	118.2	124.0	111.0	102.4	92.8	80.2	78.0	70.6	64.0	53.4	41.2	31.4
9200	153.8	142.4	137.6	128.8	120.4	126.6	113.6	105.2	95.6	83.0	81.2	73.8	67.6	57.2	44.8	35.2
9300	155.8	144.4	139.8	131.0	122.8	129.2	116.2	107.8	98.4	85.8	84.2	77.2	71.2	60.8	48.4	38.8
9400	157.8	146.6	142.0	133.2	125.0	131.8	118.8	110.4	101.0	88.4	87.2	80.2	74.6	64.2	52.0	42.4
9500	159.8	148.6	144.0	135.4	127.2	134.2	121.2	113.0	103.8	91.2	90.0	83.2	77.8	67.6	55.2	45.8

Table B.7. $y^\star$ values obtained from price sensitivity with exchange rate transition matrix and price dependent demand with gamma distribution (k=5) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	148.8	142.8	140.0	135.2	130.4	133.1	125.4	119.9	113.7	105.3	102.4	96.0	89.4	78.9	65.0	45.6
8600	144.8	139.1	136.5	131.9	127.3	130.1	122.8	117.7	111.8	103.9	101.5	95.6	89.9	80.6	68.5	54.2
8700	140.9	135.5	133.0	128.6	124.3	127.2	120.2	115.4	109.9	102.4	100.3	95.1	90.0	81.6	70.9	59.2
8800	137.1	132.0	129.6	125.5	121.4	124.3	117.6	113.1	107.9	100.8	99.1	94.3	89.8	82.1	72.4	62.5
8900	133.5	128.5	126.4	122.4	118.5	121.4	115.0	110.8	105.9	99.2	97.7	93.3	89.3	82.3	73.4	64.7
9000	130.0	125.2	123.2	119.4	115.7	118.6	112.5	108.5	103.9	97.5	96.3	92.2	88.6	82.1	73.9	66.1
9100	126.5	122.0	120.1	116.5	113.0	115.8	110.0	106.2	101.9	95.8	94.8	91.0	87.7	81.8	74.1	67.1
9200	123.2	118.9	117.1	113.6	110.3	113.1	107.6	104.0	99.9	94.0	93.2	89.7	86.8	81.2	74.1	67.6
9300	120.0	115.9	114.1	110.9	107.7	110.5	105.2	101.8	97.9	92.3	91.6	88.4	85.7	80.5	73.8	67.8
9400	117.0	112.9	111.3	108.2	105.1	107.9	102.8	99.6	95.9	90.5	90.0	87.0	84.5	79.7	73.3	67.8
9500	114.0	110.1	108.5	105.5	102.6	105.4	100.5	97.4	93.9	88.8	88.4	85.6	83.3	78.7	72.8	67.6
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	148.8	143.0	140.2	135.2	130.4	133.2	125.4	120.0	113.8	105.4	102.6	96.0	89.6	79.0	65.0	45.6
8600	144.8	139.2	136.6	132.0	127.4	130.2	122.8	117.8	112.0	104.0	101.6	95.8	90.0	80.6	68.6	54.4
8700	141.0	135.6	133.2	128.8	124.4	127.2	120.2	115.4	110.0	102.4	100.4	95.2	90.0	81.8	71.0	59.4
8800	137.2	132.0	129.8	125.6	121.4	124.4	117.6	113.2	108.0	101.0	99.2	94.4	89.8	82.2	72.6	62.6
8900	133.6	128.6	126.4	122.4	118.6	121.4	115.2	110.8	106.0	99.2	97.8	93.4	89.4	82.4	73.4	64.8
9000	130.0	125.4	123.2	119.4	115.8	118.6	112.6	108.6	104.0	97.6	96.4	92.2	88.6	82.2	74.0	66.2
9100	126.6	122.2	120.2	116.6	113.0	116.0	110.2	106.4	102.0	95.8	94.8	91.0	87.8	81.8	74.2	67.2
9200	123.4	119.0	117.2	113.8	110.4	113.2	107.6	104	100.0	94.2	93.2	89.8	86.8	81.2	74.2	67.8
9300	120.2	116.0	114.2	111.0	107.8	110.6	105.2	101.8	98.0	92.4	91.8	88.4	85.8	80.6	73.8	68.0
9400	117.0	113.0	111.4	108.2	105.2	108.0	103.0	99.6	96.0	90.6	90.2	87.0	84.6	79.8	73.4	68.0
9500	114.0	110.2	108.6	105.6	102.8	105.6	100.6	97.6	94.0	89.0	88.4	85.6	83.4	78.8	72.8	67.8

Table B.8. $y^\star$ values obtained from price sensitivity with exchange rate transition matrix and price dependent demand with gamma distribution (k=4) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	151.4	144.7	141.6	136.1	130.7	133.8	125.1	119.0	112.1	102.8	99.6	92.6	85.4	74.1	59.3	39.3
8600	147.5	141.1	138.1	132.9	127.8	130.9	122.7	117.0	110.5	101.7	99	92.6	86.4	76.3	63.4	48.4
8700	143.6	137.5	134.7	129.8	124.9	128.1	120.3	114.9	108.8	100.5	98.2	92.4	86.9	77.7	66.2	53.9
8800	139.9	134.1	131.4	126.7	122.1	125.4	117.9	112.8	107.1	99.2	97.3	91.9	87.0	78.7	68.2	57.6
8900	136.3	130.7	128.2	123.8	119.4	122.6	115.5	110.7	105.3	97.8	96.2	91.3	86.8	79.2	69.5	60.2
9000	132.8	127.4	125.1	120.8	116.7	119.9	113.1	108.6	103.5	96.3	95.0	90.4	86.5	79.4	70.4	62.1
9100	129.4	124.3	122.1	118.0	114.0	117.3	110.7	106.5	101.6	94.8	93.7	89.5	85.9	79.3	71.0	63.4
9200	126.1	121.2	119.1	115.2	111.4	114.7	108.4	104.4	99.7	93.2	92.3	88.4	85.2	79.0	71.2	64.2
9300	122.9	118.2	116.2	112.5	108.9	112.1	106.1	102.3	97.9	91.7	90.9	87.3	84.3	78.6	71.2	64.8
9400	119.8	115.3	113.4	109.9	106.4	109.6	103.8	100.2	96.0	90.1	89.5	86.1	83.4	78.0	71.0	65.0
9500	116.8	112.5	110.7	107.3	104.0	107.2	101.6	98.2	94.2	88.5	88.0	84.9	82.4	77.3	70.7	65.1
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	151.6	144.8	141.6	136.2	130.8	133.8	125.2	119.2	112.2	102.8	99.8	92.6	85.6	74.2	59.4	39.4
8600	147.6	141.2	138.2	133.0	127.8	131.0	122.8	117.2	110.6	101.8	99.2	92.8	86.4	76.4	63.4	48.6
8700	143.8	137.6	134.8	129.8	125.0	128.2	120.4	115.0	109.0	100.6	98.4	92.6	87.0	77.8	66.2	54.0
8800	140.0	134.2	131.6	126.8	122.2	125.4	118.0	113.0	107.2	99.2	97.4	92.0	87.2	78.8	68.2	57.8
8900	136.4	130.8	128.4	123.8	119.4	122.8	115.6	110.8	105.4	97.8	96.2	91.4	87.0	79.2	69.6	60.4
9000	133.0	127.6	125.2	121.0	116.8	120.0	113.2	108.8	103.6	96.4	95.0	90.6	86.6	79.4	70.6	62.2
9100	129.6	124.4	122.2	118.0	114.2	117.4	110.8	106.6	101.8	94.8	93.8	89.6	86.0	79.4	71.0	63.4
9200	126.2	121.2	119.2	115.4	111.6	114.8	108.6	104.4	99.8	93.4	92.4	88.6	85.2	79.2	71.4	64.4
9300	123.0	118.2	116.4	112.6	109.0	112.2	106.2	102.4	98.0	91.8	91.0	87.4	84.4	78.6	71.4	64.8
9400	120.0	115.4	113.6	110.0	106.6	109.8	104.0	100.4	96.2	90.2	89.6	86.2	83.6	78.0	71.2	65.2
9500	117.0	112.6	110.8	107.4	104.2	107.2	101.8	98.2	94.2	88.6	88.2	85.0	82.4	77.4	70.8	65.2

Table B.9. $y^\star$ values obtained from price sensitivity with exchange rate transition matrix and price dependent demand with gamma distribution (k=2) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	159.5	149.7	145.1	137.2	129.5	133.9	121.7	113.3	103.8	91.4	87.3	78.2	69.3	55.7	39.3	20.0
8600	155.9	146.5	142.2	134.7	127.4	131.8	120.2	112.2	103.3	91.5	88.0	79.7	71.7	59.4	44.5	28.9
8700	152.3	143.3	139.3	132.1	125.2	129.7	118.6	111.1	102.6	91.4	88.4	80.7	73.6	62.3	48.6	35.1
8800	148.8	140.2	136.4	129.6	123.0	127.6	116.9	109.8	101.8	91.1	88.5	81.5	75.1	64.5	51.8	39.9
8900	145.5	137.2	133.6	127.1	120.8	125.4	115.2	108.5	100.9	90.6	88.4	81.9	76.1	66.3	54.4	43.6
9000	142.1	134.2	130.8	124.6	118.5	123.2	113.4	107.0	99.8	90.0	88.2	82.1	76.8	67.7	56.5	46.5
9100	138.9	131.3	128.0	122.1	116.3	121.0	111.6	105.6	98.7	89.3	87.7	82.1	77.3	68.7	58.1	48.9
9200	135.7	128.4	125.3	119.6	114.2	118.8	109.8	104.0	97.5	88.5	87.2	81.9	77.5	69.4	59.4	50.8
9300	132.7	125.6	122.7	117.2	112.0	116.7	107.9	102.5	96.2	87.6	86.5	81.6	77.6	69.9	60.4	52.3
9400	129.7	122.8	120.1	114.9	109.8	114.5	106.1	100.9	94.9	86.6	85.8	81.1	77.5	70.2	61.1	53.6
9500	126.7	120.2	117.6	112.5	107.7	112.3	104.3	99.3	93.6	85.6	84.9	80.6	77.2	70.3	61.7	54.5
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	159.6	149.8	145.2	137.4	129.6	134.0	121.8	113.4	103.8	91.6	87.4	78.4	69.4	55.8	39.2	20.2
8600	156.0	146.6	142.2	134.8	127.4	131.8	120.2	112.4	103.4	91.6	88.0	79.8	71.8	59.4	44.6	29.0
8700	152.4	143.4	139.4	132.2	125.2	129.8	118.6	111.2	102.8	91.4	88.4	80.8	73.6	62.4	48.6	35.2
8800	149.0	140.4	136.4	129.6	123.0	127.6	117.0	110	101.8	91.2	88.6	81.6	75.2	64.6	52.0	40.0
8900	145.6	137.2	133.6	127.2	120.8	125.4	115.2	108.6	101.0	90.8	88.6	82.0	76.2	66.4	54.6	43.6
9000	142.2	134.2	130.8	124.6	118.6	123.2	113.4	107.2	100.0	90.2	88.2	82.2	77.0	67.8	56.6	46.6
9100	139.0	131.4	128.2	122.2	116.4	121.0	111.6	105.6	98.8	89.4	87.8	82.2	77.4	68.8	58.2	49.0
9200	135.8	128.4	125.4	119.8	114.2	118.8	109.8	104.2	97.6	88.6	87.2	82.0	77.6	69.6	59.6	51.0
9300	132.8	125.6	122.8	117.4	112.0	116.8	108.0	102.6	96.4	87.6	86.6	81.6	77.6	70.0	60.4	52.4
9400	129.8	123.0	120.2	115.0	110.0	114.6	106.2	101.0	95.0	86.8	85.8	81.2	77.6	70.4	61.2	53.6
9500	126.8	120.2	117.6	112.6	107.8	112.4	104.4	99.4	93.6	85.6	85.0	80.6	77.2	70.4	61.8	54.6

Table B.10. $y^{\star}$ values obtained from price sensitivity with exchange rate transition matrix and price dependent demand with gamma distribution (k=1) under different inventory policies.

Myopic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	164.1	149.9	143.4	132.3	121.6	127.7	111.0	99.8	87.6	72.2	67.2	56.6	46.8	32.9	18.3	5.5
8600	161.2	147.5	141.4	130.8	120.6	126.8	110.8	100.2	88.5	73.6	69.3	59.5	50.4	37.3	23.2	11.0
8700	158.3	145.2	139.3	129.2	119.5	125.8	110.4	100.3	89.2	74.9	71.1	61.9	53.6	41.1	27.4	15.9
8800	155.4	142.8	137.3	127.5	118.3	124.7	109.8	100.2	89.6	75.8	72.6	63.9	56.3	44.4	31.2	20.1
8900	152.5	140.4	135.2	125.8	116.9	123.5	109.2	100.0	89.8	76.5	73.7	65.6	58.6	47.3	34.5	23.9
9000	149.7	138.0	133.0	124.1	115.6	122.2	108.4	99.6	89.9	77	74.7	67.0	60.6	49.8	37.4	27.3
9100	146.9	135.6	130.9	122.3	114.2	120.8	107.5	99.1	89.8	77.4	75.4	68.2	62.2	51.9	39.9	30.2
9200	144.1	133.2	128.8	120.5	112.7	119.4	106.5	98.5	89.6	77.6	75.9	69.1	63.6	53.7	42.1	32.8
9300	141.3	130.9	126.6	118.7	111.2	117.9	105.5	97.8	89.2	77.6	76.3	69.8	64.7	55.3	44.0	35.1
9400	138.6	128.5	124.5	116.9	109.7	116.3	104.3	97	88.8	77.6	76.5	70.4	65.7	56.6	45.7	37.1
9500	136.0	126.2	122.4	115.1	108.1	114.8	103.2	96.2	88.2	77.4	76.5	70.8	66.4	57.7	47.1	38.8
Dynamic Inventory Policy																
p	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}
8500	164.0	150.0	143.4	132.4	121.8	126.6	110.8	99.6	87.4	72.2	67.2	56.6	46.4	32.6	18.0	5.6
8600	161.0	147.6	141.4	130.8	120.8	125.8	110.6	100.0	88.4	73.8	69.4	59.4	50.0	37.0	23.0	11.2
8700	158.2	145.2	139.4	129.2	119.6	124.8	110.2	100.2	89.0	75.0	71.2	61.8	53.2	40.8	27.2	16.0
8800	155.2	142.8	137.2	127.6	118.4	123.8	109.8	100.2	89.4	75.8	72.6	64.0	56.0	44.2	31.0	20.2
8900	152.4	140.4	135.2	125.8	117.0	122.6	109.0	99.8	89.8	76.6	73.8	65.6	58.2	47.0	34.4	24.0
9000	149.6	138.0	133.0	124.2	115.6	121.4	108.2	99.6	89.8	77.2	74.8	67.0	60.2	49.6	37.2	27.4
9100	146.8	135.6	131.0	122.4	114.2	120.0	107.4	99.0	89.8	77.4	75.4	68.2	62.0	51.8	39.8	30.4
9200	144.0	133.2	128.8	120.6	112.8	118.6	106.4	98.4	89.6	77.6	76.0	69.2	63.4	53.6	42.0	33.0
9300	141.2	131.0	126.6	118.8	111.2	117.2	105.4	97.8	89.2	77.8	76.4	69.8	64.4	55.2	44.0	35.2
9400	138.6	128.6	124.6	117.0	109.8	115.6	104.2	97.0	88.8	77.6	76.6	70.4	65.4	56.4	45.6	37.2
9500	136.0	126.2	122.4	115.2	108.2	114.0	103.2	96.2	88.2	77.4	76.6	70.8	66.2	57.6	47.0	39.0