UNIVERSITY OF SOUTHAMPTON

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AN ECONOMIC ANALYSIS OF THE SUPPLY CHAIN AND EMPIRICAL STUDY OF THE INTERACTIVE MECHANISM OF URBANISATION, INDUSTRIALISATION AND ENVIRONMENT

by

Tong Xue

Thesis for the degree of Master of Philosophy

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ABSTRACT

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With the rapid development of technology and globalization in recent years, the cost of communication among companies is reducing, which has significantly encouraged collaboration among the involved companies. Keeping a good collaborative relationship can benefit all of the companies within the supply chain. In this context, studies of the coordination/collaboration within supply chain have gained increasing prominence, and are considered to have an important role to play in improving the performance of the whole supply chain in practice.

In this thesis, I first modelled the supply chain with the consideration of the retailer's initial wealth constraint problem. To solve this problem, a bank is introduced into the mostly popular model, simple wholesale price model. The resulting supply chain model has following three parties: (1) a bank; (2) a retailer with limited initial wealth; (3) a manufacture. In the proposed model, we present a new bank financing, i.e. the risk-free interest loan program; help the retailer's initial wealth constraint problem. In the risk-free interest loan program, the interest is paid by both the retailer and the manufacturer, which is as follows: the retailer pays a risk-free rate part, and manufacturer pay the left part. Then the collaborations of this three-party supply chain are analysed in Chapter 2 and Chapter 3 respectively under different assumptions:

In Chapter 2, we study the three-party with the pre-determined retail price, the retail price is exogenous and fixed. The result show that the loan program can improve both the retailer's and the manufacturer's profits. We further compare the risk-free loan program with interest-free loan program, the results indicate

that (i) both of the retailer’s and the manufacturer’s profit with the risk-free loan program are greater than the one with interest-free loan program when the retailer’s initial wealth is smaller. (ii) both of the retailer’s and the manufacturer’s profit with the risk-free loan program are same as the ones with interest-free loan program when the retailer’s initial wealth is medium and greater, but the risk-free interest program is advantage and it can avoid the retailer’s moral hazard, i.e. the risk-free interest program can avoid the retailer borrow excessive money.

Chapter 3 further expanded this three-party model a two-period games, based on the risk-free interest loan in the first period. The financial organization only occurs in the first period and if the player bankrupts, there will not be any further game in the second period. We found that with the bank in the first period, the retailer will order more products and want to take the risk because the bank will share some risk with him. Both retailer and manufacturer are better off in the first period. However, in the second period, when the bank leaves the game, the retailer will order much less than which in the first period even its wealth grows. Compared with the case without the bank, both manufacturer and retailer are better off in the second period.

Chapter 4 is a case study which focuses on a province in China. This chapter mainly discuss about the relationship among urbanization, industrialization and environment. Many studies show that the relationship is complex, however, still follows some principles. On the other hand, Gollin (2013) shows that resource exporters that have urbanized without increasing output in either manufacturing or industrial services such as finance. Xinjiang, the province we focus on, also play a role of resource exporter in China. However, no research considers this special province in China. By establishing the index system, we find out Xinjiang follows environmental Kuznets Curve and the development of heavy industry provide a large driving force to the urbanization process. We then find out that the mainstay industries based on the advantages of resources in Xinjiang, such as oil, natural gas, coal, electricity. This type of industries’ pollution is heavy, but this is the actual situation of Xinjiang's industrial development.

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Academic Thesis: Declaration Of Authorship

I, Tong Xue, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

An Economic Analysis of the Supply Chain and empirical study of the interactive mechanism of urbanisation, industrialisation and environment

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signed: Tong Xue ....

Date: 20th October 2017 ....

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Chapter 1 Background and research aim

With the rapid development of technology and globalization in recent years, the cost of communication among companies is reducing, which has significantly encouraged collaboration among the involved companies. Keeping a good collaborative relationship can benefit all of the companies within the supply chain. In this context, studies of the coordination/collaboration within supply chain have gained increasing prominence, and are considered to have an important role to play in improving the performance of the whole supply chain in practice. However, features such as externalities, and the stability of a supply chain can affect the coordination by, for example, reducing both the profits of individual members and the aggregated profits of the whole supply chain. Thus, this thesis intends to improve our knowledge regarding the coordination of key players within a supply chain by extending the most frequently used model, the Simple Wholesale Price Model to two complex situations: (1) the situations when interest-free loan or risk-free loan programs are available; (2) the situation when the key players consider a two-period game.

Chapter 2 studies a three-party supply chain model, which introduces the bank into the supply chain, in addition to the manufacturer and the retailer. The bank is involved in order to help the retailer with its initial wealth constraints and to improve the performance of the whole supply chain. In this chapter, we designed a new loan program called the risk-free interest loan program. In this program, the bank provides loans to the retailer at given interest rate up to a credit limited (i.e. within a credit limit). However, this loan is with risk-free interest for the retailer as the manufacturer will help the retailer with a part of the interest of the loan. Since the retailer is constrained by his initial wealth for ordering from the manufacturer, he is willing to accept the loan plan and borrow money from the bank.

After building and analysing this new model with a risk-free interest loan program, we then compare our model with one under the interest-free loan program. The results indicate that, when the retailer's initial wealth is small, both the retailer's and the manufacturer's profits are greater under the risk-free interest loan program compared with the interest-free loan program, but the risk of the retailer's bankruptcy is higher. When the retailer's initial wealth is above a critical point, both the retailer's and the manufacturer's profits are the same as those in the interest-free loan program, but the efficiency of the risk-free interest loan program is higher than the one of the free-interest loan program, because money of are only used for ordering products with the risk-free interest loan program rather than saving for a risk-free interest profit with the interest-free loan program.

In Chapter 3, we studied a two-continuous-period game. In each period, the manufacturer, i.e. the leader, plays a Stackelberg game with the retailer, i.e. the retailer. The manufacturer sets the wholesale price to the retailer for profit maximization. Then the retailer decides the order to maximize his expected profit according the wholesale price since the retailer faces a Newsvendor problem. The bank will provide a one-shot loan program to the retailer to solve the retailer’s financial problem, which includes (i) the bank sets the an interest rate and a credit line (ii) the manufacturer helps the retailer pay a part of the interest, the retailer needs to pay a risk-free interest. At the end of the first period, the demand is realized, and the retailer needs to pay both the loan and the risk-free interest back to the bank. If the retailer’s final wealth is not great enough to pay the money he owes to the bank, the retailer will be bankrupt, the bank takes the retailer’s entire asset, and the game is over. Oppositely if the retailer’s final wealth is great enough, the retailer pays back to the bank, the retailer and the manufacturer play a two-party in the second period. In the future by simulation we should be able to find out how the one-shot risk-free loan program affects the supply chain.

Chapter 4 discusses urbanization, industrialization, and environmental degradation is three tightly related processes during the development of a place. Such relationship among the three processes has been generalised by researchers as theories to explain such interplay in most of the cities. However, those theories failed in some places where the development relies on resource exporting, the endowment is rich, and the environment is vulnerable. In most of such places, empirical studies showed that their urbanization proceeds without increasing either manufacturing or service industry such as finance service like other cities do. There is a need to extend our theories and improve our understanding of the urbanisation industrialization, and environmental degradation in such special areas. This paper fills this gap by conducting an empirical study in Xinjiang Province in Northwest China, where the development both relies on resource exporting and follows traditional development path to some extent. We use Vector Auto Regression (VAR) to model the relationship among the three processes in this unique case. Based on the results, we then apply Weaver-Thomas model to help the local government to select the optimum mainstay industries that can both promote the urbanisation and benefit the local environment.

Chapter 2 Collaborative Outcomes of a Three-party Supply Chain Model with a risk-free interest loan program

2.1 Introduction

The lack of capital is a critical problem for a company's setup, operation, and growth. For instance, the lack of capital will constrain the amount of product that the retailer can order, and will affect the supply chain's profit and undermine the competitiveness of the supply chain. Two financial methods to solve this capital constraint problem: (1) trade credit and (2) bank finance. The trade credit is a two-party game, which includes a manufacturer and a retailer. The manufacturer provides trade credit, allows the retailer to delay the payment for the order. Effectively, the manufacturer is willing to bear the risk of retailer's default. Bank finance is a three-party game, in which the bank is involved and provides a loan program for the other two players in the supply chain. In this case, the bank bears the risk of the bankruptcy of the borrower.

There are some theoretical studies which focus on comparing *trade credit* with *bank finance*. For example Zhou and Groenevelt (2007) introduce an interest-free loan program (which is a kind of bank finance) to solve the retailer's initial wealth constraint and compare with the *trade credit.* The *interest-free loan program* is that the bank provides a loan program to solve the retailer's initial wealth constraint program, in which the manufacturer will help the retailer pay all of the interest, the retailer needs not to pay the interest. The result show that *the bank finance* is preferable to the *trade credit* since both the retailer and the entire supply chain's profit are greater with the interest-free loan program than the ones with trade credit. In addition, the manufacturer is prefer to adopt *the bank finance* since there is no uncertainty. Kouvelis and Zhao (2008) also compare the *interest-free loan program* and the *trade credit* and proved that the retailer would prefer the *bank finance* if the loan program is well structured. According to the literature indicates that the *bank finance* has many advantage and worth noting to study and use in the business. However, the interest-free loan program has a significant disadvantage. When the retailer's initial wealth is greater, the retailer will borrow money up to the credit line from the bank (borrow excessive money). Zhou and Groenevelt (2007) point out this problem and warn that the bank and the manufacturer should set up a screening process, but they do not give the detailed method to avoid this problem.

In this Chapter, we provide a risk-free loan program to avoid the retailer borrowing excessive money. We build a three-party model, which include a bank, a retailer, and a manufacturer. The bank helps to address the retailer's constraint problem, the lack of initial wealth, by offering a *risk-free interest program*, which includes interest r and credit line $\emptyset$. Under such scheme, the retailer only need to pay a risk-free rate, r_f, of the loan to the bank. Over a given period of time, return of an investment is not any risk of financial loss, and the rate of the return is called the risk-free rate and it is a theoretical rate. The manufacture will help the retailer pay the left proportion of the interest of the loan which the retailer borrows for ordering, i.e. $(\mathrm{r} - r_f)(wq - V_0)^+$. The manufacturer, as the leader, plays a Stackelberg game with the retailer, as the follower. The manufacturer sets the wholesale price first; the retailer orders the product from the manufacturer according the wholesale price and then sells the product to the customer at a fixed retail price.

To build this three-party model, studies regarding the corporate operation and finance are relevant and are reviewed in section 2.2. Then, in section 2.3, we describe the model. The optimal decisions of the three parties in the game are presented in section 2.4. Our theoretical results are then tested with a numerical simulation, which is presented in section 2.5. Finally, a brief conclusion is given in Section 2.6.

2.2 Literature review

In the research field of the supply chain, the wholesale price contract is commonly used to describe the relationship between members in a vertical structure of supply chain. Pasternack (1999) proposed a *simple wholesale price model*, which models the interaction between two players, the manufacturer and the retailer, in a single selling period. In their model, the manufacturer sets a wholesale price at the beginning of the selling period. Then according to this given wholesale price, the retailer decides how many products to order or buy. To make this decision, the retailer faces a Newsvendor problem, i.e. the demand is unknown before the selling period. Because of this problem, the retailer could order more products than demanded and get a loss from excess inventory, or order fewer products than demanded and not be able to maximize its profit. At the end of the selling period, the demand is realized, and the actual profit of the retailer can be calculated.

This *simple wholesale price model* does not consider the retailer's initial wealth, which in real life constrains his order and thus constrains the profit of the whole supply chain. The literature contributing focuses on addressing this weakness of the *simple wholesale price model* is mainly from two fields, i.e. the corporate operation and the corporate finance.

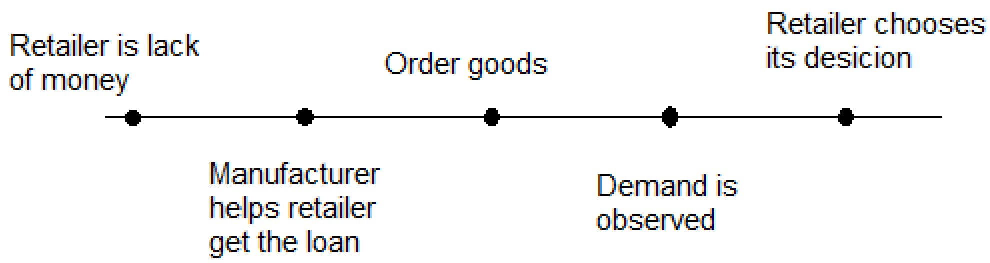
In the operation research field, such as the inventory management and so on, a lot of the literature employs wholesale price contract to model the vertical structure. The wholesale price contract is one of the most widely used contracts both in literature and in practice, in which there are two players, a manufacturer and a retailer. The manufacturer plays a Stackelberg game with the retailer. The manufacturer is the leader who then sells the products to the retailer at wholesale price, the retailer is the follower who buys the products from the manufacturer and sells them to the consumers. For example, Bresnahan and Reiss (1985) studied the wholesale price contract in the vertical structure and the demand is deterministic in his model. Spengler (1950) also analyses the wholesale price model with the deterministic demand and shows that the margin of the retailer's objective function is different from the manufacturers, which is called the problem of "double marginalisation". However, if the demand is stochastic, the retailer keep an inventory at the beginning of period, the retailer suffers a newsvendor problem. Lariviere and Porteus (2001) employ the wholesale price contract model with the Vendor Management Inventory, in which the manufacturer plays a Stackelberg game with the retailer. Their results indicate that the wholesale price contract usually cannot fully coordinate the supply chain. A detailed summary of the wholesale price contract studied in this research area is given by Cahon (2003). Those models used in the operation literature mainly focus on the coordination of the participants of the supply chain, but fail to simulate the situation where the supply chain faces financial problems, particularly the initial wealth problems of the retailer.

In the research field of corporate finance, only a limited number of papers consider the effects of corporate finance on the corporate operation. From the perspective of a single firm, Buzacott and Zhang (2004) prove that asset-based financing does affects operational decisions such as the newsvendor's ordering. Xu and Birge (2004) and (2005) also intend to address this question by studying the integrated firm's operational decision in an imperfect financial market, i.e. with bankruptcy cost and tax issues. However it is necessary to know, from the perspective of the whole supply chain, how operational and financial decisions affect each other, and more importantly, how financial decisions affect the decentralised supply chain. Zhou and Groenevelt (2007) contribute to this realm of knowledge by studying a three-party model with a capacitated retailer, in which the manufacturer teams up with the bank to offer an interest-free loan to the retailer. Their results indicate that the loan program can significantly improve the supply chain profit. Kouvelis and Zhao (2010) also build a three-party model to study the situation when the cost of bankruptcy exists. Jing, Chen and Cai (2012) discuss the retailer's optimal decision when both of the bank financial program and the opening account program are viable. The opening account program is similar to the interest-free loan program. The disadvantages of such programs are noted by Zhou and Groenevelt (2007). As they claim, the efficiency of such loan programs is expected to be improved and there are moral hazard problems. For instance, even if the retailer's initial wealth is enough, the retailer tends to keep some cash available to attain a risk-free interest but order the products with the risk-free interest loan program. In this case, the loan programme is benefit neither for the whole supply chain nor the retailer. The bank and the manufacturer need to set up a screening process to avoid this situation.

To address this issue of the interest-free loan program, in this chapter we propose a model with a risk-free interest loan program. With this loan program, the manufacturer only helps the retailer a proportion of the interest, rather than all of the interest as she does in the interest-free loan program or the trade credit program. In our new program, the retailer needs to pay the interest with a risk-free rate, so the retailer are unlikely to borrow excessive money from the bank, instead, he would probably use all his money to order products from the manufacturer. The next two sections build up a theoretical model and analyse the response of the three parties in the supply chain and the efficiency of the loan.

2.3 Model description and analysis method

In our new model, the three parties involved in the supply chain include a bank, a manufacturer and a bank, and their decisions. We assume that: (i) all three parties are risk-neutral players, and have complete information about each other, such as the retailer's initial wealth and so on; (ii) both the manufacturer and the retailer aim to maximise their individual profits; (iii) only the retailer's initial wealth is constraint; and (iv) the bank requires a fair return of loan from the program. The timeline of the model can be described as:



Before the selling period, the demand D cannot been observed, $D \in [0, +\infty]$, but we can learn demand from previous periods, such as the demand's distribution function $F(x)$ and the density function $f(x)$. F is differentiable, non-decreasing and $F(0) = 0$.

(i) The bank (denoted by the subscript B) offers a contract to the retailer. In the contract, the bank decides both the interest rate r and the credit line coefficient (also called credit limit).

(ii) The manufacturer plays a Stackelberg game with the retailer. In this game, the manufacturer is the leader who sets the wholesale price w and is willing to help the retailer pay a proportion of the interest if the retailer borrows money from the bank, i.e. $(\mathrm{r} - r_f)(wq - V_0)\ where\ wq - V_0 > 0$.

(iii) The retailer is the follower in the Stackelberg game. According to the wholesale price w set by the manufacturer, the credit line coefficient ∅ and the interest rate,r, set by the bank, and his own initial wealth, the retailer decides the quantity of the order q and the amount of loan, L,.

At the end of the period, the demand is observed. If the retailer's final wealth is more than the total amount he owes the bank (including both the loan and the risk-free interest), he will repay the bank. Otherwise the retailer will be bankrupt. In this case, the bank will take all his assets.

In this game, firstly, the bank sets the interest rate, r, and the credit line $\emptyset$ to obtain a fair return. Secondly, the manufacturer maximize her profit by setting the wholesale price w. Thirdly, the retailer maximize his final wealth by setting the order.

We use the backwards induction to analyse the game. First step, given (1) an interest rate, (2) a credit line coefficient, and (3) a wholesale price, we can maximize the retailer's profit and find the best-response order $\mathrm{q}(w)$, which is related to the wholesale price w. Second step, we assume that the credit line and the interest are known, we insert beset-response order, $\mathrm{q}(w)$, into the manufacturer's objective function and maximize her profit by the wholesale price w. Then then the optimal wholesale price $w(r,\emptyset)$ can be obtained. Then optimal order $q(r,\emptyset)$, also can be obtained. Third step, we plug optimal wholesale price $w(r,\emptyset)$, and the optimal order $w(r,\emptyset)$, into the bank's payment function, and find the final equilibrium of the variables, i.e. q,w,r and so on.

2.4 Analysis results: the response and optimum decisions of each players

Using backwards induction, we analyse how each player in the supply chain would response at the beginning of the selling period, in order to maximise his/her profit in the end of the period. This section presents the results regarding the decisions of the retailer, the manufacturer, and the bank in a separate sub-section.

2.4.1 The Retailer

As described above, we consider the situation when the retailer is constrained by his initial wealth. As the response to (i) a wholesale price w given by the manufacturer and (ii) an interest rate r and a credit line coefficient $\emptyset$ given by the bank, the retailer decides the loan amount$L$, where $L \geq 0$. Subsequently, the retailer orders q products from the manufacturer. Let V_0 denote the retailer's initial wealth and $V_0 > 0$. Then the retailer's cash position, after he orders the product, is denoted by $(L + V_0 - wq)$, which should be positive. Let p denote the retail price during the selling period, and r_f denote the risk-free interest rate in this season. We assume that there is no salvage for unsold products after the selling period. Hence, after the season, the retailer's final wealth, V_1, can be expressed by

$$V_1 = \{(1 + r_f)(L + V_0 - wq) + p\min(q, D) - (1 + r)L + (r - r_f)(wq - V_0)^+\}^+$$

$$s.t. \quad L \leq \emptyset wq \qquad (1)$$

$$L + V_0 - wq \geq 0 \qquad (2)$$

$$L \geq 0 \qquad (3)$$

The first term in the square bracket denotes the retailer's revenue from the cash position in the selling period. The second term denotes the retailer's revenue earned by selling the products. The third term is the accounts paid back to the bank by the retailer at the end of the period. Fourth term is the interest compensation from the manufacturer. If the retailer is not bankrupt, the final is positive, otherwise, the bank takes the retailer's entire asset that it can get at the end of period. In our model, we assume the bank has ability to get a ratio k of asset from the retailer. If the bank has the full information about the retailer, the ratio k=1. The retailer's final wealth should not be negative. Here we can find out the value if the retailer default:

$$V_d = p * \min(q, D) * (1 - k)$$

From the equation, we can conclude that when the bank has full information of the retailer, its value of default is 0. The retailer's value in the end of the first period is:

$$V_R = max(V_1, V_d)$$

At the same time, we can define the probability that the retailer default on purpose is:

$$P_{Dop} = Prob(V_1 < V_d)$$

This is the probability that the retailer can benefit from the default by hiding some of his asset that the bank cannot find.

COROLLARY 1 There is a unique optimal loan amount that the retailer borrows from the bank, i.e. if $wq - V_0 > 0, then\ L = wq - V_0$, otherwise $L = 0$.

Proof：all proofs are seen in **Appendix A.**

COROLLARY 1 indicates that the retailer will use up all his available cash to buy products from the manufacturer since the retailer cannot benefit from the extra money he hold. Only when the retailer's order costs more than his initial wealth, the retailer will apply a loan from the bank. Also, the corollary indicates that the retailer would not borrow excessive money even he has a great credit line. He will only borrow the optimal loan that maximise his final profit. This concept is consistent with the Buzacott and Zhang's (2004) results that the retailer will use up his initial wealth when he has independent financing. Our result is different from Zhou and Groenevelt's (2007) conclusion based on an interest-free loan program, in which the retailer would always borrow money up to the credit.

After we replace the L as $\mathrm{wq} - \mathrm{V_0}$ in the retailer's objective and the constraint, the retailer's objective function can be re-written as:

$$V_1(q) = \left[p\min(q, D) - \left(1 + r_f\right)(\mathrm{wq} - V_0)\right]^+$$

$$s.t. V_0 - (1 - \emptyset)wq \geq 0 \qquad (4)$$

The first term is the retailer's revenue. The second term is retailer's payment to bank at the end of the period. If he borrowed money from the bank at the beginning of the period, he needs to pay the bank by $\left[\left(1 + r_f\right)(\mathrm{wq} - V_0)\right]^+$. But if he did not borrow money from the bank and has some cash left, i.e. $(\mathrm{wq} - V_0)^+$, he can get a risk free interest $\left[\left(1 + r_f\right)(\mathrm{wq} - V_0)\right]^+$ and the cash at the end of the period. For instance, the retailer can lodge the money in the bank and receive a risk-free interest. Eq.(4) is the credit line given by the bank, i.e. $L \leq \emptyset wq$. Combining the equations (1),(2),(3) with $L = (\mathrm{wq} - V_0)^+$, we can get $V_0 - (1 - \emptyset)\mathrm{wq} \geq 0$ after the algebraic operation. Meanwhile, we also can get the bankrupt threshold according to retailer's objective function.

LEMMA 1 The retailer is able to repay the accounts he owns if and only if the demand is greater than the bankruptcy threshold, $b(q)$, the bankruptcy threshold can be expressed as

$$b(q) = \frac{\left(1 + r_f\right)(wq - V_0)}{p}$$

We assume that the retailer's initial wealth $V_0 > 0$. We also assume that $w < \frac{p}{(1+r_f)}$, because if the wholesale price w, is greater than the value $\frac{p}{(1+r_f)}$, the retailer cannot gain profit or even lose money from the order. In this case, the retailer would rather buy nothing and just get the risk-free interest from his initial wealth than under taking any selling activities. It make no sense for discussing the case that retailer buys nothing in this chapter. We only discuss the case that the quantity of the order is greater than zero, i.e. $0 < q$. Thus, the quantity of order is greater than the bankruptcy threshold. i.e. $\mathrm{q} > b(q)$.

LEMMA 1 indicates that if the retailer borrows money from the bank, i.e. $b(q) > 0$, the risk of its bankruptcy exists precisely because the demand is stochastic. The risk of retailer's bankruptcy risk is also determined by the size of the order.

To be specific, for $\mathrm{q} > 0$, in the case of $q > \frac{V_0}{w}$, i.e. $b(q) > 0$, the retailer would borrow money from the bank and there is a risk of bankruptcy for the retailer. The more the retailer orders, the more money he borrows from the bank, and thus the higher risk of bankruptcy he faces. At the end of the period, the demand will be realized. If the realized demand is greater than bankruptcy threshold, the retailer will not be bankrupt, otherwise, the retailer will be bankrupt.

For $0 < q$. In the case of $q \leq \frac{V_0}{w}$, i.e. $b(q) < 0$, the retailer would not borrow money from the bank, so there is no bankrupt risk for the retailer. In this case, the supply chain becomes a two-party game instead of the three-party game because the bank is not involved.

3.4.1.1 The case of $q > \frac{V_0}{w} > 0$: the retailer faces the risk of bankruptcy

For the $b(q) > 0$, *i.e.* $q > \frac{V_0}{w}$, the retailer has a risk of bankruptcy. The demand is stochastic and is realized at the end of the selling period. In this scenario, three more sub-cases can be discussed separately:

(i) If $0 \leq D \leq b(q)$, i.e. the realized demand is smaller than the bankruptcy threshold, the retailer will certainly be bankrupt, and then the bank takes all the retailer's asset away. In this situation, the retailer's final wealth is zero.

(ii) If $b(q) < D \leq q$, the quantity of the sale is the realized demand. In this situation, the retailer is not bankrupt. However, there are products left for the retailer's inventory, i.e. the retailer orders excess inventory.

(iii) If $q < D$, the quantity of the sale is the order. In this case, the retailer is not bankrupt, but he orders less than the demand.

Let $V_{1.1}(q)$ denote the retailer's final wealth with the risk of bankruptcy. According to the analysis of the three situations above, we can re-write the retailer's final wealth as:

$$V_{1.1}(q) = \begin{cases} pq - (1+r_f)(wq - V_0)\,, & \text{if } q \leq D \\ pD - (1+r_f)(wq - V_0), & \text{if } b \leq D < q \\ 0, & \text{if } D < b \end{cases}$$

After the algebraic manipulations, the retailer's objective function can be expressed as $V_{1.1}(q) = p\int_b^q \bar{F}(x)dx$.

<u>LEMMA 2</u> If the demand D has an increasing failure rate (IFR), the retailer's final wealth function, $V_{1.1}(q) = p\int_b^q \bar{F}(x)\,dx,$ is unimodal in order q.

In the literature of the supply chain, $\frac{f(x)}{\bar{F}(x)}$ is defined as the failure rate of a demand distribution, in which $f(x)$ is the Probability Density Function (PDF) of the demand distribution and $F(x)$ is the Cumulative Distribution Function (CDF) of the demand distribution. $\bar{F}(x)$ equals to $1 - F(x)$. If $\frac{f(x)}{\bar{F}(x)}$ is increasing in x,then we define this is the demand distribution as one with an increasing failure rate (IFR), such as the uniform and the normal distribution. Additionally, if $\frac{xf(x)}{\bar{F}(x)}$ is increasing in x, then we define this demand distribution as one with increasing generalized failure rate (IGFR). Examples for such distribution can include the uniform, the normal, the gamma, the power, and the exponential distributions. Obviously, the demand distribution with IFR belongs to the demand distributions with IGFR, but not every demand distribution with IGFR is the demand distribution with IFR. The demand distribution with IFR is stricter than the demand distribution with IGFR. Cachon (2003) shows that, in the simple wholesale price model, the equilibrium order of the supply chain can be attained when the demand distribution is with the increasing generalized failure rate (IGFR). In this Chapter, we assume that the demand D has an increasing failure rate to assure that the retailer's expected final wealth function is concave.

3.4.1.2 The case of $q \leq \frac{V_0}{w}$: the retailer faces no bankruptcy risk

For the $b(q) \leq 0$, *i.e.* $q \leq \frac{V_0}{w}$, the retailer has no risk of the bankruptcy because he has enough money to finance the order, and thus he has no need to borrow money from the bank. Oppositely, the retailer can attain a risk-free interest from the cash left after he ordered. Under this case, there are two situations to be discussed as follows:

(i) If $0 \leq D \leq q$, the quantity of the sale is the realized demand. There are products left for the retailer's inventory, i.e. the retailer orders excess inventory.

(ii) If $q < D$, the quantity of the sale is the order. The retailer's order is less than the demand.

Let $V_{1.2}(q)$ donate the retailer's final wealth without the risk of bankruptcy. In such case, the retailer's final wealth can be written as

$$V_{1.2}(q) = \begin{cases} pq - (1 + r_f)(wq - V_0)\,, & \text{if } q \leq D \\ pD - (1 + r_f)(wq - V_0), & \text{if } 0 \leq D < q \end{cases}$$

After algebraic manipulation, the retailer's final wealth function can be expressed as $V_{1.2}(q) = p\int_0^q \bar{F}(x)dx - pb$.

3.4.1.3 Summary of the two cases

Both of the cases discussed above are likely to exist when the retailer's initial wealth is given, and in both cases the retailer's objective function is related to the order. Therefore, by combining the two conditions discussed above, the retailer's expected final wealth can be written as

$$V_1(q) = \begin{cases} V_{1.1}(q), & \text{if } \frac{V_0}{w} < q \leq \frac{V_0}{(1-\emptyset)w} \\ V_{1.2}(q), & \text{if } 0 < q \leq \frac{V_0}{w} \end{cases}$$

When both the criterion $0 \leq V_0 - (1 - \emptyset)wq$ and the criterion that $\frac{V_0}{w} < q$ are met, the retailer's objective function could be expressed as the function $V_{1.1}(q)$. After algebraic operation, the equations, i.e. $0 \leq V_0 - (1 - \emptyset)wq \; and \; \frac{V_0}{w} < q$, can be re-written as $\frac{V_0}{w} < q \leq \frac{V_0}{(1-\emptyset)w}$. When the order that retailer chooses meets the equation: $0 < q \leq \frac{V_0}{w}$, the retailer's expected wealth could be attained from the function $V_{1.2}(q)$. The retailer's expected final wealth function is continuous.

Let $\hat{q}_L$ denote the optimal order for the function $V_{1.1}(q) = p\int_b^q \bar{F}(x)\,dx$. Let $\hat{q}_N$ denote the optimal order for the function $V_{1.2}(q) = p\int_0^q \bar{F}(x)dx - pb,$ which is unimodal in the order q. The solution $\hat{q}_L$ can be obtained from the following equation:

$$\bar{F}(q) - \frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(wq - V_0)}{p}\right] = 0$$

The other solution $\hat{q}_N$ can be obtained from the following equation:

$$\bar{F}(q) - \frac{(1+r_f)w}{p} = 0$$

<u>PROPOSTITION 1</u> The optimal solution of the retailer's final objective function is unimodal in the order, q.

(i) If $\bar{F}\left(\frac{V_0}{w}\right) \leq \frac{(1+r_f)w}{p}$, the optimal solutions is $\hat{q}_N$;

(ii) If $\bar{F}\left(\frac{V_0}{w}\right) > \frac{(1+r_f)w}{p}$, the optimal solutions is $\min\left\{\hat{q}_L, \frac{V_0}{(1-\emptyset)w}\right\}$.

Proposition 1 indicates that given a wholesale price, the retailer's objective function may be a quasi-concave function or a concave function. There is only one optimal solution for the maximization of the retailer's objective function. Additionally, according to the Proposition 1, there is a switching point, i.e. $\mathrm{w}\bar{\mathrm{F}}^{-1}\left[\frac{(1+\mathrm{r_f})\mathrm{w}}{\mathrm{p}}\right]$, for the retailer's initial wealth. The retailer cannot benefit from the loan if $\mathrm{V_0} \geq \mathrm{w}\bar{\mathrm{F}}^{-1}\left[\frac{(1+\mathrm{r_f})\mathrm{w}}{\mathrm{p}}\right]$, because the retailer can afford the order by his own initial wealth and faces no risk of bankruptcy.

<u>LEMMA 3</u> The best-response order $q(w)$ is decreasing in the wholesale price w.

The wholesale price w is determined by the manufacturer. In the Stackelberg game, the manufacturer is the leader, she chooses an optimal wholesale price to maximize his profit according to the best-response order. If the best-response order function $q(w)$ is monotonous and decreasing in w, it can be concluded that $w(q)$ is also monotonous and decreasing in best-response q. Lemma 3 is helpful for maximizing the manufacturer's objective function.

2.4.2 The Manufacturer

In this subsection, we discuss the manufacturer's decision. There is a Stackelberg game between the manufacturer and the retailer. The manufacturer is the leader, while the retailer is the follower. Before the season, the manufacturer sets the wholesale price. Subsequently, she receives the payment, $w(q)q$, from the retailer, and manufactures the products with the quantity of q. Let c denote the unit production cost. We assume that there is neither fixed cost for the products, nor uncertainty of producing by the manufacturer. For the manufacturer, we can assume that it will always repay the interest to the bank no matter what the decision made by the retailer. In reality, the manufacturer plays as a bridge between the bank and the retailer. It does not apply for the loan from the bank by itself. In addition, it always owns a factory or fixed asset that the bank can easily find out. Compared with the huge punishment of default to the bank, the manufacturer prefers to repay the small amount of interest. The manufacturer's profit is

$$\pi_M = (1 + r_f)[w(q) - c]q - (r - r_f)L^+$$

According to **COROLLARY 1,** there are two case for the manufacturer's objective: (i) if the retailer borrow the money from the bank, the manufacturer needs to help the retailer pay the interest $(\mathrm{r} - \mathrm{r_f})L \ where\ L > 0$, (ii) otherwise, the manufacturer need not since $L = 0$. Then the manufacturer's profit can also be re-written in two ways:

$$\pi_M = \begin{cases} (1 + 2r_f - r)w(q)q - (1 + r_f)cq + (r - r_f)V_0 & if\ \frac{V_0}{w} < q \leq \frac{V_0}{(1-\emptyset)w} \\ (1 + r_f)[w(q) - c]q & if\ 0 < q \leq \frac{V_0}{w} \end{cases}$$

where $w(q)$ is strictly deceasing in q. The manufacturer's profit can be denoted by the order q. From the manufacturer's perspective, she only sets the wholesale price, but this decision could affect the quantity of retailer's order. The manufacturer is able to affect the best-response order $q(w)$ though setting the wholesale price w. Essentially, the manufacturer can maximize her profit by setting the order indirectly.

3.4.2.1 If the retailer's best-response $q(w) = \min\left(\hat{q}_L(w), \frac{V_0}{(1-\emptyset)w}\right)$

According to analysis of the retailer's decision with the loan program involved, the best response order for the retailer is $q(w) = \min\left(\hat{q}_L(w), \frac{V_0}{(1-\emptyset)w}\right)$. Jointly considering *LAMMA 3*, the best-response order $\hat{q}_L$ is decreasing with the wholesale price w. The inverse of the best response order, $w(q)$, is

$$w(q)=\begin{cases}\frac{V_0}{(1-\emptyset)q}, & \text{if } w(\hat{q}_L)\hat{q}_L\geq\frac{V_0}{1-\emptyset}\\ w(\hat{q}_L), & \text{if } V_0<w(\hat{q}_L)\hat{q}_L<\frac{V_0}{1-\emptyset}\end{cases}$$

And $w(\hat{q}_L)$ is the inverse of the function $\hat{q}(w)$. Let $R_m(\hat{q}_L)=w(\hat{q}_L)\hat{q}_L$. $R_m(q)$ is the manufacturer's revenue which is paid by the retailer. The equation $V_0<w(\hat{q}_L)\hat{q}_L$, assures that the retailer's expenditure of the order is greater than his initial wealth and he borrows money from the bank, i.e. $L>0$. In addition, according to the constraint (4) in section 3.4.1, the bank set the credit limit (credit line) to the retailer, the loan should meet the equation $L\leq\emptyset wq$. Consider the **COROLLARY 1**, we can get the equation $\mathrm{w}(\hat{\mathrm{q}}_\mathrm{L})\hat{\mathrm{q}}_\mathrm{L}<\frac{\mathrm{V}_0}{1-\emptyset}$.

Furthermore, let $\tilde{q}$ denote the soliton of the equation $\frac{(1+r_f)w(\hat{q}_L)\hat{q}_Lf(b)}{p\bar{F}(b)}=1$, we can obtain the following conclusion:

LEMMA 4 If the bank is involved, the manufacturer's revenue $R_m(\hat{q}_L)$ is unimodal. let $\underline{q}$ is the minimum in left point, which can be obtained from the equation $\hat{q}_L\overline{F}(\hat{q}_L)=\frac{(1+r_f)V_0}{p}$.

Then, the best-response order meets the equation $\underline{q}<\hat{q}_L<\tilde{q}$.

Let $\bar{q}$ denotes maximum of the manufacturer's revenue $R_m(\hat{q}_L)$, which can be obtained from the equation $\frac{\partial R_m(\hat{q}_L)}{\partial\hat{q}_L}=0$. *LEMMA 4 indicates* that $R_m(\hat{q}_L)$ is increasing with best-response order $\hat{q}_L$ when $\hat{q}_L\in\left(\underline{q},\bar{q}\right)$ and decreasing with best-response order $\hat{q}_L$ when $\hat{q}_L\in(\bar{q},\tilde{q})$. Thus, there are two cases of the relationship between the manufacturer and the value $\frac{V_0}{1-\emptyset}$: (i) $R_m(\bar{q})\leq\frac{V_0}{1-\emptyset}$ and $R_m(\bar{q})>\frac{V_0}{1-\emptyset}$. In the following, we discuss them separately.

(i) If $R_m(\bar{q})\leq\frac{V_0}{1-\emptyset}$, the credit limit (credit line) the bank provides is enough great. The retailer can finance the order with the loan program by any wholesale price $w(\hat{q}_L)$ the manufacturer sets. Then, the reverse function of the best-response order is $w(\hat{q}_L)$, we insert $w(\hat{q}_L)$ into the manufacturer's objective function,

$$\pi_M=\left(1+2r_f-r\right)w(\hat{q}_L)\hat{q}_L-\left(1+r_f\right)c\hat{q}_L+\left(r-r_f\right)V_0$$

The manufacturer's objective function is related to the best-response order $\hat{q}_L$. According the algebraic operation, the manufacturer can choose the optimal $\hat{q}_L$ to maximise his profit instead of the wholesale price w. The first order derivative of the manufacturer's objective on the best-response order is

$$\frac{\partial \pi_M}{\partial \hat{q}_L} = \left(1 + 2r_f - r\right)\frac{\partial R_m(\hat{q}_L)}{\partial \hat{q}_L} - c$$

Let $\ddot{q}$ denote the optimal order chosen by the manufacturer in this situation. The manufacturer's objective function is increasing with $\hat{q}_L$ when $\hat{q}_L \in (\underline{q}, \ddot{q}]$ and decreasing with $\hat{q}_L$ when $\hat{q}_L \in (\ddot{q}, \tilde{q}]$. Since the optimal order $\ddot{q}$, meet the equation $\ddot{q} < \bar{q}$, and it can be obtained from the equation,

$$\frac{\partial R_m(\hat{q}_L)}{\partial \hat{q}_L} - \frac{c}{1 + 2r_f - r} = 0$$

(ii) If $R_m(\bar{q}) > \frac{V_0}{1-\emptyset}$, there are two detailed case to discuss. let q_1 denote the intersection of the $R_m(\hat{q}_L)$ and $\frac{V_0}{1-\emptyset}$, (i) when $q_1 < q < \bar{q}$, then $R_m(\hat{q}_L) > \frac{V_0}{1-\emptyset}$, and when $\underline{q} < q < q_1$, then $R_m(\hat{q}_L) > \frac{V_0}{1-\emptyset}$. Thus, the inverse of the best-response order is

$$w(q) = \begin{cases} \frac{V_0}{(1-\emptyset)\hat{q}_L}, & \text{if } q_1 < \hat{q}_L < \bar{q} \\ w(\hat{q}_L), & \text{if } \underline{q} < \hat{q}_L \leq q_1 \end{cases}$$

We insert the inverse of the best-response of the order into the manufacturer's objective function.

$$\pi_M = \begin{cases} \left(1 + 2r_f - r\right)\frac{V_0}{1-\emptyset} - cq + \left(r - r_f\right)V_0, & \text{if } q_1 \leq q < \bar{q} \\ \left(1 + 2r_f - r\right)\widehat{w}(q)q - cq + \left(r - r_f\right)V_0, & \text{if } 0 < q < q_1 \end{cases}$$

The manufacturer's objective is related to the best-response order $\hat{q}_L$. Thus, the manufacturer will maximize his profit by choosing the best-response order $\hat{q}_L$. There are two cases, in one scenario, when the order is in the range $q_1 < \hat{q}_L < \bar{q}$, the manufacturer's profit is decreasing in $\hat{q}_L$. The manufacturer will choose q_1 to maximize his profit. In the other scenario, when the order is in the range $0 < q < q_1$, there are also two cases, (i) if $q_1 < \ddot{q}$, the manufacturer's profit is increasing, and the optimal order for the manufacturer is q_1; (ii) But if $q_1 > \ddot{q}$, the manufacturer's profit is concave, and the optimal order is $\ddot{q}$. In summary, the optimal order for the manufacturer is $min(\ddot{q}, q_1)$ when $R_m(\bar{q}) \leq \frac{V_0}{1-\emptyset}$.

Because the wholesale price is unique for the order q^*, we can get the equilibrium wholesale price w^*. If the retailer borrows money from the bank, according to the equilibrium wholesale price w^* and the order q^*, the loan accounts also can be calculated from $L^* = w^*q^* - V_0$.

3.4.2.2 If the retailer's best-response $\boldsymbol{q(w) = \hat{q}_N}$

Given the wholesale price, the optimal order is $\hat{q}_N$. If the retailer has enough initial wealth, he will not benefit from a loan. In this case, the inverse of the retailer's best-response function is

$$w(\hat{q}_N) = \frac{p}{(1 + r_f)} \bar{F}(\hat{q}_N)$$

By bringing the inverse of the best-response function into the manufacturer's profit function, we can rewrite the manufacturer the profit function, which is only related to the order:

$$\pi_M = (1 + r_f) w(\hat{q}_N)\hat{q}_N - c\hat{q}_N$$

Let $\bar{q}_N$ denote the maximum of the quantity of order $\hat{q}_N$, The first order derivative of the manufacturer's revenue $R_m(\hat{q}_N) = w(\hat{q}_N)\hat{q}_N$ is,

$$\frac{\partial R_m(\hat{q}_N)}{\partial \hat{q}_N} = \frac{p}{(1 + r_f)} \bar{F}(\hat{q}_N) \left[1 - \frac{\hat{q}_N f(\hat{q}_N)}{\bar{F}(\hat{q}_N)}\right]$$

Since the demand distribution with the increasing failure rate, $\frac{f(\hat{q}_N)}{\bar{F}(\hat{q}_N)}$ is increasing with $\hat{q}_N$ and $\frac{\hat{q}_N f(\hat{q}_N)}{\bar{F}(\hat{q}_N)}$ is also increasing with $\hat{q}_N$. Thus, the manufacturer's objective function is unimodal.

Let $\mathring{q}_N$ denote the optimal order when maximising the manufacturer's objective function. $\mathring{q}_N$ can be obtained from the following equation, $p\bar{F}(q)\left[1 - \frac{qf(q)}{\bar{F}(q)}\right] = c$.

The corresponding optimal wholesale price is $\mathring{w}_N$. It can be seen that $\mathring{q}_N < \bar{q}_N$. Thus, $w(q)q$ is increasing in q when $q \in (0, \mathring{q}_L]$. Let V_c donate the critical point of V_0, $V_c = \mathring{w}_N \mathring{q}_N$. In the case when $V_0 < V_c$, the retailer can benefit from the loan and the optimal order is q^*. While in the case when $V_0 \geq V_c$, the retailer can also benefit from the loan but the optimal order is $\mathring{q}_N$.

Considering all of the cases, let q^* denote all of optimal order for both considering the retailer's and the manufacturer's profit. the optimal order q^* can be obtained.

<u>PROPOSTITION 2</u> The manufacturer chooses the order, which is the equilibrium order.

$$q^* = \begin{cases} \ddot{q}, & if\ R_m(\bar{q}) \le \frac{V_0}{1-\emptyset}\ \ and\ q_N^{\circ} > \underline{q} \\ min(\ddot{q}, q_1), & if\ R_m(\bar{q}) > \frac{V_0}{1-\emptyset}\ \ and\ q_N^{\circ} > \underline{q} \\ q_N^{\circ} & if\ R_m\left(\underline{q}\right) > \frac{V_0}{1-\emptyset}\ and\ q_N^{\circ} < \underline{q} \\ q_N^{\circ} & if\ R_m\left(\underline{q}\right) \le \frac{V_0}{1-\emptyset} \end{cases}$$

2.4.3 The Bank

We assume that the bank has ability to get a ratio k asset from the retailer. If the bank has the full information about the retailer, the ratio k=1. At the beginning of the season, the bank sets an interest rate r and the credit line coefficient ∅ to the retailer. At the end of the season, if the retailer chooses to repay, the bank will get both the loan and the interest. But if the retailer defaults, the bank takes the ratio k of retailer's final wealth, as the repayment of the loan and the interest.

So let $P(D)$ denote the repayment from both the retailer and the manufacturer, i.e. the bank's final wealth in this game. The expected repayment can be written as,

$$E[P(D)] = \left(1 - P_{Dop}\right) * \{\{1 - Pr[D \le (q^* - b^*)]\} r_f L^* + k * p * \int_0^{b^*} xf(x)\mathrm{d}x\} + P_{Dop} * k * \min(q, D)$$

The first part is the repayment if the retailer does not default on purpose, which includes two terms inside the brackets: the first term is the amount of full repayment in the case when the retailer is not bankrupt; The second term is the repayment of the retailer's final wealth when the retailer is bankrupt. Here we should notice that when the retailer defaults with the reason of bad demand, the bank can only get a ratio k of its asset. The second part is the asset that bank can seize from the retailer if it defaults on purpose. Its probability is as mentioned in the retailer part P_{Dop}. In the perfectly competitive financial market, using coefficient r and ∅ , we assume that the bank's expected profit is zero. The bank can give the loan to satisfy the equation,

$$\left(1+r_f\right)L^* = \left(r-r_f\right)L^* + E[P(D)]$$

The left side of the equation is the bank's expected wealth of loan at the end of the selling period. On the right side of the equation, the first term is a part of the loan interest paid back by the manufacturer. The second term is the retailer's expected payback to the bank. The bank can adjust the interest r or credit line Ø to meet the equation.

In this section, we analyse the decisions of the three parties with the risk-free loan program. According to the results in this section, we formulated the interactions among the three parties with the risk-free interest loan program, the three parties with the interest-free loan program and the two players without any loan program, and analysis of comparison in section 3.5.

2.5 numerical analysis

To further test the findings from the theoretical analysis and compare our free-risk interest loan program model with the interest-free loan program model, in this section, we employ the numerical experiment for the three-party game, i.e. the bank, the manufacturer, and the retailer. To simplify the model, we can assume that the bank has full information about the retailer, which implies that k=1. Under this assumption, the retailer will never choose to default on purpose because the constraint $V_1 > V_d = 0$ is always true. According the LEMMA 2, we may choose the demand distribution with an increasing failure rate, such as uniform, the exponential, and the truncated normal distributions. All of the results are consistent. Thus, the following analysis present the results based on a uniform distribution. The stochastic demand from the customer market follows uniform distribution, $\mathrm{D} \sim [0{,}10]$. Let the $\mathrm{p} = 1, \mathrm{c} = 0.1$ and $r_f = 5\%$, the interest can be attained from the equation, $\left(1+r_f\right)L^* = \left(r-r_f\right)L^* + E[P(D)]$. Subsequently, the equilibrium values, i.e. the order, the retailer retailer's and the manufacturer's profit, can be obtained corresponding to the retailer initial wealth under both of the loan programmes, i.e. the interest-free loan program and the risk-free interest loan program. To be notable, let $\emptyset = 0$ is the bench mark case where the bank does not help the retailer solve its initial wealth constraint problems. Then, we compare the equilibrium values under the interest-free and risk-free interest loan program against this benchmark case.

The effect of loan program can be indicated in the numerical analysis. To describe the efficiency of the loan, let $\emptyset_R$ denote the actual credit line coefficient, which contribute to the calculation of the actual loan that the retailer borrowed for ordering products and $\theta_a = \frac{L^*}{w^* q^*}$. Let θ_L denote the rate of the loan availability and $\emptyset_L = \left[\frac{w^* q^* - V_0}{L^*}\right]^+$.

2.5.1 The analysis of the game with risk-free interest loan program, i.e. $\emptyset = \mathbf{0.5}$.

Figure 2.1 and Figure 2.2 bellow show the relationship between the retailer's initial wealth and the equilibrium value, i.e. the order q, the wholesale price w, the retailer's profit, the manufacturer's profit the loan, the interest rate, and the bankrupt, with the risk-free interest loan program when the credit line $\emptyset = 0.5$. Every figure has three distinguishing intervals. In the first interval I, the equilibrium order q in Figure 2.1(a), the retailer's profit in Figure 2.1(d), the manufacturer's profit in Figure 2.1(c) are all increasing in the retailer's initial wealth since the retailer borrows the amount of money up to the credit line in Figure 2.2(d). In addition, the risk of retailer's bankruptcy is increasing in Figure 2.2(b), and so is the loan in Figure 2.2(c). The wholesale price in Figure 2.1(b) is decreasing. The bank would increase the rate in Figure 2.2(d) to cope with the retailer's increasing bankrupt risk.

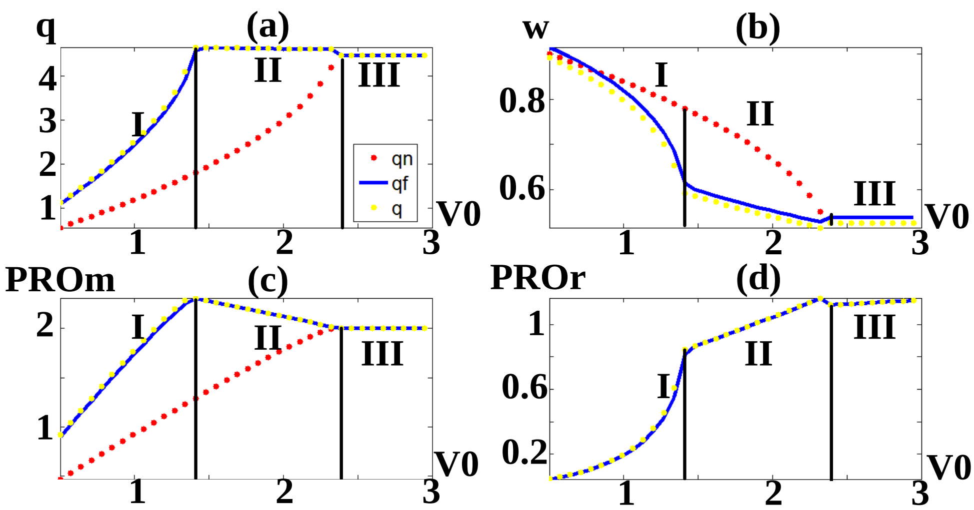


Figure 2.1The relationships between the equilibrium variables and the retailer's initial wealth

(a) the equilibrium quantity of the order $\boldsymbol{q}$,(b) the equilibrium wholesale price $\mathbf{w}$, (c) the equilibrium of the manufacturer's profit $\boldsymbol{PROm}$,(d) the equilibrium retailer's profit $\boldsymbol{PROr}$ under the uniform distribution with $\boldsymbol{\mu} = \mathbf{5}, \boldsymbol{\delta} = \frac{\mathbf{25}}{\mathbf{3}}$. The yellow dot series is for $\emptyset = \mathbf{0.5}$ with the risk-free interest loan program, the blue line is for $\emptyset = \mathbf{0.5}$ with the interest-free loan program. The red dot series is for $\emptyset = \mathbf{0}$ without the bank financing.

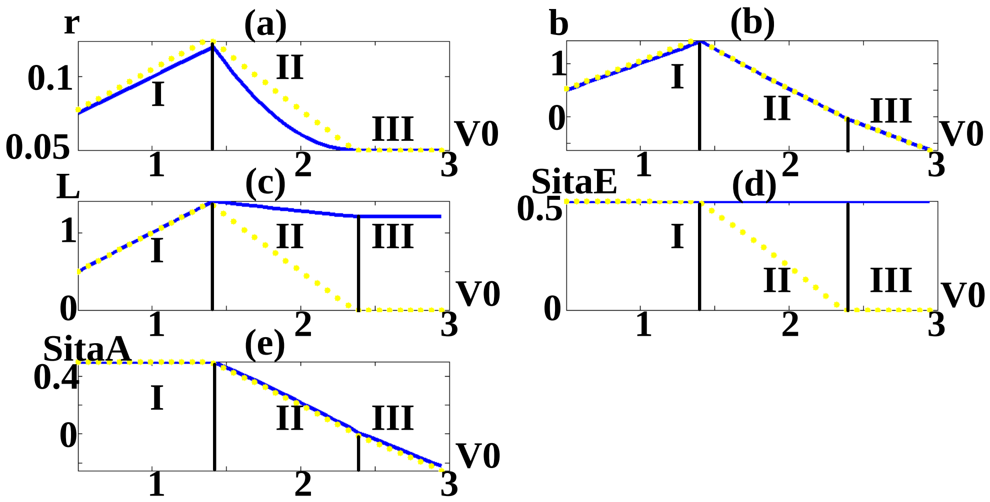


Figure 2.2 The relationships between the equilibrium variables of bank and the retailer's initial wealth

(a) the equilibrium interest $\boldsymbol{r}$, (b) the retailer's equilibrium bankruptcy threshold $\boldsymbol{b}$, (c) the equilibrium of loan $\boldsymbol{L}$, (d) the equilibrium actual used credit **SitaA**, and (d) the equilibrium efficiency of loan **SitaE** , under the uniform distribution with $\boldsymbol{\mu} = \mathbf{5}, \boldsymbol{\delta} = \frac{\mathbf{25}}{\mathbf{3}}$. The yellow dot series is for $\emptyset = \mathbf{0.5}$ with the risk-free interest loan program, the blue line is for $\emptyset = \mathbf{0.5}$ with the interest-free loan program.

In the second interval II, the retailer's profit in Figure 2.1(d) is increasing since his initial wealth is getting greater, and he does borrow up to the credit line, and the actual credit line, $\emptyset_a$, is decreasing in Figure 2.2(e). The retailer's equilibrium order in Figure 2.1(a), the manufacturer's profit in Figure 2.1(c), and the wholesale price in Figure 2.1(b) are all decreasing in the retailer's initial wealth. However, the loan in Figure 2.2(c) is getting smaller and the retailer's profit in Figure 2.1(d) is still increasing by a growth rate lower than that in the interval II. The bank is lowering the interest rate in Figure 2.2(a) and the bankruptcy threshold in Figure 2.2(b) is decreasing.

In the interval III, the retailer's equilibrium order in Figure 2.1(a), the manufacturer's profit in Figure 2.1(c), the wholesale price in Figure 2.1(b) and the retailer's profit in Figure 2.1(d) are all constant since the retailer has enough initial wealth, he does not need to borrow money from the bank and he rejects the loan program. The loan in Figure 2.2(c) is constant to be zero. The bankrupt threshold in Figure 2.2(b) is keeping decreasing and negative.

2.5.2 The analysis of the game with interest-free loan program, i.e. $\emptyset = \mathbf{0.5}$.

The blue line in the Figure 2.1 and 2.2 show the relationship between the retailer's initial wealth and the equilibrium value, i.e. the order in Figure 2.1(a), the wholesale price in Figure 2.1(b), the retailer's profit in Figure 2.1(d), the manufacturer's profit in Figure 2.1(c) , the loan in Figure 2.2(c), the interest rate in Figure 2.2(a), and the bankruptcy threshold in Figure 2.2(b), when the bank provides an interest-free loan program and a credit line coefficient $\emptyset = 0.5$ to the retailer. The manufacturer helps the retailer pay part of the interest. Again, every figure has three distinguishing intervals.

In the interval I, the equilibrium order in Figure 2.1(a), the retailer's profit in Figure 2.1(d), the manufacturer's profit in Figure 2.1(c) are all increasing in the retailer's initial wealth since the retailer borrow up to the credit and the loan is increasing. The retailer uses up all the cash to order products from the manufacturer. The rate of the loan availability $\emptyset_a = 1$. The wholesale price in Figure 2.1(b) is decreasing. The bank increases the rate in Figure 2.2(a) and the retailer's bankrupt risk is also increasing.

In the second interval II, the retailer's equilibrium order in Figure 2.1(a), the manufacturer's profit in Figure 2.1(c), the wholesale price in Figure 2.1(b) are all decreasing in the retailer's initial wealth since the retailer does not use up his cash to order products. Also, the rate of the loan availability $\emptyset_a < 1$, which indicates the retailer save some part of the cash for a risk-free interest. The loan that the retailer borrows is decreasing. The retailer's profit in Figure 2.1(d) is increasing. The bank is lowering the interest rate and the bankrupt threshold is decreasing.

In the interval III, the retailer's equilibrium order in Figure 2.1(a), the manufacturer's profit in Figure 2.1(c), the wholesale price in Figure 2.1(b), and the retailer's profit in Figure 2.1(d) are all constant since the retailer has enough initial wealth, but he would still borrow money from the bank for a risk interest loan. The rate $\emptyset_a = 0$ in Figure 2.2(e), which indicates that the loan is not benefit for neither the retailer nor the manufacturer. The bankruptcy threshold in Figure 2.2(b) is keeping decreasing and negative.

2.5.3 The analysis of the game without bank involvement, i.e. $\emptyset = 0$.

The line in the Figure 2.1 shows the relationship between the retailer's initial wealth and the equilibrium value, i.e. the order in Figure 2.1(a), the wholesale price in Figure 2.1(b), the retailer's profit in Figure 2.1(d), the manufacturer's profit in Figure 2.1(c) when the credit line $\emptyset = 0$, which is a special case that there is no bank program. Every figure has three distinguishing intervals, in the interval I and the interval II trends of the line series are same for every figure.

In the first interval I and the second interval II, the retailer's equilibrium order in Figure 2.1(a), the retailer's profit in Figure 2.1(d) and the manufacturer's profit in Figure 2.1(c) are all increasing in the retailer's initial wealth. the wholesale price in Figure 2.1(b) are decreasing. In the third interval III, Figure 1 shows that the retailer's equilibrium order in Figure 2.1(a), the manufacturer's profit in Figure 2.1(c), the wholesale price in Figure 2.1(b), and the retailer's profit in Figure 2.1(d) are all constant since the retailer has enough initial wealth, he has no need to borrow money from the back and he rejects the loan program.

2.5.4 Comparison between the result with a loan program and the one without a loan program.

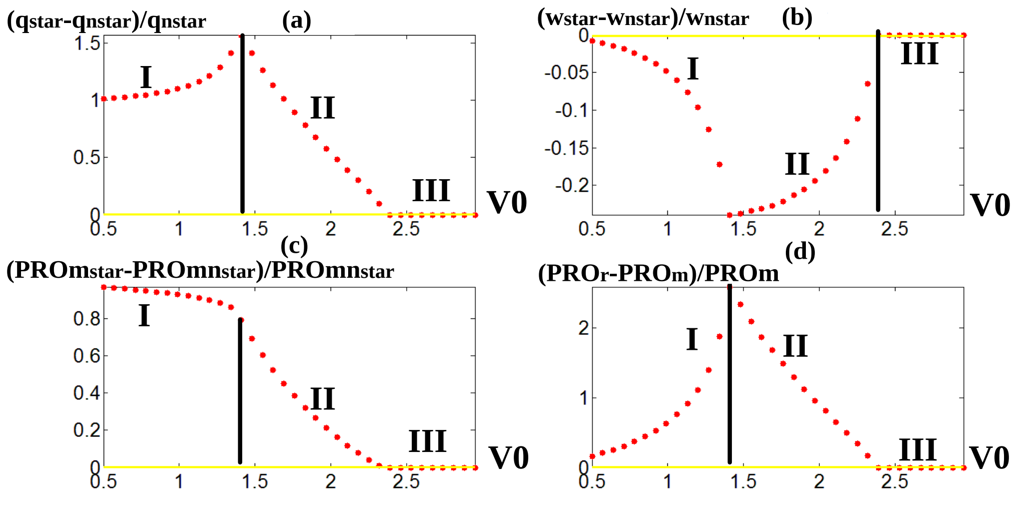


Figure 2.3 The relationships between the growth rate of variables with the risk-free interest loan program and the retailer's initial wealth

(a) growth rate of the equilibrium quantity of order q, (b) growth rate of equilibrium wholesale price $\boldsymbol{w}$, (c) growth rate of the equilibrium manufacturer's profit, (d) growth rate of the equilibrium manufacturer's profit, under the uniform distribution with $\boldsymbol{\mu} = \mathbf{5}, \boldsymbol{\delta} = \frac{\mathbf{25}}{\mathbf{3}}$. The red dot series is for $\emptyset = \mathbf{0.5}$ with the risk-free interest loan program, the yellow line is benchmark line $\mathbf{y} = \mathbf{0}$,

When the retailer is willing to borrow money from the bank, i.e. in the interval I and II of the Figure 2.3, both of the interest-free loan and the risk-free interest loan program improve the retailer and the manufacturer's profit significantly and the retailer would order more products because he has more cash available to order and the bank share the demand risk with the retailer. When the retailer's initial wealth is enough. In the interval III, both of the retailer's and the manufacturer's profit are constant and are the same as they are in a game without loan program.

2.5.5 Comparison between the risk-free interest loan program and the interest-free loan program

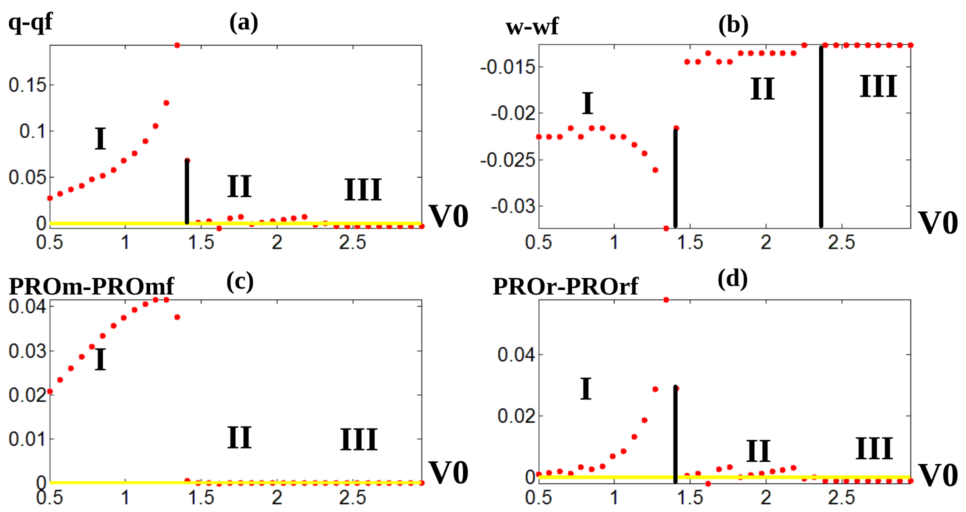


Figure 2.4 The relationships between the difference values, which between variables with the risk-free interest loan program and the ones with the interest-free loan program, and the retailer's initial wealth

(a) difference values of quantity of equilibrium order $q - qf$, (b) difference values of equilibrium wholesale price $w - wf$, (c)) difference values of equilibrium manufacturer's profit, (d)) difference values of equilibrium retailer's profit, under the uniform distribution with $\mu = 5, \delta = \frac{25}{3}$. The red dot series is for $\emptyset = 0.5$, for the risk-free interest loan program and interest-free loan program , the yellow line is benchmark line $y = 0$,

In the first interval I of the Figure 2.4, both of the retailer's profit in Figure 2.4(d) and the manufacturer's profit in Figure 2.4(c) increases faster and greater with the risk-free loan program, the retailer orders more products in Figure 3.4(a) but he faces a higher bankruptcy risk in Figure 2.5(b) and the bank sets a higher interest rate in Figure 2.5(a).

In the second interval II, the equilibrium orders in Figure 2.4(a) are same, and the retailer's profit in Figure 2.4(d) and the manufacturer's profit in Figure 2.4(c) are the same for the two programs. The bankruptcy threshold in Figure 2.4(b) is also same, and the bank provides the retailer a higher interest rate since the actual credit line is lower than the credit line provided by the bank.

In the third interval III of the Figure 2.4, the retailer's profit, manufacturer's profit, the equilibrium order with the risk-free interest loan program are all constant and same as in the interest-free loan program. But the manufacturer sets a higher wholesale price to the retailer with the interest-free loan program since the bank plays a man-in-middle role in this game, i.e. the retailer borrows money from the bank and there is no bankrupt risk. In this case, the retailer gains a risk-free interest from the manufacturer. To be respond, the manufacturer set a higher wholesale price. Contrarily, the retailer rejects the risk-free interest loan program in the interval III of the Figure 2.4.

To conclude, when the retailer's initial wealth is smaller, both the retailer and manufacturer benefit more with the risk-free loan program though the bank sets a high interest rate and the retailer has a higher bankrupt risk. When the retailer is not constrained by his initial wealth, for example in the interval III, the risk-free interest loan program can prevent the retailer from borrowing excessive money from the bank.

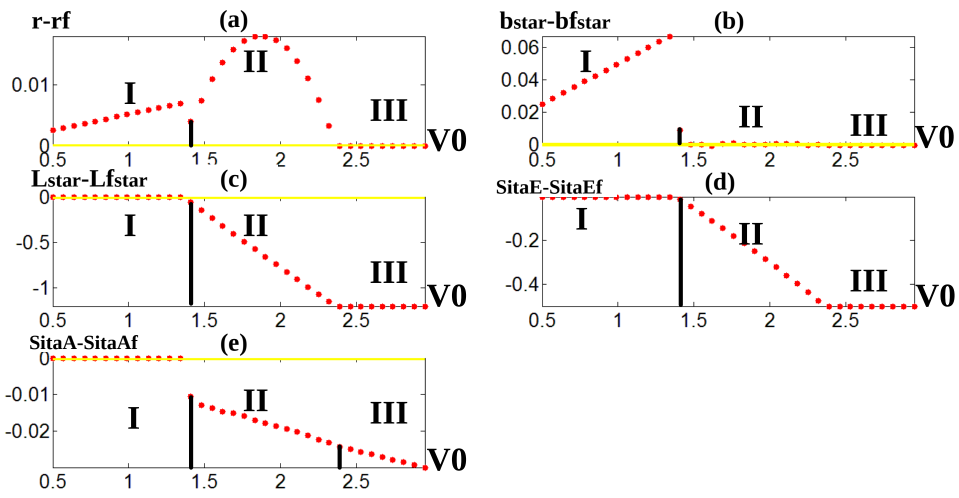


Figure 2.5 The relationships between the difference values, which between variables of the bank with the risk-free interest loan program and the ones with the interest-free loan program, and the retailer's initial wealth

(a) difference values of quantity of equilibrium interest $\boldsymbol{r-rf}$, (b) difference values of equilibrium bankruptcy threshold $\boldsymbol{b-bf}$, (c)) difference values of equilibrium the loan, (d) difference values of used credit line, (e) difference values of efficiency of the credit line, under the uniform distribution with $\boldsymbol{\mu=5,\delta=\frac{25}{3}}$. The red dot series is for $\emptyset=\mathbf{0.5}$ with both the risk-free interest loan program and interest-free loan program, the yellow line is benchmark line $\mathbf{y=0}$,

2.6 Summary

In this chapter, we studied a three-party supply chain, in which the retailer is constrained by his initial wealth. In our model, to address the issues caused by the retailer's limited initial wealth, the bank teams up with the manufacturer to provide a risk-free interest loan program. According to our analysis, this new program encourages the retailer to order more from the manufacturer than the situation without the loan program. Although there is a risk of bankruptcy of the retailer, this new program increases both the retailer's and the manufacturer's profit. We also compared the risk-free interest loan program with the interest-loan program. The results show that, when the retailer's initial wealth is small, the retailer would order more products with the risk-free loan program than he would with the interest-free loan program. Comparing to the interest-free loan program, the risk-free loan program encourages the retailer to take higher risk of bankruptcy, but increases both of the retailer's and manufacturer's profit. When the retailer's initial wealth is intermediate, the two programs will result in the same orders, the same retailer's profit, the same manufacturer's profit, and the same risk of retailer's bankruptcy, however, with the risk-free loan program, the retailer tends to borrow less than he would with the interest-free loan program. When the retailer has enough money to financial his inventory, both financial programs are rejected by the retailer, which makes the selling game a traditional two-party game with no risk of bankruptcy. To sum up all the cases, the new risk-free loan program appears more advantages than the interest-free loan program.

Chapter 3 Collaborative Outcomes of a Three-party Supply Chain Model in a Two-Period Game

3.1 Introduction

Access to finance loans is crucial for the performance of a supply chain and especially important for retailers who have limited initial wealth. Interestingly, however, there are two observations from the real world that is contrary to our common wisdom. First, it is easy to imagine that big and mature retailing companies are preferred by most banks because their transparent financial statement and stable profitability. However, De la Torre et al. (2010) found evidence from more than 60% of banks in 12 developed and developing countries, showing that almost all of the banks view Small and Medium Enterprises (SME) as their strategic sector and aim at expanding their operations aggressively in this segment. Second, it is common to expect the bank loans directly benefit the retailers. However, it is found in reality that sometimes manufacturers share the majority of the benefits from the loan programme. This paper intends to understand these two phenomenon by studying a two-period retailing game, within which the retailer has access to risk-free interest loans.

First, in our supply chain model, we consider the initial wealth of the retailers. For small and medium retailers with limited initial wealth, the lack of the capital is a critical problem for their setup, operation and fast-growing. Specifically, the lack of capital will constrain his order, and then significantly affect the supply chain's profit and weaken the supply chain's competitiveness. To solve this capital constraint issue, there are two comparable financial methods: (1) Trade credit; and (2) Bank finance. The *trade credit* is a two-party game, which can for example include a manufacturer and a retailer. The manufacturer provides a trade credit, by which the manufacturer allows the retailer to delay in paying the order cost, i.e. the manufacturer is willing to bear the retailer's default/risk. The *bank finance* is a three-party game. The bank provides a loan program for the other two supply chain members. The bank bears the bankruptcy risk of the borrower. Zhou and Groenevelt (2007) compared the advantages and disadvantages between the two methods, and suggested that *bank finance* is preferable than the *trade credit*.

Kouvelis and Zhao (2008) also found that the retailer prefers supplier accepting the *bank finance* if the loan program is optimally structured.

Among the different loan programs, we compared interest-free loan program and risk-free loan program in the preceding chapter. The results suggested that when a retailer has small initial capital, the risk-free loan program encourages the retailer to take higher risk of bankruptcy, but increases both of the retailer's and manufacturer's profit. For a medium sized retailer, the risk-free loan program prevents the retailer borrowing excessive money for saving rather than ordering. For a retailer with enough initial capital, both financial programs would be rejected. However, that single period model is not enough to explain how the profits of the retailer and the manufacturer will change in longer term after the loan programme ends, and who is benefiting from such loan programme from a long-term view. Also, we are interested to know, whether the value of risk-free interest loan programme for the supply chain varies according to the retailer's initial wealth or size.

In order to answer those questions, in this chapter, we set up a three-party model in a two consecutive periods, which includes a bank, a retailer, and a manufacturer, and discuss the retailer's constraint problem under the *bank finance scheme* in these two consecutive periods. This chapter is based on three assumptions: (1) the demand in the market is stochastic, (2) the retailer faces a classic newsvendor problem, and (3) the bank only provides loan program for the first retailing period. Before the first selling period, it is assumed that the bank puts forward a loan plan to the retailer, which includes (i) an interest rate and (ii) a fixed credit line, in order to improve the whole supply chain's performance. If the retailer is constrained by his initial wealth for ordering, he is willing to accept the loan plan and borrows money from the bank in the first period. Between the retailer and the manufacturer, it is a Stackelberg game. The manufacturer acts as a leader and dominantly sets the wholesale price, also helps the retailer pay one part of the interest of the loan. The retailer, as a follower, orders the product from the manufacturer and then sells the products to the customer as a retail price. At the end of first period, the demand is realized; the retailer needs to pay both the loan and the interest back to the bank. If the retailer's final wealth is less than the amount he owes he bank, this retailer will be bankrupt. Then the manufacturer needs to pay the promised part of the interest to the bank, and the bank will take a part of retailer's asset k which implies its ability to chase the asset from the retailer. In this case the manufacturer will pay the same promised part of the interest to the bank.At the beginning of the second period (i.e. at the end of the first period), if the retailer is bankrupt, the retailing game ends. Otherwise, the retailer and the manufacturer start a classic two-player retailer game, in which the manufacturer decides the wholesale price and the retailer decides quantity of products that he wants to order.

By analysing this model, we can study how the bank loans impact the profit of manufacturer and the retailer not only in immediate period when the loan is available, but also in the longer period after the loan program finishes. In addition, because the initial wealth of the retailer is the critical input of this model, we can study how the bank loans influence the performance of the retailer with different size. To the best of our knowledge, this research is the first to enable such analysis with two objectives:

(1) To set a risk-free interest loan for the member of supply chain who is constrained by his wealth;

(2) To extend the game from one single period to two periods.

To achieve these goals, first, in Section 3.2, we review studies that model supply chain with bank involved and that study two or multiple retailing periods. Based on that, Section 3.3 describes our model in details. Then the theoretical analysis results are presented in the Section 3.4 and numerical analysis results are presented in section 3.5. Finally a brief conclusion is given in Section 3.6.

3.2 Literature review

The problems of limited initial capital could be addressed through operational or financial measures. Modigliani and miller (1958) claimed that the retailer's financial decisions and the operational decisions were independent in the competitive financial market. Hence, most research of the operation focus on the collaboration/coordination of the supply chain and ignore the financial problem of the supply chain members (Bresnahan and Reiss, 1985; Spengler, 1950; Lariviere and Porteus, 2001; Cahon, 2003).

However, more recent studies show that financial measures do have a role in influencing the operational decisions such as the order and price, as well as the profit of the supply chain. For example, Buzacott and Zhang's (2004) study showed that the asset-based financing influences a single firm's operational decision, i.e. the newsvendor's ordering. Zhou and Groenevelt (2007) studied a three-party model with a capacitated retailer, in which the manufacturer teams up with the bank to offer an interest-free loan to the retailer. Their results indicate that the loan program can significantly improve the supply chain profit. Kouvelis and Zhao (2010) discuss the three-party model when the bankruptcy cost exists. However, all of those studies are based on a single-period game. It is unknown that how financial support could impact the profit of manufacturers and retailers in a longer term after the programme ends.

Many existing studies about long period retailing model do not consider financial issues, hence cannot answer this question either. For example, Anupindi and Bassok (1999) study the centralized model and the decentralized model in infinite horizon, but their study focuses on the impact of “market research” on the supply chain profit. More importantly, neither of the two models includes the bank or finance measures. For another example, Debo and Sun (2004) compared a single-period interaction and a long-term period interaction, but based on the simple two-player the wholesale price contract. Their results indicate that the coordination cannot be achieved in a single-period game, but can be achieved in a long-term period game if the discount factor of the supply chain members is high. The wholesale price is decreased by the manufacturer and the order is increased by the retailer in the long-period game. Swinney and Netessine’s (2009) study is also about two-party models in single-period and two-period games. The result indicates that the single period game is the optimal choice that minimises the probability of supplier’s failure; otherwise, the long-term game is better. Chao, Chen and Wang (2008) study the two-party model with the dynamic inventory, in which the retailer replenishes the stock before each sell period. The outcomes in that paper include the optimal inventory policy for each period is obtained, and the dependence of the optimal operational policy on the financial operational is characterized. Babich (2010) study a long-term game model with a risky supplier and a manufacturer, in which the supplier sells the production to a manufacturer who reserves the inventory and faces an uncertain demand. The results show that the managers can continue using the existing decision support system if the managers believe that the business situation is accurately described under the assumption that the optimal ordering decisions and the subsidy decisions are independent. These studies about multi-period games provide a new view of the supply chain and analysis tools. However the financial problem of supply chain members is not yet considered.

Studies that both address the financial problems in the supply chain and consider multiple periods are very rare. Wei and Shang (2013) build a firm's inventory which aims to satisfy a non-decreasing demand in a long-term period, the firm provides the trade credit to the customers. The results show that when the sales collection period is no less than the purchases payment period, the myopic policy is optimal. Whereas, if the collection period is short than the payment period, a lower bound the optimal cost is obtained. According to results from Zhou and Groenevelt's (2007) one-period model, we know that interest-free loan program is similar to the trade credit program, and both of them has big disadvantage if the retailer is constrained by his initial wealth, i.e. the retailer will over borrows.

This paper draw upon Zhou and Groenevelt's (2007) three-party model, but fill the gap in the literature by applying a different loan program, i.e. risk-free interest loan program to address the initial wealth constraints of the retailer. Moreover, we extend this model to consider a two-period Stackelberg game. The details of this model are presented in the next section.

3.3 Model description and analysis method

In our new model, the three parties involved in the supply chain include a bank, a manufacturer and a bank, and their decisions. We assume that: (i) all three parties are risk-neutral players, and have complete information about each other, such as the retailer's initial wealth and so on; (ii) both the manufacturer and the retailer aim to maximise their individual profits; (iii) only the retailer's initial wealth is constraint; and (iv) the bank requires a fair return of loan from the program; (5) No inventory is carried over between periods. The retail prices p are same and fixed during the two periods, the demand D during the two periods are the same distribution.

In this game, firstly, the bank sets the interest rate, r, and the credit line ∅ to obtain a fair return. Secondly, the manufacturer maximize her profit by setting the wholesale price $w1$ and $w2$.Thirdly, the retailer maximize his final wealth V2 by setting the order q1 and q2.

3.3.1 First period of the selling game:

At the beginning of the first selling period, the demand $D1$ cannot been observed, $D1 \in [0, +\infty]$, but participants know the demand's distribution function

$F(x)$ and the density function $f(x)$. F is differentiable, non-decreasing and $F(0) = 0$.

(i) The bank (denoted by the subscript B) offers a contract to the retailer. In the contract, the bank decides both the interest rate r and the credit line coefficient ∅ (also called credit limit). At the same time, it knows its ability to grab the asset k.

(ii) The manufacturer plays a Stackelberg game with the retailer. In this game, the manufacturer is the leader who sets the wholesale price and is willing to help the retailer pay a proportion of the interest if the retailer borrows money from the bank, i.e. $(\mathrm{r} - r_f)(w1q1 - V_0)$ $where\ w1q1 - V_0 > 0$. The manufacturer decides wholesale price $w1$ for first period and $w2$ for the second period, in order to maximise her profit after the two selling games.

(iii) The retailer is the follower in the Stackelberg game. He has initial wealth V_0. The retailer decides the quantity of the order $q1$ for the first period, order $q2$ for the second period and the amount of loan, L to maximise his expected profit after the selling games. His decision is based on the wholesale price $w1$ and $w2$ set by the manufacturer, the credit line coefficient ∅ and the interest rate,r, set by the bank, and his own initial wealth.

At the end of the first selling period, the demand is observed. The manufacturer pays the interest, $(r - r_f)(w1q1 - V_0)^+$, to the bank. The situation is similar to what was described in chapter 2. If the retailer does not default on purpose and retailer's final wealth is more than the total amount he owes the bank, it should pay back the amount, $L + r_f(w1q1 - V_0)^+ + r(L + V_0 - w1q1)^+$, to the bank. Otherwise the retailer will be bankrupt and the bank will take a part k of his assets. In this case, there will be no second selling period. Because we assume that no inventory is carried over between periods, all the V1 doesn't count the redundant products ordered by the retailer.

3.3.2 The second period of the selling game:

If the retailer is not bankrupted, he and the manufacturer will start the second selling period. In this second selling period, the bank is not involved, which means the loan programme has come to an end and will not be renewed.

At the beginning of the second selling period, The retailer's final wealth by the end of the first period, i.e.,V_1, becomes his initial wealth of the second period. Then the manufacturer and the retailer play a simple two-player Stackelberg game.

(i) The manufacture sell products at the wholesale price w_2.
(ii) The retailer: order product q_2 from the manufacturer considering the wholesale price w_2, and his initial wealth V1.

At the end of the second selling period, the demand $D2$ is realised. The retailer's final wealth at end of the second period game is 0 if he is bankrupted during the first period. Otherwise, his final wealth V2 can be expressed as:

$$V_2 = p\min(q_2, D_2) + \left(1 + r_f\right)(V_1 - w_2 q_2)^+$$

We use the backwards induction to analyse the game. First step, given (1) an interest rate, (2) a credit line coefficient, and (3) a wholesale price, we can maximize the retailer's profit and find the best-response order $\mathrm{q}(w)$, which is related to the wholesale price w. Second step, we assume that the credit line and the interest are known, we insert beset-response order, $\mathrm{q}(w)$, into the manufacturer's objective function and maximize her profit by the wholesale price w. Then then the optimal wholesale price $w(r, \emptyset)$ can be obtained. Then optimal order $q(r, \emptyset)$, also can be obtained. Third step, we plug optimal wholesale price $w(r, \emptyset)$, and the optimal order $w(r, \emptyset)$, into the bank's payment function, and find the final equilibrium of the variables, i.e. q,w,r and so on.

3.4 Analysis results: Three party game in Two-period game with the uniform distribution demand

In this section, we extend the one-period Stackelberg game to a two-period continuous game. Let $D_i, i \in (1,2)$, denote the demand in each period. In this section, the demands in each period are assumed as the uniform distribution demand, i.e.$(0, \xi)$, the Cumulative Distribution Function (CDF) are denoted as $F(x) = \frac{x}{\xi}$ and $\bar{F}(x) = \frac{\xi - x}{\xi}$. $f(x) = \frac{1}{\xi}$ are denoted are their Probability Distribution Function (PDF).

3.4.1 The retailer

In this section, I will discuss the retailer's decisions in each period. Firstly, I will find the retailer's objective functions in each period, then the overall objective function is found to analyse the retailer's decision.

3.4.1.1 In the first period

At the beginning of first period, the bank provides ① a loan with the interest, r, and ② a credit line, $\emptyset$, to the retailer. There is a Stackelberg game between the manufacturer (the leader),which sets the wholesale price w_1, and retailer (the follower), which borrow money, L_i, from the bank and order product q_1 from the manufacturer.

At the end of first period, the demand is realized. Let V_1 denote the retailer's final wealth in the first period. The retailer's final wealth at end of the first period game is expressed as

$$V_1 = \left[(1 + r_f)(V_0 + L - w_1 q_1) + p\min(q_2, D_2) - (1 + r_f)L\right]^+$$

$$\text{s.t. } 0 \leq L \leq \emptyset w_1 q_1$$

According to the chapter 3, let $b(q_1)$, denote the bankrupt threshold,.

$$b(q_1) = \frac{(1 + r_f)(w_1 q_1 - V_0)}{p}$$

The retailer's final wealth should not be negative. Here we can find out the value if the retailer defaults:

$$V_d = p * \min(q, D) * (1 - k)$$

From the equation, we can conclude that when the bank has full information of the retailer, its value of default is 0. The retailer's value in the end of the first period is:

$$V_R = max(V_1, V_d)$$

At the same time, we can define the probability that the retailer default on purpose is:

$$P_{Dop} = Prob(V_1 < V_d)$$

This is the probability that the retailer can benefit from the default because the retailer can hide some of his asset that the bank cannot find.

Let V_1 denote the retailer's final wealth in the first period. Like the game in the single period game we have discussed, if the demand is less than the bankrupt threshold, i.e. $D_1 \leq b(q_1)$, the retailer does not have enough money to pay back to bank，the retailer apply to go bankrupt and the bank takes away all of his asset. Otherwise, the retailer pays back the money $L + r_f(wq - V_0)^+ + r(L + V_0 - wq)^+$ to the bank.

3.4.1.2 In the second period

The retailer's final wealth, i.e. V_1, at the end of the first period is taken as the initial wealth of the second period. Let V_2 denote the retailer's final wealth in the second period. There are two situations for the value of the retailer final wealth at the end of the first period.

(1) If $V_1 = 0$, the game stops at the end of the first period, and the retailer's final wealth is zero, i.e. $V_2 = 0$.
(2) If the $V_1 > 0$, the manufacturer play a stackelberg game during the second period.

The expenditure of the products the retailer orders from the manufacturer is non-decreasing by his wealth at the end of the first period, i.e. V_1.

Lemma 1 If the retailer is not bankrupt at the end of the first period, the order at the beginning of the first period must meets the equation, $\beta \leq q_1, where\ \beta = \frac{w_2 q_2}{p} + b_1$.

Lemma 1 indicates that, once the wholesale prices, i.e. $w_1 and\ w_2$,and the retailer's initial wealth are both given, the order in the second period q_2, should be restrict in the interval （0，$\left(1 + r_f\right)V_0 + \frac{[p-(1+r_f)w_1]q_1}{w_2}\Big]$. And the upper limit is increasing with the order q_1,in the first period. The order in the first period may affect the chooses of order in the second period.

3.4.1.3 Consideration about the two periods

Overall the two conditions (1) the retailer is bankrupt and (2) the retailer is not bankrupt, at the end of the first period, all the possible retailer's final wealth with decisions in the end of the second period are as following,

① $w_1q_1 \leq V_0, 0 < D_1 \leq q_1, w_2q_2 \leq pD_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \leq q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

② $w_1q_1 \leq V_0, 0 < D_1 \leq q_1, w_2q_2 \leq pD_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

③ $w_1q_1 \leq V_0, q_1 < D_1, w_2q_2 \leq pq_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \leq q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

④ $w_1q_1 \leq V_0, q_1 < D_1, w_2q_2 \leq pq_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

⑤ $w_1q_1 > V_0, \frac{(1+r_f)(w_1q_1 - V_0)}{p} < D_1 \leq q_1, w_2q_2 \leq pD_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \leq q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

⑥ $w_1q_1 > V_0, \frac{(1+r_f)(w_1q_1 - V_0)}{p} < D_1 \leq q_1, w_2q_2 \leq pD_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_1q_1 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

⑦ $w_1q_1 > V_0, q_1 < D_1, w_2q_2 \leq pq_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \leq q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

⑧ $w_1q_1 > V_0, q_1 < D_1, w_2q_2 \leq pq_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

⑨ $w_1q_1 > V_0, D_1 < \frac{(1+r_f)(w_1q_1 - V_0)}{p},$

$$V_2 = 0$$

After the analysis and algebraic, the retailer's final wealth V_1, at the end of the second period can be expressed as

$$\mathrm{E}[\mathrm{V}_2(\mathrm{q}_1, \mathrm{q}_2)] = \frac{\mathrm{p}(1+\mathrm{r_f})(\mathrm{q}_1 - \beta)}{2}[\bar{\mathrm{F}}(\mathrm{q}_1) + \bar{\mathrm{F}}(\beta)] + \mathrm{pf}(\mathrm{x})\bar{\mathrm{F}}(\beta)\frac{\mathrm{q}_1^2}{2} + \mathrm{pq}_2\bar{\mathrm{F}}(\beta)\bar{\mathrm{F}}(q_2)$$

$$\text{s.t.} \quad \beta \leq q_1$$

$$q_1 \leq \frac{V_0}{(1-\emptyset)w_1}$$

The retailer's final wealth is decided by the retailer's orders at the beginning of the each period. Details of the analysis approach are seen in Appendix B.

Lemma 2 the retailer has the unique solution, i.e. $(q_1^{\circ}, q_2^{\circ})$ *when maximizing the retailer's expected profit function when given the wholesale price* (w_1, w_2) *.*

Given the wholesale price and the initial wealth, the retailer's only have one option to maximize his profit.

3.4.2 The manufacturer

The manufacture decides the wholesale prices to maximize profit. The manufacturer's profit function

$$\pi_m = (1 + 2r_f)(w_1 - c)q_1 + (1 + r_f)(w_2 - c)q_2 - (r - r_f)L$$

The first term is the manufacturer's revenue in the first period, the manufacturer receives the retailer's first payment of order at the beginning of the first period, and the manufacturer gets two-period risk-free interest. The second term is the retailer's revenue in the second period, there is single-period risk-free interest. The third term is the manufacturer's payment that the manufacturer help the retailer pay the part of the interest to the bank.

Lemma 3 there is the unique group of solutions, i.e. (w_1^*, w_2^*) *when maximizing the manufacturer's expected profit function.*

Lemma 3 indicates that manufacturer's optimal decisions on the wholesale price (w_1^*, w_2^*) if the interest rate and the credit line are given by the bank. According to the Lemma 1, there is only one solution for the retailer's decisions $(q_1^{\circ}, q_2^{\circ})$ which is corresponding to the wholesale price (w_1, w_2). In other word, the manufacturer can chooses the best-response order $(q_1^{\circ}, q_2^{\circ})$. Thus, there is unique *solution* (w_1^*, w_2^*) *for manufacturer's maximal profit, as well as the order optimal order* (q_1^*, q_2^*).

3.4.3 The bank

The bank has the complete information about the retailer and the manufacturer, thus the bank can anticipates all of the results of game between and the retailer. the bank only join the game in first period for a short financial help.

At the beginning of the first period, the bank teams with the manufacturer provide a risk-free interest loan program to the retailer, in which the banks decides the interest rate r and the credit line coefficient ∅.

At the end of the selling period, the manufacturer promise to pay a party of the interest $r_f(wq - V_0)^+$, at the end of the selling period. The demand is realized, the retailer's final wealth can be realized too, the retailer's payment to the bank is decided by the uncertain demand. So let $P(D)$ denote the repayment from both the retailer and the manufacturer, i.e. the bank's final wealth in this game. The expected repayment can be written as,

$$E[P(D)] = \left(1 - P_{Dop}\right) * \{\{1 - Pr[D \leq (q^* - b^*)]\} r_f L^* + \mathrm{k} * p * \int_0^{b^*} x f(x) \mathrm{d}x\} + P_{Dop} * k * \min(q, D)$$

The first term is the retailer's repayment if the retailer is not bankrupt, where $b^* = b^*(q_1^*, w_1^*)$. The second term is the retailer's final wealth if the retailer is bankrupt. The financial market is assumed as competitive, and the loan is fairly priced. The following equation will be met,

$$\left(1 + r_f\right) L^* = \left(r - r_f\right) L^* + E[P(D)]$$

The first term is interest paid by the manufacturer; the second term is the retailer's expected repayment. The equation can be meet when the retailer changes the r_f and the credit line ∅.

3.5 Numerical Analysis results

Following the theoretical model analysed in the preceding section, we applied a numerical simulation method to test the bank-manufacturer-retailer game with the uniform distribution demand. In this simulation, we assume the stochastic demand from the customer market follows uniform distribution, $D \sim [0,10]$. Let the $p = 1, c = 0.1$ and $r_f = 5\%$, the interest can be attained from the equation, $(1 + r_f)L^* = (r - r_f)L^* + E[P(D)]$. The simulation runs the following steps:

(i) First, the programme calculates the retailer's expected value V2 after the second period, for all possible wholesale price during the two periods, w1 and w2, and all possible orders in two periods, q1 and q2. This expected value V2 is the integral of the demand, D.

(ii) Second, it finds the maximum V2* and the corresponding order q1* and q2*.

(iii) Third, according to the q1* and q2* which maximised the expected value of the retailer, the programme calculate the manufacturer's profit, PROm, under each possible wholesale price, w1 and w2. It find the best combination of w1* and w2* which maximise the manufacturer's profit, which is PROm_star.

(iv) Fourth, according to the w1, w2, q1, and q2, it calculates the real optimum expected value for the retailer after two periods of selling game.

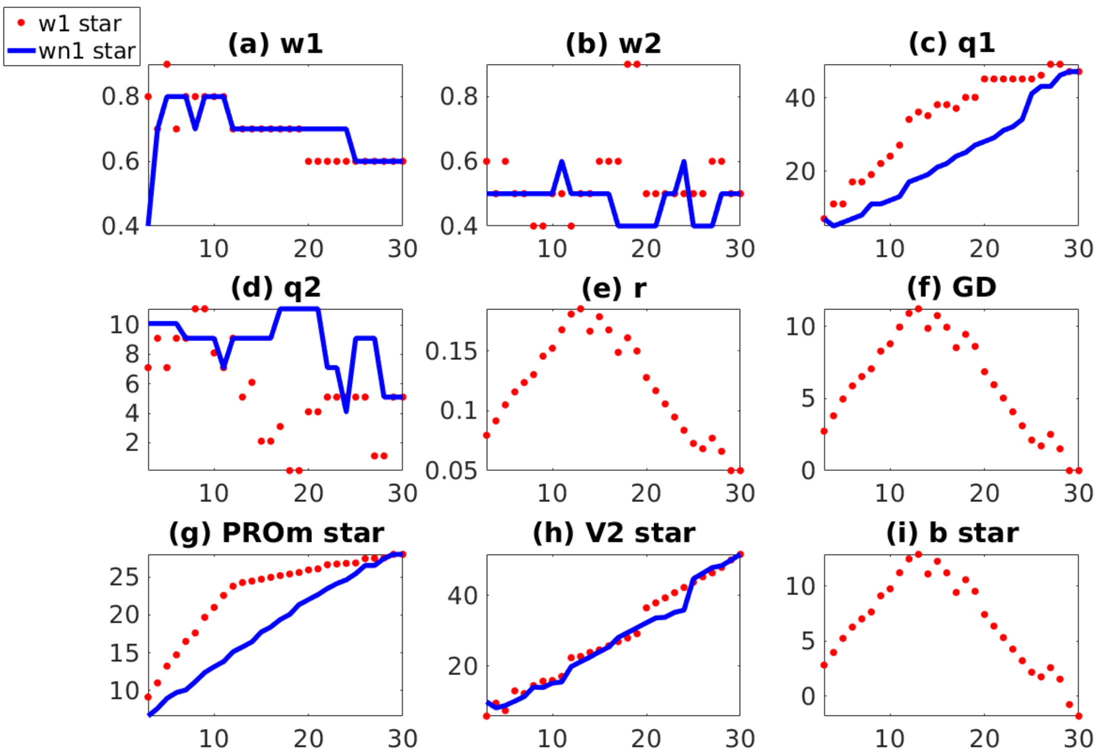


Figure 3.1 The relationships between the equilibrium variables and the retailer's initial wealth

(a) The equilibrium wholesale price w1 in the first selling period. (b) The equilibrium wholesale price w2 in the second selling period. (c) The equilibrium quantity of the order q1 in first selling period. (d) The equilibrium quantity of the order q2 in second selling period. (e) The equilibrium interest rate. (g) he equilibrium of the manufacturer's profit PROm by the end of the two selling periods. (h) The equilibrium retailer's value V2 by the end of two selling periods. (i) Bankruptcy threshold.

In the Figure 3.1, there are three distinguish intervals. (1) With the loan program, the retailer accept the bank's help of the loan program and borrow money up to the credit line, the orders in the first period are increasing with the retailer's initial wealth in the both the interval I and II , however the order in the second period are decreasing with the retailer's initial wealth in the interval I and II. The retailer's and the manufacturer's profit is increasing with the retailer's initial wealth in the both the interval I and II. The wholesale prices in the first period is decreasing with the retailer's initial wealth in the both the interval I and II. In the interval III, all the results are constant since the retailer has enough initial wealth, he does not borrow money from the bank. (2) Without the loan program, the orders in the first period are increasing with the retailer's initial wealth in the both the interval I and II , however the order in the second period are decreasing with the retailer's initial wealth in the interval I and increasing in the interval II, The retailer is increasing with the retailer's initial wealth in the both the interval I and II. The manufacturer's profit is increasing sharply with the retailer's initial wealth in the interval I and increasing gently in the interval II. The wholesale prices in the first period is increasing in the interval I and decreasing in the interval I. The wholesale prices in the second period are decreasing in the interval I and II. In the interval III, all the results are constant since the retailer has enough initial wealth.

3.5.1 The different benefits of bank loan on manufacturer and retailer from a long term perspective

Compared with results, both the manufacturer's profit and the retailer's profit are improved with the one-short loan program though the bankruptcy exists. The retailer orders more than ones without the loan program and the retailer's profit is greater in the first period. However, in the second period, the retailer orders less and the profit is less than the ones without the loan program. The manufacturer sets a lower wholesale price in the first period, the manufacturer is greater than ones without the loan program, he sets a greater wholesale price in the second period, the manufacturer is less than the one ones without the loan program.

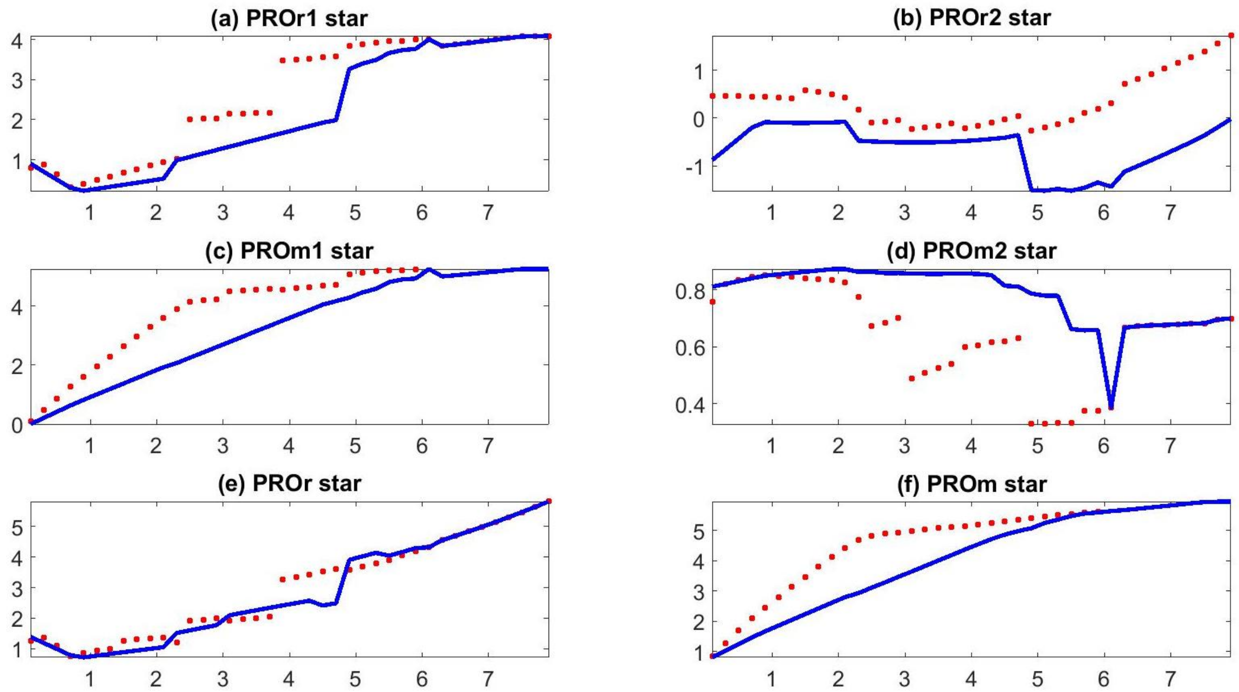


Figure 3.2 The equilibrium profit of the manufacturer and the retailer in each selling period under the constraints of the retailer's initial wealth (a) The equilibrium retailer's profit PROr1 by the end of first selling period. (b) The equilibrium retailer's profit PROr2 by the end of second selling period. (c) The equilibrium manufacturer's profit PROm1 by the end of first selling period. (d) The equilibrium manufacturer's profit PROm2 by the end of second selling period. (e) The equilibrium retailer's profit PROr by the end of two selling periods. (h) The equilibrium of the manufacturer's profit PROm by the end of the two selling periods.

3.5.2 The different benefits of bank loan on retailers with different initial wealth from a long term perspective

Comparing the results, both the manufacturer's profit and the retailer's profit are improved with the one-short loan program though the bankruptcy exists. The retailer orders more than ones without the loan program and the retailer's profit is greater in the first period. However, in the second period, the retailer orders less and the profit is less than the ones without the loan program. The manufacturer would set a lower wholesale price in the first period if the loan program is available than she would without the loan program. However, in the second period, she would set a higher wholesale price if the loan program is available.

3.6 Summary

In this chapter, I study a two-period game. The bank only joins the game in the first period and quit at the end of the first period (at the beginning of the second period). The results shows that the one-shot risk-free loan program can encourage the retailer to order more products in the first period, the manufacturer also sets a lower wholesale price, both the retailer and the manufacturer’s profit is improved. However, when the bank leave the game in the second period, the retailer orders even less than the one without the bank in the first period if the retailer is still constrained by his initial wealth. The manufacturer sets a higher wholesales price. Both the retailer and the manufacturer’s profit reduce in the second period. In the end of second period, the one-shot risk-free loan program improves the profits of the supply chain, both the retailer and the manufacturers are better off though the bankruptcy exists.

Chapter 4 The interactive mechanism of urbanisation, industrialisation and environment in Xinjiang province, China

4.1 Introduction

In recent years, the relationship among urbanization, industrialization and environment has been increasingly studied. One of the most widely applied theories is “the Environmental Kuznets Curve”, proposed by Simon Kuznets (1955), which shows a ‘U’ shape of relationship of between urbanization and environment. There are also studies and theories indicate the positive relationship between the urbanization and the industrialization (Chenery, 1975). Such relationship between urbanization, industrialization, and environment are considered as a traditional path that most of the countries follow. However, empirical studies in resource exporter countries show a different relationship among the three indexes. For example, Gollin (2013) shows that resource exporters that have urbanized without increasing output in either manufacturing or industrial services such as finance. They also document empirically that there is a distinction in the employment composition of cities between developing countries that rely on natural resource exports and those that do not.

As the largest developing country in the world, China’s urbanization rate has increased sharply in last 30 years. On the other hand, the pollution also influences people’s health and wellbeing heavily. A large amount of literature has shown that the development of urbanization in most provinces in China follows the traditional path. However, Xinjiang province as a very special province in China has a very similar situation as resource exporting countries. This area has very rich oil and gas, but very vulnerable environment. Arid climate and desertification constrain the development of the area. For this unique case, however, there is no existing study focus on whether Xinjiang’s development followed the traditional path or the path of the resource exporting countries and limited knowledge to guide the future development in this area. In this paper, we will model how urbanization, industrialisation, and environment in Xinjiang interact with each other during the past thirty years and suggest mainstay industries for cities in Xinjiang.

In this chapter, we conducted an empirical study in Xinjiang Province to improve our understanding of the urbanisation industrialization, and environmental degradation. To achieve this aim, first, this chapter reviewed the literature in Section 4.2. Then, Section 4.3 describes the two regression models we applied to study the relationship among environment, urbanisation, and industrialisation. The results are presented in Section 4.4. Based on the knowledge of the interactions among the three processes and the uniqueness of Xinjiang, we could give further recommendations to policy making. Therefore, in Section 4.5, we conducted a further study which helps the cities in Xinjiang to select the mainstay industries, which coordinates the need of urbanisation and environment protection.

4.2 Literature review

Early studies of urbanization have emphasized that urbanization is the transfer of population from rural to urban areas (Wilson, 1979). Some scholars define urbanization from the perspective of economic growth, economic agglomeration and economic structural change (Clark, 1945).

With the deepening of research, David Pearce (1990) classifies the major resource and environmental problems that occur according to the different stages of urbanization development, such as overuse of land, air pollution, noise pollution, excessive consumption of water resources, traffic congestion, etc. Then he proposed the famous model of urban development stage and environmental countermeasures. American environmental economist Grossman and Krueger (1995) used econometric methods to analyse the data of 42 developed countries, and proposed that the relationship between the improvement of urban economic level and the urban ecological environmental shows a "U" shape which is well-known as the environmental Kuznets curve (EKC). Daigee et al. (2010) analysed the relationship between air quality and urbanization in China and found that only SO2 emissions meet EKC curves. Habib et al. (2005) emphasize that the industrialization and urbanization of developing countries have had a tremendous impact on human and natural ecosystems. On the other hand, the sustainable development of the urban economy and the further improvement of the urbanization level will surely lead to the increase of the ecological environment restoration investment, and then gradually make the ecological environment tend to develop benignly. Sjak et al. (2011) pointed out that the improvement of the ecological environment is more affected by scientific and technological progress and environmental policy. It can be seen that the relationship between urbanization and the ecological environment is not yet fully understand in developing countries.

On the other hand, there are plenty literature studied the relationship between the urbanization and the industrialization. Hudson (1969) and Pederson (1970) find that urbanization is the inevitable process of economic transformation from traditional agricultural societies to modern industrial societies. Urbanization provides labour for industrialization, creates consumption demand and ultimately drives the whole country towards modernization. Chenery (1975) finds that there is a shift toward manufacturing accompanied with the growth process. Kuznets (1985) reveals that with the increase in the level of per capita national income, there is a transfer of industry and employment structure. Scholars generally believe that urbanization process is driven by the agricultural development, industrialization and the development of service industry. Many researchers argued that tradable manufacturing and service sectors are capable of higher labour productivity growth than non-tradable services (Rodrik, 2011; Buera & Kaboski, 2012). However, a few studies indicated that some parts of the world have urbanized without manufacturing growth (Hoselitz, 1955; Bairoch, 1988; Fay & Opal, 2000). Jedwab's (2013) study further supported this proposition by showing several countries that are rich in natural resources have experienced urbanization without industrialization.

Most Chinese scholars agree that China's urbanization process satisfies the environmental Kuznets curve and the driving force is the industrialization, especially the manufacture. Fang C. (2004) found the environmental Kuznets curve in northwest of China. Fang X. and Zheng H. (2013) found that the more efficient urbanization process depends on the agricultural modernization and industrial innovation. Ren and Luo (2013) argued that the tertiary industry is an important engine to promote the development of urbanization from the aspects of labour absorptive capacity, energy consumption and output value.

Government intervention also has a large influence of urbanization. Song S. (2002) pointed out that the main driving force for promoting urbanization in China is urban policy changes, economic growth and structural adjustment. Hinderson (2010) pointed out that the control and intervention of the governments to the urbanization process from the developing countries is much higher than that from the developed countries. Justin et al. (2011) claim that it is the government's development policy leads to low urbanization rate and the gap between urban and rural areas. To promote the development of urbanization, we should formulate the policies that make the mainstay industries suitable with the local endowment and environment. The mainstay industries play an increasing role in the development of urbanization in the developing countries.

4.3 Methodology to study the interaction among urbanisation, industrialisation, and environment

The literature review section found that most of existing literature focuses on the bilateral relationship either between environment and urbanisation, between urbanisation and industrialisation, or between environment and industrialisation (Hudson, 1969; Pederson, 1970; Daigee et al., 2010; Fang X. and Zheng H. 2013). Very little research studied the trilateral relationship among all the three factors: environment, urbanisation, and industrialisation (Ren and Luo, 2013). In our research, we believe that such trilateral relationship worth more in-depth study, especially in areas like Xinjiang with vulnerable environment and rely on resource exporting economy.

This section first introduces the unique environment and development situation in Xinjiang. Then, it describes indicators selected to measure factors of environment, urbanisation, and industrialisation, as well as the data source. The collected data were pre-processed before they can be applied to model the relationships among the three factors. In order to achieve more reliable results, we applied two different methods to study such relationships: the Vector Auto Regression (VAR) model and the Principle Component Regression (PCR) model. The rest of this section introduces our methods in details.

4.3.1 The case study area: Xinjiang province, China

Xinjiang province is located in the northwest border of China with large core and oil reserves. Currently there are 138 kinds of minerals, 83 of them are proven reserves. According to the second assessment of oil and gas resources, the estimated oil reserves in Xinjiang are about 20.86 billion tons, which is 30% of the country's total onshore oil reserves. The estimated natural gas reserves in Xinjiang are about 10.3 trillion cubic meters which constitutes 34% of the country's onshore natural gas. Coal reserves in Xinjiang are about 2.19 trillion tons which is 40% of the country's forecast reserves. These properties make Xinjiang the main resource exporting province in China and make Xinjiang’s development rely heavily on resource.

In the past six decades, both urbanisation rate and industrialisation rate in Xinjiang increased, but the improvement of the industrial structure was also seen. In 1957, there were three cities and 83 counties in Xinjiang. The urban population was only 940.7 thousands. The urbanisation level is 16.86%. In 1990, there were 16 cities, 71 counties and 57 small towns, the urban population is 4.42 million and the city's basic network and the spatial layout improved gradually. By 2014, the urban population had increased to 10.59 million and the rate of urbanization had reached 46.07%.

Before 1978, when the Reform and Opening Policy of China came into force, Xinjiang’s production mainly relied on secondary industry. In 1978, the rate among primary, secondary, tertiary industries in Xinjiang was 35.8: 47.0: 17.2. During the 36 years of after 1978, the primary sector output value declined year by year, the secondary sector remained stable and the tertiary sector was rising rapidly. By 2014, the industrial structure became 16.6: 42.6: 40.8, which showed a great increase of the tertiary industry or service section. The size of service sector had caught up and gradually replaced the secondary sector to become the crucial engine of economic development. At present, the core productions of agricultural sector are cotton and food crops. The secondary sector are constitute of oil and gas extraction, electricity and heat production, chemical raw materials and chemical products manufacturing, agricultural and side line food processing and textile industry and so on. As to the service sector, the wholesale and retail trade, transportation, warehousing, the financial industry and real estate provided a huge driving-force for the growth of economy.

However, the climate in Xinjiang is extremely arid, and the vegetation coverage is very low, which make the environment in Xinjiang particularly vulnerable and sensitive to any changes. The area of extreme arid and arid regions in Xinjiang accounts for 65.5% of the total area of Xinjiang. If the semi-arid zone is included, the area accounts for 88.7% of the total area of Xinjiang. Due to the lack of water, vegetation in vast area of Xinjiang is scarce. The vegetation coverage in northern Xinjiang is only about 0.3%, while the vegetation coverage in southern Xinjiang is less than 0.1%. Such desert ecosystem is vulnerable and poor resilient. It is easy to be damaged and extremely difficult to recover. In this situation, majority of the cities, towns, and villages are located near the foot of mountains where water resource is accessible. Urban expansion and economic development is competing with local ecology on water resources and land. Even worse, mining industry for development and energy consumption increase the deterioration of the ecological environment. For example, coal burning is the main source of heating in winter when the average temperature is as low as -25 °C. It causes severe air pollution. For instance, the total amount of sulphur dioxide emissions in 2014 increased 132% comparing with that in 1995.

In this context, it is necessary to review and analyse the relationship among urbanisation, industrialisation, and environment in Xinjiang during the past three decades. Such knowledge will not only help us to design the new industry structure in Xinjian that balance environment with the development demand, but also help to understand and optimise the development in similar areas with vulnerable environment and rich nature endowment, such as Iraq, Iran, Kuwait, Saudi Arabia, and Venezuela, etc.

4.3.2 Data

Data applied in this Chapter are collected from the Xinjiang Statistical Yearbook, Xinjiang Fifty Years: 1955-2005, Taxation Yearbook of China and Labour Statistical Yearbook of China. The data covers 26 years which is from 1978 to 2014. Based on these data, we establish measurements for three factors: environment, industrialization, and urbanization. The following subsections defined these three concepts, and the indicators to measure them.

4.3.2.4 Environment impact indicator

In this research, the environment factor is measured as the performance or impact of human activities, i.e., urbanisation and industrialisation, on environment. Such impact could be either harmful or helpful for environmental capacity. We consider energy consumption and emissions as the two sources of environment pollutions. As Suri and Chapman (1988) suggested, the consumption of energy is the power of modern economy and indicates the level of environment pollution. For example, most air pollutants are highly close to the consumption of coal and petroleum, moreover, the emissions of carbon dioxide has a positive relationship with the energy cost. Therefore, we collected data of the total energy consumption (X_1) and the percentage of clean energy (X_2), i.e., solar energy, wind energy and natural gas consumption, to measure the impact on environment. In addition to energy consumption, emissions in forms of liquid, gas, and solid from industry or daily life have an adverse impact on the environment (Wangshanshan, 2010). Considering that, we use sewage discharge (X_3), waste gas emission on industry (X_4) and the industrial solid waste discharge (X_5) to indicate the pressure of urban life and industry on environment. However, human activities are not always harmful for the environment, especially when the awareness of environment protection increase and legislation and policy are introduced. Hence, we also measure the investment on environmental protection (X_6) as the parameter to represent the improvement of the environment.

4.3.2.1 Urbanization indicators

Urbanization in this research is defined as the process that non-agricultural industries gather to urban area and the rural population transfer to towns. Other researchers also consider the life style changes among rural population as a phenomenon of urbanisation (Chen and Sun N., 2000; Sun Z., 2001). However, it is difficult to distinguish urban and rural life style in different cultural context and not easy to measure quantitatively. Therefore, in this research, we measure urbanisation with urban population and urban built-up areas and excluding life style measurements. In Jian and Huang's (2010) research, the urbanization rate is measured by the percentage of the population in cities and towns. Referring to their study, we apply urban population (X_7) as one of the indicators to stand for the size of towns. We also use the proportion of the permanent residents in cities and towns (X_8) to represent the urbanization level. However, some permanent residents in cities and towns do not have the household registration in the city that cannot enjoy the full public services. Hence, we use town registered population rate (X_9) on behalf of the public service. Wang G. (2010) pointed out that the urbanization process is effective to solve the serious shortage of problem such as living, medical treatment and studying. These problems refer to the economy product such as homes, schools, hospitals and roads in cities and towns. So this article use urban built-up area is (X_{10}) as a major aspect of urbanization.

4.3.2.2 Industrialisation indicators

Paul Krugman (1991), from the perspective of economic geography focusing on increasing returns, claims that industry, namely secondary and tertiary industry, is the basis of the modern cities, and industry growth is the core of metropolitan development. Therefore, in this research, we define the industrialisation as the proportion of secondary and tertiary industry in the total industries. We measure such proportion from three aspects: the production value, the employment, and tax revenue. First, we consider the proportion of non-agricultural industry output value (X_{11}) and the proportion of tertiary industry output value (X_{12}) as indicators for. Second, we use employment in non-farming industries is a relevant measure for industrialisation. As Guojun (2006) suggested, the key contribution of industry to urbanisation is to generate enough employment, which will attract a large number of migrants and gradually make the farmers to citizens. Hence, in this research, we will include the indicators of non-farm employment proportion (X_{13}) and the tertiary industry employment proportion (X_{14}). Third, we measure industrialisation by tax revenue from secondary and tertiary industry because it is a measurement of the contribution of industry to infrastructure construction, education, health care, social security and other urban and economic growth (Michael Spence, 2009). Therefore, the proportion of non-agricultural industries tax (X_{15}) and tax expenditure proportion of non-agricultural industry (X_{16}) is applied to describe how the mainstay industries affect tax revenue which will be used during urbanization.

In summary, we collected data for 16 indicators (Table 4.1). Among the six indicators for environment, only two indicators: the percentage of clean energy consumption (X_2) and government investment on environment management (X_6), are expected to have positive to the environment. For the urbanisation factor, all the four indicators are expected to have positive relationship with the urbanisation level. For industrialisation, the six indicators are also considered as positive related to the industrialisation level.

Table 4.1 Indicators for environment, urbanisation, and industrialisation

Factors	Indicators		Unit	Expected Relationship with the factor
Environment	Total energy consumption	X_1	10,000 tons	-
	Percentage of clean energy	X_2	%	+
	Sewage discharge	X_3	100 million tons	-

	Waste gas emission on industry	X_4	100 million standard cubic meters	-
	Industrial solid waste discharge	X_5	10,000 tons	-
	Investment on environmental protection	X_6	100 million yuan	+
Urbanisation	Urban population	X_7	10,000 people	+
	Proportion of the permanent residents in cities and towns	X_8	%	+
	Town registered population rate	X_9	%	+
	Urban built-up area	X_{10}	Square kilometres	+
Industrialisation	Non-agricultural industry output value proportion	X_{11}	%	+
	Tertiary industry output value proportion	X_{12}	%	+
	Non-farm employment proportion	X_{13}	%	+
	Tertiary industry employment proportion	X_{14}	%	+
	Proportion of non-agricultural industries tax	X_{15}	%	+
	Tax expenditure proportion of non-agricultural industry	X_{16}	%	+

4.3.3 Data pre-processing

Before modelling and analysis, we need to address the data comparability issue. In this research two reasons could affect the data comparability: money inflation and change of census standards. First, because the investment on environmental protection (X_6) is monetary data, its comparability across time is affected by inflation. Thus, in order to eliminate the impact of inflation on monetary investment, we calculate X_6 as the real data of investment divided by the corresponding year's GDP index.

Second, because the official definition of cities and towns came into force since 2000, which caused the urban population data significantly different before and after 2000. Since the third national census in 1982, a large number of villages were defined as cities or towns. However according to the new definition in 2000, those areas with population density less than 1,500 persons/km^2 should not be accounted as urban areas. Thus, the urban population data before 2000 were inflated. For example, in 2000, the town population is 6.24 million and urbanization rate 33.75%. Comparing with town population in 1999, it reduced more than 3 million and urbanisation rate dropped 18.59%, which is clearly inconsistent with the actual situation of urbanization development. In order to address this issue, we correct the urban population during 1949 and 1999 by polynomial regression method. The regression function is $y = 0.188x^2 - 730.78x + 710203$ and the Goodness of Fit is $R^2 = 0.9889$.

4.3.4 Modelling methods: Vector Auto Regression (VAR) and Principle Component Regression (PCR)

The objective of this research is to study the trilateral relationship among Environment, urbanisation and industries. In this study we decided to apply VAR and PCR two methods to achieve this goal.

The VAR model is not based on economic theory; it is used in the form of multi-equation joint regression. In each equation of the model, the endogenous variable regress the lag of all the endogenous variables to estimate the dynamic relationship of all endogenous variables. Therefore, it is suitable for the analysis of the relationship between environment, urbanization and mainstay industry in Xinjiang. The PCR model can transform large number of explanatory variables into several principal components and regress the weight or contribution of each indicator to the overall factor. The rest of this subsection introduces modelling process in details.

4.3.4.1 Synthesised index for environment, urbanisation, and industrialisation

In order to apply this VAR model and PCA model, we need one index for each of the factor: environment, urbanisation, and industrialisation. To achieve this goal, we applied the Entropy Method to determine the weights of different indicators to each factor and then synthesise the indicators as one index. Entropy is originally a physics concept and widely applied in information system studies (Shannon, 1948). If the system is well organised and in a scientific order, it will have big information entropy, and vice versa. According to the characteristics of entropy, we can calculate the randomness and the disorder degree of a scheme by calculating the entropy value.

The entropy value is used to determine the weight of each indicator because the smaller the degree of discretization of the indicator (i.e., the greater the entropy value is), the less impact the indicator has on the comprehensive evaluation. We assume that the greater the degree of entropy value of one indicator, the higher impact it will have on the synthesised index of environment, urbanisation or industrialisation. In specific, for data of each indicator, the greater the difference it has in comparison with the whole matrix of data, the more important role that indicator plays for the synthesised factor. If all the data are equal for an indicator, this implies that this indicator has very little impact on the system.

In this research, we use software Eviews 6.0 to calculate the entropy value e_j. The details of the equation to calculate entropy value is presented in Appendix C. The weight for indicator j to the synthesised factor is calculated by the Equation (1):

$$w_j = \frac{1-e_j}{\sum_{j=1}^{j=m}(1-e_j)} \qquad (1)$$

The synthesised index of i (environment, urbanisation, or industrialisation) is calculated via Equation (2):

$$y_i = \sum_{j=1}^{j=m} W_j \times X_j \qquad (2)$$

4.2.4.2 Vector Auto Regression (VAR)

After we calculated the synthesised indexes: $y_{\text{environment}}$, $y_{\text{urbanisation}}$, and $y_{\text{industrialisation,}}$ for each year from 1978 to 2014, the results are the input of the VAR model. The dependent variable in the VAR model for each year is:

$$y_t = \begin{bmatrix} y_{\text{environment}} \\ y_{\text{urbanisation}} \\ y_{\text{industrialisation}} \end{bmatrix} \qquad (3)$$

The VAR model can be expressed with the following equation:

$$y_t = \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + Hx_t + \varepsilon_t \quad t = 1, 2, \cdots, T \qquad (4)$$

In which,

y_t is a k-dimension vector of endogenous variables;

x_t is a d-dimension vector of exogenous variables;

T is the number of samples;

p is the lag orders;

Φ is a $k*k$ matrix;

H is the matrix of coefficients to be estimated;

ε is a white noise and doesn't correlate with its lags and variables on the right hand side of the equation

If we assume Σ is the covariance matrix of ε_t and is a $k*k$ positive definite matrix, the Equation (1) can be expressed as:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{kt} \end{bmatrix} = \Phi_1 \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \\ \vdots \\ y_{kt-1} \end{bmatrix} + \cdots + \Phi_p \begin{bmatrix} y_{1t-p} \\ y_{2t-p} \\ \vdots \\ y_{kt-p} \end{bmatrix} + H \begin{bmatrix} x_{1t} \\ x_{2t} \\ \vdots \\ x_{kt} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{kt} \end{bmatrix} \quad (2)$$

In the practical application, because the VAR model is a non-theoretical model, it does not need to make any priori constraints on the variable. Thus, instead of analysing the impact of the changes of one variable on the other variable, the VAR model analyse the dynamic response of a system when an error term changes or the model is affected by a certain impact. This method is called the Impulse Response Function (IRF). This method analyse the relationship between variables by decomposing the variance. Using the variance as a measurement, it assesses contribution of each structural impact to the change in endogenous variables. Thus, variance decomposition gives information about the relative importance of each random perturbation that affects the variables in the VAR model.

Therefore, the VAR model can be expressed as an infinite order of the vector process. The VAR model can also be rewrite as an infinity Moving Average (MA) process:

$$Y_{t+s} = U_{t+s} + \psi_1 U_{t+s-1} + \psi_2 U_{t+s-2} + \cdots + \psi_s U_t + \cdots \quad (3)$$

where, $\Psi_s = \dfrac{\partial \mathbf{Y}_{t+s}}{\partial \mathbf{U}_t}$ means that when all other errors are fixed, how will a shock to this error influence the variable y. We call it the impulse-response function.

Applying this method in Eviews 6.0, the results are impulse-response figures showing how one factor (environment, urbanisation, or industrialisation) changes over time after a shock or change occurred in other factors. Through these figures, we can analyse the inter-relationship among the three factors.

4.3.4.2 The Principle Component Regression (PCR)

The main function of principle component analysis is to transform large number of explanatory variables into several principal components, normally less than five principal components. The extracted principal components are linear combinations of the original explanatory variables and are not related to each other. The PCR model regresses the dependent variable with the principal components.

In this regression method, the dependent variable is one of the synthesised indexes: $y_{\text{environment}}$, $y_{\text{urbanisation}}$, and $y_{\text{industrialisation,}}$ from 1978 to 2014. The explanatory variables are the data for each indicator. In order to make the result not affected by the dimension, we standardised the original data. Secondly, seek the eigenvalues and variance. Thirdly, make the orthogonal transformation, and the principal component scores are calculated according to the factor scores of each factor, and the new principal component variables are obtained. Fourthly, we regress the dependent variable with the new main component variables. Finally, according to the correspondence between the principal component and the original explanatory variable, the regression coefficients of the original variable are obtained.

4.4 Modelling results

4.4.1 Results of indicator synthesis

After the processing date by entropy method, we have three indexes which are environment (Eco), Urbanisation (Urb) and mainstay industries (Ind), they can be interpreted as:

$$Eco = 0.1250 \times X_1 + 0.2620 \times X_2 + 0.1873 \times X_3 + 0.1030 \times X_4 + 0.1133 \times X_5 + 0.2095 \times X_6$$

$$Urb = 0.2844 \times X_7 + 0.2368 \times X_8 + 0.2179 \times X_9 + 0.2609 \times X_{10}$$

$$Ind = 0.2180 \times X_{11} + 0.1444 \times X_{12} + 0.1429 \times X_{13} + 0.1751 \times X_{14} + 0.1661 \times X_{15} + 0.1536 \times X_{16}$$

The results are shown in Table 4.2.

Table 4.2 The synthesised results of environment, urbanization, and industrialisation from 1978 to 2014

Year	Env	Urb	Ind	Year	Env	Urb	Ind
1978	0.528559	0.008557	0.116359	1997	0.523368	0.396914	0.516425
1980	0.543814	0.097009	0.156068	1998	0.528527	0.419258	0.556123
1981	0.545281	0.110281	0.177219	1999	0.567456	0.434287	0.618595
1982	0.554643	0.110012	0.209899	2000	0.560595	0.411855	0.602241
1983	0.549020	0.069399	0.222993	2001	0.623214	0.430241	0.652623
1984	0.544104	0.104765	0.246499	2002	0.619072	0.444128	0.646617
1985	0.540672	0.131152	0.326866	2003	0.613333	0.480965	0.602697
1986	0.543091	0.156101	0.386056	2004	0.605144	0.505358	0.612615
1987	0.526077	0.188352	0.410224	2005	0.568470	0.620882	0.715218
1988	0.520495	0.202842	0.409555	2006	0.560638	0.671549	0.737073
1989	0.519448	0.233045	0.461293	2007	0.540223	0.702997	0.750635
1990	0.512730	0.219008	0.421104	2008	0.520776	0.752763	0.761795
1991	0.502642	0.241806	0.528730	2009	0.498882	0.772260	0.763390
1992	0.501962	0.271141	0.570054	2010	0.461999	0.835725	0.736026
1993	0.501685	0.291134	0.629241	2011	0.476840	0.884811	0.770625
1994	0.496090	0.308205	0.441667	2012	0.421454	0.907889	0.794120
1995	0.504731	0.348209	0.435087	2013	0.422622	0.906212	0.843520
1996	0.503464	0.381757	0.496481	2014	0.490014	0.912054	0.853274

For a better illustration, the results are shown in Figure 4.1. It is found that, the environment reaches the highest level around 2001 and degraded afterwards. It becomes better in 2014 but is still lower than it used to be. The urbanisation degree forms an “S” shape since 1978, which implies it slows down around 1998 (maybe influence by the financial crisis), and grows faster afterwards. The level of industrialisation is higher than urbanisation before 2009, and it is exceeded recently.

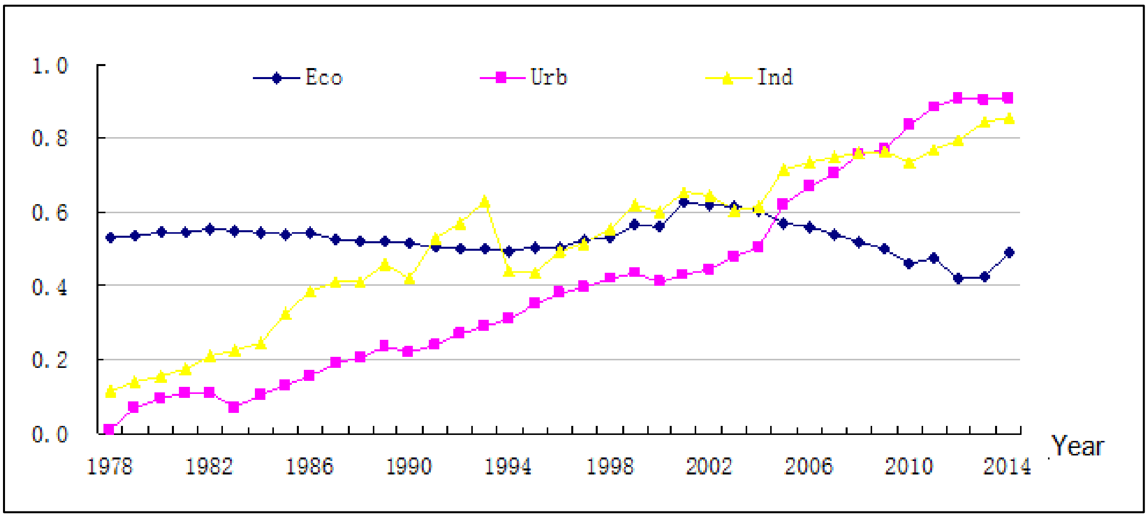


Figure 4.1 Synthetic indexes of environment, urbanisation, and industrialisation

4.4.2 Results based on Vector Auto-Regression Model

After we got the synthesised indexes, we tested the relationship among three factors by VAR model. Before reducing the fluctuation of the data, we need to take the logarithm firstly.

To exhibit pseudo-regression, we have to take a stationary test for all the time series data. After the Augmented Dickey-Fuller (ADF) test, we can conclude that after first order difference. The results in Table 4.3 shows that, the ln(Eco), ln(Urb) and ln(Ind) all reject the Null hypothesis with more than 95% confidence (p value smaller than 0.05). Table 4.4 shows that one lag VAR fits the data best.

Table 4.3 Unit root test results

Variables	**Test** (c,t,k)	**ADF**	**Critical Value** 1%	5%	10%	**P value**	**Result**
$\Delta\ln(Eco)$ *	(c,t,3)	-4.1984	-3.6463	-2.9540	-2.6158	0.0024	Stationary
$\Delta\ln(Urb)$ *	(c,t,0)	-5.1406	-3.6268	-2.9458	-2.6115	0.0002	Stationary
$\Delta\ln(Ind)$ **	(c,t,0)	-3.2974	-3.6268	-2.9458	-2.6115	0.0224	Stationary

Note: Δ is the first order difference, * is significant under 1% level, ** is significant under 5% The second step is to decide the order of lags p.

Table 4.4 Lag order determination result

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	18.15	NA	0.0001	-0.8913	-0.7566	-0.8454
1	117.36	175.0694*	0.0000*	-6.1975*	-5.6588*	-6.0138*
2	119.95	4.1224	0.0000	-5.8208	-4.8781	-5.4993
3	126.38	9.0687	0.0000	-5.6693	-4.3225	-5.2100

* is significant under 5%level.

After decided the order of lags, we then established the VAR model.

$$\begin{bmatrix} \ln(Eco)_t \\ \ln(Urb)_t \\ \ln(Ind)_t \end{bmatrix} = C + \Phi \begin{bmatrix} \ln(Eco)_{t\text{-}1} \\ \ln(Urb)_{t\text{-}1} \\ \ln(Ind)_{t\text{-}1} \end{bmatrix} + \varepsilon_t \quad (5)$$

The three variables ln(Eco), ln(Urb) and ln(Ind) are endogenous and C is a constant. The coefficient matrix is:

$$\Phi = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

The stochastic error is $\varepsilon_t = \left(\varepsilon_{1t} \quad \varepsilon_{2t} \quad \varepsilon_{3t}\right)' \sim N(0,\Omega), iid.$

In this case, the VAR model is:

$$\begin{pmatrix} \ln(Eco)_t \\ \ln(Urb)_t \\ \ln(Ind)_t \end{pmatrix} = \begin{pmatrix} 0.0506 \\ 1.4705 \\ 0.1485 \end{pmatrix} + \begin{pmatrix} 0.8576 & -0.0031 & -0.0070 \\ -0.4980 & 0.3677 & 0.7218 \\ -0.0266 & 0.0393 & 0.8357 \end{pmatrix} \begin{pmatrix} \ln(Eco)_{t\text{-}1} \\ \ln(Urb)_{t\text{-}1} \\ \ln(Ind)_{t\text{-}1} \end{pmatrix} + \varepsilon_t$$

We can rewrite the matrix as three equations:

$$\ln(Eco)_t = 0.0506 + 0.8576\ln(Eco)_{t\text{-}1} - 0.0031\ln(Urb)_{t\text{-}1} - 0.0070\ln(Ind)_{t\text{-}1} + e_t$$
$$(1.15066) \quad (9.43248) \qquad (-0.13784) \qquad (-0.17036)$$
$$R^2 = 0.752532 \qquad F = 32.43653$$

R^2 is 0.7525 which implies the estimation is quite good. The coefficient is 0.8576, -0.0031 and -0.0070 respectively. The environment of Xinjiang is better than that of the previous year. Last year environment's coefficient is positive and large (T value of 9.432), which indicate that the environment is more affected by its own development. Urbanization and mainstay industries have a negative impact on the development of environment, but the impact is very limited. The mainstay industry's negative impact is more than double of the urbanization. However, the T value of two coefficients is small which indicate that their influence on the environment is not significant. The reason is that Xinjiang is drought and the environment is fragile. Water resources play a very important role of environment. Nevertheless, urbanization and mainstay industry only consume less than 5% of total water consumptions, agricultural costs more than 90% water resources.

$$\ln(Urb)_t = 1.4705 - 0.4980\ln(Eco)_{t\text{-}1} + 0.3677\ln(Urb)_{t\text{-}1} + 0.7218\ln(Ind)_{t\text{-}1} + e_t$$
$$(6.51699) \quad (-1.0667) \qquad (3.18267) \qquad (3.50759)$$
$$R^2 = 0.914642 \qquad F = 114.2979$$

The R2 is 0.9146 which indicates that the variables can explain more than 90% of the model. The coefficients are -0.4980, 0.3677 and 0.7218 respectively and T values are -1.0667, 3.1827 and 3.5076 respectively. The regression results show that: firstly, the higher the level of urbanization, the lower the level of environment. The development of urbanization sacrifices the environment. Secondly, the urbanization development is affected by the level of urbanization in the last period. One percentage improvement of urbanization in the last period can promote the urbanization by 0.37 for today which is very significant. Thirdly, the mainstay industries play a significant role for urbanization. We can conclude that the important driving force for the Xinjiang's urbanization is mainstay industries. On the other hand, we cannot forget that the environment provides all the basic endowment of both urbanization and mainstay industries.

$$\ln(Ind)_t = 0.1485 - 0.0266\ln(Eco)_{t\text{-}1} + 0.0393\ln(Urb)_{t\text{-}1} + 0.8357\ln(Ind)_{t\text{-}1} + e_t$$
$$(1.61425) \quad (-0.13986) \qquad (0.83379) \qquad (9.96268)$$
$$R^2 = 0.965244 \qquad F = 296.2363$$

The R2 is 0.9652 shows that the model explains more than 96% of the relationship. The coefficients are -0.0266, 0.0393 and 0.8357 and T values are -0.1399, 0.8338 and 9.9627 respectively. We can firstly find out that the development of mainstay industries is constrained by the environment. Secondly, urbanization has a positive impact to mainstay industries because urbanisation can provide market and service to the industries. Thirdly, the mainstay industries are influenced greatly by itself. This implies that the mainstay industries have strong path dependence. This show the existing industries will cost a lot of resources and the emerging industries are difficult to develop.

4.4.1.1 Impulse Response to environment

Environment, urbanization and mainstay industries dependent on and influence each other. However, because of different policies related to their fields, their development can produce certain impact to the other two variables. As is seen in Figure 4.2, after a positive shock of urbanization, the impact on the environment increases rapidly in the first 3 periods. From the fourth period, it began to be flat. This suggests that the development of urbanization brings negative impact to environment through the emissions of pollutants. And this is a long-term impact and is significantly negative. At the same time, when a positive shock happen to the mainstay industries, less impact on the environment can be observed at the beginning. However, this influence is increasing and keeps steady as the time goes on. This indicates that the pollutant emissions by the mainstay industries have a continual expanded negative impact on the environment. It is obvious to conclude that the development of urbanization and mainstay industries will have a negative impact on environment.

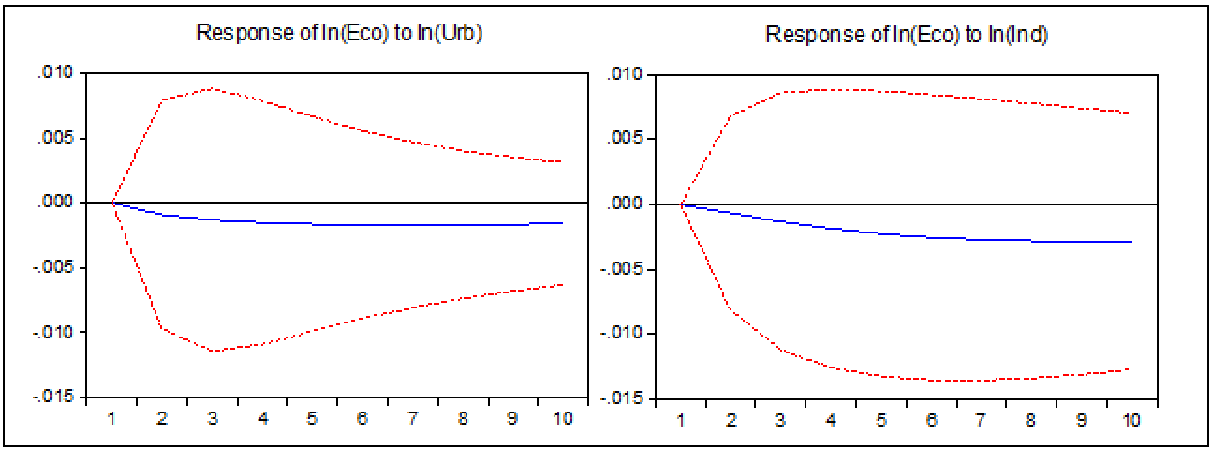


Figure 4.2 The response of Environment to Urbanisation (Left) and Industrialisation (Right)

4.4.1.2 Impulse Response to urbanisation

From the Figure 4.3, given a positive shock to the environment, there is a negative impact on urbanization in the beginning. At the third period, it reached the maximum value of the negative impact of urbanization and began to decrease. This indicates that the improvement of environment has an insurmountable contradiction with urbanization development. This tells us the current development concept and the level of technology is difficult to realize the harmonious development of both. The environment’s recovery is always accompanied with using the money that can be used to implement urbanization. This delays the process of urbanization. Figure 4.3 also shows that there is a positive shock to the mainstay industries, the speed of the urbanization increased quickly. In the third period, it began to decrease after the peak. This showed that the mainstay industries stimulate the development of urbanization through the fiscal expenditure and employment. Moreover, this effect is long-lasting and positive. Therefore, low-speed urbanization problem should be resolved through the development of mainstay industries in Xinjiang, especially to develop the tertiary industry which is environment friendly to accelerate the urbanization process.

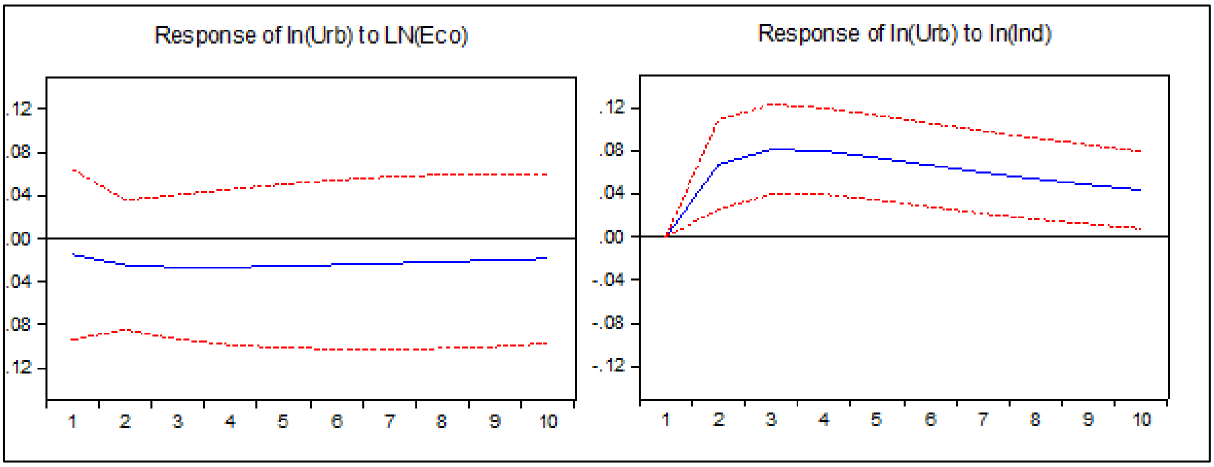


Figure 4.3 The response of Urbanisation to Environment (Left) and Industrialisation (Right)

4.4.1.3 Impulse Response to mainstay industries

The results in Figure 4.4 show that, given a positive shock to the environment, there is a positive impact to the mainstay industries in the beginning. However, it will reduce gradually, and in the third period, it shifted from positive to negative and was stable from the 8th period. This indicates that the improvement of the environment provides a good foundation to support the industry development. Nevertheless, it has a limit to accommodate pollutants. Once exceeds its limit, it will have a negative effect on the development on the mainstay industries. Figure 4.4 also shows that after a positive shock of urbanization, there is a positive impact on the mainstay industry. From the second period, it began to attenuate. Compared with the figure above, we find out that the impact of urbanization to mainstay industries is weaker than which of mainstay industries to urbanization.

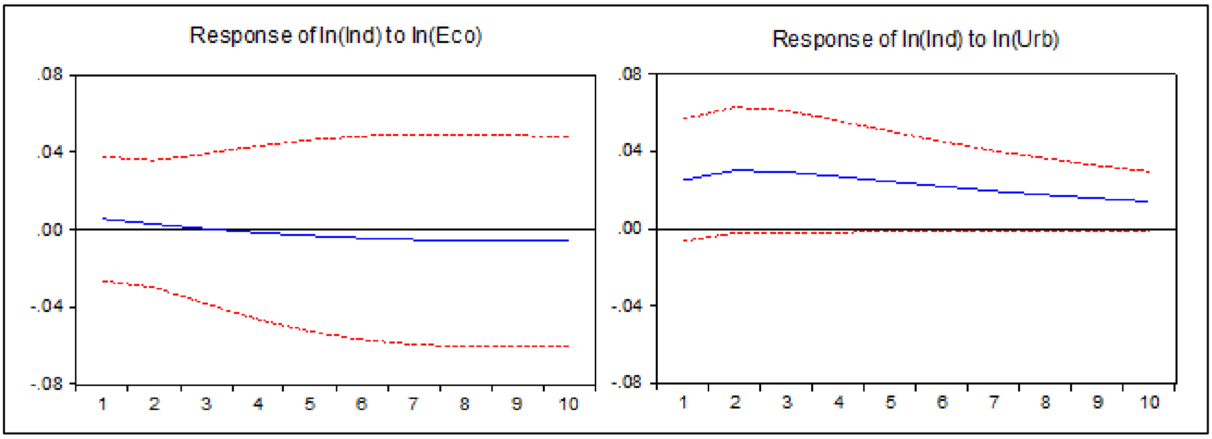


Figure 4.4 The response of Industrialisation to Environment (Left) and Urbanisation (Right)

4.4.2 Results based on Principal Component Regression

4.4.2.1 Urbanization and Mainstay industries to Environment

We are going to formulate the case to:

$$\ln(Eco) = \beta_0 + \beta_i \sum_{i=7}^{16} X_i + \varepsilon_t \qquad (i = 7, \cdots, 16)$$

Beta is the elasticity coefficient to environment. If xi increases 1%, the environment will change B%.

The KMO index is 0.859 and Bartlett's Sphericity test for X2 statistics is 815, and the p-value under the 45 degree of freedom is almost 0. These suggest that it is available to apply Factor Analysis Method. From the PCR results in Table 4.5, it can be found that the first principle factor explains 63.755% of the data and the second one explains 25.93%. The two factors explain 89.684%.

Table 4.5 The total variance of the explanatory variables

Component	Initial Eigenvalue			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.949	79.486	79.486	7.949	79.486	79.486	6.375	63.755	63.755
2	1.020	10.199	89.684	1.020	10.199	89.684	2.593	25.930	89.684
3	.632	6.318	96.003						
4	.209	2.092	98.095						
5	.105	1.047	99.142						
6	.056	.562	99.704						
7	.014	.139	99.843						
8	.008	.075	99.918						
9	.006	.064	99.982						
10	.002	.018	100.000						

The two factors are

$$\begin{aligned} F_1 = {} & 0.985z\ln X_7 + 0.951z\ln X_8 + 0.961z\ln X_9 + 0.989z\ln X_{10} + 0.938z\ln X_{11} \\ & + 0.815z\ln X_{12} + 0.978z\ln X_{13} + 0.989z\ln X_{14} + 0.639z\ln X_{15} - 0.553z\ln X_{16} \\ F_2 = {} & -0.01z\ln X_7 - 0.051z\ln X_8 - 0.052z\ln X_9 + 0.07z\ln X_{10} + 0.063z\ln X_{11} \\ & + 0.518z\ln X_{12} + 0.151z\ln X_{13} + 0.078z\ln X_{14} - 0.453z\ln X_{15} + 0.709z\ln X_{16} \end{aligned}$$

By principal component analysis and regression analysis, we can find that the first principal component has a high value on: Urban Population (X7), Proportion of the Permanent Residents in Cities and Towns (X8), Tertiary Industry Employment Proportion (X14), Town Registered Population Rate (X9), Urban Built-up Area (X10), Non-Agricultural Industry Output Value Proportion (X11) and Non-Agricultural Employment Proportion (X13). These indicators represent the economic quantity, size and growth. We define the first principle component as growth of economy. The second principal component has high value on Tertiary Industry Output Value Proportion (X12), Proportion of Non-Agricultural Industries Tax (X15) and t Tax Expenditure Proportion of Non-Agricultural Industry (X16). These indicators represent the optimization and upgrading of economic structure at the present stage. We define the second principle component as the economic development.

We use F1 and F2 and ln(Eco) to regress, DW value is 0.2897, however, under the 5% level, dL=1.36, du=1.59, which implies that there exists auto-regress. We have to use Cochrane-Orcutt Iterative Procedure to adjust the model by adding an AR(1) process to the model.

Now the DW value is 1.6857 and dl=1.31, du=1.66 $d_U < DW < 4 - d_U$, which implies there is no auto regression. By Harvey heteroscedasticity test, we can conclude there is no heteroscedasticity. According to $z\ln X_i = (\ln X_i - \overline{X_i}) / \sqrt{D_{X_i}}$ we can take F1 and F2 to this equation and get all the coefficient of each variables.

$$
\begin{aligned}
&\ln(Eco) = 0.2400 - 0.0454F_1 + 0.0045F_2 + 0.8490AR(1) \\
&T = 3.9437 \quad -0.8645 \quad 0.1473 \quad 8.4244 \\
&P = 0.0004 \quad 0.3938 \quad 0.8838 \quad 0 \\
&R^2 = 0.7543 \quad \bar{R}^2 = 0.7312 \\
&F = 32.7379 \quad DW = 1.6857
\end{aligned}
$$

Combined with the regression results, the coefficient of first principal component on the environment is - 0.0454, which shows that the traditional way of pursuing GDP growth have a negative impact on environment. The coefficient of second principal component is 0.0045, which proves that a healthy and efficient development on economy can promote the environment. However, the second coefficient is far less than the results of the first coefficient also suggest that even after 30 years' reform and opening up, Xinjiang's energy-consuming, high pollution economic development mode is still difficult to change. By adding an AR (1) process to the model, we also conclude that urbanization and mainstay industries have a long-term influence on environment. We should pay more attention to the long-term effects on environmental by the economic development.

From Table 4.6, four elasticity coefficient of index of the environment are negative. Proportion of the Permanent Residents in Cities and Towns (X8) and Town Registered Population Rate (X9) have a higher impact on the environment. This shows that urbanization, especially the increase of urban population enlarge the pressure of environment. However, compared with mainstay industries, this impact is weak. Among 6 industry index, only Proportion of Non-Agricultural Industries Tax (X15) has a positive elastic coefficient, all other variables' coefficient are negative. Tertiary Industry Output Value Proportion (X12). Non-Agricultural Industry Output Value Proportion (X11) and Non-Agricultural Employment Proportion (X13) have a large impact on environment. This implies that Xinjiang is still on the left of the environmental Kuznets curve. There is still a long way to reach the "inflection point". Generally, mainstay industries have a negative impact on the environment.

Table 4.6 Elasticity coefficient of each indictor of urbanization and industrialisation towards the environment

Parameter	Elasticity estimates	Indicators
β_7	-0.0130	Urban population
β_8	-0.0220	Proportion of the permanent residents in cities and towns
β_9	-0.0284	Town registered population rate
β_{10}	-0.0123	Urban built-up area
β_{11}	-0.0462	Non-agricultural industry output value proportion
β_{12}	-0.0599	Tertiary industry output value proportion
β_{13}	-0.0451	Non-farm employment proportion
β_{14}	-0.0219	Tertiary industry employment proportion
β_{15}	0.1444	Proportion of non-agricultural industries tax
β_{16}	-0.0471	Tax expenditure proportion of non-agricultural industry

According to the coefficient of X_{11} and X_{12} in the table above, it is interesting to find that the increase of tertiary industry has a greater adverse impact on environment comparing with non-agricultural industry. The possible reason is that, in Xinjiang, the production of secondary industry is far more than that of tertiary industry. In this situation, the increase of secondary industry generates greater tax. The positive effect from tax exceeds the negative effect of pollution.

4.4.2.2 Environment and Mainstay industries to Urbanization

The KMO index is 0.849 and Bartlett's sphericity test for X2 statistics is 1105, and the p-value under the 66 degree of freedom is almost 0. These suggest that it is available to apply Factor Analysis Method. From the results in Table 4.7, we find that the first principle factor explains 63.211% of the data and the second one explains 27.246%. The two factors explain 90.475%.

Table 4.7 The total variance of the explanatory variables

Component	Initial Eigenvalue			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.810	81.752	81.752	9.810	81.752	81.752	7.585	63.211	63.211
2	1.047	8.723	90.475	1.047	8.723	90.475	3.272	27.264	90.475
3	.706	5.883	96.358						
4	.215	1.795	98.154						
5	.102	.846	99.000						
6	.053	.444	99.444						
7	.035	.293	99.737						
8	.016	.131	99.868						
9	.008	.071	99.939						
10	.004	.031	99.970						
11	.003	.022	99.992						
12	.001	.008	100.000						

Two factors are

$$\begin{aligned} F_1 = & -0.987z\ln X_1 + 0.947z\ln X_2 - 0.987z\ln X_3 - 0.979z\ln X_4 - 0.951z\ln X_5 + 0.98z\ln X_6 \\ & + 0.973z\ln X_{11} + 0.805z\ln X_{12} + 0.969z\ln X_{13} + 0.985z\ln X_{14} + 0.627z\ln X_{15} - 0.56z\ln X_{16} \\ F_2 = & -0.005z\ln X_1 - 0.107z\ln X_2 - 0.105z\ln X_3 + 0.011z\ln X_4 + 0.111z\ln X_5 - 0.012z\ln X_6 \\ & + 0.087z\ln X_{11} + 0.536z\ln X_{12} + 0.176z\ln X_{13} + 0.1z\ln X_{14} - 0.426z\ln X_{15} + 0.704z\ln X_{16} \end{aligned}$$

The first principal component's elements from environment index: Total Energy Consumption (X1), Sewage Discharge (X3), Waste Gas Emission on Industry (X4) and Industrial Solid Waste Discharge (X5) are larger and negative. On the other hand, Percentage of Clean Energy (X2) and Investment on environmental protection (X6) are both large and positive. The element from mainstay industries: Non-Agricultural Industry Output Value Proportion (X11), Non-Agricultural Employment Proportion (X13), Tertiary Industry Employment Proportion (X14) and Tertiary Industry Output Value Proportion (X12) have a large coefficient. Thus, the first principal component is defined as how the traditional development mode of mainstay industries promotes urbanization progress. There are an obvious complementarity between second principal component and the first principal component. Thus, we can define the second principal component as the mainstay industries that new urbanization process requires.

We use F1 and F2 and ln(Urb) to regress, DW value is 1.0611, however, under the 5% level, dL=1.36, du=1.59, which implies that there exists auto-regress. We add an AR (1) process to the model and DW value is 0.9694 which is still lower than the level. By adding an AR(2) process to the model, it is significant.

$$\ln(Urb) = 3.5791 + 0.7461F_1 - 0.2644F_2 + 0.6276AR(1) - 0.1116AR(2)$$

$$\begin{array}{llllll} T= & 79.9140 & 13.2621 & -6.6771 & 3.9294 & -1.7778 \\ P= & 0 & 0 & 0 & 0.005 & 0.0856 \end{array}$$

$$R^2 = 0.9796 \qquad \bar{R}^2 = 0.9736$$

$$F = 314.9468 \qquad DW = 1.9865$$

From the regression results, it is obvious that the first principal component is still an important driving force of urbanization in Xinjiang. If F1 increases 1%, the urbanization level will be raised by 0.75%. The second principal component has a negative influence. It shows that to develop new kinds of urbanization in Xinjiang, this shows that the new type of urbanization in Xinjiang will restrict the development of urbanization process. Finally, by adding AR (1) and AR (2) process, we know that the promotion from mainstay industries to urbanization is long-term. Mainstay industries and environment will have positive and negative effects on urbanization respectively in the first two periods.

By looking at the elasticity coefficient of each index (Table 4.8), it is easy to find that on the aspect of environment, only Percentage of Clean Energy (X2) and Investment on environmental protection (X6) are positive, this implies that carbon emissions and other wastes emissions seriously hinder the development of urbanization. On the other hand, green and clean energy, ecological management can greatly promote the urbanization process. On the aspect of mainstay industries, except Proportion of Non-Agricultural Industries Tax's coefficient is negative, all the other variables' elasticity coefficient is positive. We can conclude that mainstay industries are the core promoting power of urbanization process. Among all the elasticity coefficients, Non-Agricultural Industry Output Value Proportion (X11), Tertiary Industry Output Value Proportion (X12), Non-Agricultural Employment Proportion (X13) and Tertiary Industry Employment Proportion's coefficient of urbanization are: 0.6598, 0.5358, 0.5611, 0.5358, namely the four variables increase 1% will promote urbanization increase by 2%. This also proves the primary role of mainstay industry to promote urbanization. In addition, if we observe the relationship between tax and urbanization, we can find that Proportion of Non-Agricultural Industries Tax (X15) and Tax Expenditure Proportion of Non-Agricultural Industry (X16) produce the same size but in the opposite direction effects on urbanization. A higher the Proportion of Non-Agricultural Industries Tax also represents that the business tax burden is heavier, which will have a negative impact on urbanization. A greater Proportion of Non-Agricultural Industries Tax means more endogenous driving force of the development for the regional economy, which implies a stronger ability to provide public products and services. Therefore, it can promote the development of urbanization.

Table 4.8 Elasticity coefficient of each indicator of environment and industrialisation towards urbanisation

Parameter	Elasticity estimates	Indicators
β_1	-0.0986	Total energy consumption
β_2	0.1323	Percentage of clean energy
β_3	-0.1410	Sewage discharge
β_4	-0.0660	Waste gas emission on industry
β_5	-0.0550	Industrial solid waste discharge
β_6	0.0313	Investment on environmental protection
β_{11}	0.6598	Non-agricultural industry output value proportion
β_{12}	0.5358	Tertiary industry output value proportion
β_{13}	0.5611	Non-farm employment proportion
β_{14}	0.3052	Tertiary industry employment proportion
β_{15}	-0.2287	Proportion of non-agricultural industries tax
β_{16}	0.1953	Tax expenditure proportion of non-agricultural industry

4.4.2.3 Environment and Urbanization to Mainstay industries

The KMO index is 0.849 and Bartlett's sphericity test for X2 statistics is 1103, and the p-value under the 45 degree of freedom is almost 0. These suggest that it is available to apply Factor Analysis Method. The Table 4.9 shows that the first principle factor explains 95.113% of the data.

Table 4.9 The total variance of the explanatory variables

Component	**Initial Eigenvalue**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.511	95.113	95.113	9.511	95.113	95.113			
2	.191	1.913	97.026						
3	.151	1.508	98.534						
4	.067	.673	99.208						
5	.045	.445	99.653						
6	.016	.158	99.810						
7	.012	.121	99.932						
8	.005	.046	99.978						
9	.001	.013	99.991						
10	.001	.009	100.000						

There is only one principal component F. All the coefficient of index is relatively large. The sub index of environment Total Energy Consumption (X1), Sewage Discharge (X3), Waste Gas Emission on Industry (X4) Industrial Solid Waste Discharge (X5) are negative. Thus we can define the main component as environment-friendly development mode of urbanization. The factor is

$$F = -0.995 z\ln X_1 + 0.933 z\ln X_2 - 0.989 z\ln X_3 - 0.986 z\ln X_4 - 0.966 z\ln X_5 + 0.981 z\ln X_6 + 0.995 z\ln X_7 + 0.975 z\ln X_8 + 0.938 z\ln X_9 + 0.992 z\ln X_{10}$$

We use F1 and F2 and ln(Ind) to regress, DW value is 0.1584, however, under the 5% level, dL=1.42, du=1.53, which implies that there exists auto-regress. We add an AR(1) process to the model and dw value is 1.9765 which has reduced the auto-regression.

$$\ln(Ind) = 1.5791 + 0.2515F_1 + 0.8409AR(1)$$
$$T = 10.4571 \quad 2.2161 \quad 15.2659$$
$$P = \quad 0 \quad 0.0337 \quad 0$$
$$R^2 = 0.9673 \quad \bar{R}^2 = 0.9653$$
$$F = 488.4055 \quad DW = 1.9765$$

Combining with the regression results, the coefficient of component is 0.2515, which shows that whenever the environment-friendly urbanization process increases 1%, mainstay industries will increase by 0.25%. From the results, we can declare that urbanization play a role to mainstay industries, but the effect is relatively small. Adding the AR (1) process to the model shows that an environment-friendly urbanization have both long-term and lagging effect on mainstay industries.

By discussing the elasticity coefficient (Table 4.10), we can find that the 4 variables mentioned above still have a negative coefficient. This suggests that the level of environmental can no longer accommodate energy intensive and highly polluting industries. And the clean energy and ecological management have a positive coefficient, which indicates that the improvement of the environment will promote the development of mainstay industries. Proportion of the Permanent Residents in Cities and Towns (X8) and Town Registered Population Rate (X9)'s coefficients are 0.1571 and 0.1926 respectively, which implies that if the Town Registered Population and the urbanization rate increased 1%, mainstay industries will be increased by 0.1571% and 0.1926% respectively. Generally, the urbanization level increases 1%, mainstay industries will increase about 0.5%. We can conclude that mainstay industries play a more important role to urbanization rather than the opposite way.

Table 4.10 Elasticity estimate of each indicator of environment and urbanisation towards industrialisation

Parameter	Elasticity estimates	Indicators
β_1	-0.0329	Total energy consumption
β_2	0.0544	Percentage of clean energy
β_3	-0.0396	Sewage discharge
β_4	-0.0226	Waste gas emission on industry
β_5	-0.0235	Industrial solid waste discharge
β_6	0.0107	Investment on environmental protection

β_7	0.0736	Urban population
β_8	0.1571	Proportion of the permanent residents in cities and towns
β_9	0.1926	Town registered population rate
β_{10}	0.0500	Urban built-up area

The findings in this chapter show that both urbanization and industrialisation have negative impact on environment through the emissions of pollutants. Moreover, industrialisation has a continual expanded negative impact on the environment. On the other hand, the improvement of environment has an insurmountable contradiction with urbanization development. The reason could be that current development concept and the level of technology is difficult to realize the harmonious development of both. However, industrialisation stimulates the development of urbanization through the fiscal expenditure and employment and this effect is long-lasting. Another result is the improvement of the environment provides a good foundation to industrialization. This implies that Xinjiang is still on the left side of the “U” in the Environmental Kuznets Curve. There is still a long way to reach the "inflection point". And the clean energy and ecological management can promote the development of mainstay industries.

4.5 Policy implementation: Selecting the Mainstay industries Under the constraints of environment

The previous section showed that the secondary industry in Xinjiang has less negative impact on the environment. However, we also target at suggesting more specific mainstay industries for Xinjiang province that suit best for the environment. Currently, there are 18 major types of non-agriculture industries in Xinjiang (Table 4.11), which is classified according to the International Standard Industrial Classification of All Economic Activities.

Table 4.11 The classification of second and tertiary industries

Number	Name	Details
01	Mining	Mining, oil and gas extraction industry, ferrous metal mining industry, non-ferrous metal mining industry, non-metallic mining industry
02	Agricultural and Sideline Food Processing Industry	Agricultural and sideline food processing industry, food manufacturing industry, wine, beverage and refined tea manufacturing, tobacco manufacturing
03	Textile and Garment Industry	Textile and garment, shoes, hats manufacturing, leather, fur, feathers (velvet) and its products industry
04	Paper and Furniture Manufacturing	Wood processing and wood, bamboo, rattan, brown, grass products, furniture manufacturing, paper and paper products,

		printing and recording media reproduction
05	Oil Refinery Industry	Oil refinery, coking and nuclear fuel processing industry
06	Chemical Industry	Chemical raw materials and chemical products manufacturing, pharmaceutical manufacturing, chemical fiber manufacturing, rubber and plastic products industry
07	Metal Smelting Products Industry	Ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, metal products industry, metal products, machinery and equipment repair industry, non-metallic mineral manufacturing industry
08	Machinery, Electronics Manufacturing Industry	General equipment manufacturing, special equipment manufacturing, automobile manufacturing, electrical machinery and equipment manufacturing, computer, communications and other electronic equipment manufacturing, instrumentation manufacturing
09	Infrastructure	Electricity, heat production and supply, gas production and supply, water production and supply
10	Construction Industry	Construction industry
11	Wholesale and Retail	Wholesale and retail
12	Transportation, Warehousing, Postal Services	Rail transport, road transport, urban public transport, air transport, pipeline transportation, handling and other transport services, warehousing, postal services
13	Accommodation and Catering	Accommodation and catering
14	Financial Industry	Banking, securities, insurance, other financial activities, leasing and business services
15	Real Estate	Real estate development and management, property management, real estate intermediary services
16	Public services	Research and development, professional and technical services, science and technology exchange and promotion services, geological prospecting, water management, environmental management, public facilities management, primary education, secondary education, higher education, health, social security, Welfare industry
17	Resident Services, Culture, Sports, Entertainment and Other Services	Resident services, other services, press and publishing, radio, film, television and audiovisual, arts and culture, sports, entertainment
18	Governance	The Communist Party of China, the state organs, the CPPCC and the democratic parties, mass organizations, social organizations and religious organizations

To support the selection of mainstay industry, we collected data for 7 indicators (Table 4.12). These indicators can effectively cover the properties of the industries.

Table 4.12 The indicators applied to select the mainstay industries

	Indicators	**Explanation**	**Calculation**
1	Ind_vl	The scale of industries' added value	Ind_vl = $Z/\sum Z$ Z is the amount of added value of one type of industry.
2	Emp	The scale of employment	Emp = $L/\sum L$

			L is the average employee of one type of industry
3	Tax	The scale of tax	Tax = $R/\sum R$ R is the total tax of one type of industry
4	Lbr	Labour productivity	Lbr = $\Delta Y_i/\sum W_i$ ΔY_i is the increment of industry W_i is the working force of ith industry
5	Enrg	The energy consumption per added value	Enrg = $EC/\sum Z$ EC is the energy consumption of one industry; Z is the added value
6	Tax_R	The rate of tax	Tax_R = $R/\sum Z$ R is the total tax of one type of industry Z is the added value
7	Coef_emp	The elastic coefficient of employment	Coef_emp =$(\Delta P_i/P_i)/(\Delta W/W_0)$ $\Delta P_i/P_i$ is the increase rate of employment. $\Delta W/W_0$ is the growth rate of GDP.

4.5.1 Weaver-Thomas (W-T) model to select the mainstay industries

We applied the Weaver-Thomas (W-T) model to deal with the data. W-T model is an effective method for choosing a strategic industry. It was proposed by Weaver (1954) and improved by Thomas. The principle of the W-T model compares an observation distribution with the hypothesis distribution and establish a nearest approximate distribution. The advantage of W-T model is that it can effectively overcome the shortcomings of single index evaluation. According to the regional competition index system of various industries, the region has the core of the strategic industry. Therefore, this paper adjusts the index system of industrial choice and uses the indexes which are closely related to the development of urbanization such as the industrial output value, taxation and employment.

The specific steps in applying the W-T model for the industry selection includes follows:

(i) First, we ranked all industries from large to small, and then use of W-T model to calculate the ranking value for each industry in each index. The details of W-T model for calculating the ranking value is shown in Appendix D.

(ii) Second, we calculated the average ranking value of mainstay industries for each index, and the results are a number of mainstay industries determined by the model for all the indicators.

(iii) Third, for the ith industry, its ranking according to the jth indicator compose a vector of ranking value. For each index given, calculate the ranking of each industry value, then select the optimum industries in the mainstay industry for the industry.

4.5.3 The suggested industries for Xinjiang under the constraints of environment

According to the number of mainstay industries in each of the indicators above, the average of the number of mainstay industries in Xinjiang is 8. In the process of selecting mainstay industries, we can focus on different part of mainstay industries. If we want to select the eco-environmental protection industry, we can give a 0.4 weight on the energy consumption and all the other indicators have a same weight. Secondly, if we want to have employment priority mainstay industries, we should mainly highlight the industry in the absorption of employment capacity. We offer the scale of employment and the elastic coefficient of employment a 0.2 weight and all the other indicators have a same weight. Finally, if we pay more attention to the town's construction, we need to stress the positon of the scale of tax and the rate of tax because tax is the guarantee of urban infrastructure construction and public service provision. We give a 0.2 weight to both the scale of tax and the rate of tax and all the other indicators have a same weight. Now we have 8 important mainstay industries selected for Xinjiang in different considerations (Table 4.13).

Table 4.13 The ranking value of top eight mainstay industries for each the composite factor

Ranking	Environment		Employment		Urbanisation	
	Ranking Value	Ind	Ranking Value	Ind	Ranking Value	Ind
1	2901.12	Mining	2598.39	Mining	3713.43	Mining
2	2379.31	Real Estate	2092.23	Infrastructure	1723.91	Oil Refinery Industry
3	2015.90	Oil Refinery Industry	2078.50	Real Estate	1715.54	Real Estate
4	1986.15	Public service	2032.28	Public services	1482.76	Public services
5	1720.95	Wholesale and Retail	1779.31	Oil Refinery Industry	1373.79	Wholesale and Retail
6	1616.74	Construction Industry	1313.56	Wholesale and Retail	1239.43	Constructio n Industry
7	1557.72	Infrastructure	1265.30	Construction	1226.80	Infrastructur

				Industry		e
8	1550.41	Paper and Furniture Manufacturing	1103.17	Accommodation and Catering	896.69	Governance

The mainstay industries selected by W-T model has the following two important characteristics: Firstly, the selected industries are based on the advantages of resources in Xinjiang, such as oil, natural gas, coal, electricity. This type of industries' pollution is relatively large, but this is the actual situation of Xinjiang's industrial development. Secondly, the service industry can create more employment and its environmental pollution is relatively low. However, these service industries such as the wholesale and retail trade, accommodation and catering industry and real estate are traditional. The modern service is very few.

Unselected industries include: 02 agricultural and sideline food processing industry, 03 textile and garment industry, 06 chemical chemical industry, 07 metal smelting products industry, 08 machinery, electronics manufacturing industry, 12 transportation, warehousing, postal industry, 14 financial industry and 17 residents services, culture, sports, entertainment and other services. These industries are not selected because of Xinjiang's location and its environmental limits. These results show that the mainstay industries in Xinjiang mainly rely on industries such as mining, petroleum processing, wholesale and retail, construction, real estate, electricity, gas and water production and supply industries. Most of them are the resource-intensive industries. However, with the development of China and the process of globalization, we need more mainstay industries because the natural resource is limited. We need to use to revenue from resource-intensive industries to establish some new mainstay industries.

4.6 Summary

This chapter discussed the relationship among urbanisation, industrialization, and environment degradation. The findings showed that urbanization and industrialisation have a negative impact on the environment, but the adverse impact of tertiary industry is more significant in the industrialisation history in Xinjiang. The reason could be that current development concept and the level of technology is difficult to realize the harmonious development of both. However, industrialisation stimulates the development of urbanization through the fiscal expenditure and employment and this effect is long-lasting.

On the other hand, the most important driving force for the Xinjiang's urbanization is mainstay industries. This result is similar with the resource export countries. Moreover, the development of mainstay industries is constrained by the environment and itself, mostly by itself. This implies that the mainstay industries have strong path dependence and the existing industries will cost a lot of resources which induce the emerging industries are difficult to develop. This suggests that the development of Xinjiang could bypass the manufacture industries. The most important industries are the oil industries and some traditional service industries.

Especially, when we focus on the mainstay industries, we will select industries based on the advantages of resources in Xinjiang, such as oil, natural gas, coal, electricity. This type of industries' pollution is heavy, but this is the actual situation of Xinjiang's industrial development. This satisfies the result of Gollin (2013). With the vision for the future development, the service industry can create more employment and less environmental pollution. However, these service industries are mostly traditional services such as catering, tourism, and retailing. The reason for this is that modern service such as finance and logistics services are mainly located in the coast areas, whereas Xinjiang has very week competitiveness in such modern service industries.

Chapter 5 Conclusion and future study

In this thesis, we focused on the collaboration in the supply chain. Because of the externalities of a supply chain such as the stochastic demand and limited initial capital, the efficiency of supply chain can be constrained. Our aim in this thesis was to find an effective contract or a program to internalize the externalities and to improve the efficiency and the profit of the whole supply chain. To achieve this aim, we adopted Lariviere and Porteus (2001)'s two-party supply chain model as the basic model, in which the retailer faces a Newsvendor problem. Then we extended the basic model with a third party, the bank, and compared the function of different loan programs (Chapter 2). We then further studied the three-party supply chain model in two periods (Chapter 3). Our findings show that with the bank, the retailer prefers a higher risk. It will order less when the bank gets out even its wealth grows.

In Chapter 2, we focused on addressing the problems of the retailer's initial wealth constraints. To this end, we introduced the bank as the third party into the supply chain model. In our model, the bank offers two different loan programs to help the retailer: the interest-free loan program (adopted from Zhou and Groenevelt (2007)) and the risk-free loan program (proposed in this research). By comparing the coordination and profit of the supply chain under these two loan programs, we found that the risk-free interest loan program improved both of the manufacturer's and the retailer's profits in the case when the retailer was constrained by his initial wealth. Comparing with the interest-free loan program, the risk-free interest loan program has advantages in the following two aspects: (i) the risk-free interest loan program can avoid the retailer to borrow excessive money from bank, and thus increase the efficiency of the loan; (ii) Both the retailer's and the manufacturer's profits are greater with the risk-free interest loan program than the ones with the interest-free loan program.

In chapter 3, we extend the problem to two periods. All the players will maximize their expected wealth in the second period to choose their first period order and price. The results show that the one-shot risk-free loan program can enough the retailer order more product in the first period and both the retailer and the manufacturer's profit is improved. However, without the bank in the second period, the retailer order even less than the ones without the bank in the first period if the retailer is still constrained by his initial wealth. Both the retailer and the manufacturer's profit are less in the second period. Overview of the two periods, the one-shot risk-free loan program can improve the profits of the supply chain; both the retailer and the manufacturer's profits are increased though the bankruptcy exists.

The chapter 4 shows us that Xinjiang province, as a resource rich area in China, also satisfies the environmental Kuznets Curve and now it is on the left part of the curve. Furthermore, this province has a different development path in urbanization. Traditionally, urbanization is accompanied with the development of manufacture and modern services. In some resource exporter areas, the urbanization process depends on the heavy industries instead of the manufacture. Xinjiang also satisfies this path. With the vision for the future development, the service industry can create more employment and less environmental pollution. However, these service industries are mostly traditional services such as catering, tourism, and retailing. It cannot compete with the coastal area in modern service industries.

However, in our research, the retail price is exogenous, pre-determined and fixed. For the next step, we can assume the demand is affected by the retail price and the retailer is constrained by his initial wealth. This can better describe and understand the incompletely competitive products market as is seen in reality. On the other hand, further study could be done by considering the retailing game in multiple periods or an infinity periods. Studies on the profit of the supply chain with long-term loan program would also be helpful. It might give us different results regarding the benefit of loan programs if they were applied in a long term instead of one-shot period. There is also a possibility to extend our three-party model by releasing the assumptions of the manufacturer's unlimited capital and stochastic of supply.

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Appendix A Proving process for Chapter 2

<u>COROLLARY 1 proof:</u> *according to the objective function,*

$$V_1 = \{(1+r_f)(L+V_0-wq) + pmin(q,D) - (1+r)L + (r-r_f)(wq-V_0)^+\}^+$$

there are two cases,

(1) if $\boldsymbol{wq} > \boldsymbol{V_0}$*, then* $(wq-V_0)^+ = wq-V_0$ *which means that retailer's initial wealth is constrained by his initial wealth, so the retailer borrows money from the bank, then the loan account should meets the equation, i.e.* $wq-V_0 \le L \le \emptyset wq$*. The retailer's objective can be re-written as,*

$V_1 = \{(r-2r_f-1)(wq-V_0) + pmin(q,D) - (r-r_f)L\}^+$ *because* $r > r_f$, V_1 *is decreasing with* L*, when* L *choose the minimum, i.e.* $\mathrm{L} = (wq-V_0)$, V_1 *can get its maximum.*

(2) if $\boldsymbol{wq} \le \boldsymbol{V_0}$*, then* $(wq-V_0)^+ = 0$*, which means that retailer's initial wealth is enough, so the retailer does not use the borrowed money for ordering, then* $0 \le L \le \emptyset wq$*. The retailer's objective can be re-written as,*

$V_1 = \{(1+r_f)(wq-V_0) + pmin(q,D) - (r-r_f)L\}^+$ *because* $r > r_f$, V_1 *is decreasing with* L*, when* L *choose the minimum value, i.e.* $\mathrm{L} = 0$, V_1 *can get its maximum.*

Thus, COROLLARY 1 is proved.

<u>Lemma 1 proof:</u> *according to the simplified objective function*

$$\mathrm{V_1} = [\mathrm{pmin(q,D)} - (1+\mathrm{r_f})(\mathrm{wq} - \mathrm{V_0})]^+$$

we can get $min(q,D) \ge \frac{(1+r_f)(wq-V_0)}{p}$. Additionally, since the retailer has no inventories left, so $\mathrm{pq} - (1+\mathrm{r_f})(\mathrm{wq}-\mathrm{V_0}) > 0$ must be true and the retailer must has the choice for getting profit from the ordering ,otherwise, he will order nothing, in this chapter, we only discuss the case that the retailer has the choice for getting the profit, i.e. $\mathrm{pq} - (1+\mathrm{r_f})(\mathrm{wq}-\mathrm{V_0}) > (1+\mathrm{r_f})\mathrm{V_0}$ must be true, then we can get $w < \frac{p}{1+r_f}$, $q > \frac{(1+r_f)(wq-V_0)}{p}$. Thus, at the end of the period, the demand is realized, there are two cases, (i) if $> \frac{(1+r_f)(wq-V_0)}{p}$, the retailer will not be bankrupt, (ii) if $\mathrm{D} \le \frac{(1+r_f)(wq-V_0)}{p}$, $pD - (1+r_f)(wq-V_0) \le 0$, then $D \le \frac{(1+r_f)(wq-V_0)}{p} < q$, the retailer will bankrupt. the summary is that the bankrupt threshold is $\frac{(1+r_f)(wq-V_0)}{p}$.

LEMMA 2 Proof ,

When the expenditure of the order is greater than the retailer's initial wealth, the retailer borrow money form the bank, the objective is

$$V_{1.1}(q,p) = p\int_{b}^{q}\bar{F}(x)dx$$

the retailer's profit is function related to the order q, Let $\nabla = \frac{(1+r_f)V_0}{p}$, then $b(q) = \Delta * q - \nabla$. the first order derivative of the retailer's objective on q is

$$\frac{d\,V_{1.1}(q)}{dq} = p[\bar{F}(q) - \Delta\bar{F}(b)] = p\bar{F}(q)\left[\frac{\bar{F}(q)}{\bar{F}(b)} - \Delta\right]$$

If the demand D has an increasing failure rate, then

$$\frac{d}{dz}ln\frac{\bar{F}(q)}{\bar{F}(b)} = -\frac{f(q)}{\bar{F}(z)} + \Delta\frac{f(b)}{\bar{F}(b)} < -\frac{f(q)}{\bar{F}(q)} + \frac{f(b)}{\bar{F}(b)} < 0$$

We can get that $\frac{\bar{F}(q)}{\bar{F}(b)}$ is strictly decreasing. Additionally, when $\frac{\bar{F}(q)}{\bar{F}(b)} > \Delta$, then$\frac{d\,V_{1.1}(q)}{dq} > 0$ the $V_{1.1}(q)$ is increasing in q, when $\frac{\bar{F}(q)}{\bar{F}(b)} < \Delta$, then$\frac{d\,V_{1.1}(q)}{dq} < 0$ the $V_{1.1}(q)$ is decreasing in q. So $V_{1.1}(q)$ is unimodal in q.

Proposition 1 given the wholesale price by the retailer, according to the retailer's objective function when $\mathrm{q} < \frac{V_0}{w}$,

$$V_{1.2}(q,p) = p\int_{o}^{q}\bar{F}(x)dx - b$$

The first order derivative of the retailer's objective function, i.e.$V_{1.2}(q,p)$, is

$$\frac{d\,V_{1.2}(q)}{dq} = p\bar{F}(q) - \Delta$$

The second order derivative is

$$\frac{d^2V_{1.2}(q)}{dq^2} = -pf(q) < 0$$

Thus, $V_{1.2}(q)$ is concave and increasing in q when $q \in (0,\hat{q}_N]$ and non-increasing when $q \in (\Delta,+\infty]$. Combine the Lemma 2,i.e. $V_{1.1}(q)$ is increasing in q when $q \in (0,\hat{q}_N]$ and non-increasing when $q \in (\Delta,+\infty]$. The retailer's objective function is

$V_1(q)$ is decreasing in q when $q \in (0,\Delta]$ and non-increasing when $q \in (\Delta,+\infty]$. Thus , retailer's objective function is $V_1(q)$ unimodal in q.

(I) If $\bar{F}\left(\frac{V_0}{w}\right) \leq \Delta$, since $\bar{F}(\hat{q}_N)$ exist and $\frac{d\,V_{1.2}(\hat{q}_N)}{dq} = 0$, then $V_{1.2}(q)$ is decreasing in q when $q \in (0,\hat{q}_N]$ and non-increasing when $q \in (\hat{q}_N,\frac{V_0}{w}]$, $V_{1.1}(q)$ is decreasing with q when $q \in (\frac{V_0}{w},\frac{V_0}{(1-\emptyset)w}]$. then optimal solution of the retailer's finial function V_1 is $\hat{q}_N$,

(II) If $\bar{F}\left(\frac{V_0}{w}\right) > \Delta$, then $V_{1.2}(q)$ is increasing with q when $q \in$ $q \in (0,\frac{V_0}{w}]$,then for $q \in (\frac{V_0}{w},\frac{V_0}{(1-\emptyset)w}]$, there are two cases,(i) if $\hat{q}_L \geq \frac{V_0}{(1-\emptyset)w}$ then $V_{1.1}(q)$ is increasing in q when $q \in (\frac{V_0}{w},\hat{q}_L]$ and non-increasing when $q \in (\hat{q}_L,\frac{V_0}{(1-\emptyset)w}]$, the optimal of the retailer's finial function V_1 is $\hat{q}_L$, ,(ii) if $\hat{q}_L < \frac{V_0}{(1-\emptyset)w}$ then $V_{1.1}(q)$ is increasing in q when $q \in (\frac{V_0}{w},\frac{V_0}{(1-\emptyset)w}]$ the optimal of the retailer's finial function V_1 is $\frac{V_0}{(1-\emptyset)w}$. In conclusion, the optimal solution of the retailer's finial function V_1 is min $\left(\hat{q}_{L,}\frac{V_0}{(1-\emptyset)w}\right)$.

LEMMA 3 Proof *There are there cases according to the best-response order from the retailer's objective function.*

(i) if the best-response order is $\hat{q}_N(w)$, then $\hat{q}_N(w)$ is obtained from the equation

$$\bar{F}(\hat{q}_N) - \frac{(1+r_f)w}{p} = 0$$

Then, $\frac{d\,\hat{q}_N(w)}{dw} = \frac{d\,w(\hat{q}_N)}{d\hat{q}_N} = -\frac{\Delta}{f(q)} < 0$,

(ii) If the best-response order is $\frac{V_0}{(1-\emptyset)w}$, it is obviously that the best-response order is decreasing with w

(iii)) If the best-response order is $\hat{q}_L(w)$, then $\hat{q}_L(w)$ is obtained from the equation

$$\bar{F}(\hat{q}_L) - \frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] = 0$$

The wholesale price is w, is a function of the best-response order Then the first order derivative on q is as following

$$-f(\hat{q}_L) = \frac{(1+r_f)}{p} * \frac{d\,w}{d\hat{q}_L} \bar{F}\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] - \frac{(1+r_f)w}{p} f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right]\left[\frac{(1+r_f)w}{p} + \frac{(1+r_f)\hat{q}_L}{p} * \frac{d\,w}{d\hat{q}_L}\right]$$

Then are can get

$$\frac{d\,w}{d\hat{q}_L} * \frac{(1+r_f)}{p} * \left\{\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] - w * \frac{(1+r_f)\hat{q}_L}{p} * f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right]\right\} = -f(\hat{q}_L) - \left[\frac{(1+r_f)w}{p}\right]^2 * f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right]$$

Since $-f(\hat{q}_L) - \left[\frac{(1+r_f)w}{p}\right]^2 * f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] < 0$ then , whether $\frac{d\,w}{d\hat{q}_L}$ is positive is determined by the term, i.e. $\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] - \frac{(1+r_f)w\hat{q}_L}{p} * f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right]$. for simple operation, let $\frac{(1+r_f)w\hat{q}_L}{p} = s$, $\frac{(1+r_f)V_0}{p} = t$, then

$$\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] - \frac{(1+r_f)w\hat{q}_L}{p} * f\left[\frac{(1+r_f)(w\hat{q}_L - V_0)}{p}\right] = \bar{F}[s-t]\left\{1 - \frac{s * f[s-t]}{\bar{F}[s-t]}\right\}$$

Let $G(s) = s\bar{F}[s-t]$ *and* $V_0 \leq s < +\infty$, *then*

$$G(V_0) = \frac{(1+r_f)V_0}{p}$$

Since the first order derivative of the $G(s)$ *is*

$$\frac{\partial G(s)}{\partial s} = \bar{F}[s-t]\left\{1 - \frac{s * f[s-t]}{\bar{F}[s-t]}\right\}$$

And since the demand has the increasing failure rate, the $\frac{s*f[s-t]}{\bar{F}[s-t]}$ *is also increasing with the first order derivative of the* $G(s)$ *is increasing with* s *when* $s \in \left[V_0, \frac{s*f[s-t]}{\bar{F}[s-t]}\right]$ *and decreasing with* s *when* $s \in \left[\frac{s*f[s-t]}{\bar{F}[s-t]}, +\infty\right]$. $G(s)$ *is quasi-concave in* s. *And the* s *for the maximum of the* $G(s)$ *can be obtained from the equation* $\frac{s*f[s-t]}{\bar{F}[s-t]} = 1$.

According to the equation $\hat{q}_L\bar{F}[\hat{q}_L] = s\bar{F}[s-t]$, *when* $\hat{q}_L = \frac{V_0}{w}$, *according the lemma*

$$\hat{q}_L\bar{F}[\hat{q}_L] = \frac{V_0}{w}\bar{F}\left[\frac{V_0}{w}\right] > \frac{(1+r_f)V_0}{p}$$

Let $\mathrm{H}(\hat{q}_L)=\hat{q}_L\bar{F}[\hat{q}_L]$,,*then* $G(s(\frac{V_0}{w}))<\mathrm{H}\left(\frac{V_0}{w}\right)$,*which means that , the left point value of the function* $G(s(\frac{V_0}{w}))$, *is smaller than the one of the function* $\mathrm{H}\left(\frac{V_0}{w}\right)$.

the first order of $\mathrm{H}(\hat{q}_L)$ *is*

$$\frac{\partial H(\hat{q}_L)}{\partial \hat{q}_L}=\bar{F}[\hat{q}_L]\left\{1-\frac{\hat{q}_L*f[\hat{q}_L]}{\bar{F}[\hat{q}_L]}\right\}$$

And since the demand has the increasing failure rate ,it also has the General increasing failure rate, i..e $\frac{\hat{q}_L*f[\hat{q}_L]}{\bar{F}[\hat{q}_L]}$ *is increasing with*$\hat{q}_L$ *. The function* H（$\hat{q}_L$) *has unique soliton on* $\hat{q}_L$*when maximize function* H（$\hat{q}_L$) *, which meet the equation*$1=\frac{s(\hat{q}_L)*f[s(\hat{q}_L)-t]}{\bar{F}[s(\hat{q}_L)-t]}$

Additionally, $\hat{q}_L>s(\hat{q}_L)$ *and* $\hat{q}_L>s(\hat{q}_L)-t$ *since the equation* $\frac{(1+r_f)w}{p}<1$ *and* $t>0$.

Let q_H^* *denote the solution of the equation* $1=\frac{\hat{q}_L*f[\hat{q}_L]}{\bar{F}[\hat{q}_L]}$,*and* q_G^* *denote the solution of the equation* $1=\frac{s(\hat{q}_L)*f[s(\hat{q}_L)-t]}{\bar{F}[s(\hat{q}_L)-t]}$*. We can get* $q_H^*<q_G^*$*.Then Compare the function* $\mathrm{H}(\hat{q}_L)$ *with the function* $G(s(\hat{q}_L)$*, the function* $H(\hat{q}_L)$ *is above on the function* $G(s(\hat{q}_L)$ *when* $\hat{q}_L\in\left[\frac{V_0}{w},q_H^*\right]$*, However, the function* $H(\hat{q}_L)$ *is below on the function* $G(s(\hat{q}_L)$ *when* $\hat{q}_L\in\left[q_{H,}^*\frac{V_0}{(1-\emptyset)w}\right]$*. Thus the unique intersection of the two functions meets* $\hat{q}_L\in[q_H^*,q_G^*]$

And the equation, $\bar{F}(\hat{q}_L)-\frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L-V_0)}{p}\right]=0$*, we can get that the soliton of the function ,*$\hat{q}_L\bar{F}(\hat{q}_L)=\frac{(1+r_f)w\hat{q}_L}{p}\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L-V_0)}{p}\right]$*,meets* $\hat{q}_L\in[q_H^*,q_G^*]$*,and* $\frac{\partial G(s)}{\partial s}>0$ *when*$\hat{q}_L\in[q_H^*,q_G^*]$ *, i.e.* $1-\frac{s*f[s-t]}{\bar{F}[s-t]}>0$ *. thus* $\frac{d\,w}{d\hat{q}_L}<0$*, the best response order*$\hat{q}_L$ *is decreasing with the wholesale price* w.

LEMMA 4 proof

The $\hat{q}_L$ *is the unique solution of the equation* $\bar{F}(q)-\frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(wq-V_0)}{p}\right]=0$*,* $R_m(\hat{q}_L)=w(\hat{q}_L)\hat{q}_L$ *,*

according to the equation $\bar{F}(\hat{q}_L)=\frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L-V_0)}{p}\right]$*,then* $\hat{q}_L\bar{F}(\hat{q}_L)=\frac{(1+r_f)R_m(q)}{p}\bar{F}\left[\frac{(1+r_f)(R_m(q)-V_0)}{p}\right]$ *, the first order derivative of the equation* $R_m(q)=w(\hat{q}_L)\hat{q}_L$*, is*

$$\bar{F}(\hat{q}_L)\left[1-\frac{\hat{q}_L f(\hat{q}_L)}{\bar{F}(\hat{q}_L)}\right]=\left[\frac{(1+r_f)}{p}\bar{F}(b)-\left(\frac{(1+r_f)}{p}\right)^2 Rf(b)\right]\frac{dR}{dq}$$

Then ,

$$\frac{dR}{dq}=\frac{\bar{F}(\hat{q}_L)\left[1-\frac{\hat{q}_L f(\hat{q}_L)}{\bar{F}(\hat{q}_L)}\right]}{\frac{(1+r_f)}{p}\bar{F}(b)\left[1-\frac{\frac{(1+r_f)}{p}w(\hat{q}_L)\hat{q}_L f(b)}{\bar{F}(b)}\right]}$$

Let $\bar{q}$ be the soliton for equation $1=\frac{\hat{q}_L f(\hat{q}_L)}{\bar{F}(\hat{q}_L)}$, $\frac{\hat{q}_L f(\hat{q}_L)}{\bar{F}(\hat{q}_L)}$ is increasing with $\hat{q}_L$ when$\hat{q}_L \in (0,\bar{q}]$ and decreasing with $\hat{q}_L$ when$\hat{q}_L > \bar{q}$. In lemma 2 (iii), we have proved that the soliton for equation $1=\frac{\hat{q}_L f(\hat{q}_L)}{\bar{F}(\hat{q}_L)}$,is smaller than the solution for the equation $1=\frac{\frac{(1+r_f)}{p}w(\hat{q}_L)\hat{q}_L f(b)}{\bar{F}(b)}$,and $1-\frac{\frac{(1+r_f)}{p}w(\hat{q}_L)\hat{q}_L f(b)}{\bar{F}(b)}>0$ when . Thus, $\frac{dR}{dq}$ is increasing with $\hat{q}_L$ when$\hat{q}_L \in (0,\bar{q}]$ and decreasing with $\hat{q}_L$ when $\hat{q}_L > \bar{q}$. $R(\hat{q}_L)$ is unimodal and the maximum can be obtained when $\hat{q}_L=\bar{q}$. when $\hat{q}_L$ exist, the anther requirement is that $R_m(\hat{q}_L)>V_0$, Let $\underline{q}$ donate the $\hat{q}_L$ which meets the equation $R_m(\hat{q}_L)>V_0$. Then $\underline{q}$ can be obtained from the equation $\hat{q}_L\bar{F}(\hat{q}_L)=\frac{(1+r_f)V_0}{p}$.

<u>PROPOSITION 2 proof</u>

<u>when</u> *$R_m(\bar{q})\le V_0$, There is no solution for the equation* $\hat{q}_L\bar{F}(\hat{q}_L)=\frac{(1+r_f)R_m(q)}{p}\bar{F}\left[\frac{(1+r_f)(R_m(q)-V_0)}{p}\right]$, the manufacturer will set the wholesale price $w(q_N^{\circ})$ which can be obtained from the equation $\bar{F}(q_N^{\circ})=\frac{(1+r_f)w}{p}$,*the optimal order for retailer is q_N°.*

<u>when</u> $R_m(\bar{q})>V_0$, the manufacturer's revenue is increasing with $\hat{q}_N$ when $0<R_m(\hat{q}_N)\le V_0$, and continue increasing with $\hat{q}_L$ when $0<R_m(\hat{q}_L)\le V_0$. (i) If $q_N^{\circ}<\underline{q}$, the manufacturer will set the wholesale price $w(q_N^{\circ})$) which can be obtained from the equation $\bar{F}(q_N^{\circ})=\frac{(1+r_f)w}{p}$. Otherwise , (ii) If $q_N^{\circ}<\underline{q}$, then $p\bar{F}(\underline{q})\left[1-\frac{qf(\underline{q})}{\bar{F}(\underline{q})}\right]-c>0$. The best-response order should be obtained from the equation $\bar{F}(\hat{q}_L)=\frac{(1+r_f)w}{p}\bar{F}\left[\frac{(1+r_f)(w\hat{q}_L)-V_0)}{p}\right]$, there are two case (a) if $R_m(\bar{q})>\frac{V_0}{1-\emptyset}$, the optimal order is $min(\ddot{q},q_1)$, (b) if $R_m(\bar{q})\le\frac{V_0}{1-\emptyset}$, the optimal order is $\ddot{q}$.

Appendix B Analysis process for Chapter 3

(1) $w_1q_1 \le V_0, 0 < D_1 \le q_1, w_2q_2 \le pD_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \le q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

(2) $w_1q_1 \le V_0, 0 < D_1 \le q_1, w_2q_2 \le pD_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

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(3) $w_1q_1 \le V_0, q_1 < D_1, w_2q_2 \le pq_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \le q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

(4) $w_1q_1 \le V_0, q_1 < D_1, w_2q_2 \le pq_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

----

(5) $w_1q_1 > V_0, \frac{(1+r_f)(w_1q_1 - V_0)}{p} < D_1 \le q_1, w_2q_2 \le pD_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \le q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

(6) $w_1q_1 > V_0, \frac{(1+r_f)(w_1q_1 - V_0)}{p} < D_1 \le q_1, w_2q_2 \le pD_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pD_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

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(7) $w_1q_1 > V_0, q_1 < D_1, w_2q_2 \le pq_1 - (1+r_f)(w_1q_1 - V_0), 0 < D_2 \le q_2,$

$$V_2 = pD_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

(8) $w_1q_1 > V_0, q_1 < D_1, w_2q_2 \le pq_1 - (1+r_f)(w_1q_1 - V_0), q_2 < D_2,$

$$V_2 = pq_2 - (1+r_f)\{w_2q_2 - [pq_1 - (1+r_f)(w_1q_1 - V_0)]\}$$

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(9) $w_1 q_1 > V_0, D_1 < \frac{(1+r_f)(w_1 q_1 - V_0)}{p}$

$$V_2 = 0$$

If we let $= \frac{w_2 q_2 + (1+r_f)(w_1 q_1 - V_0)}{p} = \frac{w_2 q_2}{p} + b_1$, $b_1 = \frac{(1+r_f)(w_1 q_1 - V_0)}{p}$,then

(1) $q_1 \le \frac{V_0}{w_1}, 0 < D_1 \le q_1, D_1 \ge \beta, 0 < D_2 \le q_2,$

then $\beta < q_1 \le \frac{V_0}{w_1}, \beta < D_1 \le q_1, 0 < D_2 \le q_2$

$$V_2 = pD_2 - (1 + r_f)[w_2 q_2 - p(D_1 - b_1)] = \Psi_1$$

(2) $q_1 \le \frac{V_0}{w_1}, 0 < D_1 \le q_1, D_1 \ge \beta, q_2 < D_2,$

then $\beta < q_1 \le \frac{V_0}{w_1}, \beta < D_1 \le q_1, q_2 < D_2$

$$V_2 = pq_2 - (1 + r_f)[w_2 q_2 - p(D_1 - b_1)] = \Psi_2$$

(3) $q_1 \le \frac{V_0}{w_1}, q_1 < D_1, q_1 \ge \beta, 0 < D_2 \le q_2,$

then $\beta \le q_1 \le \frac{V_0}{w_1}, q_1 < D_1, 0 < D_2 \le q_2$

$$V_2 = pD_2 - (1 + r_f)[w_2 q_2 - p(q_1 - b_1)] = \Psi_3$$

(4) $q_1 \le \frac{V_0}{w_1}, q_1 < D_1, q_1 \ge \beta, q_2 < D_2,$

then $\beta \le q_1 \le \frac{V_0}{w_1}, q_1 < D_1, q_2 < D_2$

$$V_2 = pq_2 - (1 + r_f)[w_2 q_2 - p(q_1 - b_1)] = \Psi_4$$

(5) $q_1 > \frac{V_0}{w_1},\ b_1 < D_1 \le q_1, D_1 \ge \beta, 0 < D_2 \le q_2, b_1 < \beta$

then $min\left(\beta, \frac{V_0}{w_1}\right) < q_1, \beta < D_1 \le q_1, 0 < D_2 \le q_2$

$$V_2 = pD_2 - (1 + r_f)[w_2 q_2 - p(D_1 - b_1)] = \Psi_1$$

(6) $q_1 > \frac{V_0}{w_1}, b_1 < D_1 \le q_1, D_1 \ge \beta, q_2 < D_2,$

then $min\left(\beta, \frac{V_0}{w_1}\right) < q_1, \beta < D_1 \le q_1, q_2 < D_2$

$$V_2 = pq_2 - (1 + r_f)[w_2 q_2 - p(D_1 - b_1)] = \Psi_2$$

(7) $q_1 > \frac{V_0}{w_1}, q_1 < D_1, q_1 > \beta, 0 < D_2 \le q_2,$

then $min\left(\beta, \frac{V_0}{w_1}\right) < q_1, q_1 < D_1, 0 < D_2 \le q_2$

$$V_2 = pD_2 - (1 + r_f)[w_2 q_2 - p(q_1 - b_1)] = \Psi_3$$

(8) $q_1 > \frac{V_0}{w_1}, q_1 < D_1, q_1 > \beta, q_2 < D_2,$

then $min\left(\beta, \frac{V_0}{w_1}\right) < q_1, q_1 < D_1, q_2 < D_2$

$$V_2 = pq_2 - (1 + r_f)[w_2 q_2 - p(q_1 - b_1)] = \Psi_4$$

(9) $q_1 > \frac{V_0}{w_1}, D_1 < b_1, \quad V_2 = 0$

In this case, V2 can be merged and expressed as bellow:

When $\beta < q_1 \le \frac{V_0}{w_1}$ $\{(1), (2), (3), (4)\}$

$$\beta = \frac{w_2 q_2 + (1 + r_f)(w_1 q_1 - V_0)}{p} = \frac{w_2 q_2}{p} + b_1, \quad b_1 = \frac{(1 + r_f)(w_1 q_1 - V_0)}{p}$$

Let $= (1 + r_f)[w_2 q_2 + p b_1] = p(1 + r_f)\beta$, $f(x) = \frac{1}{\bar{\xi}}$, then

$$\Psi_1 = p(1 + r_f)x_1 + p x_2 - \alpha \ ,$$

$$\Psi_2 = p(1 + r_f)x_1 + p q_2 - \alpha,$$

$$\Psi_3 = p(1 + r_f)q_1 + p x_2 - \alpha,$$

$$\Psi_4 = p(1 + r_f)q_1 + p q_2 - \alpha,$$

$$E(V_2) = \int_{\beta}^{q_1} dx_1 \int_0^{q_2} \Psi_1 f^2(x) dx_2 + \int_{\beta}^{q_1} dx_1 \int_{q_2}^{\bar{\xi}} \Psi_2 f^2(x) dx_2 + \int_{q_1}^{\bar{\xi}} dx_1 \int_0^{q_2} \Psi_3 f^2(x) dx_2 + \int_{q_1}^{\bar{\xi}} dx_1 \int_{q_2}^{\bar{\xi}} \Psi_4 f^2(x) dx_2$$

$$pf^2(x)(1+r_f)\left[\int_{\beta}^{q_1}dx_1\int_{0}^{q_2}x_1dx_2+\int_{\beta}^{q_1}dx_1\int_{q_2}^{\bar{\xi}}x_1dx_2\right]=p(1+r_f)f(x)\frac{(q_1^2-\beta^2)}{2}$$

$$pf^2(x)\left[\int_{\beta}^{q_1}dx_1\int_{0}^{q_2}x_2dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{0}^{q_2}x_2dx_2\right]=pf(x)\bar{F}(\beta)\frac{q_1^2}{2}$$

$$pq_1f^2(x)(1+r_f)\left[\int_{q_1}^{\bar{\xi}}dx_1\int_{0}^{q_2}dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{q_2}^{\bar{\xi}}dx_2\right]=pq_1(1+r_f)\bar{F}(q_1)$$

$$pq_2f^2(x)\left[\int_{\beta}^{q_1}dx_1\int_{q_2}^{\bar{\xi}}dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{q_2}^{\bar{\xi}}dx_2\right]=pq_2\bar{F}(\beta)\bar{F}(q_2)$$

$$\alpha f^2(x)\left[\int_{\beta}^{q_1}dx_1\int_{0}^{q_2}dx_2+\int_{\beta}^{q_1}dx_1\int_{q_2}^{\bar{\xi}}dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{0}^{q_2}dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{q_2}^{\bar{\xi}}dx_2\right]$$
$$=\alpha\bar{F}(\beta)$$

So,

$$E(V_2)=p\big(1+r_f\big)f(x)\frac{(q_1^2-\beta^2)}{2}+pf(x)\bar{F}(\beta)\frac{q_1^2}{2}+pq_1\big(1+r_f\big)\bar{F}(q_1)+pq_2\bar{F}(\beta)\bar{F}(q_2)$$
$$-p\big(1+r_f\big)\beta\,\bar{F}(\beta)$$
$$=\frac{p\big(1+r_f\big)(q_1-\beta)}{2}[\bar{F}(q_1)+\bar{F}(\beta)]+\frac{p}{2}\bar{F}(\beta)[q_1F(q_1)+2q_2\bar{F}(q_2)]$$
$$=\frac{p\big(1+r_f\big)(q_1-\beta)}{2}[\bar{F}(q_1)+\bar{F}(\beta)]+pf(x)\bar{F}(\beta)\frac{q_1^2}{2}+pq_2\bar{F}(\beta)\bar{F}(q_2)$$

If $\min\left(\frac{V_0}{w_1},\beta\right)\leq q_1$ $\{(5),(6)(7),(8)\}$, then

$$E(V_2)=\int_{\beta}^{q_1}dx_1\int_{0}^{q_2}\Psi_1f^2(x)dx_2+\int_{\beta}^{q_1}dx_1\int_{q_2}^{\bar{\xi}}\Psi_2f^2(x)dx_2+\int_{q_1}^{\bar{\xi}}dx_1\int_{0}^{q_2}\Psi_3f^2(x)dx_2$$
$$+\int_{q_1}^{\bar{\xi}}dx_1\int_{q_2}^{\bar{\xi}}\Psi_4f^2(x)dx_2$$

Appendix C The calculation of entropy value for Chapter 4

If there are m plans and n evaluation indexes, which are the formation of the original index data matrix $X=(Xij)m*n$. The steps are followed:

(1) Data matrix

$$A=\begin{pmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \vdots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{pmatrix}_{n\times m}$$

i is indicator number and j is data orders. In this paper, i is 3 and j is 6, 4, 6 respectively

(2) 2, Non-negative processing of data

Positive indicator:

$$X_{ij}^{'}=\frac{X_{ij}-\min(X_{1j},X_{2j},\cdots,X_{nj})}{\max(X_{1j},X_{2j},\cdots,X_{nj})-\min(X_{1j},X_{2j},\cdots,X_{nj})}+1,\ i=1,2,\cdots,n;\ j=1,2,\cdots,m$$

Reverse indicator:

$$X_{ij}^{'}=\frac{\max(X_{1j},X_{2j},\cdots,X_{nj})-X_{ij}}{\max(X_{1j},X_{2j},\cdots,X_{nj})-\min(X_{1j},X_{2j},\cdots,X_{nj})}+1,\ i=1,2,\cdots,n;\ j=1,2,\cdots,m$$

Moderate indicators:

$$X_{ij}^{'}=\frac{1}{1+\left|X_{ij}-X_{js}\right|}+1,$$

i=1,2,...n, j=1,2,...m Xjs is the standard value

3,Calculate the weight of plan i and index j.

$$P_{ij}=\frac{X_{ij}}{\sum_{i=1}^{n}X_{ij}}\quad (j=1,2,\cdots m)$$

4, Calculate the value of entropy

$e_j = -k * \sum_{i=1}^{n} P_{ij} \ln(P_{ij})$; k>0,ej>0, k depends on m, normally assume $k = 1/\ln m$

5, Calculate the Coefficient of difference

The more different of Xij, the higher influence it has, which implies a smaller entropy value. The Coefficient of difference is gj=1-ej.

Appendix D The calculation method of W-T ranking value for Chapter 4

The calculation is as followed:

$$WT_{nj} = \sum_{i=1}^{m} (C_i^n - 100EN_{ij} / \sum_{i=1}^{m} EN_{ij})^2 \qquad (5\text{-}1)$$

$C_i^n = \begin{cases} 100/n, i \le n \\ 0, i > n \end{cases}$, n is the order number of j indicators (in our case, jis 7), WT_{nj} is the combination of industry n and indicator j.

$$nq_j = k, nq = (\sum_{j=1}^{m} nq_j)/n \qquad (5\text{-}2)$$

When $WT_{1j} = \min WT_{kj} (K = 1,2,\cdots m)$, the smallest WT's order is k. EN_{ij} is the value of industry I and indicator, m is the total number of industry(in this paper is 18), N is total number of indicator (in this paper is 7), nq_j is the number of mainstay industries of indicator j, nq is the number of mainstay industries of all the indicators.

$$D = \begin{bmatrix} D_{11} & D_{12} & \cdots & D_{1n} \\ D_{21} & D_{22} & \cdots & D_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ D_{m1} & D_{m2} & \cdots & D_{mn} \end{bmatrix} = \left\{ D_{ij} \right\}_{m \times n} \qquad (5\text{-}3)$$

$$E_i = \sum_{j=1}^{N} e_j D_{ij} \qquad (5\text{-}4)$$

D is the matrix of mainstay industries, D_{ij} denotes the index value of industry I and indicator j, e_j is the weight of indicator j and E_i is the ranking value of industry i.