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Simulation of Economic Effects of Mechanical Technology Transfer in Cereal Agriculture

by

Ying Li

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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Abstract

The purpose of this study was to simulate the possible economic effects of technology transfer from Alberta to cereal unit-farms in Heilongjiang Reclamation Area (HRA).

Based on the production function and the concept of *birth cohort*, a simulation model was built to estimate the possible effects of technology transfer both from Alberta to GROUPH (high capital/labor ratio group of cereal farms) and from GROUPH to GROUPL (low capital/labor ratio group of cereal farms) according to a predetermined planning path.

Four scenarios were investigated in the simulation analysis. The first was to estimate the effects of the change in capital formation only; the second was to explore the effects of simultaneous changes in capital formation and production elasticities; the third was to explore further the effects of simultaneous changes in capital formation, production elasticities and the price ratio of capital to labor; the final scenario was to examine the effects of changes in both capital formation and the price ratio.

The results of all scenarios showed that the second scenario produced relatively significant effects in HRA unit-farms in the short run; the third scenario would be appropriate to GROUPH's development in the long run. It implies that Alberta technology embodied in capital formation would promote cereal production in HRA but more employment opportunity creation is required to accomodate a great amount of labor displacement by capital. These

scenarios do not advocate any effective technology transfer from GROUPH to GROUPL due to their similarity of technology use. Adjustment of relative factor costs and capital formation would be more appropriate to production of GROUPL than other alternatives.

To avoid distortion of technology transfer, policy considerations should be underscored on efficient factor use, especially capital and labor, and employment opportunity creation.

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I. Introduction

A. Problem Definition

Technical change as a thrust of growth and development in agriculture has drawn considerable attention since the Green Revolution took place in Asia. The rates of technology advance are, however, still low in the low income countries (LICs), which are in urgent need of advanced technology for expanding food production. Thus technology transfer as a source of technical change has long been in vogue.

The transferability of Alberta's technology in cereal production to Heilongjiang state farms in China is examined in this thesis. The technology transfer faces at least two serious conflicts. One concerns the structural impact should Alberta's capital-intensive mechanical technology be transferred to the labor intensive structure of Heilongjiang state farm agriculture. The second arises from different motivations for technology change in the two economic systems. For Alberta, one of the most remarkable motivations is cost-saving. But for Heilongjiang, the motivation is production-increasing. To meet the basic need of the expanding population by all means is the main purpose of agricultural production in Heilongjiang.

Undoubtedly, labor release will be one of the most prominent phenomena in Heilongjiang state farms if Alberta's cereal techonology is transferred. In the situation that secondary and tertiary industries have not been developed and "disguised unemployment" or underemployment exists in state farms, labor displacement by mechanical technology from Alberta will likely exacerbate the employment situation in Heilongjiang if there is no accommodation of the conflicts addressed in the previous paragragh. Hence, the following question should be asked and answered: is the technology transfer from Alberta appropriate to the motivational context of Heilongjiang agriculture, especially to its agricultural employment?

To avoid the negative impact of Alberta technology transfer on Heilongjiang agriculture and to facilitate the rate of technology change as well as to increase grain production, it is important to understand the relationship between technology and structural change. The focus of this study is to explore the possible economic effect of technology transfer on the structure of the grain production farming system in Heilongjiang state farms; specifically, on labor use, capital labor ratio and labor productivity.

B. Objectives and Significance

To be more specific, the main objectives of this study are:

1. to explore the differences in socioeconomic contexts between the two agricultures within the Heilongjiang state farms and in Alberta;
2. to estimate quantitatively the effect of various scenarios for technology transfer on labor use and

the capital/labor ratio as well as labor productivity in Heilongjiang state farm agriculture, on the assumption that Heilongjiang grain technology will catch up with the 1981 levels for Alberta in 20 years (1984-2004);

3. to propose some appropriate conditions for successful Western technology transfer to Heilongjiang state farms.

The significance of this study lies in the interest of both Heilongjiang and Alberta in attempting technology transfer on grain production. By anticipating the influences of technology transfer in Heilongjiang, the results may contribute to decision-making processes as well as facilitate the agricultural cooperation of the two provinces and their countries, Canada and China.

C. Organization of The Thesis

This thesis consists of six chapters. Chapter One delineates the research problem, objectives and significance of this study, and the organization of the thesis. Chapter Two highlights the state farm system in China, provides the natural and socioeconomic background of the Heilongjiang reclamation area (HRA), and identifies the similar and dissimilar characteristics between HRA and Alberta. Chapter Three reviews relevant theoretical studies and research. Chapter Four discusses research methodology and data analysis. It reports the sampling process, builds up a simulation model of technology transfer and explains the way of analysing the collected data. Chapter Five presents and discusses the results of simulation analysis. Chapter Six provides policy implications and conclusion.

II. Grain Agriculture: The State Farm System And Alberta Family Farm

Clearly, the background of natural and socioeconomic circumstances in HRA and Alberta is a prerequisite to considering technology transfer. This chapter first provides a brief overview of the state farm component of Chinese agriculture, then turns to HRA's natural and socioeconomic milieu. This chapter also compares the structures of HRA and Alberta cereal systems. With these considerations and comparisons, the technology gaps between Alberta and HRA are revealed.

A. Overview: The State Farm System In China

Historical Background

In 1949, China's historical agricultural economy of semi-feudalism and semi-colonialism came to end when the Communist government came into power. A new agricultural ector has thereby gradually emerged. This sector is composed of two systems: the collective and the state farm systems. For the purpose of this research, only the state farm system is addressed.

The state farm system was established mainly on the basis of land reclamation. From the viewpoint of both military defence and economic development, land reclamation highly focused on the border provinces of northeast, northwest, farwest and along the coast. The majority of state farms were sited on wasteland or uninhabitable land subject to drought or waterlogging, on difficult alkaline or acid soils and in areas regularly hit by sand and wind storms[1]. The earliest group of state farms was set up by army soldiers in 1947-1949 in Heilongjiang province. A climax of land reclamation and farm establishment was reached in 1958-59. At that time, thousands of veterans and youngsters came from all over the country and settled down in the marginal and inhospitable regions of the border provinces like Heilongjiang, Yunnan, Guangdong and Xinjiang Autonomous Region (A. R.). State farms used to have the characteristic of army organization, but now they are only agricultural production enterprises.

State Farm Distribution

There are 2,048 state farms across the country (See Figure II.1). These farms cover 27 million hectares[2] of land, 4.1 million hectares of which is cultivated[3]. Four major reclamation areas contain 431 state farms of 2.9 million hectares of cultivated land and 0.34 million hectares of rubber area. The largest reclamation area is in Heilongjiang province, which has 84 state farms occupying 1.78 million hectares of cultivated land. The second largest is in Xinjiang A. R. which contains 169 state farms with

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[1] T. R. Tregear, *An Economic Geography of China*, 1970, p. 45.
[2] 1 ha.= 15 mu in Chinese unit measurement.
[3] Bureau of Land Reclamation and Agriculture, Beijing(BLRA), *Statistics Yearbook, 1984*.

1.06 million hectares of cultivated land. The third one, Guangdong province, 140 state farms with 61 thousand hectares of cultivated land and 281 thousand hectares of rubber area. The fourth, Yunnan province, 38 state farms having 13 thousand hectares of cultivated land and 60 thousand of rubber aera. According to 1984 statistics, those four reclamation areas account for 21% of all state farms, 62% of total factories, 50% of commerce, 87% of transportation, 78% of construction, 46% of total population, 47% of total employed workers and 45% of gross output of agriculture and industry in the whole state farm system (See Appendix A).

The reclamation areas of Heilongjiang and Xinjiang are specialized in grain production; in the other two areas, Guangdong and Yunnan, rubber production is most important. State farms in the provinces other than those four major reclamation areas are allocated relatively small amount of land. Hence, their importance is not as great as those of the four reclamation areas mentioned above. [4]

Characteristics

The state farm system is one of the major components of China's agricultural sector, and it is quite different from the collective system in the following aspects.

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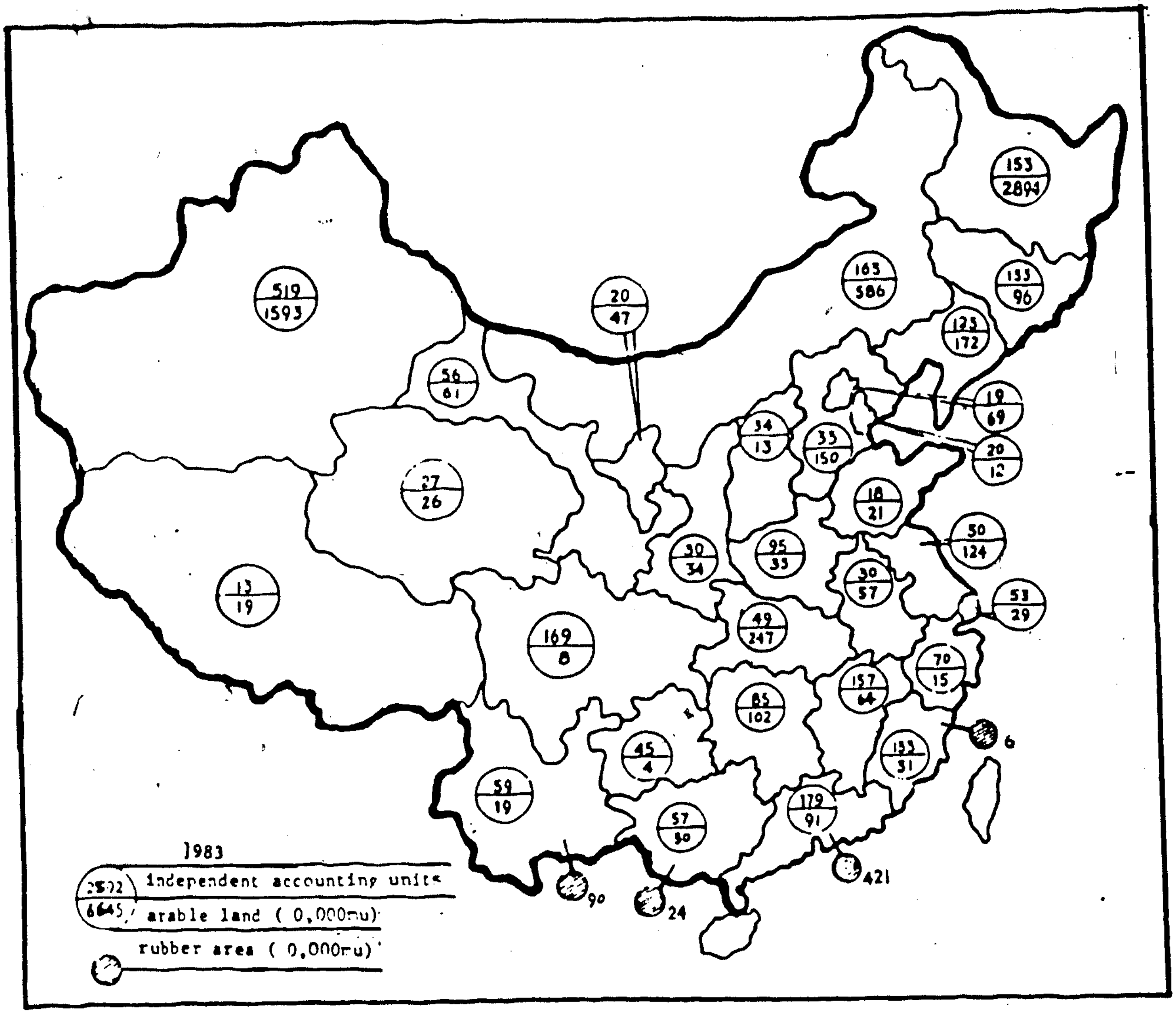
[4] Even though the state farm system owns only 4.5% of China's cultivated land, it plays an important role in the country's food supply. This aspect is nicely presented in Pang and Boer's article "Management Decentralization on China's State Farms", in *American Journal of Agricultural Economics*, Nov., 1983.

Figure II.1 Map of State Farm Distribution Nationwide.



Source: It is adapted from *Statistics Yearbook, 1983*. Beijing: General Bureau of Land Reclamation And Agriculture, 1984, p. 3.

(i) Property Ownership

State farms are wholly owned by the state. The farms were built up mainly on reclaimed land and all their production means and materials were allocated by the state.

The collective system was established on the basis of agricultural cooperation and collectivization of individual farmers who obtained land from the land reform in 1950 and had their own other production means and materials. All the assets of a collective farm are owned in common by its members[5].

(ii) Organization System

The structure of the state farm system is shown in Figure II.2, which will give us an entire picture of how the state farm systems are organized across the nation.

The ministry of agriculture, animal husbandry and fishery controls both the collective and the state farm systems. The general bureau of land reclamation and agriculture, through the provincial general bureaus of state farms, controls all the state farms across the nation. In some provinces, like Heilongjiang, there is a level between the general bureau and the state farms, which is called the sub-bureau of state farm management.

State farms are organised in three management levels: at the top is overall farm management in state farms. The

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[5] Since 1978, family production has taken over in the collective system, but the ownership of the production means remains the same.

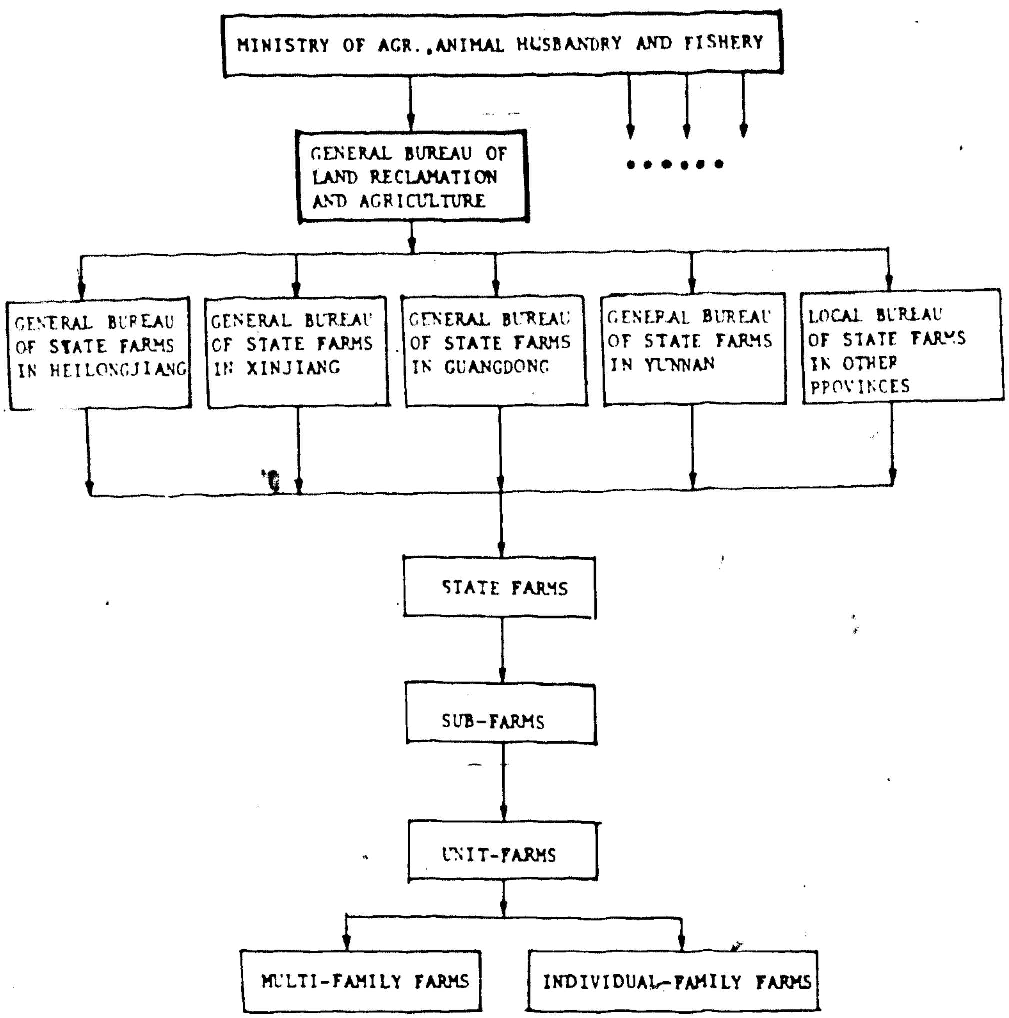
basic production units used to be unit-farms. But now the different family farms become the basic production units. So under unit-farms there is a new family farm system. Sub-farms exist only if state farms are extremely large and need to be further divided. Before 1978, the collective agriculture system was organized by the following structu the Ministry of Agriculture, Animal Husbandry and Fishery the highest authority for the collective system, through the provincial agricultural bureaus and the county's agricultural bureaus, controled communes all over the nation. Then the commune system was organized in three management levels: commune, brigade and production team. Following the agricultural reform in 1978, this system changed. Family production units now constitute the main part of the collective economy.

(III) *Management Features*

Before 1978, the management features of state farms, compared with communes, can be distinguished by what follows. First, state farm production decisions were made mainly by the central government through provincial bureaus. All farm profits went to the state and the state covered all farm losses if there were any. By contrast, communes were financially independent. Profits and losses were shared by commune members.

Secondly, the central government was responsible for every state farm investment expenditure. However, communes

Figure II.2 Organization of The State Farm System in China, 1985.



had to finance their own investment expenditures except for government grants for basic irrigation and drainage construction.[6]

Thirdly, state farms employ permanent workers who are paid by wages. Although this "wage class system" has broken down during the recent agricultural reform, the state continues to offer substantial subsidy to permanent workers in some state farms. By contrast, commune members used to be paid according to "work point system"[7]; however, this system has no longer been used since 1980.

(iv) Mechanization

State farms hold a safe lead in the process of China's agricultural mechanization. For each 666 hectares (ten thousand *mu*) of cultivated land, they possess 416 horse power of large and medium tractors, 2.4 grain combines, 3 transport vehicles and 60% of comprehensive mechanization in

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[6] Ibid.

[7] "Work point" was a measurement of a commune member's labor, which became the basis of labor's income from the collective economy. The point scale was from 0 to 10. A male worker's labor was measured by 10 points, while a female worker's job might be, on average, measured by 6-8 points a day. By the end of a year, commune members had to convert their total work points into "work days", which were measured by total work points divided by 10. This meant that a work day was worth 10 work points. After production teams sold their products and subtracted their costs, they obtained total incomes. Then using the total incomes to divide by total work days, they got an exchange rate which stated how much a work day was worth. The exchange rate varied widely with different production teams in a commune. Commune members accordingly figured out their own incomes multiplying their total work days in a year by the exchange rate.

farming. In contrast, the national average possession of large and medium tractors is 216 horse power, 0.18 grain combines, 0.9 transport vehicles, and 30% of comprehensive mechanization in farming (see Table II.1). The degree of mechanization in the state farm system is twice as high as that of average national level. In other data (Peng and Boer, 1983), it is documented that 9% of all large and medium tractors, 70% of all combines and 25% of agricultural transport vehicles in the nation are controlled by state farms. Obviously, these farms play a very important role in extension of new technology, experimentation on scientific farming and in the process of agricultural transformation.

At present, the newly-built family farm system, along with the responsibility system, has brought about a change in the production relationship in the state farm economy and possibly presented a new strategy for development of state farms in the near future.

In summary, China's state farm system was established mainly on the basis of land reclamation in the border provinces. The main reclamation areas are Heilongjiang, Yunnan, Guangdong provinces and Xinjiang A.R.. The state farm system and collective system differ in ownership, organization, management and mechanization. To some extent, the agricultural reform movement has changed the original organization and management features of the state farms

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• Percentage of comprehensive mechanization in farming means the ratio of the cultivated land tilled, seeded and harvested by machinery to the total cultivated land.

Table II.1 Comparison of Mechanization: State Farm System And Nationwide (per 666 hectares cultivated land).

	large and medium tractor (HP)	grain combines	degree of mechanical farming (%)
State Farm System	416	2.4	60
Nationwide	216	0.18	30

Source: the material was provided by the Department of Agricultural Engineering and Agricultural Modernization, Heilongjiang "August 1st" Land Reclamation University, China, 1983.

system.

B. Heilongjiang Reclamation Area (HRA)

Geographical Background

Landform

The Heilongjiang reclamation area (HRA) lies in northeast China. State farms occupy 5.6 million hectares of land, stretching from 123°40'(E) to 134°40'(E), and 44°10'(N) to 50°20'(N). The northern end of the area is the Black Dragon River. The east is bounded by the Ussuri River. The west is adjacent to Inner Mongolia A.R. and the southern end is Jilin province. The Heilongjiang reclamation area is vast in territory. A variety of landforms is composed of mountains, hills and plains. A characteristic of this area is that the land declines from the northwest to the southeast. The majority of state farms in HRA are located on the following five types of landforms:

(i) Lesser Hingan Mountainous Area

This area is northwardly adjacent to the Great Hingan Mountains, and eastwardly to the Black Dragon River. Its elevations range from 600 to 1000 meters above sea level.

(ii) Southeast Hilly Land

A part of the Changpai Mountains is in this area. The elevations range from 400 to 1000 meters above sea level.

(iii) Song-Nen Plains

This area lies on the west Heilongjiang. It is an alluvial plain of the Songhua River and the Nenjiang River. The elevation is from 150 to 200 meters above sea level. A number of livestock farms are located in this area.

(iv) Low Three-River Plains

This area covers the delta of the Black Dragon River, the Songhua River and the Ussuri River. The elevation is from 40 to 90 meters above sea level. It has been largely explored and reclaimed. It is a major base of grain food production in the province.

(v) Low Muxin Plains

It is a lake-alluvial plain. The elevation is from 60 to 80 meters above sea level.

Climate

The majority of state farms in this reclamation area are dispersed in the frigid-temperate, continental monsoon climate zone. Because the whole reclamation area covers 6 degrees in latitude from the south to the north, temperature varies widely in the span of the region. The average of annual temperatures runs from -0.9°C to 3°C. The average of max~~imum tempe~~rature in July is about 20°C to 22°C. The extreme temperatures in July were recorded historically at about 37.6 - 38.5°C. The average minimum temperatures in January is about -19 - -22°C. The extremely low temperatures in historical record were about -42 - -44°C.

Frost starts in late September, and ends in the middle of May in the east; starts in the middle of September, and ends late in May in the north . Frost-free periods range 120 to 140 days in the east; 100 to 120 days in the north. The freezing period in a year is about 150 to 200 days. The frozen layer of land can be as deep as 1.5 - 2.5 meters.

Daylight hours between April and September amount to 1300 to 1500; 500 hours in spring; 650 hours in summer; 250 hours in fall. The thermal resource in Heilongjiang province plentifully meets the need of growing annual crops such as wheat and soybean. The Three-River plains in the east is favourable for cultivating maize and rice'.

Rainfall in this reclamation area is relatively plentiful. Annual mean precipitation is 540 mm (from the west to the east: 450 - 600 mm). Rainfall not only varies widely from year to year but is also unevenly distributed through a year. Sometimes the extremes for a single year range 800 to 300mm. More than 60-70% of the annual rainfall occurs in the summer season from June to August. This provides enough moisture for crops in farm fields, but the rainy season does affect heavily the harvest time of wheats. Only 10 to 15% of the annual rainfall comes between the latter part of May and the beginning of June. The early summer drought does affect crops, especially wheat production.

Soil

There are five main types of soils in HRA[10].

First, brown soil is 16.2% of the total land and 9.5% of the total cultivated land in this area. This kind of soil mainly ranges in the Lesser Hingan Mountains, eastern mountains and hill zones.

Secondly, plano-soil, one of the black soils, amounts to 24.5% of the whole area, but only 0.13% of the cultivated land. This type of soil is liable to drought and waterlogging.

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[9]Heilongjiang GYNCJJFZS bianXieZu, *History of Economic Development in Heilongjiang State Farms*, 1984, p. 5.
[10]Ibid., pp. 8 - 10.

Thirdly, black soil occupies 16.4% of the total land and 24.4% of the total cultivated land. This is the best soil in HRA. It mainly ranges in hill zones.

Fourthly, meadow soil takes 22.2% of the total land and 30.8% of the cultivated land. This is also a productive soil. Most of this type of earth is distributed in the plains, lowlands and along rivers.

Fifthly, marshy soil occupies 16.3% of the total land and 3.63% of the cultivated land.

Socioeconomic Properties of HRA State Farms

Population and Labor

A population of 1.45 million inhabits the reclamation area (1984). About 44.1% of the population, or 640 thousand people are employed as permanent workers in state farms[11]. The proportion of population in this area to the total rural population in the province is 7.68% [12], but the proportion of cultivated land to the total in the province is 22.4%. The mean ratio of land to man in the area is 52.3 *mu* (3.5 hectares) per person, while the ratio in the whole province is 20.87 *mu* (1.4 hectares) per person[13]. Compared with other provinces in China, the population density in Heilongjiang

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[11] GBSFH: *Introduction to General Bureau of State Farms in Heilongjiang Province*, 1985, p. 2.
[12] This figure is counted from *Chinese Statistics Abstract, 1984*, P. 16.
[13] The number is figured from the total population and he total land area in the province. See *Chinese Statistics Abstract, 1984*, p. 16.

province is remarkably low, much lower than the national mean population density[14]. In spite of this, the population crude growth rate in this area is still relatively high, which is 5.16 per thousand[15]. This rate of growth forms the main source of labor for the coming decades.

The labor supply in HRA, in general, exceeds its demand. The total number of employed people in the HRA in 1984 was 640,000, but the whole labor force numbered 732,606. In the same year, the number of people waiting for employment was recorded at 61,516 in the whole HRA, but only 20,925 people obtained employment. The rate of labor absorption each year is documented at around 50 percent of the total job seekers. The rest of the laborers have to be self employed. Normally, they are involved in some collective enterprises or family farms or individual businesses. By the end of 1984, about 45,945 people worked in collective enterprises and about 6,660 people were engaged in individual businesses[16].

Organization of HRA State Farms

The General Bureau of State Farms in Heilongjiang (GBSFH) is the headquarters of all state farms in Heilongjiang province. Through nine sub-bureaus of

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[14] National mean population density in China is 107 people per square kilometer; while only 70 people per square kilometer inhabit in Heilongjiang. *Chinese Statistics Abstract, 1984*, p. 16.
[15] GBSFH: *Statistics Yearbook, 1984*.
[16] The above numbers are from my interviews in the labor and wage division in GBSFH.

management, it controls 84 state farms, 24 factories, 14 commercial enterprises, 5 transportation enterprises and 9 construction units[17] Each sub-bureau of management has 5 to 14 state farms. Organizations and functions in a state farm have been noted in the previous section, so here, only new organizations which have functioned since late 1984 are emphasized.

Agricultural economic reform greatly influenced unit-farm levels. Many unit-farms functioned as unique independent accounting units until 1984. Starting from late 1984, Staff family farms were established. These family farms play the same role as unit-farms and the unit-farms' functions have been changed to some extent. By the end of 1985, most unit-farms in Heilongjiang had functioned as production service stations which supply inquiry and marketing services. The new-built family farm system in unit-farm level can be categorized as the two major types:

1. Multi-family farms with some machinery and equipments
2. Individual family with or without machinery and equipments

A multi-family farm is composed of a few families. It has more labor, more land, more machinery and equipment than individual family farms. In general, it operates 67 - 133 hectares or more cultivated land and specializes in wheat and soybean production. It owns its machinery and equipment,

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[17] BLRA, *Statistics Yearbook,1984*.

completing the whole production process with its own machinery. This kind of farm can take advantage of economies of size.

Income distribution among the families in farms of this sort is a potential problém. All members in the multi-family farm receive equal income for their work which may not be of similar quality and/or quantity. Accordingly inefficiency of labor use resulting from equalitarianism might occur in the multi-family farms.

An individual family farm is operated by one family. The individual family normally does not own its machinery and equipment, and operates approximately 4 - 5 hectares of cultivated land. This small type of farm cannot complete the whole process of production with its own resources. Labor and machinery are hired when needed in the process.

Grain production is not the main occupation in this type of small individual farms. Animal raising, service and even construction are involved in their production activities and become more and more dominant over time.

It can also be found that the individual family farm with machinery operates as much as 67 - 133 hectares of cultivated land. Its specialization is grain production. The owners, as operaters of this type of farms, are supposed to have the most incentive to become as efficient as posssible because only owners are responsible for the best and the worst of their production. However, there are not many of this type of farms at the present time.

Increasing flexibility within the family farm system does not mean that planning control by the state has been completely annuled. Most production from family farms is still arranged by commanding quotas, which determine acreage, input levels, and the species of grain.

Grain Production

The agricultural economy in HRA mainly concentrates on crop production. The majority of crop production is grain, where grain means wheat, maize, barley, rice and soybeans. In 1984, the area sown to grain was 91.8 percent of the total area cropped; cash-crop, 2.4 percent; and other crops, 5.67 percent in the whole HRA (see Appendix B). Normally within grain production, wheat accounts for between 46% and 57% of the total area cropped; soybean, 33.8 - 46.3%; maize, 3.5 - 7.8%; rice, 0.7 - 1%; and others, 1.2 - 2.3%. In the period of time 1976 - 1983, yield of grain was 1522 kgs. per hectare, up to 1627 kgs. per hectare in 1984; labor productivity of grain was 11.7 tons per worker a year; the average commercial rate for grain was 48.6%, which meant that grain sales were 48.6% of grain production[18]. The balance of the grain was used within the state farms. In the best year 1980, output of grain was 3.4 million tons, which was 23% of the total output of grain in the whole province, and 44% of the total output of grain nationwide within the state farm system. The amount of HRA state farm grain

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[18] GBSFH: *An Introduction to GBSFH*, 1985, pp. 5-7.

purchased by the state was 40% of the total state purchased in the province[19]. Obviously, grain production in HRA plays an important role in the supply of commercial food grain in the province and the nation. Even though the area sown to grain has decreased a bit in the period of 1976-81, due to changes in crop prices and rationalization by growing crops suited to local conditions[20], the importance of grain production in HRA is not dwindled.

Technology Employed

HRA is the most mechanized agricultural region in rural China. It owns about 1.2 million mechanical horse power, which is 37.5% of the total mechanical horse power in the state farm system; and 65% of combines of the total in the national state farm system[21]. Apart from the state farm system, compared with other provinces, Heilongjiang province holds highest degree of mechanization. Around 70% of arable land is tilled by machinery; 43% is sown by machinery; 22% is harvested by mechinery (see table II.2). Consequently, the technology employed in agricultural production in HRA is generally more mechanized than other places in the nation.

The majority of machinery used in HRA was imported from the Soviet Union and other east European countries in the 1950's. A small part of the machinery employed was domestic products. Before 1970's, the kinds of combines used mainly

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[19] Heilongjiang GYNCJJFZS bianxiezu: *op.cit.*, 1984, p. 348.
[20] Pang and Boer: *op.cit.*, 1983, pp. 662-3.
[21] GBSFH, *Statistics Yearbook, 1984*,

Table II.2 Degree of Mechanization by Selected Provinces.

Province	mechanized tilling (%)	mechanized seeding (%)	mechanized harvesting (%)
Heilongjiang	69.4	43.4	22.0
Sichuan	8.4	0.2	0.0
Shandong	59.5	19.0	2.3
Guangdong	38.0	0.1	0.2

Source: the material is provided by Dept. of Agricultural Engineering and Mechanization, August 1 Agricultural Reclamation University, 1983.

consisted of Russian CK-3 and CKn-4, Hungarian ACD-330, and Dongfeng combines which were produced domestically. The number of imported tractors and combines has increased since 1976. Imported tractors and combines, such as CK-5 from Russia, E-512 and E-516 from East Germany, as well as others from the John-Deere machinery company in the United States, have formed the most productive and updated part of mechanical technology in HRA. Other self-propelled machinery and traditional methods are still highly utilized in post-harvesting process, transportation, and some other production fields.

In fact, the existing technology in HRA consists of mechanization, semi-mechanization and traditional means. In terms of the Chinese agricultural reality, the mechanization degree in HRA has reached an important position. But it is still poor by the Western standard. This situation implies that agricultural economy in HRA is still in the process of transformation from its traditional agriculture to the modern one.

Bottlenecks

Two major bottlenecks exist in the agricultural development of rural China: (i) absorption of the flow of surplus labor from agriculture, and (ii) financial basis for technological advancement and agricultural development. No doubt, HRA faces the same bottlenecks in its process of development.

First of all, the shortage of capital to develop agricultural production technology and other industries is relatively severe for many state farms. Since agricultural reforms were implemented in 1978, farms have been financially independent. However, it is difficult for most state farms to make large investment without any government's aid, because most statefarms did not make any reliable profits from their production except for deficits before 1978.

Secondly, the structure of the agricultural economy is based on crop monoculture. Crop production accounts for 90.6% of the gross value of agricultural output (GVAO), while the sum of forest, livestock, sideline and fishery is less than 10% of the GVAO (see Appendix C). Since grain is less profitable than cash-crops and industrial products, it is difficult for state farms to get reliable and adequate income from this specialized output structure to enable significant investment in technology for diversification. This may become an obstacle to creating employment opportunities for surplus labor in the near future.

Thirdly, rapid growth and irrational constitution of the labor force provide a reserve army of labor. A tendency of annually increasing labor by more than 40,000 people will continue up to the year 2000[22]. But the capacity of absorbing labor each year is only about half of that number. Most of the newly-employed people are assigned in crop sector. This situation has made the labor productivity decline and the underemployment rate increase in HRA.

Fourthly, tertiary industries in HRA, namely, service, commerce, communication, and transportation, etc., are relatively weak. The number of the people engaged in this sector are around 15.6% of the total number of the workers, like that in other low income countries. The relatively low commercial rate and the poor marketing mechanism indicate an underdeveloped commercial economy. The commercial rate for grain averaged 49.7% in the period 1980-84[23]; the commercial rate for output of livestock, like pork, averaged 38.9%. The existing marketing mechanism appears to limit considerably the circulation of commodities in better harvest years, in which producers find difficulty selling their products. Thus commodity production is to some extent restricted by the

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[22] The figure is from the author's discussion with officers in the Division Labor and Wage in General Bureau of State Farms in Heilongjiang.

[23] GBSFH, *Statistics and Financial Statement Book*, 1984.

capacity of the marketing mechanism.

In summary, the lack of capital, relatively undiversified agricultural economy, irrational composition of labor force and underdeveloped tertiary industries result in underemployment and low productivity. And the combination of these hinders the process of agricultural growth and economic development in HRA.

C. Comparison of Two Agricultures: Alberta and HRA

Alberta Agriculture

Alberta agriculture started with settlement of the first immigrants from the east at the turn of the century. It has experienced the transition from hunting and gathering to one of the most productive and sophisticated type of agricultures in the world. At present, one-fifth of Canada's total rural population, which amounts to 200,000 people, inhabit Alberta; about 20% of Canada's total agricultural output is produced by this province[24].

Alberta is one of the western prairie provinces in Canada. It covers an area of 660,411 square kilometers[25], which is 6.6% of the entire Canadian land. Approximately 28 million acres are classed as cultivated land for crop and pasture. This accounts for 25% of the total cultivated land in Canada; about 39 million acres are reserved as forest

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[24] Byfield, T., *The Atlas of Alberta*, 1984, p. 142.
[25] Ibid., p. 24.

land, which is 60% of the land in Alberta[26].

Cattle and grain are the leading sectors in Alberta agriculture. "The provincial farm income for the year 1981 was $3.9 billion, of which cattle accounted for 1.2 billion, hogs a fifth of a billion, wheat 1.1 billion, and barley almost half a billion, canola earned better than a quarter billion dollars"[27]. Wheat, Alberta's dominant grain crop, is largely exported, making an important contribution to Canada's balance of trade picture. Grain yields have been increasing over the past forty years. These increases have resulted primarily from technological advances, such as the use of machinery, fertilizers, pesticides, more efficient farm practices, and higher-yielding crop varieties. With the boom of the oil industry in Alberta, labor has been leaving agriculture. It resulted in labor scarcity and generated substitution of capital and energy for labor. Since then, Alberta farming has rapidly shifted into the category of energy-intensive and capital-intensive ag-industry.

Since the transferability of grain production technology from Alberta to HRA is under consideration, some physical and socioeconomic aspects of both agricultures should be clarified.

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[26] Alberta Agriculture, *This Land of Alberta*, 1977, p. 7.
[27] Byfield, T., *op.cit.* p. 142.

Similar Characteristics

Physiographically, Alberta and HRA have some characteristics in common. As far as geographic location is concerned, Alberta is situated in the northwestern part of North America between 49° (N) and 60° (N), 110° (W) and 120° (W); while HRA lies in the very northeastern area of China between 44° (N) and 50° (N), 123° (E) and 134° (E). There is not much difference in their geographic positions in north latitude. Their similar latitudes provide a clue to understanding their natural resource situations. Farming in a northernly latitude in Alberta or HRA with a continental type of climate is strongly affected by a number of factors.

Table II.3 summaries a number of natural environmental features of the two agricultures. Temperature, precipitation, frost-free period, growing degree days, daylight hours and major farming soils, are very much similar. Their crop production is dominated by wheat. The primary hazard to agriculture is drought and waterlogging.

Dissimilar Characteristics

Their socioeconomic aspects are dissimilar relative to their natural environmental characteristics. A number of distinguishing features indicated in Table II.4 give people a general impression of the difference between the two agricultures. HRA, a part of Heilongjiang province in China, has a population of 1.4 million, which is 64.8 percent of that in whole Alberta, with 1.8 million hectares of total

Table II.3 Comparison of Natural Environment and Crop.

	Alberta	HRA
Climate	frigid continental	frigid continental monsoon
Mean July Temp. (max. °C)	15 - 24	20 - 22
Mean Jan. Temp. (min. °C)	-15 - -25	-19 - -22
Annual Mean precipitation(mm)	350 - 650	450 - 600
Frost-free days	68 - 125 or over	120 - 140
Daylight(hrs)	448*	480**
Growing degree day	2000 or more	1000 - 1800
Major farming soil	brown, black soils	brown, black soils
Major crop	wheat, barley	wheat, soyabean
Natural hazard	hail, drought and waterlog	drought, waterlog

Source: Alberta's data from *This land of Alberta*, 1977, p. 13. and p. 22.
HRA's data from *History of Economic Development in Heilongjiang State Farms*, 1984, pp. 3-6.
* from a major grain area in Alberta in July.
** HRA's average daylight hours in July.

arable land, which is only 15.8 percent of Alberta's. The farm population in HRA amounts to 1.3 million, which is 6.8 times more than Alberta's. The land-man ratio in terms of arable land in HRA is 1.3 hectares per person, while it amounts to 57.4 hectares per person in Alberta. The number of people employed in HRA agriculture is 11 times greater than that in Alberta. Total output of grain production in HRA reaches 2.4 million tons, which is 22.4 percent of that in Alberta. Yield per hectare in HRA is 1627 kilograms per hectare, which is 85 percent of Alberta's.

Four factors, such as farm organization, farm size, finance and capital formation and partial productivity are singled out for our comparison of the two different agricultural systems in detail.

Farm Organization of Alberta Grain Farms

Farm organizations in Alberta are mainly classified into three categories: individual proprietorship, partnership and corporation. The majority of Alberta farms are individual proprietorships constituting 88% of the total number of farms (see Table II.5). This phenomenon represents a free individual economy controlled by market institutions. However, about 71% of the farms in HRA are under the state farm system; and 29% of the farms are owned by collective people who are nonemployed workers in state farms. This situation reflects the state ownership and a central planning control economy. The difference in the economic and social institutions between the two provinces will constitute some difficulty in technology transfer from Alberta to HRA.

Farm Size

Table II.4 General Comparison of Two Agricultures, HRA And Alberta.

	HRA	Alberta	HRA as % of Alberta
total arable land (000 ha.)	1,777[a]	11,200[b]	15.8
total population (000 people)	1,452	2,238[c]	64.8
farm population (000 people)	1,328	195[c]	6.8 times
land-man ratio (ha./man)	1.3	57.4	2.3
employed workers (000 people)	640	58[c]	11 times
grain production (000 tons)	2,413[d]	10,787[e]	22.4
yield per ha. (kgs./ha.)	1,627	1,904[e]	85.0

Sources: GBSFH: *Statistics Yearbook, 1984*, pp. 10-2. Statistics Canada: Grain Trade of Canada, 1984/85, p. 20.

a: from Appendix A
b: from Alberta Agriculture, *This Land of Alberta*, 1977.
c: from Statistics, Canada, *1981 Census Statistics*, 1982.
d: GBSFH, *Statistics Yearbook, 1984*. It includes wheat, rice, millet, corn, sorghum, barley, mixed food grain and soybean.
e: calculated from Statistics, Canada, *Grain trade of Canada, 1984/85*, 1986. It includes wheat, oats, barley, mixed grain, corn and rye.

Table II.5 Comparison of Farm Organization Between HRA (1984) And Alberta (1981).

Alberta Farm Organizion	Number of farms	% of farms	HRA Farm Organizion	Number of farms	% of farms
Individual farm	30,322	88.5	SF System		
Partnership	3,010	8.8	state farms	84	71
Corporation	846	2.5	unitfarms	1,919	
-family corp.	764				
-other corp.	82		collective	966	29
Other Organization	90	0.2			
*total	34,268	100			

Source: Commercial grain farms cross classified by type of organization, Alberta, 1981, Census of Agriculture. Data for HRA is from GBSFH: *Statistics Yearbook, 1984*.
*here total means total commercial grain farms in Alberta

The average farm sizes of different sorts of farms are shown in Table II.6. The size of unit-farms in HRA is close to that of family company farms in Alberta. The average farm size provincewide in Alberta had increased from 277 improved hectares in 1971 to 349 improved hectares in 1981[28]. The tendency of increase in farm size in Alberta still continues. However, with management decentralization in the state farm system, family farms gradually replace parts of functions of unit-farms, hence the scale operation tends to be a smaller one. The largest scale of family farms in HRA operates about 133 hectares. Perhaps the smallest size of individual family farm in Alberta has the same scale. Farm sizes over the provincial level of 349 hectares are under our consideration of technology transfer. Our research focuses on unit-farms rather than on family farms in HRA.

Finance And Capital Formation

The financial sources of the state farms in HRA can be approximately classified into four categories:

1. Finance allocation from the State. This allocation is mainly utilized in capital formation, like construction, the purchase of machinery and equipments, reclamation, and irrigation projects, etc. Before 1985, production activities in state farms heavily depended on it.
2. Bank loans or credits. Before 1985, due to finance allocation directly from the State, there was not many

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[28] Keir Packer, M.Sc. thesis, "Structural Changes in Cereal Agriculture", University of Alberta, 1986, p. 69.

Table II.6 Comparison of Farm Size Between HRA (1984) And Alberta (1981).

Alberta	Ave. Farm Size (hectares)	HRA	Ave. Farm Size (hectares)
Individual farm	304	State Farm	21,107
Partnership		unit-farm	746
-written	466	family farm	5 - 133
-verbal	363		
Corporation			
-family corp.	727		
-other corp.	1,028		
Provincewide	349*		

Source: Commercial grain farms cross classified by type of organization, Alberta, 1981 census of Agriculture.
GBHSF: *Statistics Yearbook 1984*. Figure for state farms is calculated from the total cultivated land divided by the total state farms. The way of figuring out the average farm size for unit-farm is similar.
*this figure comes from Keir Packer, M.Sc. thesis, "Structural Changes in Alberta Cereal Agriculture Systems Between 1971 and 1981", 1986, p. 69.

activities of bank loans or credits. It is required that all capital constructions from 1985 have to be loaned by construction banks. Therefore, capital formation in state farms is no longer given by the State, but by themselves. However, the allocation from the State still exists and reduced to a very limited extent.

3. State farms' own accumulations. This accumulation comes from profit after quota, renewal fund and private

investment. This source was very little in the past three decades because then they did not have self-governed right to determine their own financial activities.

4. External investment. This source consists of investments from other state-owned, collective-owned and individual-owned enterprises, overseas Chinese and foreign companies. As the open-door policy is being implemented, this source will become more significant to state farms.

In general, capital formation in state farms was mainly financed by the State according to the practice of production in the past three decades. In that period of time, the Chinese government had made a great effort to develop capital formation of those state farms. The priorities given by the government allowed state farms to purchase machinery and equipments constantly. This priority caused the phenomenon that some farms own relatively large amount of capital regardless of their poor return from production. The economic reform seems to remove this kind of priority and requires state farms to develop capital formation with their own financial ability. However, their present levels of production may not sustain the present growth rate of capital formation. This would possibly cause a decrease in the rate of capital formation in a few years.

In contrast, agriculture in Alberta is mainly financed by government financial institutions and banks. There probably exist four ways of capital formation:

(i) Government financial institutions, like Farm Credit Corporation. Farm Credit Corporation (FCC) aims to assist Canadian farms to establish and develop viable farm enterprises through the use of long-term credit. The corporation also provides loans to groups or syndicates of farmers in the purchase and use of farm machinery, buildings and installed equipment[21]. (ii) Bank loan or credits, (iii) manufacture trade and (iv) personal income. The first three ways are involved in most farmers' production activities due to Alberta's highly-mechanized agriculture. Most farmers cannot finance their production by their own financial ability and have to resort to loans from FCC and banks or get big machinery and equipments directly from manufacturers on credit. The loans or credits will be paid back in different terms, like 5, 10 or 20 years.

Although government financial services have played an important role in Alberta agricultural capital formation, it is very much different from the Chinese financial allocation by the state before the economic reforms carried out in China. The former mainly uses long-term loans or credits through the financial market; the latter, however, largely depended upon channels of the government administration.

The capital labor ratio and capital land ratio are selected as the main indicators of the present capital formation for both HRA and Alberta. They gives us a picture

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[21] Farm Credit Corporation Canada, *Annual Report*, 1984/85, p. 29.

of how different the technologies employed in the two agricultures really are.

As mentioned before, Alberta agriculture is rapidly becoming an energy or capital-intensive ag-industry, machinery capital labor ratio has increased by about 2.5 times in the last decade, namely, increased from $41,000 per person in 1971 to $104,000 per person in 1981 (in 1981 dollars). Machinery capital land ratio has increased from $165 per hectare in 1971 to $328 per hectare in 1981[30]. Farm machinery tends to be larger and larger. For instance, tillage equipment, seeding equipment, sprayers and combines have all increased in size and capacity especially during the last 10 years[31].

By contrast, the capital labor ratio in HRA is $1,860 per person year[32], which is approximately 1.8% of Alberta's; cultivated land in HRA is 15.6% of Alberta's, but its capital land ratio is only 0.2% of that in Alberta (see Table II.7). This gap in capital formation, of course, results in the gap of their productions.

Partial Productivity Index

Some partial productivities, like labor and land productivities, are used for comparison of their production

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[30] Ibid., pp. 80-82.

[31] G.C. Zoerb, "Energy and Machinery", in *Prairie Production Symposium: Plant Science and Technology*, 1980, p. 19.

[32] This figure uses the capital value including machinery and buildings in both agriculture and industries in HRA due to difficulty in data separation. Therefore, this capital labor ratio is greater than that from the sample of unit-farms later on.

Table II.7 Comparison of Capital Formation Between HRA (1984) And Alberta (1981).

	cap./labor (ALTA:1981 $ HRA:1984 $)	cap./ha. (ALTA:1981 $ HRA:1984 $)
Alberta	104,000	328
HRA*	1,859.5	67
HRA as % ALTA	1.8	0.2

Source: Alberta's data are from Keir Packer's thesis, 1986, p. 80, p. 82.
* HRA's data are from *Statistics Yearbook, 1984*, GBHSF.

efficiency.

With an advanced technology, agricultural output in Alberta is outstandingly high. In general, by 1981, a worker per year could produce 242 tons of grain or 74,000 dollars of sales. Sales per acre amount to 94 dollars.[33]. However, the labor productivity in HRA is 3.2 - 3.3% of that in Alberta in terms of both output per person year of labor and sales per person year of labor. The land productivity of HRA was 28.7% of that of Alberta (see Table II.8).

D. Summary

The findings of this chapter indicate that HRA is one of the largest and the most important grain production bases as well as the most mechanized agricultural regions in

[33] K. Packer, *op.cit*, p. 83.

Table II.8 Comparison of Partial Productivity Index Between HRA And Alberta.

	output/labor (tons)	sales/labor (Alta:1980 $ HRA:1984 $)	sales/acre (Alta:1980 $ HRA:1984 $)
Alberta	242**	74,000	94
HRA*	7.8	2,409	27
HRA as % Alta	3.2	3.3	28.7

Source: The sales/labor and sales/acre are quoted from Keir Packer's thesis, 1986, p. 86.
* The data for HRA are calculated from *Statistics Yearbook, 1984*, GBHSF.
** This data is calculated from gross output value of agriculture divided by labor in Alberta in 1980. Alberta Statistics, 1980.
China.

Compared with Alberta grain farming, HRA has a number of natural environmental features similar to those in Alberta. Both of them are similar on natural resources, such as temperature, precipitation, frost-free period, growing degree days, daylight hours and major farming soils, and large scale of grain production.

These two provinces differ, however, very much on socio-economic context, like farm organization and market machanism, and techniques of resource use, like capital formation and labor participation. Low labor productivity and low capital labor ratios are major features in HRA grain production compared with those in Alberta. HRA attempts to improve its production efficiency, especially labor productivity, by technology transfer from developed countries. However, capital shortage and labor surplus form a major constraint in the process of technology change.

The similar characteristics of natural resources in both HRA and Alberta provide a potential of technology transfer from Alberta to HRA; while the dissimilar features, like relatively cheap capital in Alberta but relatively expensive capital in HRA, relatively expensive labor in Alberta but relatively cheap labor in HRA, will possibly constitute difficulty in the technology transfer.

III. Theoretical Background

This chapter presents an overview of international technology transfer in agriculture, develops the concept of technology transfer, discusses the determinants and motivations of technology transfer and finally points out the factors affecting success of technology transfer. This chapter lays a theoretical foundation of interpretations in Chapter Five and Chapter Six.

A. International Technology Transfer in Agriculture

Overview

A great number of countries in the third world have experienced increasing agricultural output during the last two decades. Nevertheless, many of them, with a rapid rate of population growth, have been confronted with persistent food shortages and widespread malnutrition. To solve this problem, technological change has been identified as an "engine of growth" for developing countries. The rates of indigenous technological change in developing agricultures have been low and variable due to economic, social and political instability and unfavorable natural conditions. These circumstances have induced an international technology transfer in agriculture, which has made it possible for developing countries to achieve substantial gains in agricultural productivity.

International cereal technology transfer has been contributing to increased food security and overall economic growth in such developing countries or areas as India, Korea, Taiwan, and the Philippines. The new cereal production technology, which is employed in these countries, is a result of agricultural technology transfers between different ecological zones through the exchange of scientific knowledge and the development of local experimental station capacity[34]. East Asian rice technology and Western wheat technology were transferred successfully from the temperate to the tropical and subtropical zones. This cereal technology transfer has played an important role in the world's food production.

The early rice technology transfer from Japan to Taiwan and Korea occurred during the 1920's and 1930's[35]. The green Revolution in Asia and Latin America reflects the cereal technology transfer worldwide. The term "Green Revolution" is most properly used to refer to the rapid development and diffusion of new early maturing, fertilizer responsive varieties of wheat, rice and other food grains throughout developing countries in the tropics and semi-tropics during the mid-1960's. Reports from India, Pakistan and the Philippines showed that yield potentials of these new varieties were double or triple the maximum yields of the traditional varieties. Combined with favorable prices, good

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[34] Hayami & Ruttan, "Theories of Agricultural Development" in *Agricultural Development*, 1985, p. 274.
[35] Ibid., p. 280.

weather and increased fertilizer supplies, food grain output in these countries has risen well beyond the levels of the preceding years[36]. V. W. Ruttan points out that the new HYV wheat and rice technology has resulted in an increase in the demand for labour, one effect of which has been a widening wage and income differential among regions. The effect of the technology transfer has been also to dampen the rate of increase in food grain prices at the consumer level. Low income consumers especially benefit from this situation[37]. Moreover, with introduction of the new cereal technology, the demand for fertilizers, pesticides, farm machinery and more adequate water supplies is rising sharply over previous expectations. Facilities for the production, storage, distribution and marketing of inputs have to be expanded to meet these higher demands[38]. This high pay-off technology has induced a change from traditional non-cash inputs to high levels of cash inputs in those developing countries, so that their traditional agricultures began to face the modern marketing linkage.

The success of the international cereal technology transfer was based on three major advances: (i) new varieties and associated production technologies were made available to farmers, and in turn, were adopted by these farmers; (ii) sources of chemical and financial inputs; and

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[36] G.M. Meier, *Leading Issues in Economic Development Studies in International Poverty*, 2nd edition, 1970, p. 452.
[37] V. W. Ruttan, "The Green Revolution: Seven Generalizations", *IDR*, 1977, pp. 16-20.
[38] G. M. Meier, *op.cit*, p. 453.

(iii) government polices were such as to make it profitable for farmers to adopt these varieties and associated production technologies[39]. In addition, international research centres have contributed very much to the success of technology transfer.

Concept of Technology Transfer

Apedaile defines technology as the way things are done which ranges from decision-making and accounting to manufacturing and growing crops[40] He divides technology into three categaries:

> "Mechanical technology has been the best known form in which technology is embodied in capital equipment such as ploughs, milking machines, biogas digestors and mills. Technology is also inherent in genetic material such as new rice varieties or animal embryos transplants. Biotech is extending into genetic engineering with ways of recombining genes to generate new life with prescribed specifications. Infotech is evident in the information content of services and economic decisions. Infotech is exploding the capability to store, process and analyse large quantities of data and logic to generate information on demand."[41]

What is presented above by Apedaile is appropriate for the present research. However, the focus of the research is on mechanical technology and its transfer.

It is generally held that the term of technology transfer designates the complex process by which applied

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[39] N. C. Brady, "International Technology Transfer" in *Transferring Food Production Technology to Developing Nations*, edited by J. J. Molnar and H. A. Clonts, A Westview Replica Edition, 1983, p. 19.
[40] Apedaile, L.P., "Appropriate Technology and Aid: The Case of Rural Transport in Nepal", an unpublished paper, Dept. of Rural Economy, University of Alberta, June 1984, p. 3.
[41] Ibid., p. 3.

scientific principles, technologies and practices move or flow from their originators to users[42] The practical application by farmers of new machines, chemicals and production techniques and management skills developed by researchers is considered as technology transfer. Concepts related to technology transfer are often designated by the terms "adoption", and "diffusion" etc.[43]. The original meaning of technology transfer has been extended to international agricultural development as interdependence of countries in the world has been strengthened.

Historically, technological transfer has been carried out in various forms. Hayami and Ruttan have summarized them as three phases: (1) material transfer, (2) design transfer, and (3) capacity transfer[44]. Material transfer involves transferring from more developed countries such materials as seeds, plants, machinery, pesticides and fertilizers. This phase was remarked in the early history of agricultural development. However, many developing countries continue to be actively engaged in this phase. In the second phase the designs, blueprints, formulas and books utilized by scientists and technologists are transferred. Design transfer also involves domestic multiplication of plant materials, expanded local production of machinery, parts and building, and strengthening experiment stations. Capacity transfer is a more advanced phase. It requires the transfer

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[42] Development Policy, Agriculture Canada, Working Paper: *Technology Transfer in Agriculture*, 1984.
[43] Ibid.
[44] Hayami & Ruttan, *op.cit.*, pp. 260-2.

of scientific knowledge and capacity which enable international technology to be adaptable and viable in local places. The migration of agricultural scientists such as is beginning to occur between China and the West becomes an important indicator in the process of capacity transfer. However, like in other developing countries, material transfer is greatly involved in China. As for HRA, material transfer like modern machinery, HYV's seeds and pesticides are preferable to others at present. Alberta's technology transfer is considered a sort of material transfer by many people. However, according to most scientists' opinion, the technology transfer from Alberta to HRA should be emphasized on design transfer and capacity transfer as to develop and use effiently HRA's indigenous resources.

Robert D. Stevens[45] argues that in many developing countries, low cost labor and high cost capital make the highly capital intensive agricultural technologies from more developed nations unprofitable in less developed nations. The reason is that the different ratios between the cost of varied resources used in agricultural areas around the world cause varied technologies to be profitable in diverse locations. Different technologies are induced by dissimilar relative prices in the various economic environments. Specifically, in many developing countries with low labor costs relative to capital costs, labor-intensive

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[45] Stevens, "Inducing Develoopment at The Micro-Level: Theory and Implications For Technology Transfer Strategies", in Molnar & Clonts (edited), *op.cit.*, pp. 67-84.

technologies are more profitable than capital-intensive technologies. Thus he questions how technology transfer activities can aid in developing the most profitable, labor-intensive technologies. In his opinion, design transfer would have opportunities for a higher return. A large number of technologies which would be profitable in low labor cost developing countries have probably not been developed due to a low level of domestic design capacity both in experimental stations and in agricultural input industries. Moreover, he holds that capacity transfer is the longer range high pay-off objective of technology transfer. Planning for and carrying out some activity in this phase of technology transfer at this time is likely to be highly productive. This activity will include selected overseas doctoral-level training or its equivalent.

B. Labor Surplus And Absorption

One of the acute problems of LIC's is rural unemployment arising from a growing labor surplus in agriculture. This problem may occur as visible or open unemployment, underemployment or "disguised unemployment". In rural China, open unemployment is largely absent and does not appear as part of the headache issue either before or after 1949. However, underemployment is prevalent in the rural areas. China's labor force rose at a rate equal to, or perhaps slightly greater than the rate of population growth. This rise produced a la[illegible] increase in the supply of labor, most of which occurred in the countryside[46]. Consequently, with a relatively slower grouth in agricultural output, labor productivity has declined since 1952, and is likely to continue to decline in the decade ahead as more people join the work force[47].

Underemployment is defined, in terms of low earnings, as an indication of the excessive size of the labor force relative to complementary factors of production[48]. L. Squire classifies underemployment into two categories: one is visible underemployment defined to include those who are employed but would like to work longer hours; the other one is invisible underemployment generally defined to include those whose earnings lie below a given level. He thinks that visible underemployment reflects labor market imperfections and invisible underemployment is considered as a measure of poverty.[49]

Evidences on underemployment in HRA will be produced later on.

Lolyd G. Reynolds uses labor "surplus" to describe either underemployment or "disguised unemployment". He defines the supposed labor "surplus" in at least six types of ways[50]:

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[46] T. G. Rawski, *Economic Growth And Employment In China*, Oxford University Press, 1976, p. 36.
[47] Randolph Barker, *et al*, A Brief Overview of Major Developments And Future Prospects For the Chinese Agricultural Economy, A.E. Research 82-16, Dept. of Agricultural Economics, Cornell University, 1982, p. 9.
[48] L. Squire, *Employment Policy In Developing Countries: a survey of issures and evidece*, 1981, p. 74.
[49] Ibid., p. 69.
[50] Lloyd G. Reynolds, *Agricultural In Development Theory: An*

Type One is that people are working fewer hours than they would be willing to work if demand for labor were higher. This type is similar to Squire's visible underemployment.

Type Two is that the curve of labor supply to the industrial sector is perfectly elastic at a constant real wage. This is what Lewis calls "unlimited supplies of labor".

Type Three is that the private marginal productivity of labor in agriculture is zero. This is the "redundant labor" of the Fei-Ranis model.

Type Four is that the private marginal product of a man-hour of labor is below the hourly return to labor. The case of a divergence between earnings and marginal product is often termed "disguised unemployment", which means that workers' productivity in their current employment is below their potential productivity on their regular job. There is a hidden labor potential which can be activated as demand rises when the economy gets better.

Type Five is that given the social objective of maxinmizing the value of current income, the combination of techniques and resources is such that the shadow wage and hence the social marginal productivity of labor is zero.

The final type is that surplus labor exists if workers can be withdrawn from the agricultural sector without reducing agricultural output. This type of labor surplus can

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[50](cont'd) *Overview*, Yale University Press, 1975, pp. 11-3.

be found for HRA in the simulation later on.

One of these concepts does not necessarily imply the others. One or more of them can be true without all being true.

Mobilization of unutilized labor potential requires mainly an intensification of demand for labor. First, within the agricultural sector, intensification of demand means mainly technical changes that shift the labor productivity curves upward. Second, technical change would be needed in any event to compensate workers who are being asked to work harder and who will demand a reward in terms of higher consumption, including higher food consumption[51]. Adequate food supply is the first condition for labor surplus transfer from agriculture. Reynolds proposes an internally consistent model of labor transfer which may "involve population growth of 3 percent, agricultural output rising at 5 percent, and direct farm labor requirements rising at 2 percent"[52]. Under this condition rural-urban migration would be allowed because of the adequate food supply. On the other hand, such migration is required to avert increasing rural underemployment.

In reality, however, rural-urban migration in developing countries does not really solve the problem of redundant labor. Conversely it brings some troubles in urban employment. This urban problem may be caused by the fact that industrial employment lags behind growth in industrial

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[51] Ibid., p. 14.
[52] Ibid., p. 15.

output, and behind growth of the urban population. Thus the urban industrial sector absorbs only a portion of the annual increase in the urban labor force[53]. High rates of urban unemployment correspond to migration rates in excess of urban job opportunity growth rates. This indicates that rural-urban migration is not a perfect solution to the growing rural underemployment.

In HRA, as in most places of developing countries, rapid population growth and lack of nonfarm employment opportunities form two major obstacles to the absorption of labor surplus in agriculture. Limited creation of employment outside agriculture forces much of labor absorption onto the rural economic sectors. The magnitude of labor absorption heavily depends on the growth rate of rural nonfarm employment and intensification of demand for labor in the agricultural sector instead of the rural-urban migration.

As Reynolds mentions, intensification of demand for labor means mainly technical change that promotes labor productivity[54]. Creation of nonfarm employment also depends upon technical change. Consequently, technical change is a crucial factor to absorption of labor surplus. But what type of technical change should be designed for labor surplus economies? This question leads us to explore appropriate technologies for those developing countries with labor surplus problems.

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[53] G. M. Meier, *op.cit.*, 1976, pp. 170-6.
[54] Reynolds, *op.cit.*, p. 14.

C. Determinants and Motivation

Theoretically, determinants of technology transfer come from three aspects: physical difference, economic difference and institutional difference[55]. Not surprisingly, the technology transferred from advanced countries to less advanced countries is of some inappropriate nature, because it is produced according to the economic environments in the advanced countries, so it is conditioned by temperate physical conditions, capital-intensive production, and competitive market institutions. By contrast, the third world is different with tropical physical conditions, labour surplus, low income level, and imperfectly competitive market institutions. These different physical and economic as well as institutional environments in the third world possibly distort the impacts of technologies transferred from advanced nations. If technologies are directly transferred without any accommodation of these contradictions, recipient countries in the third world would suffer the traps of unemployment, underemployment and worsening inequality of income distributions. The question is how to avoid the traps. This question also forms an essential part of discussion of the determinants of technology transfer/choice, which directs attention towards the appropriateness of technology for developing regions and countries.

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[55] F. Stewart, *Technology and Underdevelopment*, chap.1,3,4, 1978.

What is an appropriate technology? W. G. Matlock provides the following definition:

> "An appropriate technology is one which meets the perceived needs or desires, makes the fullest possible use of locally available resources for construction, operation and maintenance, minimizes secondary problems of environmental degradation, and is compatible with social, political and economic constraints of both men and women users, and their community."[16]

Further, Clarence D. Long terms appropriate technology as "light-capital", which should include the following three aspects:

1. "It is not primitive or obsolete, but is economic, 'culturally congenial' and ingenious in its design;
2. It should represent the 'least-cost' solution, taking into account the factor cost of production;
3. It is defined by low capital investment per worker, preferably in small enterprises that can be managed with local talents."[17]

From many descriptions of appropriate technology, it may be concluded that the essence of appropriate technology discussion is fixed insofar as the terms of labour-intensiveness or capital-intensiveness, which emphasizes the employment factor in technology choice.

Evans & Adler[18] think that maximization of net national output and income has been a prime development objective historically and conventionally. Moreover, maximization of consumption is assumed to be the

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[16] W. G. Matlock, "Problems And Solutions in Agricultural Technology Change or Transfer" in *International Journal For Development Technology*, vol. 2, 1984, pp. 93-105.
[17] Evans & Adler, *Appropriate Technology for Development: A Discussion And Case Histories*, 1979, pp. 43-9.
[18] Evans & Adler, *op.cit.*

economic goal. Labour-intensiveness is thus considered as a criterion of appropriateness reflecting this basic requirement. However, some different views appear in G. M. Meier's account of this issue. He points out that if the policy objective in a labor surplus economy is to maximize the growth rate, it will choose more capital-intensive technology than when the policy objective is to maximize immediate output per unit of investment; if the objective is "something intermediate beteen the maximization of immediate output and maximization of the growth rate"[5], it may choose some kind of intermediate technology.

Peter Hall's views on this issue almost support Meier's points. He believes that a relatively labour-intensive technique would improve employment, income distribution and poverty in the short-run, but with less saving and less growth in the future. Important developmental objectives seem to be met in a short time with labor intensive technology, while the relatively capital-intensive approach would result in less employment, greater inequality of income distribution, less consumption, more saving and consequently more growth in future[6]. In both Meier and Hall's opinion, the choice of technology affects not only the achievement of today's objectives but the

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[5] Meier, G. M., *Leading Issues In Economic Development*, third edition, 1976, p. 442.
[6] Peter Hall, *Growth And Development*, 1983, pp. 126-31.

potential for achieving them in the future. An appropriate technology to be adopted for a labor surplus economy highly depends upon "the urgency with which an LDC wishes to achieve one type of objective rather than another and the constraints it believes to be operating upon it."[61]

This topic has been a classic dilemma. Thirlwall points out that the conflicts between employment and saving, and between employment and output in the choice of new technology have been exaggerated. He argues that in both practice and theory there is probably not such a sharp conflict as theoretical research would suggest if output is redefined by giving different weights to the investment and consumption components of ouput using shadow prices. In his opinion, techniques can be more labor intensive as long as the level of the investible surplus or the level of output is unimpaired. The direction that development strategy for maximization of the general welfare ought to move is more rural-based labor-intensive projects[62].

These determinants contribute to a developing country's motivations for technology transfer. To increase national technology capacity, improve the balance of payments, reduce technological dependence abroad, reduce unemployment and support certain values

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[61] Ibid.
[62] Thirlwall, A. P., *Growth And Development*, 2nd edition, 1977, pp. 203-211.

or sectors of the population are some of the possible components of motivations in international technology transfer.[63]

The determinants which contribute to HRA's motivations for technology transfer from Alberta should be (i) their similar natural resource environments, (ii) maximization of output or labor productivity on unit-farms and (iii) promotion of cereal production technology on unit-farms.

However, other determinants, such as labor surplus, low income level and imperfect market institutions, especially pricing system in HRA, possibly constitute an obstacle to the technology transfer and distort the impacts of technology transferred from Alberta.

An appropriate technology for HRA may be an intermediate technology which can absorb more labor and make a choice between immediate output maximization and growth rate maximization in the short run. However, an appropriate technology for HRA in the relatively long run should be emphasized on growth rate maximization.

D. Factors Affecting Success

In order to gain a successful technology transfer, a number of factors influencing the success should be clearly understood. Hayami and Ruttan[64] conclude that the

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[63] Derakhshani, Shidan. "Factors Affecting Success in International Transfers of Technology", *The Developing Economies*, 1984, p. 28.
[64] Ibid., p. 264.

development and diffusion of new cereal technology in the last several decades were made possible by a series of institutional innovations in the organization, management and financing of agricultural research in developing countries.

Shidan Derakhshani stresses more specifically the following factors: [45]

1. The environmental characteristics in receiving and supplying countries. Those include:

> "market size, absence of factor price distortions in the recipient country, the existence of a good infrastructure, similarity of recipient and supplier environments in terms of such characteristics as skills, factor prices, endowments, ..., recipient country science and technology base, the social value system, mobility, working traditions and habits, government support and regulation, effective organization structure of recipient firm and its size and experience."[46]

In any case, any one or number of those factors could decide the favorable or unfavorable nature of technology transfer conditions.

2. The nature and sophistication of the technology. The following natures or characteristics of technology carries more weight: product characteristics, manufacturing process characteristics, marketing characteristics, capital intensity and R and D intensity. Those aspects are recognized as major factors in the requirement of a successful technology transfer.

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[45] Ibid., pp. 30-39.
[46] Ibid., p. 30.

3. The importance of transfer mechanisms. The mechanisms of technology transfer usually are presented as: "transfer of published materials; transfer of machinery and intermediate inputs; the movement of personnel; personal interaction;, various forms of legal arragements between the recipient and supplier; and turnkey contracts among others."

Derakhshani believes that transfer of technology mechanisms should be classified according to these four basic characteristics: "the location of control, the level of personal interaction, the level of initial supplier involvement and the stability of the relationship between the recipient and the supplier."[47]

According to him, location of control refers to who makes decisions regarding the various aspects of the operation. He also stresses that increased foreign control and unrestricted freedom of the technology supplier would result in decapitalization of the host economy; transfer of inappropriate technology; economic dependence and disruption of local income distribution.[48]

Personal interaction refers to face-to-face contacts between supplier and recipient personnel. Thus it requires international mobility of supplier and/or recipient personnel.

Initial supplier involvement is defined to include preinvestment studies, process choice, engineering design, personnel training, management of production facilities and

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[47] Ibid., p. 31.
[48] Ibid., p. 34.

improvements to products and processes.

An important potential cost to the recipient can result from an excessively unstable relationship with the supplier. "Such instability would disrupt the flow of information from the supplier and also discourage the supplier from providing optimal support for the operation."‘’

The environmental characteristics and transfer mechanism in HRA are extremely important to the success of Alberta technology transfer. This is because the technology transfer is mainly involved in factor prices, finance ability, labor skills and market conditions, as well as more person to person contacts. The differences in social, economic and political characteristics between HRA and Alberta may provide some unfavorable conditions for the success of technology transfer, such as inflexible capital and labor markets, relatively low labor skills and imperfect transfer mechanism in HRA. Derakhshani's opinion will contribute to a theoretical foundation for interpretation of the results from this study later on.

‘’ Ibid., p. 39.

IV. Research Methodology And Data Analysis

A simulation approach is used to estimate quantitatively the effects of transferring mechanical technology on agricultural output, labor use, capital labor ratios and labor productivities. Randomly based sampling is employed to provide the basis for inference from the results of the simulation. Three sections are discussed in this chapter: simulation method, sampling procedure and data analysis. The first section skims theoretically the simulation method, and builds simulation models for the technology transfer from Alberta to HRA. In the second section, the instrument of collecting data in HRA is explained. The third section highlights an analysis of the collected data.

A. Simulation Method

Concept of Simulation

Economic phenomena are so complicated that any experiments with the real economic system, as in the physical or biological sciences, are almost impossible. The suitable way for economists to deal with the matter is to substitute experiments on models for experiments on the real system. By definition, a model is an abstraction of an economic environment or relationship. A series of rules for manipulation of the model is called simulation.[70]

[70] James, L.M., *Simulation Gaming For Management Development*, Harvard University, Boston, 1967, p. 2.

Specifically, simulation is a numberical technique for solving complex socio-economic models. The analytic technique of model solution attempts to deduce general relationships that express endogenous variables in terms of the given parameters and exogenous variables. Models which consist of sets of mathematical equations and logical identities dealing with the dynamic behavior of economic systems over time are usually involved in simulation. Thus a model solved by the simulation method is named a simulation model [71].

Simulation models have been long used by economists in at least three areas: (1) dynamic macroeconomics, particularly business cycle theory and "cobweb theory"; (2) operations research and management science; and (3) theory of economic decision-making (Clarkson and Simon, 1960). Although simulation is not always the best technique for studing an economic system, it does provide the following advantages:

1. "It enables the study of systems where real-life experimentation would be either impossible, inordinately costly or disruptive.
2. By synthesising systems in model-form, it permits the exploration of systems that do not exist.
3. It permits the study of long-term effects since the time horizon over which a model is run is within the control of the model-builder.
4. It forces those concerned with building the simulation model to examine the system objectively and consequently undertake a thorough and critical review of knowledge concerning the system. The enlightenment that

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[71] Heady *et al*, "A Simulation Model For Agricultural Policy," in *Future Farm Programs*, 1972, p. 276.

this process provides is often surprising."[11]

There exist, at least, two approaches to simulation models. One is largely based on econometric features. This type of simulation model is composed of simultaneous equations which are estimated using standard econometric techniques.

For instance, Tyner and Tweeten (1968) constructed a recursive economic model to simulate the production process of agricultural firms. They established a set of regressions for pre-input factors which influenced input factors in the production, and then upon those pre-input equations, a set of input-equations on the econometric base were built. Finally, those input-equations were linked with output equations by econometric means. Although some accounting relationships were used in their model, the econometric features were dominant in the study. The major feature of their study was constructing a simulation model of a set of regressions which were estimated from a time-series of 1930-60 data. They used the simulation model to simulate firms' production behaviors in the same period of time to test various hypotheses about the impact of commodity programs on farming efficiency.

Another approach is called the data-less approach, which allows values for coeffients to be spcified on the basis of either "intuition" or else of estimates generated by examining averages, sporadic data points, or just the opinion of experts. This approach is useful for simulation

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11 Dent & Blackie, *Systems Simulation in Agriculture*, 1979, p. 11.

in that a simulation model may be formed without the use of econometric estimation. For example, some variables are unobservable and unmeasurable, like attitudinal parameters in sociological models; or the variable may be observable, but data possibly have never been collected. Or even if data were available, they might be continuous only for a short time period. These situations often arise in developing countries. Under these circumstances, a set of hypothetical relationships should be specified into models, while in the case of an econometric model, those relationships would be estimated and tested by fitting them to available data. The study by Denton and Spencer (1973) utilizes the approach. It establishes a simulation model by a set of hypothetical and behavior relationships, and uses the artificial data to predict the impact of changes in some variables on the behavior of the economic system.

The data-less approach is convenient to use for a simulation model, but it may cause some problems with predicting results. One of the problems of the data-less approach is that there is no standard check provided on the reasonableness of the individual relationships that make up the model. This drawback does reduce the ability to validate the model as a whole[73]. Therefore, it is important that this approach be used with great caution.

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[73] Pindyck and Rubinfeld, *Econometric Models and Economic Forecasts*, 1981, p. 379.

The Technology Transfer Model

General Characteristics of The Model

To explore the impacts of a mechanical technology transfer from Alberta to unit-farms in HRA on cereal production, especially on labor use, capital/labor ratios and labor productivities, a simulation model is used. The model simulates mainly labor demand and supply, capital/labor ratios, surplus labor and labor productivities according to a predetermined planning horizon.

The model consists of two submodels: labor demand and labor supply. The labor demand submodel is based on the conventional production economics theory. The linear, Cobb-Douglas, quadratic, and trans-log production forms were tried. The Cobb-Douglas production function produced the best estimates for the two farm groups in HRA. Consequently, the Cobb-Douglas form was selected to simulate the production process of grain on unit-farms in HRA. From the production function, a labor demand function is derived.

The labor supply submodel is built upon the concept of *birth cohort* in which a group of persons born in a given time period is followed through a span of life. It is supposed that the natural population growth rate and labor participation rate remain constant over a certain period of time. This cohort approach generates a stream of labor supplies. It is also applied to the process of capital formation and may be applied to other economic processes (Denton & Spencer, 1973).

Labor Demand Submodel

According to the classic theory of production economics, an input demand function can be derived from a given production function. Where Y is a function of input factors, capital K, labor Nd, and fertilizer F. For the Cobb-Douglas form of function, the following relation holds:

$$(1)\ Y_t = A\ K_t^{\beta_k}\ Nd_t^{\beta_n}\ F_t^{\beta_f}$$

where β_k, β_n and β_f are production elasticity parameters estimated with the cross-section data from the HRA unit-farms and Alberta large farms respectively. The subscript, t, represents the dynamic sense of the function for later use in the simulation. The symbol Nd indicates labor demand to distinguish it from labor supply expressed by Ns in the simulation.

Land input was not included in this function because of the assumption that land in HRA is not constrained. With more land reclamation, arable land in HRA may increase. In our simulation model, fertilizer was assumed to grow at an annual rate of 7% for both groups. Therefore, changes in capital formation, labor demand and fertilizer use imply an increase in land area for output growth in both groups.

In general, deriving demand functions for inputs follows the rule:

$$MVP_{x1} = P_{x1}$$
$$MVP_{x2} = P_{x2}$$
$$......$$

$$MVP_{xn} = P_{xn}$$

Solving the equations simultaneously for inputs X1, X2 ... Xn, where MVP_{xn} is the marginal value of product of input Xn.

In this case, only the labor demand function is to be derived. However due to the importance of investigating the substitution between capital and labor in this study, an equation of marginal rate of substitution between capital and labor is selected as a starting point. Thus the following relation holds:

(2) $MPP_k/MPP_n = P_k/P_n = \gamma$[74]

where MPP_k is the marginal physical product of capital and MPP_n is the marginal physical product of labor[75]. P_k is the capital price and P_n, the labor price. γ represents the price ratio of capital and labor.

MPP_k and MPP_n can be obtained by the partial derivative of equation (1) with respect to K_t and Nd_t respectively. A little arithmetic produces equation (3).

(3) $\gamma = (\beta_k/\beta_n)\ (Nd_t/K_t)$

The price ratio γ is obtained using the initial data for labor use from equation (1) in equation (3).

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[74] Doll & Orazem, *Production Economics: Theory With Applications*, 1984, p. 139.
[75] Due to our production function in value term, there is no difference between MPP and MVP.

Deriving Nd from equation (3) produces equation (4):

(4) $Nd_t = \gamma K_t(\beta_{nt}/\beta_{kt})$.

Now, the labor demand is a function of the price ratio of capital to labor, ratio of elasticities of labor to capital and of capital formation. All these structural variables are expressed in dynamic terms.

To investigate the impact of changes in capital formation alone on labor demand, suppose capital formation of unit-farms in HRA (K_h) can catch up with that of Alberta (K_a) in an arbitrary period of 20 years. The annual growth rate of K_h (k) following a compound path may be obtained as follows

(5) $k = (K_a/K_h)^{0.053} - 1$

where $0.053 = 1/(20 - 1)$

Capital formation for unit-farms along the time path can be represented in a cohort equation such as:

(6) $K_t = K_0 (1 + k)^t$

where K_0 is the capital value of unit-farms in the initial year of the simulation.

To investigate the impact of changes in factor elasticities, the elasticities of capital and labor can be supposed to reach the levels of those in Alberta in 20 years. Using the same method to get the annual rates of change of those production elasticities:[74].

(7) $\epsilon_k = (\beta_{ka}/\beta_{kh})^{0.053} - 1$

where ϵ_k represents the annual rate of change of elasticity of capital in unit-farms. β_{ka} is Alberta's elasticity of capital and β_{kh} the elasticity of capital for unit-farms in HRA.

(8) $\epsilon_n = (\beta_{na}/\beta_{nh})^{0.053} - 1$

where ϵ_n refers to the annual change rate of elasticity of labor in unit-farms. ϵ_{na} is Alberta's elasticity of labor and β_{nh} the elasticity of labor for unit-farms in HRA.

β_{ka} and β_{na} are estimated from Alberta's grain production function, using capital and labor in a Cobb-Douglas form.

Through ϵ_k and ϵ_n, the elasticities of capital and labor on HRA unit-farms may be made to approach those of Alberta in 20 years. This approach represents a gradual process of substitution of capital for labor on unit-farms. The following two equations represent the process:

(9) $\beta_{kt} = \beta_{k0} (1 + \epsilon_k)^t$

(10) $\beta_{nt} = \beta_{n0} (1 + \epsilon_n)^t$

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[74] At a point in time, β's are fixed or constant. With technological change they alter over time.

where β_{k0} and β_{n0} are the values of β_k and β_n for HRA unit-farms in the initial year.

Different price ratios apply for unit-farms in HRA (γ_h) and Alberta's farms (γ_a). According to the principle of induced innovation theory, technology change is a function of relative factor prices, which implies that a new technology is induced to facilitate the substitution of increasingly more expensive factors for less expensive factors[17]. It is believed that changes of relative factor prices in HRA would induce a technological change. The idea implied here is that to achieve the technological change or the successful technology transfer from Alberta to HRA, compatible relative factor prices are required.

To investigate the impact of changes in γ on labor demand, suppose γ_h is approaching to γ_a in 20 years. The annual change rate is:

$$(11)\quad \delta = (\gamma_a/\gamma_h)^{0.053} - 1$$

Therefore, what is simulated is the gradual adjustment of a price discovery market process in China to reflect changes in relative factor costs and productivities. This process is demonstrated by:

$$(12)\quad \gamma_t = \gamma_0 (1 + \delta)^t$$

where γ_0 is the ratio of the price of capital to the price of labor in the initial year of the simulation.

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[17] Hayami & Ruttan, *op.cit.* pp. 84-87.

By definition, the capital/labor ratio is of the form:

(13) $\eta = K_t/Nd_t$

where η represents the capital/labor ratio.

By definition, labor productivity is expressed as follows:

(14) $\theta = Y_t/Nd_t$

Substituting equation (1) in (14), the expression for labor productivity becomes .

(15) $\theta = (A K_t^{\beta_k} Nd_t^{\beta_n} F_t^{\beta_f}) / Nd_t$

Assume the fertilizer function is of the form:

(16) $F_t = F_0 (1 + f)^t$

where F_0 is the value of fertilizer used in the initial year. f is the annual compound rate of change, determined exogenously from past experience.

Labor Supply Submodel

The concept of *birth cohort* is used to estimate population change over time. The population function is of the form:

(17) $P_t = P_0 (1 + p)^t$

where P_t represents population within a time path, P_0 is the population in the initial year, and p is the natural population growth rate specified exogenously.

Assume the labor supply function is:

$$(18)\ Ns_t = R_t P_t$$

where Ns_t represents labor supply along a time path, and R_t represents a labor participation rate, shaped as follows:

$$(19)\ R_t = R_0 (1 + r)^t$$

where R_0 refers to the initial value of labor participation rate and r is the annual change rate of R_0. The value of r is determined exogenously.

By definition, it may be postulated that

$$(20)\ Ns_t = Nd_t$$

This equilibrium normally would occur only in a perfectly competitive economy. In cases of chronic or potential surplus labor, the gap (G) between labor supply and demand may be expressed as:

$$(21)\ G_t = Ns_t - Nd_t$$

where G is surplus labor in each time period corresponding to changes in labor supply and demand over time.

Model Application

The above model is used to simulate the impacts of grain production technology transfer from Alberta to unit-farms in HRA according to four different scenarios.

Scenario One: Capital formation on unit-farms in the high K/N ratio group in HRA catches up with the 1981 capital levels of Alberta large farms in 20 years, with other factors unchanged. The impacts on labor demand, capital/labor ratio and labor productivity are derived. This scenario attempts to explore the implication of a strategy of capital formation only without embodied technology transfer. This strategy corresponds to what appears to have been the principal strategy of the past twenty years on state farms.

Scenario Two: Capital formation and the production elasticities of capital and labor reach the 1981 levels for Alberta simultaneously in 20 years, with other factors unchanged. This simulation attempts to synthesize the impacts of technology transfer by means of capital formation where new technology is embodied in capital. This scenario corresponds to the post World War II thinking on agricultural development.

Scenario Three: Capital formation, production elasticities of capital and labor and the price ratio of capital to labor simultaneously approach the 1981 levels for Alberta in 20 years. This scenario explores the impacts of technology transfer where the technology reflects capital-augmentation, relative factor costs and productivities.

Scenario Four: Capital formation and the price ratio of capital to labor move to the 1981 levels of Alberta in 20 years, with production elasticities unchanged. This scenario tries to find the impacts of capital formation linked to relative factor costs and productivities which are dominant in investment decision-making.

The simulation model discussed before explores the four scenarios for the two farm groups in HRA respectively. But the low K/N ratio group of unit-farms is assumed to approach the 1984 levels for the high K/N ratio group instead of those for Alberta in 1981.

B. Sampling Procedure

A two-stage sampling procedure was employed in this research. The population for the first stage was the state farms. The second stage population was composed of the unit-farms within the selected state farms.

The farm profile in GBSFH provided the sampling frames in the form of the 1984 Agricultural Census and statistical yearbooks for the state farms. The 1984 statistical yearbooks for each state farm provided the sampling frame for the unit-farms.

Stage One: Method and Size For State Farms

The criteria used to delimit the population of state farms were:

(i) The total area of land sown on a state farm cannot be greater than 40,000 hectares or smaller than 6,667 hectares.

(ii) The percentage of wheat acreage on a state farm cannot be less than 50%.

(iii) The state farm with large sideline operations and irrigation should be eliminated from the sampling population.

(iv) The difficult condition of transport to farms on the north border should be taken into account.

According to those considerations, 68 state farms were removed from the total 84 leaving 16 grain based state farms as the sampling population for state farms. The 16 state farms were numbered on 16 pieces of paper [illegible]d those pieces of paper were mixed up in a small [illegible] We repeatedly drew a piece of paper five times out of [illegible] random to identify the 5 sa[illegible]ate farms among the 16. The locations of the [illegible]ate farms and basic information are respectively show[illegible] Appendix D and Appendix E.

Stage Two: Method And Size For Unit-farms

There were 101 unit-farms within the 5 selected state farms, with 91 of these inv[illegible]ed in grain production. With different numbers of grain unit-farms in each selected state farms, a constant sampling fraction was used to decide how many unit-farms should be surveyed within each sampled state farm.

$$S_i = P_i * w$$

where w: constant sampling fraction.

S_i: number of unit-farms which should be selected in the ith state farm.

P_i: size of sampling population meaning the total number of unit-farms in the ith state farm.

The sampling fraction was arbitrarily set at 0.5. According to this ratio, the second stage sample size is 46 unit-farms.

This ratio, however, does not explain how to get the sample of 46 unit-farms. The criterion used for this purpose was:

$v = K / N$

v: ratio of capital to employed labor.

K: productive capital which means machinery value.

N: number of permanently employed laborers.

All unit-farms in each of the selected state farms were ranked by the ratio v. The middle one third of the ranked farms was discarded except in the case of one state farm with only twelve cereal unit-farms where none were discarded. Equal numbers of unit-farms were selected randomly from each of the remaining high v and low v groups. In all 46 unit-farms were selected from the 91 in the five selected state farms.

Supplementary Data

To predict the behavior of inputs and output in a simulation model, some annual growth rate data are needed for the following variables.

1. fertilizer use
2. labor participation rate
3. population

The annual growth rate of fertilizer use is calculated from the data in the article of Y. Y. Kueh (1984). Some adjustment in fertilizer use is made for HRA's agricultural development over the next 20 years based on the growth rate of fertilizer use in China in the last decade.

The annual growth rate of population is from *Statistics Yearbook*, 1984, GBSFH.

The growth rates for the labor participation rate is given exogenously by 0.5 % by the author on the basis of the annual growth rate of population in HRA and discussion with Dr. L. P. Apedaile.

The values of those rates are specified in Appendix F.

C. Data Analysis

GROUPH and GROUPL Data

The sample of 46 unit-farms noted in the previous section is ranked again according to the K/N ratios from small to large. The sample from the one third of unit-farms with the highest K/N ratio is called GROUPH and the other sample of low K/N ratio unit-farms is called GROUPL. Subsequently the sample farm with the lowest and highest K/N ratio from each group respectively is discarded to enhance separation of GROUPH from GROUPL in the estimation of production functions.[7]. Therefore, each group contains 22 unit-farms. The reason to classify the unit-farms into two

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[7] A common practice is to remove the middle third of the observations to effect separation (see Koutsoyiannis, A., *Theory of Econometrics*, 1984, pp. 193-4.).

groups is to investigate the different aspects of technology transfer relative to the high and low ratios of capital to labor on HRA grain farms.

The general information of the two farm groups is presented in table IV.1.

All monetary values expressed in Chinese yuan are for 1984. For purposes of comparison, Chinese Renminbi are converted to Canadian dollars at an average exchange rate of CAN 1 $ = 1.9 yuan for 1984.

Estimation of Production Functions

Estimation of production functions of the two HRA farm groups and for large Alberta grain farms is one of the basic steps of the data analysis. The reason to have the same form of production function for large Alberta farms is for comparison with unit-farms in HRA. The data for Alberta farms are from the 1981 Census of Agriculture[11]. Forty-two large farms, whose sizes approximate those of the HRA unit-farms, from all 15 census divisions in Alberta, are selected. Unfortunately, fertilizer data for the 42 sampled large farms were not available, so the input variables of the Alberta farms include only machinery value and labor. General descriptive information about the 42 Alberta large farms is provided in table IV.2.

Three production functions in Cobb-Douglas form were built for the two farm groups and for the large Alberta

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[11] Statistics Canada, "Commerical Grain Farms Cross Classified by Agricultural Products Sold and Selected Ratios, Alberta, 1981 Census of Agriculture", organized by L.P. Apedaile and K. Packer.

Table IV.1 General Information of The Two Groups of HRA Grain Unit-farms (CAN dollars, 1984).

variable	High K/N Ratio Group			Low K/N Ratio Group		
	mean	minimum	maximum	mean	minimum	maximum
output($)	539,889	127,508	1,049,782	488,384	144,272	776,986
labor(people)	186	90	329	174	54	284
capital($)	162,391	70,100	217,900	70,000	29,500	148,600
culti. area(ha.)	978	370	1,935	784	347	1,160
fertilizer(tons)	105	25	271	116	64	216
output/labor	2,862	1,417	3,763	2,827	1,956	4,154
capital/labor	886	609	1465	421	209	899
hectare/labor	6	4	11	5	3	9

Source: Unit-farm records.

farms. All of them were assumed under the first order condition. All data was edited in computer files and then analyzed using the SPSS-X statistical package. Through analysis of t-tests, F-tests and the R^2, it was found that the estimates from those functions are reasonably reliable. The estimates and the results of the first order tests are presented in table IV.3.

All the production elasticities are positive except that of fertilizer for GROUPL. Those production elasticities indicate the contribution of a 1 percent increase in an input factor to output growth; moreover, they can reflect different techniques used in production. Since the production elasticity of capital is larger than that of labor in Alberta grain production function, it is indicated that Alberta cereal production employs a capital-using technology, and capital plays a more important role than labor in its production.

Not much difference can be discovered in the technology pattern used in GROUPH and in G[illegible]y examining their production elasticities. The signs and magnitudes of production elasticity of capital in both groups are very similar. The production elasticity of labor in GROUPL is slightly larger than that in GROUPH. The indication is that labor input makes more contribution to output growth in GROUPL than in GROUPH. Production processes in GROUPL employ slighly more labor than they do in GROUPH.

The addition of production elasticities $\beta_k + \beta_n + \beta_t$ is considered as the 'scale factor' in the production

Table IV.2 Structural Variables of 42 Large Farms in Alberta, 1981.

variable	mean	minimum	maximum
output($)	257,673	67,463	771,830
workers (person yr.)	2	1	9
capital($)	281,954	141,984	599,129
area(ha.)	673	297	1826
output/labor ($/person yr.)	138,249	37,510	290,936
capital/labor ($/person yr.)	164,896	46,010	299,564
ha./person yr.	405	82	1,031

Source:Statistics Canada, "Commercial Grain Farms Cross Classified By Agricultural Products Sold And Selected Ratios, Alberta, 1981 Census of Agriculture", organized by L.P. Apedaile and K. Packer.

function.[10] The scale factor is greater than one for GROUPH. It would indicate that the production of GROUPH was characterized by increasing returns to scale. However, the scale factor for GROUPL, which is approximate to one, would show constant returns to scale in the production process of GROUPL.

It may be necessary to study the efficiency of resource use to explore further the present situation of production in both groups. Conventionally efficiency of resource use is

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[10] Mayes, D.G. *Applications of Economics*, 1981, p. 84.

expressed by the ratio of marginal value product to factor cost. If the ratio is greater than one, it means that the resource is underutilized; if the ratio is less than one, the resource is overutilized. A ratio of one indicates absolute efficiency (Hopper, 1965; Sahota, 1968; Bagi, 1981; Tabor, 1985).

Table IV.4 presents marginal value of products for factors, factor costs and allocative efficiency ratios. It was found that capital and labor are underutilized in both groups since the allocative efficiency ratios were greater than unity for capital and labor. The ratio was less than one for fertilizer in GROUPL, which indicated that fertilizer use was overutilized in GROUPL. In contrast, fertilizer use was slightly underutilized since the ratio was greater than one to a small extent for fertilizer. Both GROUPL and GROUPH were inefficient in the use of all inputs since the ratios for all inputs were not close to one.

Labor input had been expected to be overutilized in both groups according to the present socio-economic context in HRA, but the allocative efficiency ratio shows the opposite result: labor input was underutilized in both groups since the ratios were much greater than one for labor in both groups.

This phenomenon can be explained in two aspects: first, the wage per labor-year is undercalculated in statistical yearbooks in unit-farms, because many things in kind which provide farmers benefits and profits are not counted into their wages; second, in China, the labor market is imperfect. The labor wage is institutionally set and it cannot reflect labor marginal productivity and the real situation in the labor market. In developing countries, low wage rates are considered to promote employment opportunities for surplus labor.

A Chow test[4] was applied to confirm whether or not the production functions of the two HRA farm groups were different. The Chow test produced F* = 2.3. Since the theoretical value of $F_{0.05}$ = 2.6 is very close to the estimate, it is concluded that the functions would be statistically different from each other except for the empirical method used. If more unit-farms in the middle of the K/N ranking had been removed to improve the separation of the two groups, the F would have been significant. However, more degrees of freedom were preferred to stronger separation for purposes of simulation later on.

Simulation Approach

The estimated production functions form the technical base of the simulation model. All the estimates and other exogenously specified variables constitute the set of given data. To simulate the previously mentioned four scenarios in the model, a FORTRAN language program is developed by the author.

To streamline the FORTRAN program, such parameters as k, ϵ_k, ϵ_n and δ are calculated in advance outside the model. To simulate the structural implications of the high K/N ratio group of unit-farms catching up with the 1981 Alberta K,

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[4] Koutsoyiannis, *op.cit.* pp. 164-8.

Table IV.3 Estimates of Production Functions For Heilongjiang-Unit-farms 1984 and Alberta Large Farms 1981.

farms	A	β_k	β_n	β_f	F-test	R^2
Alberta	4.1	0.64	0.43	-	27.29**	0.58
	(1.33)	(2.58)*	(2.75)**			
HRA: GROUPH	4.7	0.36	0.62	0.19	50.25**	0.89
	(3.59)**	(2.08)*	(3.07)**	(2.07)*		
HRA: GROUPL	5.4	0.34	0.77	-0.02	32.74**	0.85
	(4.21)**	(2.56)*	(5.47)**	(-0.19)		

Source: Results of production function analysis.

Note:
GROUPH: the high K/N ratio group of unit-farms.
GROUPL: the low K/N ratio group of unit-farms.
A: the constant of the Cobb-Douglas production function in natural log value.
β_k: the production elasticity of capital.
β_n: the production elasticity of labor.
β_f: the production elasticity of fertilizer.
Figures in parentheses are t-values, with significance level indicated by * (5%) and ** (1%).

Table IV.4 Marginal Productivity, Factor Cost And Allocative Efficiency Ratio For HRA Unit-farms, 1984.

	GROUPH	GROUPL
Marginal Value of Product		
capital (CAN$/CAN$)	1.19	2.37
labor (CAN$/labor-year)	1,799	2,161
fertilizer (CAN$/ton)	977	-84
Factor Cost		
capital (CAN$/CAN$)	0.5	0.7
labor (CAN$/labor-year)	412	357
fertilizer (CAN$/ton)	517	393
Alloca. Efficiency Ratio		
capital	2.38	3.39
labor	4.37	6.05
fertilizer	1.89	-0.21

Source: MVP is calculated by β multiplying from average output of a factor input.
Factor cost of capital = (total machinery cost)/(capital stock), where total machinery cost includes depreciation of capital, repair expenditure, and other expenses in wheat and soybean production.
Factor cost of labor = (total labor wage)/(number of employed laborers).
Factor cost of fertilizer=(total fertilizer cost)/(tonnes of fertilizer).

β_k, β_n and γ values in 20 years, rates of change, k, ϵ_k, ϵ_n and δ, are calculated using equations (5), (7), (8) and (11). By the same method change rates are calculated for the low K/N ratio group of HRA unit-farms as their K, β_k, β_n and γ values are pushed to reach the levels of those in the high group. The rates of change are treated as parameters in the computer file. The entire set of parameters in the simulation model is presented in Appendix F.

A summary of the computing flow chart is made in figure IV.1. This simple flow chart briefly expresses the simulation structure. Four scenarios are conducted in separate subprograms titled by 1, 2, 3 and 4. It starts by reading the initial conditions and parameters for each of the four scenarios. Then the computer is asked to check if S = 1. If yes, the computer goes to Subprogram 1 to undertake Scenario One. Once the computer follows Blocks A1, B1 and C1 to run 20 years, it will stop running. The next step is to check if S = 2. When the answer is positive, the computer goes to Subprogram 2 to conduct Scenario Two. The computer run terminates when the last year is run following the route of Blocks A2, B2 and C2. The similar approach is also applied for Scenarios Three and Four.

Block A1 describes the impacts of a change in capital formation only on labor demand and capital/labor ratio. Block B1 calculates output and labor productivity which are affected by changes in capital formation and labor demand in Block A1. Block C1 measures labor supply and the labor surplus from the labor demand in Block A1 and labor supply in Block C1.

Block A2 portrays the impacts of simultaneous changes in capital formation and production elasticities of capital and labor on labor demand and capital/labor ratio. Based on the changes, Block B2 calculates output and labor productivity. Block C2 measures labor supply and obtains the labor surplus using the labor supply and labor demand in Block A2.

Block A3 describes the synthetic impact of simultaneous changes in capital formation, production elasticities and the price ratio of capital to labor on labor demand and capital/labor ratios. According to the impacts, Block B3 calculates output and labor productivity. Then Block C3 figures out labor supply and labor surplus based on the labor demand in Block A3.

Block A4 examines the synthetic impact of simultaneous changes in capital formation and the price ratio of capital to labor on labor demand and capital/labor ratio. Further Block B4 calculates output and labor productivity which are influenced by the impact from Block A4. Block C4 measures labor supply and labor surplus based on changes in labor demand in Block A4.

This simulation structure is carried out for both GROUPH and GROUPL.

Figure IV.1 A Computer Flow Chart of The Simulation Structure.

Definitions:

S: scenario

K: capital formation

Y: total output

Nd: labor demand

Ns: labor supply

G: labor surplus

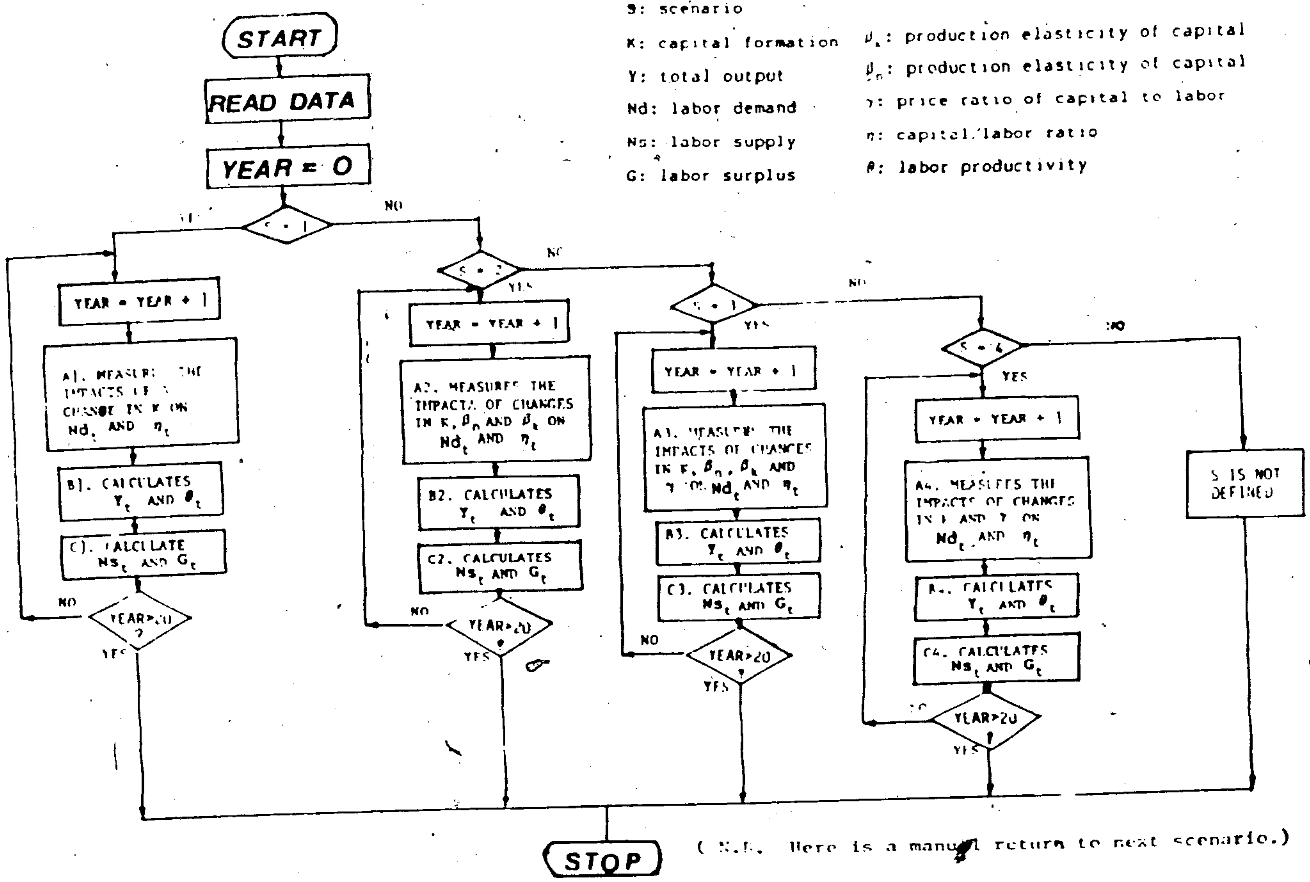
β_k: production elasticity of capital

β_n: production elasticity of capital

γ: price ratio of capital to labor

η: capital/labor ratio

θ: labor productivity



(N.B. Here is a manual return to next scenario.)

V. Results: Interpretation and Comparison

In the previous chapter, a production function analysis, a simulation model and the application of the model in four different scenarios were presented. A FORTRAN program designed by the author was used to run the simulations.

This chapter presents the results of the simulation model and interprets by means of comparing the different scenarios within GROUPH and GROUPL. From the discussion of the results, some conditions for successful technology transfer from Alberta to HRA emerge.

A. Results of Four Scenarios in GROUPH

Scenario One: Capital Formation Alone to Reach 1981 Alberta Levels, 1984-2004

The simulation model for GROUPH in this scenario generates the following results.

1. Capital formation would have to increase by 77% in 20 years. It is assumed to reach Alberta's 1981 capital formation level by that time.
2. Labor demand would increase by 77% in 20 years.
3. The capital/labor ratio stays constant over 20 years.
4. Labor supply increases by 25% in 20 years.
5. Surplus labor declines gradually, resulting in a labor shortage after 17 simulated years.
6. Labor productivity slightly increases. Output per person year of labor increases by 28% in 20 years.

This scenario presumes Hicks neutrality in capital formation.[62] As capital increases, labor demand increases proportionally. Therefore the capital/labor ratio remains constant over time. The consequent change rate of labor demand exceeds that of labor supply resulting in a shortage of labor after the 17th year of simulation. Although this strategy absorbs considerable labor, it makes little contribution to the growth of production and labor productivity. The small increase in output and labor productivity mainly comes from fertilizer increase.

Table V.1 briefly demonstrates the results. Details of the simulation results year by year are presented in Appendix H.

Scenario Two: Adjustment of Capital Formation And Production Elasticities to 1981 Alberta Levels, 1984-2004

1. Capital formation increases by 77% in 20 years, as in Scenario One.
2. Labor demand gradually declines by 33% in 20 years.
3. Capital/labor ratio grows 1.65 times in 20 years.
4. Labor supply increases by 25% in 20 years.
5. Surplus labor increases 1.8 times in 20 years.
6. Output increases by 17 times and labor productivity increases 26 times in 20 years.

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[62] Herrick & Kindleberger, "Hicks neutrality: description of one variety of technological change in which the optimal factor proportions remain constant despite the change." See *Economic Development*, 1983, p. 514.

Table V.1 Results of Simulation For GROUPH in Scenario One (1984 CAN $).

	In Simulated years				
subject	0	5	10	15	20
Ns_t(peo.)	257	271	286	302	319
Nd_t(peo.)	188	216	249	288	332
G_t(peo.)	69	55	37	15	-13
K_t($)	162,391	187,272	215,883	249,696	287,653
K/N_t	867	867	867	867	867
Y_t($)	513,228	629,592	772,337	947,448	1,162,261
Y/N_t	2,739	2,912	3,097	3,293	3,502

Source: Simulation Results.

Note: Ns_t: labor supply in person years in time path.
Nd_t: labor demand in person years in time path.
G_t: the gap between supply and demand of labor in person year in time path.
K_t: value of the capital formation in time path.
K/N_t: capital/labor ratio in $/person year of labor in time path.
Y_t: total output in time path.
Y/N_t: labor productivity in $/person year of labor in time path.

The results as expected show that when capital formation is accompanied by labor-saving technology, the labor demand declines. Although increases in capital formation result in some increase in labor demand, the labor-saving nature of Alberta's technology (β_k increases, β_n decreases) constantly displaces labor, so that the general tendency of labor demand in this situation is to decline. Consequently the capital/labor ratio constantly increases.

Transfer of Alberta's capital-using technology increases the contribution of capital to output growth in GROUPH relative to that of labor. Thus output increases more rapidly than that in Scenario One. The technology change and fertilizer increase mainly contribute to the growth of output. The decrease in labor demand and increase in output are the principal contributor to the rapid increase of labor productivity.

Table V.2 demonstrates the results and more details are provided in Appendix H.

Scenario Three: Adjustment of Capital Formation, Production Elasticities and Price Ratio to 1981 Alberta Circumstances, 1984-2004

1. Capital formation increases by 77 % in 20 years.
2. Labor demand rapidly declines from 188 person years to 2 person years in the period of simulation (20 years).
3. The capital/labor ratio increases from $867 per person year of labor to $155,417 per person year of labor, or 178 times in 20 years.
4. Labor supply grows by 25% in 20 years.
5. Surplus labor increases 3.6 times in 20 years.
6. Output increases 2.1 times, but labor productivity goes up 311 times in 20 years.

Table V.2 Results of Simulation For GROUPH in Scenario Two (1984 CAN $).

	In Simulated years				
subject	0	5	10	15	20
Ns_t(peo.)	257	271	286	302	319
Nd_t(peo.)	188	169	153	139	125
G_t(peo.)	69	102	133	164	194
K_t($)	162,391	187,272	215,883	249,696	287,653
K/N_t	867	1,106	1,411	1,800	2,297
Y_t($)	513,228	811,651	1,515,523	3,402,062	9,387,775
Y/N_t	2,739	4,791	9,894	24,565	74,972

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

The results indicate that capital formation with labor-saving technology and labor price adjustment would make a great contribution to a decrease in labor demand which to some extent increases labor productivity. But the great decrease of labor demand would reduce the total output in the first 9 simulated years (see Appendix H). In the tenth simulated year, the output would return to the level of the initial year and then start to increase. However, this increase would possibly have resulted from technology change and fertilizer increase.

A change in the price ratio of capital to labor is the main cause of rapidly decreasing labor demand. The price ratio of capital to labor in GROUPH is 0.00067, while that of Alberta is 0.00001[*]. Taking the inverse form of the price ratio, we obtain the price ratio of labor to capital, which indicates that the price of labor in GROUPH is 67 times cheaper than that in Alberta. When the price ratio in GROUPH approaches that of Alberta, the price of labor has to increase. An increase in labor price must result in a decrease of labor demand.

Table V.3 shows the above results and more details are provided in Appendix H.

Scenario Four: Adjustment of Capital Formation And Price Ratio to 1981 Alberta Circumstances, 1984-2004

1. Capital formation increases by 77 % in 20 years.
2. Labor demand declines from 188 person years to 5 person years, which means that the labor demand will decrease by 97 % by the last year of the simulation period.
3. Capital/labor ratio increases 67 times in 20 years.
4. Surplus labor grows 3.5 times in 20 years.
5. Total output decreases by 83 %, but labor productivity increases 5.3 times in 20 years.

Adjustment of the price ratio of capital to labor in GROUPH to that in Alberta results in a large increase in labor price which would cause labor demand to decline under market circumstances. The rapid decrease in labor demand

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[*] These figures are calculated from equation (3) by the author.

Table V.3 Results of Simulation For GROUPH in Scenario Three (1984 CAN $).

	In Simulated years				
subject	0	5	10	15	20
Ns_t(peo.)	257	271	286	302	319
Nd_t(peo.)	188	59	19	6	2
G_t(peo.)	69	212	269	296	317
K_t($)	162,391	187,272	215,883	249,696	287,653
K/N_t	867	3,171	11,606	42,470	157,417
Y_t($)	513,228	448,352	515,476	782,463	1,582,555
Y/N_t	2,739	7,590	27,680	133,278	855,053

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

makes total output decrease: However, labor productivity still increases due to the faster speed of displacement of labor compared to that of decline in total output. The capital/labor ratio tends to increase because capital formation keeps increasing and the labor inputs keep decreasing.

Table V.4 demonstrates the results and more details are presented in Appendix H.

Table V.4 Results of Simulation For GROUPH in Scenario Four (1984 CAN $).

	In Simulated years				
subject	0	5	10	15	20
Ns_t(peo.)	257	271	286	302	319
Nd_t(peo.)	188	75	30	12	5
G_t(peo.)	69	196	256	290	314
K_t($)	162,391	187,272	215,883	249,696	287,653
K/N_t	867	2,486	7,128	20,444	58,632
Y_t($)	513,228	327,614	209,129	133,495	85,215
Y/N_t	2,739	4,347	6,897	10,946	17,370

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

B. Results of Four Scenarios in GROUPL

Scenario One: Capital Formation Only to 1984 GROUPH levels, 1984-2004

The simulation model for GROUPL in this scenario produces the following results.

1. Capital formation increases 1.4 times in 20 years.
2. Labor demand accordingly increases 1.4 times in 20 years.
3. The capital/labor ratio remains unchanged over 20 years.

4. Labor supply increases by 25% in 20 years.
5. Surplus labor decreases rapidly. There will be a labor shortage in 10 years.
6. Labor productivity increases slightly. Output per labor will increase by only 7.2% in 20 years.

The production technology of GROUPL is very similar to that of GROUPH except for the gap in capital formation. For GROUPL's capital formation to catch up with that of GROUPH, GROUPL's capital formation should grow at an annual rate of 4.5%. Consequently the labor demand under the assumptions of this scenario would also grow at the same rate. However, the labor supply increases at the slower rate of 1.1% each year causing a labor shortage to emerge in 10 years. Although capital formation develops rapidly, its contribution to growth of labor productivity is very limited. This is caused by the rapid growth of labor demand. The slow growth of output mainly results from increases in labor and fertilizer use.

Table V.5 presents the brief results. More details are provided in Appendix I.

Scenario Two: Adjustment of Capital Formation And Production Elasticities to The 1984 Levels For GROUPH, 1984-2004

1. Capital formation increases 1.4 times in 20 years.
2. Demand for labor increases by 82% in 20 years.
3. Capital/labor ratio increases by 33% in 20 years.
4. Labor supply increases by 25% in 20 years.
5. Surplus labor declines gradually, but not as rapidly as that in Scenario One for this group. There will be a

Table V.5 Results of Simulation For GROUPL in Scenario One (1984 CAN $).

subject	In Simulated Years 0	5	10	15	20
Ns_t(peo.)	240	253	267	282	298
Nd_t(peo.)	175	217	271	338	421
G_t(peo.)	65	36	-4	-55	-123
K_t($)	70,000	87,224	108,708	135,470	168,820
K/N_t	401	401	401	401	401
Y_t ($)	485,410	615,550	780,583	989,858	1,255,246
Y/N_t	2,784	2,833	2,882	2,933	2,985

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

shortage of labor in 17 years.

6. Total output increases very slightly over time. It will grow by 11% in 20 years. Labor productivity decreases by 39% in 20 years.

Capital formation leads to an increase in labor demand. However, adjustment of production elasticities (β_k up, β_n down) offsets a part of the increase in this labor demand. The effects of changes in production elasticities are smaller than the labor increasing effect of capital formation. The surplus labor declines so that in 17 years a shortage of labor appears. The capital/labor ratio increases by a small margin, because only a small amount of labor is displaced. A slight increase in total output results from increases in capital formation and labor demand as well as fertilizer use. However, the growth rate of labor demand exceeds that of total output, so that labor productivity decreases by a large extent.

Table V.6 presents the results and more details of the results are provided in Appendix I.

Scenario Three: Adjustment of Capital Formation, Production Elasticities And Price Ratio to The 1984 Levels For GROUPH, 1984-2004

1. Capital formation increases 1.4 times in 20 years.
2. Labor demand increases by 10% in 20 years.
3. Capital/labor ratio increases 1.2 times in 20 years.
4. Labor supply grows by 25% in 20 years.
5. Surplus labor increases by 65 % in 20 years.
6. Total output decreases by 19 % in 20 years, accordingly labor productivity decreases by 26 % in 20 years.

The price ratio of capital to labor in GROUPH is 0.00067, while that of GROUPL is 0.0011 **. Taking the inverse form of the price ratio of capital to labor, we obtain the price ratio of labor to capital, and find that the labor price in GROUPH is about 1.6 times as expensive as that in GROUPL. As mentioned before, there is little difference between the production elasticities of capital and labor in GROUPH and in GROUPL. Adjustment of production

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** These figures are calculated by the author from equation (3).

Table V.6 Results of Simulation For GROUPL in Scenario Two (1984 CAN $).

	In Simulated Years				
subject	0	5	10	15	20
Ns_t(peo.)	240	253	267	282	298
Nd_t(peo.)	175	203	235	273	317
G_t(peo.)	65	50	32	9	-19
K_t($)	70,000	87,224	108,708	135,470	168,820
K/N_t	401	431	462	496	532
Y_t($)	485,410	496,076	508,456	522,872	539,675
Y/N_t	2,784	2,449	2,161	1,913	1,700

Source: Simulation Results
Note: The definitions of the above subjects are as those in table V.1.

elasticities and the price ratio of capital to labor can displace some labor, but this displacement is smaller than the increment resulting from increasing capital formation. So the labor demand still tends to slightly increase.

Production elasticity of capital changes very little and the contribution of capital increases very slowly, while the labor demand and elasticity of labor decrease relatively faster. This phenomenon causes a great deal of decrease in total output. Due to the decrease in total output and a slight increase in labor demand, labor productivity still decreases, but not as much as that in Scenario Two.

Table V.7 gives the brief results and more details are presented in Appendix I.

Scenario Four: Adjustment of Capital Formation and Price Ratio to The 1984 Levels For GROUPH, 1984-2004

1. Capital formation increases 1.4 times in 20 years.
2. Labor demand increases by 45 % in 20 years.
3. Capital/labor ratio increases by 66 % in 20 years.
4. Labor supply increases by 25 % in 20 years.
5. Surplus labor decreases by 32 % in 20 years.
6. Total output increases by 75 %, and labor productivity increases by 20 % in 20 years.

When the price ratio of capital to labor in GROUPL moves to the level of GROUPH, GROUPL's labor wage has to increase 1.6 times due to the fact that the labor price in GROUPH is 1.6 times as high as that in GROUPL. The increase in labor price in GROUPL results in a decrease in labor demand, but this decrease in labor demand is smaller than the increase in labor demand caused by capital formation, so labor demand still tends to increase.

The capital/labor ratio increases because increases in capital formation are more rapid than those in labor demand.

Increases in capital formation and labor demand are the contributors to output growth. Total output increases faster than labor demand, therefore labor productivity still increases.

Table V.8 presents the results and more details are provided in Appendix I.

Table V.7 Results of Simulation For GROUPL in Scenario Three (1984 CAN $).

	In Simulated Years				
subject	0	5	10	15	20
Ns_t(peo.)	240	253	267	282	298
Nd_t(peo.)	175	179	183	187	191
G_t(peo.)	65	74	84	95	107
K_t($)	70,000	87,224	108,708	135,470	168,820
K/N_t	401	489	596	725	882
Y_t($)	485,410	452,370	427,026	408,144	394,828
Y/N_t	2,784	2,535	2,338	2,183	2,063

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

C. Interpretation and Comparison of Results

Interpretation

Scenario One in both groups entails a large amount of capital investment, accompanied by increasing labor input. The capital/labor ratio stagnates during the simulation period. Although total output grows rapidly, labor productivity develops only moderately due to the large increase in labor at the same time.

This scenario is considered to be similar to the early stage of state farm development in Heilongjiang. Capital formation principally oriented to land reclamation kept increasing, but it was accompaned by labor shortages. These shortages were overcome by inmigration from elsewhere in China. For instance, thousands of young students from all over China moved into HRA in the 1960's and 1970's. The result, however, was a decrease in labor productivity, which impeded agricultural development in HRA during that period of time[85].

Evidence produced in the first scenario shows that this kind of capital formation accompanied by a large labor requirement would add to output but also add to consumption. The volume of investible surplus could not be as much as could be expected since labor productivity stagnates or at best grows slowly. Moreover, the strategy requires a continuing financial investment, which is normally a major constraint in developing agricultures. Accordingly with consideration of financial constraints and efficiency in production, this scenario can no longer satisfy the development objectives on the state farms.

Scenario Two introduces the impacts of a labor-saving technology embodied in capital formation. This scenario indicates that with the labor-saving technology, capital formation would not increase the labor requirement. Conversely, it would displace workers and promote total output in GROUPH. This scenario provides evidence for the assumption that labor surplus or underemployment exists in HRA because labor can be withdrawn from agriculture without any decrease in agricultural output (Reynolds, 1975).

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[85] Heilongjiang GYNCJJFZS BianXieZu, *op.cit*, p. 217.

Table V.8 Results of Simulation For GROUPL in Scenario Four (1984 CAN $).

subject	In Simulated Years 0	5	10	15	20
Ns_t(peo.)	240	253	267	282	298
Nd_t(peo.)	175	192	210	231	254
G_t(peo.)	65	61	57	51	44
K_t($)	70,000	87,224	108,708	135,470	168,820
K/N_t	401	456	517	587	666
Y_t($)	485,410	558,382	642,325	738,885	849,964
Y/N_t	2,784	2,916	3,055	3,201	3,353

Source: Simulation Results.
Note: The definitions of the above subjects are as those in table V.1.

In GROUPL, however, output grows very moderately and labor productivity actually decreases with GROUPH technology. There may be two reasons for the decrease. One is that there might not be a substantial labor surplus in GROUPL when GROUPL uses the technology of GROUPH, because their technologies are similar. Even withdrawing labor does not cause any decrease in the initial ouput. The withdrawal makes output grow much slower than that in Scenario One for GROUPL. The other reason is that the growth of labor demand caused by capital formation is faster than the growth of output, therefore, labor productivity decreases.

This capital intensification approach to development has been common in developing countries in the past two or three decades, because it has largely satisfied the need to improve production technology and food output in those countries.

Scenario Three searches for a technology transfer by a means of capital-intensive technology coupled to adjustment of relative factor prices. This scenario, based on Scenario Two, largely emphasizes the importance of using correct relative factor prices derived within marketing systems.

Alberta's price ratio of capital to labor, with production elasticities of capital and labor and capital formation together, reflects a complete cereal production technology used in Alberta cereal agriculture. So this scenario, compared with Scenario Two, is more complete.

According to the price ratios of labor to capital in GROUPH and Alberta, the labor cost in Alberta is 67 times as high as that in GROUPH. If the impacts of the complete Alberta cereal production technology are not to be distorted by the different factor prices and marketing institutions currently found in China, the price ratio of capital to labor, or labor price and pricing system for GROUPH should be adapted within a factor pricing environment.

The price ratio of capital to labor of Alberta is appropriate to the technology being transferred in the sense that it reflects efficiency of resource use and development of capital formation in Alberta where the technology originates. However, the reduction of output in the first 9 simulated years in Scenario Three for GROUPH shows that the price ratio in Alberta might not be appropriate in GROUPH since adjustment of the price ratio in HRA to Alberta would lead to a great amount of labor withdrawal which would impair the level of output for about a decade.

The extent of possible factor price changes is limited by opportunity costs of factors in Heilongjiang. The phenomenon of unemployment or underemployment in China makes the opportunity cost of labor very low or even close to zero. Therefore, the possibility of adopting Alberta technology depends upon the availability of employment opportunities for both the labor displaced by new mechanical technology in cereal agriculture, and for those who are otherwise unemployed or underemployed in society. If work opportunities through job creation, for example, industrial diversification of state farm enterprises, develop too slowly the modern technology in cereal production may not be acceptable in the short run.

Usually, market prices in most countries do not reflect the true scarcity values or marginal productivities of resources used [16]. It is obvious that the present labor wages in HRA do not reflect labor values or labor marginal productivity. The wages are lower than the marginal value of labor. To address this situation, shadow prices normally are assigned to adjust prices observed in the market to reflect more nearly the goods' scarcity values[17]. By definition, shadow price is the price that reflects the opportunity cost to society as a whole of a good, service, or factor of

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[16] Herrick & Kindleberger, *op.cit. p. 289.*
[17] Ibid., p. 289.

production. •• Labor shadow price is considered as the marginal product of the labor•', but in a developing cour with severe underemployment or unemployment, the shadow price of labor is less than the theoretical labor price or the market price. So in planning technology investment, the labor cost should be calculated at the shadow price.

Factor price changes also imply factor mobility. Factor mobility facilitates technology change. In HRA, institutional arrangements of labor employment and wage rate cannot successfully reflect labor market activities and cannot stimulate labor's production interests. More flexibility in labor arrangements is required for realization of employment opportunity creation, adjustment of wages and improvements to labor productivity.

For GROUPL, however, this scenario is not impressive. Even if labor demand and capital/labor ratios in GROUPL reach the 1984 position of GROUPH in 20 years, total output and labor productivity do not improve. A decrease in total output in GROUPL could be caused in the model by the decrease in the production elasticity of labor, which makes a smaller contribution to output growth. Labor costs between GROUPH and GROUPL are not very much different. The labor price in GROUPH is 1.6 times as high as that in GROUPL. Adjustment in the labor cost will not cause a large labor displacement. This scenario indicates that it is not useful for GROUPL to copy completely the technology in GROUPH.

•• Ibid., p. 519.
•' Ibid., p. 289.

Scenario Four explores the impacts of a technology transfer by means of capital formation and adjustment of relative factor prices. Here capital formation is without any consideration of technology change. It could be some sort of labor-using technology, like a new capital construction, or any kind of job creation, which can absorb considerable labor. Adjustment of labor price can displace a great number of labor. This scenario implies that with displacement of labor caused by improving labor opportunity costs, capital formation could provide some employment opportunities for the displacement of labor.

Results in Scenario Four have shown that this scenario fails to produce an effective technology for GROUPH. The reason is that the price ratio, with production elasticities unchanged and only capital formation, indicates an incomplete system of Alberta technology. For GROUPL, however, this scenario produces some impressive results: labor demand is lower than that in Scenario One and Two, and slightly higher than that in Scenario Three. The capital/labor ratio becomes the second highest in the four scenarios; and labor productivity becomes the highest of all the scenarios for the group. It seems that improvement of capital formation and labor price in GROUPL can make a larger contribution to growth of output and labor productivity. In reality, it means that the labor wage in GROUPL should be gradually increased to the level of GROUPH. This adjustment will make production in GROUPL more efficient.

Comparison of Results

According to the four criteria: output, labor demand labor productivity and capital/labor ratio, the four scenarios are ranked within each group respectively. The ranking is on a 4-point scale. The best scenario in terms of different criteria is given 1 point. The worst one is assigned 4 points. The total points are used to comprehensively appraise a scenario. The lower the total points, the better the scenario. Tables V.9 provides the results of the rankings, referring to Tables V.10, V.11 and V.12 which present more details of the four scenarios in terms of the above criteria.

GROUPH

In appraising all scenarios and the different criteria for ranking them, we found that Scenarios Two and Three have the same points which mean that they deserve the same priority in consideration of technology choice.

However, we consider Scenario Two as an appropriate technology for GROUPH in the short run. This scenario has the highest output, the second highest labor productivity, the least labor displacement and the second lowest capital labor ratio. If GROUPH's objective is the maximization of immediate output and minimization of a labor surplus, this technology would be appropriate. But, it could not be appropriate for development in the long run because its labor productivity and capital/labor ratio, which are critical to the growth rate, are not maximized.

Table V.9 Ranking of Scenarios For Technology Transfer in 20 Years For Both Groups According to Four Criteria.*

subject	Y	Nd	Y/N	K/N	Σ
GROUPH					
Scenario #1	3	1	4	4	12
Scenario #2	1	2	2	3	8
Scenario #3	2	4	1	1	8
Scenario #4	4	3	3	2	12
GROUPL					
Scenario #1	1	1	2	4	8
Scenario #2	3	2	4	3	12
Scenario #3	4	4	3	1	12
Scenario #4	2	3	1	2	8

Source: Tables V.10, V.11 and V.12.
* On this scale, the smaller the number is, the better the scenario would be.
Y: output.
Nd: labor demand.
Y/N: labor productivity.
K/N: capital/labor ratio.
Σ: the total ranking point.

Scenario Three would be considered an appropriate technology for GROUPH in the long run. It has the second highest output but the highest labor productivity and capital/labor ratio. The weakness of this scenario is that it would result in the most labor surplus and impair output level during the first part of the simulation period. The results, compared with numbers of the same items in table

V.13 indicate that if GROUPH adopts Alberta's technology in cereal production, GROUPH would have very similar characteristics of Alberta large farms in cereal production. For instance, the average labor use per unit-farm in GROUPH would be the same size in year 2004 as as that in Alberta's large farms in 1981. The average capital/labor ratio per unit-farm would be very close to the 1981 level for Alberta large farms in 2004 (see tables V.12 and V.13). The average labor productivity per unit-farms would reach the 1981 level for Alberta in 15 simulated years (see tables V.10 and V.13)

If GROUPH's objective is to maximize the growth rate and to lay a good economic foundation for development in the long run, this capital-intensive technology should be adopted. As discussed before, the possibility of adoption of this kind of technology largely depends on employment opportunity creation. The factor mobility in China is also prerequisite for success of this technology transfer from Alberta to HRA. Therefore, under the circumstances where secondary and tertiary industries have not been developed and underemployment or "disguised unemployment exist on a state farm, Scenario Two would have higher priority than Scenario Three for GROUPH in the short run.

GROUPL

Scenarios in GROUPL produce corroborative evidence for G.M. Meier and P. Hall's theory discussed in Chapter Three. If GROUPL's production objective is to maximize its immediate output, it would choose a labor-intensive technology at the expense of rapid growth in the future.

Scenario One may satisfy this need, because this scenario provides the highest output, the most labor input and the second highest labor productivity. But its capital/labor ratio remains low and constant. This would impede economic development in the future.

Scenario Four may be more appropriate than Scenario One for GROUPL. After appraising the scenarios in terms of different criteria, we found that Scenario Four in GROUPL results in the highest labor productivity, the second highest output and capital/labor ratio, but the second lowest labor demand. This scenario implies that adjustment of labor price in GROUPL would induce a slightly labor-saving technology, and this technology with capital formation would produce higher output, labor productivity and capital/labor ratio. Although those develop at the cost of more labor surplus, they would be very important to economic development in the long run.

Table V.10 A Summary of Four Scenarios: Total Output And Labor Productivity* (1984 CAN $).

	In Simulated Years				
subject	0	5	10	15	20
GROUPH					
Scenario #1	513,228	629,592	772,337	947,448	1,162,261
	(2,739)	(2,912)	(3,097)	(3,293)	(3,502)
Scenario #2	513,228	811,651	1,515,523	3,402,062	9,387,775
	(2,739)	(4,791)	(9,894)	(24,565)	(74,972)
Scenario #3	513,228	448,352	515,476	782,463	1,582,555
	(2,739)	(7,590)	(27,680)	(133,278)	(855,053)
Scenario #4	513,228	327,614	209,129	133,495	85,215
	(2,739)	(4,347)	(6,897)	(10,946)	(17,370)
GROUPL					
Scenario #1	485,410	615,550	780,583	989,858	1,255,246
	(2,784)	(2,833)	(2,882)	(2,933)	(2,985)
Scenario #2	485,410	496,076	508,456	522,872	539,675
	(2,784)	(2,449)	(2,161)	(1,913)	(1,700)
Scenario #3	485,410	452,370	427,026	408,144	394,828
	(2,784)	(2,535)	(2,338)	(2,183)	(2,063)
Scenario #4	485,410	558,382	642,325	738,885	849,964
	(2,784)	(2,916)	(3,055)	(3,201)	(3,353)

Source: Simulation Results.
* Figures in parentheses are labor productivity.

Table V.11 A Summary of Four Scenarios: Labor Demand And Surplus Labor* For Both Groups in HRA (number of people).

subject	In Simulated Years 0	5	10	15	20
GROUPH					
Scenario #1	188 (69)	216 (55)	249 (37)	288 (15)	332 (-13)
Scenario #2	188 (69)	169 (102)	153 (133)	139 (164)	125 (194)
Scenario #3	188 (69)	59 (212)	19 (268)	6 (297)	2 (318)
Scenario #4	188 (69)	75 (196)	30 (256)	12 (290)	5 (314)
GROUPL					
Scenario #1	175 (65)	217 (36)	271 (-4)	338 (-55)	421 (-122)
Scenario #2	175 (65)	203 (50)	235 (32)	273 (9)	318 (-19)
Scenario #3	175 (65)	179 (75)	183 (85)	187 (95)	191 (107)
Scenario #4	175 (65)	192 (62)	210 (57)	231 (52)	254 (45)

Source: Simulation Results
* Figures in parentheses are surplus labor.

Table V.12 A Summary of Four Scenarios: Capital/labor Ratio For Both Groups in HRA (1984 CAN $).

	In Simulated Years				
subject	0	5	10	15	20
GROUPH					
Scenario #1	867	867	867	867	867
Scenario #2	867	1,106	1,411	1,800	2,297
Scenario #3	867	3,171	11,606	42,470	155,417
Scenario #4	867	2,486	7,128	20,444	58,632
GROUPL					
Scenario #1	401	401	401	401	401
Scenario #2	401	431	462	496	532
Scenario #3	401	489	595	725	882
Scenario #4	401	456	517	587	666

Source: Simulation Results

Table V.13 Average K/N And Y/N of Alberta Farms (in 1981 CAN dollars).

year	N	K/N	Y	Y/N	CPI
1951[a]		10,962		7,219	2.37[b]
1961[c]		32,668		17,180	
1971		41,000		37,000	
1981		104,000		74,000	
1981[d]	2	164,896	257,673	138,249	

Source: Keir Packer, M.Sc. thesis, "Structural Changes in Cereal Agriculture". 1985, p. 82. and p. 86.
a. These figures are calculated by K/N and Y/N in 1950 times CPI respectively. K/N and Y/N are calculated from *1951 Census of Canada: Alberta*, Historical tables: table 2, table 8, and table 13 , 1953.
b. CPI is from Lynn Malmberg, "Source of Variation in Farm Income in Alberta 1926-1981", Department of Agriculture, Alberta.
c. This figure is obtained by K/N and Y/N ratios in 1961 times CPI in 1981 respectively.
d. These figures are from the large farms in Alberta cereal production, which are extracted from table IV.2.

VI. Summary, Policy Implications And Research Limitations

In this final chapter all works in this study are summarized, some policy implications are drawn based on the results, and finally limitations of this study are pointed out.

A. Summary

In recent years, technology transfer from developed countries has been considered as a source of technological change for agriculture in China. To avoid distortion of impacts of cereal technology transfer from Alberta to Heilongjiang state farms, or to avoid its negative effects on Heilongjiang state farms' agricultural employment, this study attempted to investigate the transferability of Alberta cereal technology to Heilongjiang state farms.

Three objectives for this study were established to examine possible economic effects of technology transfer on Heilongjiang state farms. First of all, the similarity and dissimilarity of natural resource environment and socioeconomic context between the two agricultures within HRA and in Alberta were explored to understand the prerequisites to technology transfer.

The second objective was to simulate quantitatively the impacts of technology transfer on labor demand, capital/labor ratio and labor productivity in HRA state farms.

The third objective was to propose some appropriate conditions for successful technology transfer to HRA state farms.

A random sample of 5 state farms was selected from the total 84 state farms in HRA under consideration of cereal production and medium size of farms. There were 91 unit-farms involved in cereal production within the 5 selected state farms. A second stage sample of 46 cereal unit-farms was randomly selected from the 91 unit-farms.

The 46 unit-farms were divided into two groups: the high capital/labor ratio group (GROUPH) and the low capital/labor ratio group (GROUPL), according to the ranking of their capital/labor ratios. Using a Cobb-Douglas production function, production elasticities of capital, labor and fertilizer were estimated for both groups. For simulation of technology transfer, a sample of 42 large Alberta cereal family farms was selected to estimate their production elasticities of capital and labor using the Cobb-Douglas production function form.

Exploring further, we found that resources were inefficiently used by both groups of unit-farms in HRA. Capital and labor were underutilized in both groups; fertilizer was overutilized by GROUPL, but slightly underutilized by GROUPH. Labor input had been expected to be overutilized by both groups, but the results were opposite: labor was underutilized. This could be explained by underestimation of wages and imperfections of the labor market. A Chow test applied to compare the functions for the two groups indicated that they were slightly different from each other.

A simulation method was used to estimate the possible impacts of technology transfer. The simulation model consisted of two submodels: labor demand and labor supply. The labor demand submodel was derived from the Cobb-Douglas production function, and the labor supply submodel built upon the concept of *birth cohort*.

The model simulated the impacts of technology transfer in cereal production both from Alberta to GROUPH and from GROUPH to GROUPL in four different scenarios according to a predetermined planning path.

Scenario One: Capital formation on unit-farms of GROUPH in HRA to reach the 1981 level of Alberta large farms in 20 simulated years, with production elasticities and the price ratio of capital to labor unchanged. The impacts on labor demand, capital/labor ratio and labor productivity were estimated for 20 simulated years. The same procedure was used for GROUPL where GROUPL's capital formation was to catch up with the 1984 level of GROUPH.

Scenario Two: GROUPH's capital formation and production elasticities of capital and labor to approach the 1981 levels for Alberta; the same two factors in GROUPL were simulated to approach the 1984 levels for GROUPH, with the price ratio of capital to labor unchanged. The impacts on labor demand, capital/labor ratio and labor productivity were simulated for 20 years.

Scenario Three: GROUPH's capital formation, production elasticities and the price ratio of capital to labor to move to the 1981 levels for Alberta; those three factors in GROUPL moved to the 1984 levels for GROUPH. The impacts on labor demand, labor productivity and capital/labor ratio were described.

Scenario Four: GROUPH's capital formation and the price ratio of capital to labor to approach the 1981 levels for Alberta; and those two factors in GROUPL approached the 1984 levels for GROUPH, with production elasticities unchanged. The impacts on labor demand, capital/labor ratio and labor productivity were measured for 20 years.

The above four scenarios were explored using a FORTRAN computer program designed by the author.

The results of Scenario One showed that with increases in capital formation, a large amount of labor input was required. Compared with other scenarios, this scenario produced the lowest capital/labor ratio and the highest labor demand for both groups in HRA, and produced the lowest labor productivity for GROUPH and the second highest labor productivity for GROUPL. The results in GROUPL provided evidence that the maximization of immediate output and labor employment was achieved at the expense of rapid growth in the future. If GROUPL's objective is to maximize the immediate ouput and labor employment, this scenario may be appropriate but not for GROUPH.

The results of Scenario Two indicated that the labor-saving technology embodied in capital formation produced the highest output, the second highest labor productivity, the second lowest capital/labor ratio and the second highest labor demand for GROUPH, compared with other scenarios. This scenario was not efficient for GROUPL but could be recommended for GROUPH in the short run if GROUPH's objective is to maximaze its immediate output with not much displacement of labor.

The results of Scenario Three indicated that the labor-saving technology with adjustment of the price ratio of capital to labor and capital formation were not appropriate to GROUPH in the first 9 simulated years when levels of output were impaired. But it produced the second highest output, the highest labor productivity, the highest capital/labor ratio and the lowest labor demand for GROUPH over the whole 20 year simulation. Conversely this scenario produced the lowest output, the second lowest labor productivity, the highest capital/labor ratio and the lowest labor demand for GROUPL, compared with other scenarios. This scenario might propose an appropriate technology for GROUPH in the long run but not for GROUPL. The success of this technology transfer from Alberta to GROUPH depends upon factor price changes and factor mobility as well as non-grain production employment opportunity creation.

The results of Scenario Four indicated that capital formation with adjustment of the price ratio of capital to labor generated the lowest output, the second lowest labor productivity, the second highest capital/labor ratio and the second lowest labor demand for GROUPH; however, for GROUPL, it produced the second highest ouput, the highest labor productivity, the second highest capital/labor ratio and the second lowest labor demand. The results of this scenario for GROUPL seemed more successful than those for GROUPH. In practice, those results could be achieved using a relatively labor-saving technology induced by adjustment of the labor price or labor opportunity costs in GROUPL.

B. Policy Implications

The following implications may arise from the findings in the study:

1. The underutilization of capital in both groups of HRA may indicate that capital markets in HRA have not been well developed. There is a need for development of different financial channels to accelerate capital formation. Government credits, bank loans or credits, manufacture credits and individual funds should be efficiently utilized for the purchase of modern machinery, the renewal of old equipment and the provision of facilities for transportation and communication.

   The solution to the constraints of capital shortage is a prerequisite to the technology transfer.

2. The inefficiency of labor use in HRA was likely created by low institutional wage arrangements, an incomplete accounting system and inflexible labor markets. The success of Alberta technology transfer requires a suitable accounting system to account for factor costs, and productivities in economic activities. Therefore, underestimation or overestimation of any resource costs and productivities should be improved in the accounting systems

3. Even though the allocative effiency ratio of fertilizer showed that fertilizer was slightly underused by GROUPH and overused by GROUPL, there would be a tendency for both groups to overuse fertilizer if they keep increasing their fertilizer use at the annual rate of

about 10%, which was the average annual growth rate in the past decade in China. Consequently, it is necessary for the state farms to consider a policy to avoid overutilization of fertilizer for grain production in the near future.

4. There is no particularly advanced technology transfer from GROUPH to GROUPL except for their different capital formations. The results from the simulation analysis showed that if state farm policy requires GROUPL to follow a strategy of catch-up to GROUPH's technology, its production could not be improved. Therefore, the technology used by GROUPH would not be a good example for GROUPL to follow. A better alternative for GROUPL to improve its production may lie on adjustment of its labor costs or labor opportunity costs and capital formation. A relatively labor-saving technology would be induced by this method. In this situation, the government should underscore a policy which guides new capital formation to create employment opportunities other than in cereal production and to allow free movement of surplus labor within farms or even provinces.
5. Alberta technology transfer in cereal production implies capital-intensiveness and factor price change. The capital-intensive technology applied to HRA must cause a great amount of labor displacement by capital. One of the crucial prerequisites for the technology transfer should be to create any possible non-grain production employment opportunities for the potential labor surplus

transfer from cereal production to other fields. Accordingly, a policy to increase employment opportunity is in the high demand if the mechanical technology is transferred to HRA.

Factor price change is understood to be induced by relative factor scarcity. This principle of the induced innovation theory reminds us of that campatible relative factor prices are needed to achieve the successful technology transfer. Even if the findings in Scenario Three for GROUPH indicated that the price ratio change would not have positive impacts on output in the first part of the simulated period, the results of its last part of the simulation showed that the price ratio change had an important role in growth of the capital labor ratio and labor productivity in the long run. This phenomenon implies that the price ratio change might not be very important to the present circumstances of HRA, but might be very important in the near future.

Factor price change also means factor mobility which is a neccessary condition for technology change. The implication is that factor mobility is needed for technology transfer in HRA. In particular, flexibility of capital and labor markets is required.

C. Research Limitations

Initially, the sample of 46 unit-farms for this study seemed to be below the average level for state farms in HRA in terms of capital stock. For instance, the average level of capital/labor ratio in HRA in 1984 was 1,860 Canadian dollars, while in the sample, the average capital/labor ratio for GROUPH was 886 Canadian dollars; for GROUPL, 421 Canadian dollars. The average capital/labor ratio of the entire HRA in the statistical yearbook was accounted by dividing all capital stock by all employed workers in HRA. However, capital stock included machinery and equipment, buildings and other big constructions used in agriculture, industries and services. In this research, capital means only machinery value used in agriculture which is consistent with the meaning of capital in the Alberta data. There is no way to check that the capital use on sampled farms is biased other than by the assumption of accuracy associated with random sampling.

Another problem with data resulted from the substitution of factor costs for factor prices and the aggregation of factor costs. Due to difficulty in availability of factor prices, factor costs were substituted for factor prices (Banskota, Phillips and Williamson, 1985). The factor costs for capital and fertilizer in our study were involved in only wheat and soybean production. Those factor costs in wheat production were obtained from statistical yearbooks, while those in soybean production were calculated by the author using average factor cost per *mu* of the whole HRA multipled by total area sown of soybean production for each of the selected unit-farms. This may cause inaccuracy of factor costs for capital and fertilizer in our production analysis.

Secondly, conversion of the Chinese currency to the Canadian one using the official exchange rate may cause misleading results. This is because the official exchange rate is a poor guide to relative purchasing power[10], and cannot reflect the real pruchasing power of chinese currency in China.

Thirdly, cross-section data for a single period has particular drawbacks for a long-time simulation analysis. Conventionally, a simulation analysis is based on time-series data. Estimates derived from production functions or other techniques over the past time-series are normally compared with results from the simulation analysis for the same period of time. This comparison would produce a set of standard checks on the reasonableness of the simulation model. After this check, the predicting results from the simulation model for the future period would be more reliable (Tyner and Tweeten, 1968; Pindyck and Rubinfeld, 1981).

In the situation of cross-section data for a single period, the historic validity of the simulation model could not be examined, and further there could not be a proper method to check its predicting results.

Fourthly, the 'A' parame of production function, which is also called the "shift factor", represents a neutral technological change. Variation in A does not affect the marginal rate of substitution between labor and capital[11]. In our simulation model, however, the shift factor was assumed constant. Neutral technological changes were not considered in this study because our focus was on

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[10] P. Hall, *op.cit*. p. 6.
[11] Brown, M., *On The Theory And Measurement of Technological Change*. 1968, p. 42.

the relationship of labor and capital.

Fifthly, it is noted that the fertilizer variable used in production functions of HRA unit-farms mixed the effects of technology transfer and fertilizer own increase. However, it did not play a substantial role in this research. It would be helpful to examine the effects of fertilizer, however fertilizer data were not available for Alberta's 42 large family farms.

Finally, the simulation model was undertaken according to a predetermined planning horizon meaning that GROUPH had to catch up with the 1981 levels for Alberta in 20 years. This assumption was made for simplification of the analysis process. However, it could not reflect the dynamic development of Alberta technology in agriculture. Even though GROUPH might catch up with the 1981 levels for Alberta in 20 years, it would be still 20 years behind Alberta.

In spite of the above limitations and problems for data and the simulation model, the approach of simulation is shown to be a valuable technique to explore possible effects of technology transfer on agricultural systems. The results from the production and simulation analyses should add useful reference material for addressing technology transfer/choice questions in policy-making by Alberta and Heilongjiang as part of their international sister relationship.

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Appendix A: Basic Statistics of State Farms Nationwide, China, 1984

	HRA	Xinjiang A.R.	Guangdong	Yunnan	Nationwide
farms	84	169	140	38	2048
population ('000 people)	1453	2250	1262	243	11363
workers ('000 people)	640	913	658	126	4928
cultivated land ('000 ha.)	1,773[a]	1,062	341	73	4,430
factories	24	122	24	12	296
commerces	14	69	8	10	203
transportations	5	20	-	1	30
constructions	9	30	2	2	55
GVAIO[b] (mill. CAN $)	1,224	1,367	769	142	7,725

Adapted from the following:
Source: Bureau of Land Reclamation and Agriculture, Beijing, *Statistics Yearbook, 1984*.
a: *Statistics Yearbook, 1984*, GBSFH.
b: GVAIO means Gross Value of Agricultural and Industrial Output.

Appendix B: Composition of Crop Production in HRA, China, 1981 and 1984

	acreage sown	grain sown				cash-crop	others
	(mill. ha.)	grain: (%)	wheat (%)	corn (%)	soybean (%)	(%)	(%)
1981	2.0	92.68	53.3	4.7	32.9	1.4	5.9
1984	1.6*	91.80**				2.4**	5.7**

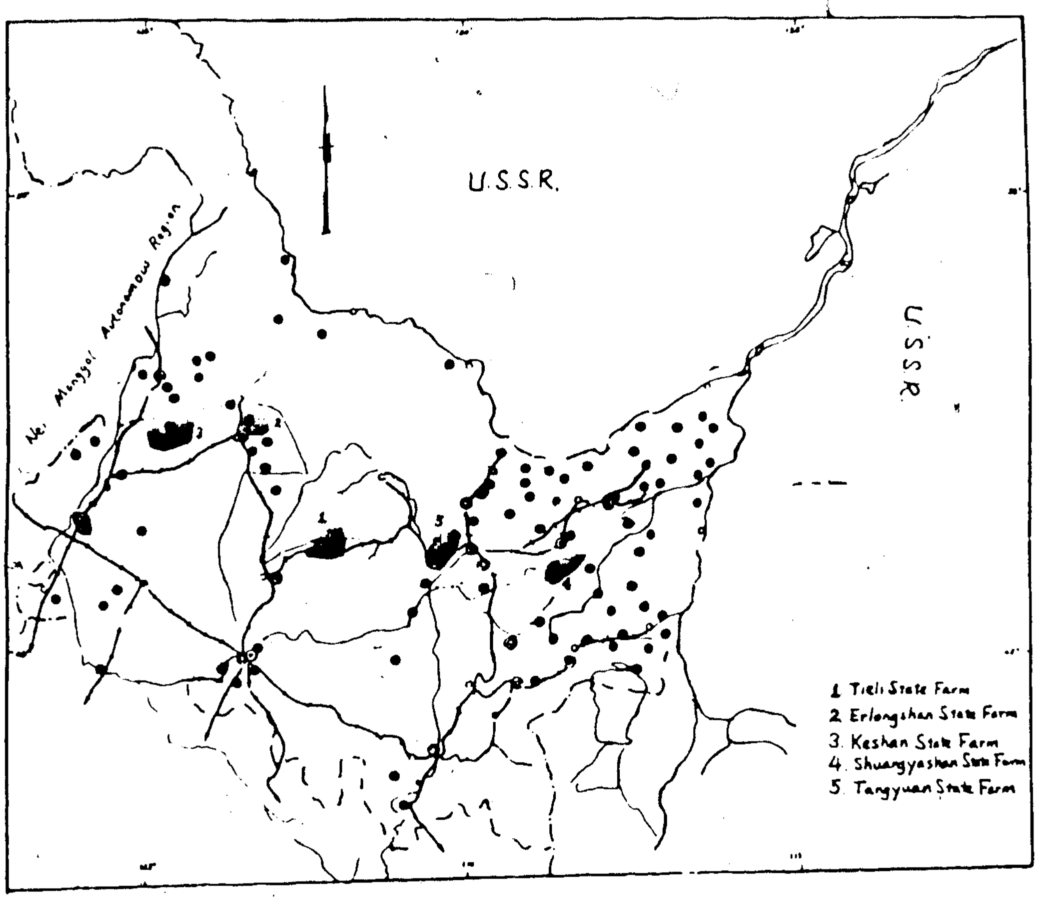
Adapted from the following
Source: *History of Economic Development of Heilongjiang State Farms*, Harbin: Heilongjiang People Publication Agency, 1984, p. 11.
* *An Introduction to GBSFH*, GBSFH, 1984, p. 5.
** Sun Ren-song *et al*, " On Production Structure in HRA ", an unpublished paper for National Academic Conference of The State Farm Economy, 1984, p. 2.

Appendix C: Constitution of GVAO* in HRA, China, 1984

	GVAO (million yuans)	percentage (%)
total	1371	100.00
crop	1243	90.64
forest	37	2.70
livestock	45	3.29
sideline	43	3.10
fishery	3	0.24

Adapted from the following:
Source: Sun Ren-song *et al*, "On Production Structure in HRA", 1984, p. 2.
* GVAO means Gross Value of Agricultural Output.

Appendix D: Locations of 5 Selected State Farms in HRA, China, 1984



Source: It is adapted from the official abstract map of the state farms in Heilongjiang in *An Introduction to GBSFH*, GBSFH, 1984.

Appendix E: Basic Statistics of The 5 Selected State Farms in HRA, China, 1984

subject	Name of State Farm				
	Tieli	Erlongshan	Keshan	Shuangyashan	Tangyuan
total unit-farms	18	36	29	21	14
--grain unit-farms	17	23	26	16	11
population (persons)	9,562	23,037	27,243	18,913	6,655
labor force (persons)	4,605	10,713	10,647	9,018	4,043
employed workers	3,926	9,509	10,598	7,389	2,839
cultivated land (hectares)	12,449	23,641	24,676	12,716	7,813
GVAIO*(mil. CAN $)	84	168	223	123	50
labor productivity ($/worker)	2,602	2,230	2,271	2,064	1,898

Adapted from the following:
Source: GBSFH, *Statistics Yearbook, 1984*, p. 182, p. 186, p. 188, p. 254, p. 258 and p. 260.
*: GVAIO means Gross Value of Agricultural and Industrial Output

Appendix F: Data Set of The Simulation Model

variable	GROUPH	GROUPL
K_0($)	162,391	70,000
F_0(tons)	105	116
P_0(persons)	484	479
R_0	0.53	0.50
A	110	221
β_k	0.36	0.34
β_n	0.62	0.77
β_f	0.19	-0.02
ϵ_k	0.03	0.003
ϵ_n	-0.019	-0.011
γ	0.00067	0.0011
δ	-0.19	-0.025
k	0.029	0.045
f	0.07	0.07
p	0.006	0.006
r	0.005	0.005

Source: see Chapter Four

Appendix G: Definitions of Symbols in Simulation

K: capital stock in Canadian dollars

F: fertilizer in tons

P: population in no. of persons

R: labor participation rate

A: parameter of production function

Y: output in Canadian dollars

Nd: labor demand in no. of persons

Ns: labor supply in no. of persons

G: labor surplus in no. of persons

θ: labor productivity

η: capital/labor ratio

β_k: production elastici[illegible] capital

β_n: production elasticity of labor

β_f: production elasticity of fertilizer

ϵ_k: change rate of production elasticity of capital

ϵ_n: change rate of production elasticity of labor

γ: price ratio of capital to labor

δ: change rate of price ratio of capital to labor

k: annual change rate of capital

f: annual change rate of fertilizer

p: natural population growth rate

r: annual change rate of labor participation rate

t: time (year)

Appendix H Simulation Results of Four Scenarios For GROUPH

Scenario One: capital formation only

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	256.5	187.4	69.1	886.6	513227.8	2738.0
1985	259.3	192.8	66.5	886.6	534837.8	2772.8
1986	262.2	198.4	63.8	886.6	556942.0	2807.1
1987	265.1	204.2	60.9	886.6	580175.6	2841.6
1988	268.0	210.1	57.9	886.6	604378.6	2876.9
1989	271.0	216.2	54.8	886.6	629582.0	2912.4
1990	274.0	222.4	51.6	886.6	655856.3	2948.4
1991	277.0	228.9	48.1	886.6	683216.1	2984.9
1992	280.0	235.5	44.5	886.6	711717.8	3021.6
1993	283.1	242.4	40.8	886.6	741408.7	3058.1
1994	286.3	249.4	36.9	886.6	772337.0	3096.6
1995	289.4	256.6	32.8	886.6	804557.0	3135.2
1996	292.6	264.1	28.5	886.6	838120.1	3173.8
1997	295.8	271.7	24.1	886.6	873084.1	3213.2
1998	299.1	279.6	19.5	886.6	909506.6	3252.9
1999	302.4	287.7	14.7	886.6	947448.4	3293.1
2000	305.7	296.1	9.7	886.6	986972.3	3333.8
2001	309.1	304.6	4.5	886.6	1028145.0	3375.0
2002	312.5	313.5	-1.0	886.6	1071036.0	3416.7
2003	316.0	322.6	-6.6	886.6	1115715.0	3458.8
2004	319.4	331.9	-12.5	886.6	1162281.0	3501.7

Scenario Two: changes in capital formation and production elasticities of capital and labor

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	256.5	187.4	69.1	886.6	513227.8	2738.0
1985	259.3	183.6	75.7	909.8	555486.8	3024.8
1986	262.2	180.0	82.2	956.4	604941.5	3361.2
1987	265.1	176.4	88.7	1003.1	662936.5	3758.4
1988	268.0	172.9	95.2	1053.2	731155.4	4229.6
1989	271.0	169.4	101.6	1105.4	811651.3	4790.8
1990	274.0	166.0	107.9	1161.0	907007.9	5462.6
1991	277.0	162.7	114.3	1218.0	1020443.7	6271.0
1992	280.0	159.5	120.5	1279.9	1155010.0	7248.6
1993	283.1	156.3	126.8	1343.8	1316869.0	8438.3
1994	286.3	153.2	133.1	1411.0	1515523.0	9893.9
1995	289.4	150.1	139.3	1481.4	1754355.0	11685.2
1996	292.6	147.1	145.5	1555.4	2048152.0	13907.5
1997	295.8	144.2	151.6	1633.1	2404898.0	16678.6
1998	299.1	141.3	157.8	1714.7	2846856.0	20159.6
1999	302.4	138.5	163.9	1800.4	3402082.0	24564.7
2000	305.7	135.7	170.0	1890.3	4096209.0	30178.7
2001	309.1	133.0	176.1	1984.7	4974014.0	37382.3
2002	312.5	130.4	182.1	2083.6	6092240.0	46731.0
2003	316.0	127.8	188.2	2187.9	7578290.0	58922.0
2004	319.4	125.2	194.2	2297.2	9387775.0	74971.6

Scenario Three: changes in capital formation, production elasticities and the price ratio of capital to labor

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	256.5	187.4	69.1	886.6	513227.8	2738.0
1985	259.3	148.6	110.8	1123.4	488668.3	3285.1
1986	262.2	118.1	144.1	1455.1	470441.6	3984.0
1987	265.1	93.7	171.4	1887.5	457904.1	4884.9
1988	268.0	74.4	193.6	2446.6	450525.3	6055.7
1989	271.0	59.1	211.9	3171.4	448352.2	7589.9
1990	274.0	46.9	227.1	4110.9	451011.6	9617.7
1991	277.0	37.2	239.8	5328.7	458691.5	12321.7
1992	280.0	29.6	250.5	6907.2	471959.7	15950.8
1993	283.1	23.5	259.7	8953.3	490384.4	20902.6
1994	286.3	18.6	267.6	11606.6	515476.4	27679.6
1995	289.4	14.8	274.6	15043.5	547919.8	37082.9
1996	292.6	11.7	280.9	19499.9	588838.3	50183.1
1997	295.8	9.3	286.5	25278.4	640157.1	68713.6
1998	299.1	7.4	291.7	32764.2	703730.2	95156.1
1999	302.4	5.9	296.5	42470.0	782463.2	133277.6
2000	305.7	4.7	301.1	55051.1	880029.7	188828.1
2001	309.1	3.7	305.4	71358.9	1001272.1	270534.0
2002	312.5	2.9	309.6	92497.8	1152595.0	392441.1
2003	316.0	2.3	313.6	119898.7	1342536.0	575628.9
2004	319.4	1.9	317.6	155416.6	1582565.0	855052.8

Scenario Four: changes in capital formation and the price ratio of capital to labor

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	256.5	187.4	69.1	886.6	513227.8	2738.0
1985	259.3	156.2	103.2	1069.9	469159.1	3004.0
1986	262.2	130.2	132.0	1320.9	428875.3	3294.6
1987	265.1	108.5	156.6	1630.7	392049.9	3613.4
1988	268.0	90.4	177.6	2013.2	358385.6	3963.0
1989	271.0	75.4	195.6	2485.5	327614.0	4346.5
1990	274.0	62.8	211.1	3068.5	299483.6	4767.0
1991	277.0	52.4	224.6	3786.3	273769.1	5228.3
1992	280.0	43.6	236.4	4676.9	250261.4	5734.1
1993	283.1	36.4	246.6	5773.9	228772.6	6288.9
1994	286.3	30.3	255.9	7128.3	209128.9	6897.4
1995	289.4	25.3	264.1	8800.4	191172.0	7564.6
1996	292.6	21.1	271.5	10864.7	174758.9	8296.7
1997	295.8	17.6	278.3	13413.2	159761.8	9099.6
1998	299.1	14.6	284.5	16559.5	146034.6	9980.0
1999	302.4	12.2	290.2	20443.8	133495.4	10945.8
2000	305.7	10.2	295.5	25238.2	122032.7	12004.6
2001	309.1	8.5	300.6	31159.5	111554.3	13166.2
2002	312.5	7.1	305.4	38468.9	101976.8	14440.1
2003	316.0	5.9	310.1	47492.[illegible]	93219.6	15837.2
2004	319.4	4.9	314.5	58633.2	85216.4	17369.6

Appendix I Simulation Results of Four Scenarios For GROUPL

Scenario One: only capital formation

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	239.5	174.4	65.1	401.4	485410.1	2783.5
1985	242.1	182.2	59.9	401.4	509025.8	2793.3
1986	244.8	190.4	54.4	401.4	533789.6	2803.1
1987	247.5	199.0	48.5	401.4	559759.8	2812.9
1988	250.2	208.0	42.2	401.4	585892.4	2822.7
1989	253.0	217.3	35.7	401.4	615550.4	2832.6
1990	255.8	227.1	28.7	401.4	645497.9	2842.5
1991	258.6	237.3	21.3	401.4	678802.0	2852.4
1992	261.5	248.0	13.5	401.4	70[illegible]33.9	2862.4
1993	264.3	259.1	5.2	401.4	744188.1	2872.4
1994	267.3	270.8	-3.5	401.4	780142.9	2882.4
1995	270.2	283.0	-12.8	401.4	818598.3	2892.5
1996	273.2	295.7	-22.5	401.4	856382.0	2902.6
1997	276.2	309.0	-32.8	401.4	900144.1	2912.7
1998	279.3	322.9	-43.7	401.4	943938.6	2922.9
1999	282.3	337.5	-55.1	401.4	989658.4	2933.1
1999	285.4	352.7	-67.2	401.4	1038017.8	2943.4
2001	288.6	368.6	-79.9	401.4	1088517.0	2953.7
2002	291.8	385.1	-93.3	401.4	1141478.0	2964.0
2003	295.0	402.4	-107.5	401.4	1197008.0	2974.4
2004	298.2	420.6	-122.3	401.4	1255248.0	2984.8

Scenario Two changes in capital formation and production elasticities of capital and labor

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	239.5	174.4	65.1	401.4	485410.1	2783.6
1985	242.1	179.7	62.5	407.1	487420.8	2712.8
1986	244.8	185.2	59.7	412.9	489489.4	2643.7
1987	247.5	190.8	56.7	418.7	491819.8	2578.8
1988	250.2	196.6	53.7	424.5	493815.7	2512.0
1989	253.0	202.6	50.4	430.8	496076.3	2449.0
1990	255.8	208.7	47.1	436.7	498405.3	2387.9
1991	258.6	215.1	43.5	442.9	500805.1	2328.5
1992	261.5	221.6	39.9	449.2	503278.5	2271.0
1993	264.3	228.4	36.0	455.5	505827.8	2215.1
1994	267.3	235.3	32.0	462.0	508458.0	2160.9
1995	270.2	242.5	27.6	468.6	511168.7	2108.3
1996	273.2	249.8	23.4	475.2	513959.8	2057.3
1997	276.2	257.4	18.8	481.9	516840.2	2007.7
1998	279.3	265.3	14.0	488.7	519810.6	1959.7
1999	282.3	273.3	9.0	495.5	522871.8	1913.0
2000	285.4	281.5	3.8	502.5	526030.4	1867.8
2001	288.6	290.3	-1.8	509.6	529285.9	1823.9
2002	291.8	299.0	-7.3	517.0	532644.4	1781.3
2003	295.0	308.1	-13.1	524.3	536105.8	1739.9
2004	298.2	317.5	-19.2	531.7	539674.7	1699.8

Scenario Three changes in capital formation, production elasticities and the price ratio of capital to labor

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	239.5	174.4	65.1	401.4	485410.1	2783.8
1985	242.1	175.2	66.9	417.5	478113.3	2729.1
1986	244.8	176.0	68.8	434.3	471173.4	2677.0
1987	247.5	176.8	70.7	451.7	464578.6	2627.3
1988	250.2	177.7	72.6	469.9	458316.1	2579.9
1989	253.0	178.5	74.5	488.8	452369.8	2534.6
1990	255.8	179.3	76.5	508.4	446730.5	2491.6
1991	258.6	180.1	78.5	528.8	441388.5	2450.2
1992	261.5	181.0	80.6	550.0	436327.9	2410.9
1993	264.3	181.8	82.5	572.1	431543.6	2373.4
1994	267.3	182.7	84.6	595.1	427028.4	2337.7
1995	270.2	183.5	86.7	619.0	422767.0	2303.7
1996	273.2	184.4	88.8	643.9	418755.8	2271.2
1997	276.2	185.2	91.0	669.7	414985.9	2240.4
1998	279.3	186.1	93.2	696.6	411451.9	2211.0
1999	282.3	187.0	95.4	724.9	408144.4	2183.1
2000	285.4	187.8	97.6	753.7	405050.6	2158.5
2001	288.6	188.7	99.9	784.0	402181.3	2131.3
2002	291.8	189.6	102.2	815.4	399533.9	2107.5
2003	295.0	190.5	104.5	848.2	397080.7	2084.6
2004	298.2	191.3	106.9	882.2	394826.4	2063.4

Scenario Four: changes in capital formation and the price ratio

time (year)	Ns (people)	Nd (people)	G (people)	K/N ($/person)	Y ($)	Y/N ($/person)
1984	239.5	174.4	65.1	401.4	485410.1	2783.8
1985	242.1	177.7	64.5	411.7	499199.0	2809.9
1986	244.8	181.0	63.8	422.3	513376.2	2836.9
1987	247.5	184.4	63.1	433.1	527961.8	2862.5
1988	250.2	187.9	62.3	444.2	542959.0	2889.2
1989	253.0	191.5	61.5	455.8	558382.1	2916.3
1990	255.8	195.1	60.7	467.3	574243.6	2943.5
1991	258.6	198.8	59.8	479.3	590555.3	2971.1
1992	261.5	202.6	58.9	491.6	607330.8	2998.9
1993	264.3	206.3	58.0	504.1	624582.5	3026.9
1994	267.3	210.2	57.0	517.1	642324.5	3055.2
1995	270.2	214.2	56.0	530.3	660570.1	3083.6
1996	273.2	218.2	54.9	543.9	679333.9	3112.7
1997	276.2	222.4	53.8	557.8	698631.7	3141.8
1998	279.3	226.6	52.7	572.2	718478.6	3171.2
1999	282.3	230.8	51.5	586.8	738888.1	3200.9
2000	285.4	235.2	50.2	601.9	759874.3	3230.8
2001	288.6	239.6	49.0	617.3	781458.7	3261.0
2002	291.8	244.2	47.6	633.2	803658.1	3291.5
2003	295.0	248.8	46.2	649.4	826486.6	3322.3
2004	298.2	253.5	44.8	666.0	849963.9	3353.4