MULTIVARIATE SPATIAL INTERACTION MODELS AS APPLIED TO CHINA'S INTER-PROVINCIAL MIGRATION, 1982-1990

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ABSTRACT

By using spatial interaction models (SIMs) to estimate place-to-place migration, it usually means that we employ some known information to estimate migration flow patterns. The conventional spatial interaction modelling of migration has been questioned for its lack of explanatory power. The present study takes a new perspective that has not been attempted before; that is, multiple socioeconomic variables can be included in the conventional SIMs. Models based on this new approach are termed Multivariate Spatial Interaction Models (MSIMs). This particular study involves using two additional variables, the total annual investment and migrant stock, together with total out-migrants of each province and a distance matrix, to estimate China's province-to-province migration flows. The fundamental idea behind this new perspective is to weigh the socioeconomic importance of each province, so that migration flows will not only be accounted for by the traditional spatial distance but also be accounted for by socioeconomic conditions of provinces.

The proposed MSIMs are derived under the framework of the information minimisation principle. MSIMs are calibrated successfully utilising the 1982-87 and 1985-90 province-to-province migration data for the 28 provinces of China. The models are calibrated by iterative procedures written in FORTRAN 77. The MSIMs are further extended to estimate the origin-specific migration flows. The importance of the two additional variables is evaluated in terms of the relative contribution to the performance of the models. The original contribution of the present research can be understood to lie in the new proposed MSIMs, in the extension to modelling origin-specific flows, which has not been attempted before, and in the successful empirical application of the models to the Chinese inter-provincial migration data.

The empirical results illustrate that all the MSIMs produce better results than the conventional SIMs. In other words, all models with the additional variable(s) are capable of replicating migration flows with a much-improved degree of accuracy, in comparison with the conventional model. The calibration has therefore provided empirical support for the validity and utility of the multivariate approach to the spatial interaction modelling of migration. However, the results do not necessarily imply that more variables included in the model would result in a corresponding improvement in model performance. Furthermore, a comparison of performance level between the MSIMs and origin-specific MSIMs indicates that the estimation of origin-specific migration flows can further improve the degree of accuracy in replicating the observed migration.

Major forces that influence China's inter-provincial migration are represented by the two additional variables — migrant stock and total annual investment. These two variables are appropriate in that they reflect both migration policy change and economic development strategy. The empirical results also imply that selecting appropriate variables is crucial in calibrating migration flows within the proposed framework, because variable selection must be based on the specific country or areal contexts, on the one hand, and is also dependent upon the availability of data, on the other.

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DEDICATION

I dedicate this work to my parents, who live in Hunan, China, and have sacrificed so much for me.

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Chapter One Introduction

1.1 Introduction

Migration, together with fertility and mortality, is considered as one of the three conventional components that influence the size and composition of national or regional population. As the population of a nation or a region experiences the demographic transition in which birth and death rates change from high to low equilibrium, migration will eventually become preeminent in affecting internal population change and redistribution. The effect of migration on population change is particularly evident in developed countries, such as Canada, as well as in developing countries where economic development is already on the track of fast growth.

According to Davis (1962), migration, coupled with other mechanisms such as abortion, use of contraceptives, and delayed marriage, can be employed as an adjustment, to the emerging new opportunities provided by industrialisation, and as a means by which population pressure may be relieved. Viewed at the household level, migration in developing countries is often assumed as a family strategy, either as an approach to risk reduction or for a strategy for accumulation (Stark, 1991; Guest, 1993: 234). Migration decisions are based on differences between actual and expected income, along with an evaluation of chances of obtaining employment at the destinations (Todaro, 1969, 1971). Alonso (1980) argues that labour migration can reduce socio-economic and demographic disparities among regions in all countries.

From a regional perspective, migration is regarded as a more dynamic component than birth and death rates to influence population change. This implies that migration can redistribute population more rapidly, and its selective nature can modify the population composition of a region more efficiently (Sly, 1972). As a result, population migration can exert more immediate effects on economic development than birth and death rates. A concrete example is that population migration will result in a spatial variation in the growth and size of the labour force at both destinations and origins. Such a variation will pose considerable challenges to both migration researchers and policy planners. An immediate task is to forecast the migration patterns at national or local scales in order to meet the future demands for provision of social and economic services as the population increases (or declines). Due to the importance of this subject, migration research has been given a considerable attention in a variety of disciplines, in particular in the disciplines of economics, sociology and geography.

In geography and regional science, modelling of inter-regional migration flows is usually conducted by two approaches; that is, regression analysis and spatial interaction modelling. Modelling migration by the spatial interaction approach is an extension of the migration modelling using gravity models prior to the period of the 1970s. The gravity models are based on the concept of Isaac Newton's gravity forces. The basic idea of the gravity model is that spatial distance is an impediment to population migration, and migration is proportional to the sizes of both destination and origin. The major shortcoming of the gravity model is its lack of theoretical justification. The well-known Wilson's (1967) Spatial Interaction Models (SIMs) fill this gap (Senior, 1979).

By using SIMs to estimate migration, it usually means that we employ some known information to estimate migration flow patterns. Specifically, suppose that a region has four zones, A, B, C, and D (Figure 1.1). The given information is: (1) the number of people leaving zones A and B (out-migrants), (2) the number of people arriving in zones C and D (in-migrants), and (3) the moving distance or cost between the zones. Based on this known information, the purpose of spatial interaction modelling is to estimate the <u>zone-to-zone migration flows</u>. Later, in order to test the model, the estimated migration flows will be evaluated against the observed ones.

Figure 1.1 The known information of migrants leaving A, B, and migrants arriving C, D in spatial interaction modelling

One of the salient features of SIMs is that the known information can be employed alone or in combination as constraint(s). Based on such constraint(s), four types of models can be distinguished.

(1) <u>Origin Constrained</u>: when the number of migrants leaving A and B is constrained (so that the <u>predicted</u> number of out-migrants matches the <u>observed</u> number), but the number of migrants entering C and D is unconstrained.

(2) Destination Constrained: the reverse of (1), when the number of migrants leaving A and B is unconstrained, but the number entering C and D is constrained (so that the predicted number of in-migrants matches the observed number of in-migrants);

(3) Doubly or Origin-Destination Constrained: when both the number of migrants leaving A and B and the number entering C and D are constrained; and

(4) Totally or Cost Constrained: when the conditions of (3) are used and a constraint is enforced such that the model's mean distance travelled matches the observed mean distance travelled.

A related concern about the spatial interaction modelling of migration is how the employed data (or the given information) are organised. Figure 1.2 shows the organisation and forms of the data employed in the circumstance of the conventional spatial interaction modelling of migration. First, it usually involves an observed migration flow pattern that is represented in matrix form. By a matrix form, we mean that the migration flow pattern can be expressed in a rectangular (or square) array of numbers arranged in rows and columns. Figure 1.2 also shows that there are total out-migrants and in-migrants for each zone, which are represented by O_i, and D_j, respectively. The employed input data also includes a distance matrix. Using in- and out-migrants, and the distance data, a predicted migration matrix can be derived. In order to know how good the spatial interaction model is, the predicted migration matrix is evaluated against the observed one by employing goodness-of-fit statistics.

All of the four instances above are well-known 'classic' or 'conventional' SIMs. The conventional approach of spatial interaction modelling of migration has been questioned for its lack of explanatory power (Hua and Porell, 1979; Hay, 1991).

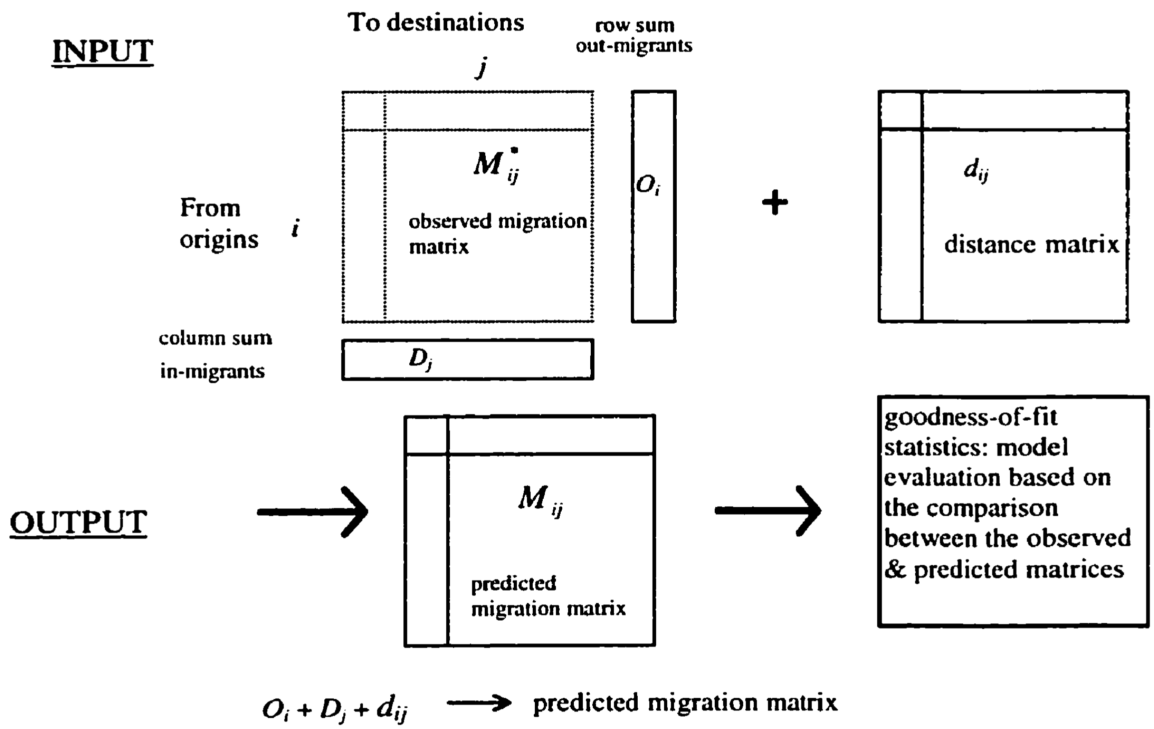

Figure 1.2 A conventional spatial interaction modelling of migration and its constraints

The present study takes a new perspective that has not been attempted before; that is, multiple socioeconomic variables will be included in the conventional SIMs.

This new approach produces Multivariate Spatial Interaction Models (MSIMs) as shown in Figure 1.3. It involves using total out-migrants of each province (O_i), a variable (defined in a later section) at destination province, a distance matrix, and a variable represented in a matrix of migrant stock (defined as number of migrants who moved previously to a destination) to estimate the province-to-province migration flows. The MSIMs attempted in the present study can still be production (origin)- and cost-constrained, or have other constraint forms described above, even though the new variables are included. The purpose of including such variables is to weigh the socioeconomic importance of each province, so that migration flows will not only be accounted for by the traditional spatial distance but also be accounted for by socioeconomic conditions of provinces. It is hoped that by this new approach that the conventional SIMs' explanatory power will be improved and expanded.

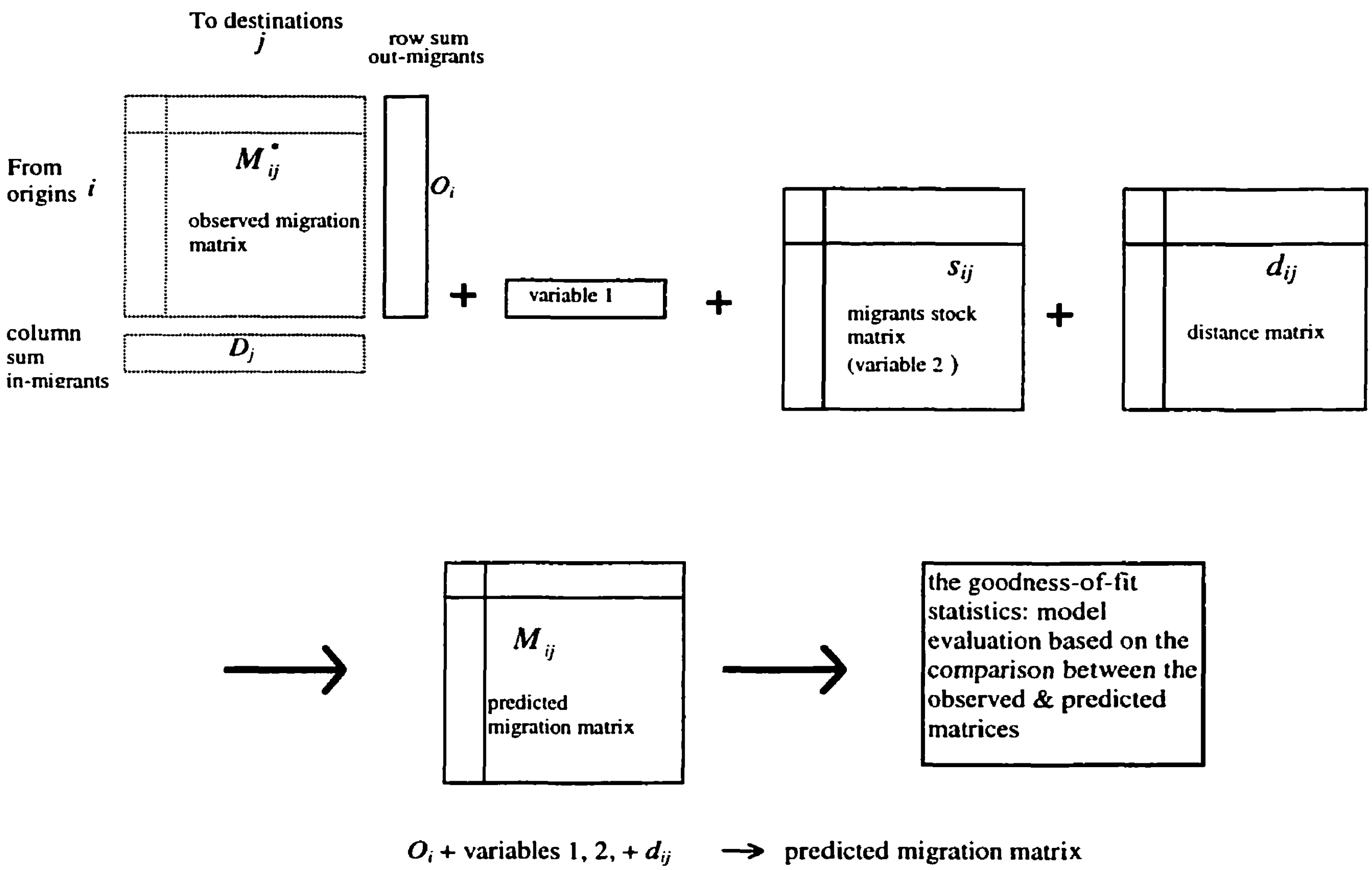

Figure 1.3 A multivariate spatial interaction modelling of migration (origin-constrained)

1.2 Significance of the present research

As mentioned in the previous section, in the past conventional SIMs have not included additional variables that improve the model's explanatory power and accuracy. The present research seeks to address this issue by incorporating more variables into the conventional SIMs. The fundamental idea behind the new approach is to weight the destinations in the modelling of regional migration flows. Empirical studies show that distance variable cannot fully account for patterns of migration flows (Plane, 1982). The original contribution of the present research can be understood to lie in the new proposed MSIMs, which have been not attempted before, and in the successful empirical application of these models to Chinese inter-provincial migration data. This implies that further application of the MSIMs to other circumstances can also be carried out.

The importance of studying China's population has long been recognised because of the absolute size and the fast growth of the country since the 1950s. Therefore, population issues in China have been not only a national but also a world concern (Ho, 1959). As one of the important components, migration is more dynamic than birth and death rates in the growth of population. And migration research constitutes one of the important subjects in China's population studies. Interest in the patterns and forces of China's migration is therefore confined neither to demographers nor to geographers.

Migration has become an increasingly significant element in the redistribution of population and in the planning of socioeconomic development in China. This is due to the fact that China's birth and death rates have been reduced to a relatively low and stable level which is comparable to that of other East Asian nations (Feeney, 1994; Nolan and Sender, 1994). Compared with studies of fertility and mortality issues in China, migration research has been given less attention due mainly to the unavailability of data. Research has been done concerning temporary migration in China from a sociological perspective on very few occasions (Goldstein and Goldstein, 1984; Goldstein, 1985). Migration analysis based on China's 1990 census also has been undertaken (Fan, 1996). Prior to the 1990 census, migration studies were attempted using materials from the 1986 Chinese Academy of Social Science Migration Survey (Day and Ma, 1994), or employing information derived from the 1987 China's One Percent Population Survey (Goldstein, 1990b; Li and Li, 1995). Another source has been data obtained from the 1988 China's Two Per Thousand Fertility Survey (Liang and White, 1996).

Investigation of Chinese inter-provincial migration has been very limited. In particular, in China, attempts to model inter-provincial migration flows have been lacking. Hence, the present research is significant in two ways for Chinese migration studies. In the first place, migration modelling undertaken so far has been primarily based on concepts from Western free-market economies (Haynes and Fotheringham, 1984: 78). Little attention has been given to migration in other types of nations in which a mixed economy with planned and free-market mechanism exists. Therefore, it may be useful and interesting to model migration patterns in a socioeconomic setting such as China's. This research would help us to understand the courses and consequences behind China's inter-provincial migration and ultimately, enrich migration theory. In the second place, because the migration process is a response to socioeconomic differentials, it would be equally appealing to model inter-provincial migration to provide some scientific guide for China's socioeconomic planning. It is on these considerations that this dissertation is motivated.

1.3 Objectives of the study

The family of spatial interaction models due to Wilson (1967, 1971) has been regarded as a seminal work. However, it was criticised on the grounds that not much behavioural explanation can be gained from it because of the distributional nature of the model (Hay, 1991). The spatial separation, usually expressed as distance, time, or travel costs between regions, is the only variable for explanation both for traditional gravity and for Wilson-type models (Fotheringham, 1997). However, the significance of distance or travel costs in spatial interactions, such as migration and commodity flows, has been questioned (Chisholm, 1996).

With this background in mind, the purpose of the dissertation is to incorporate additional socioeconomic variables into conventional SIMs. Several such variables will be selected to indicate attractiveness at destinations on an experimental basis in order to see if any such variable(s) may improve performance of the SIMs. The new models are called Multivariate Spatial Interaction Models, or MSIMs. Including variables at the destination is a process of weighing the destination's capability to attract migrants from the origin.

A second purpose of the dissertation is to extend the general MSIM framework to include origin-specific MSIMs. Such origin-specific MSIMs are also applied to the Chinese inter-provincial migration data. The conventional SIMs are applied to a complete set of inter-provincial migration in such a way that the distance-decay parameter is representative of the inter-provincial flow matrix as a whole. If, however, the distance-decay parameter of the SIMs is estimated for *each origin*, such models are called origin-specific SIMs (Stillwell, 1978). In this way, migration patterns can be further explored on the basis of observing the spatial variations of the parameters for specific origins. Very few studies deal with the conventional origin- and destination-specific SIMs. However, some exceptions can be found. For example, Southworth (1974) applies an origin-specific SIM to West Yorkshire's journey-to-work data. Stillwell (1978) tests origin- and destination-specific SIMs on inter-county migration data for England. In the present research, an origin-specific MSIM will be used to estimate the Chinese inter-provincial migration. It is expected that the accuracy of migration modelling can be improved further in comparison with the MSIMs.

A third purpose of the dissertation is to define a measure of chain migration, called migrant stock, which is based on the concept of migration chain effect, and to use it as a complement for spatial separation in spatial interaction modelling of China's migration. Migrant stock, in the present study, is defined as the number of migrants who moved previously between an origin and a destination. One important assumption is that the costs of moving to a region are reduced considerably when previous migrants are already there. In other words, the volume of would-be migrants is an increasing function of the stock of previous origin-to-destination migrants. The migrant stock is usually derived from a previously observed migration matrix. Due to the migration chain effect, it can be expected that two migration matrices can be closely related at two different points of time within a migration system. Pooler (1988) confirms this assertion using Canadian inter-provincial migration data. The performance of the MSIMs that incorporate the additional variables will be assessed in comparison with that of the conventional spatial interaction models (SIMs).

Finally, as a subsidiary purpose of the dissertation, some evaluation of the importance of the additional variables in the MSIMs will be made. In the usual multivariate regression approach to modelling migration, an examination of the standardised regression coefficients can assess importance of the independent variables for the model. However, in the multivariate spatial interaction approach to migration proposed in the present research, the method used in the regression approach to evaluate the importance of the variables is not valid. Some new approaches will be investigated in this regard. One approach is to examine the change in value of the goodness-of-fit measure. Another way is to calculate a Spearman rank correlation coefficient for values of A_i, the balancing factor of the MSIMs. The idea behind this new method is that when a variable is entered into the MSIM, the change in magnitude of the rank correlation coefficient can be regarded as an effect brought about by the variable.

To reach these ends, production- and cost-constrained MSIMs will be calibrated and the conventional spatial interaction models will also be calibrated for comparative purposes. The selected final models are based on two criteria: one is whether there is a multicollinearity problem among the variables that would likely to enter into the model. This means any variables with such a problem are not employed in the model. The second criterion is whether the entered variables improve the model's performance. Based on these two conditions, two new variables, annual average total investment and the migrant stock measure, are used in the MSIMs.

1.4 Organisation of the dissertation

The focus of the present research is on the use of the MSIMs to estimate the aggregate spatial migration flows based on the two Chinese migration data sets. Therefore, the explanatory capacity of the conventional SIMs can be enhanced, and the performance of the models can be improved. The implication is that the spatial interaction modelling approach can demonstrate its greater flexibility to respond to challenges from both academic circles and real world problems. Following the introduction of Chapter 1, Chapter 2 provides a review of the background literature, including mainly previous studies of the spatial interaction modelling approach to migration flows. Factors that influence migration in the less developed countries are also included in the review. The historical, regional and policy backgrounds of Chinese inter-provincial migration are discussed in Chapter 3. This background is crucial to understanding why the two additional variables used in the model are appropriate.

The data sources and methodology of the present research are described in Chapter. In Chapter 5, inter-provincial migration patterns based on the empirical data are presented. Chapter 6 includes the analysis and discussion of the modelling results. Finally, a summary of the present research results and areas for further exploration are included in Chapter 7.

Chapter Two Review of the Literature

2.1 Introduction

Several disciplines attribute the roots of migration research to work by Ravenstein (1885). Since 1885 a vast literature has accumulated. This has led to several reviews on migration research and modelling, such as Greenwood (1975, 1985) and Molho (1986) in economics, and Olsson (1965), Carrothers (1956), Thomas and Hugget (1980), Pooler (1994a), and Plane (1997) in geography.

In this chapter, following a brief description of the migration studies in less developed countries (LDCs), and two approaches employed in migration studies, attention is focused on the development of the gravity and spatial interaction models in geography. Specifically, section four presents a brief history of migration modelling. Section five deals with ideas of social gravity models. Section six concentrates on the entropy-maximising (EM) spatial interaction models (SIMs). Section seven discusses the spatial interaction models derived from the information minimising (IM) principle. Section eight summarises some related extensions of the EM models.

2.2 Migration in less developed countries

As mentioned in Chapter 1, migration studies have attracted considerable attention in a variety of disciplines of social sciences. Since the Second World War, migration analysis has been undertaken often in the context of economic development strategy. For example, Sjaastad (1962) argues that human migration is an economically calculated action based on the costs and returns of migration. Although his analysis was concerned with rural-to-urban migration in the United States, the essential theoretical ideas can be applied in migration context in less developed countries.

In LDCs, a prevailing phenomenon is that high unemployment and underemployment rates in urban areas have not hindered rural-to-urban migration. Confronted with this seemingly conflicting observation, Todaro (1969, 1971) asserts that rural-to-urban migration in LDCs is a rational response to the expected income difference between urban and rural areas. The size of migration flows to cities is also dependent upon the probability of finding employment in cities. The longer a migrant stays in the urban area, the more likely he or she will obtain formal employment. The Todaro Model was limited to explaining the migration of persons who possessed sufficient education and skills to qualify them for employment in the formal sector. The employment opportunities in the urban informal, or subsistence sector, such as domestic service, petty tradesmen, and the like, attracted those who have little education or skills from the rural areas (Cole and Sanders, 1985). Not only rural-urban income disparity but also intra-rural income differentials caused rural people to migrate to cities (Lipton, 1988). Although Todaro's inter-sector (rural versus urban) income-maximising notion has been a ruling economic explanation for rural-to-urban migration taking place in LDCs, its behavioural foundation is suspect.

Stark (1991) argues that even if there were no income differential between rural and urban areas, rural-to-urban migration would not have stopped. Moreover, migration to urban areas is still rational "even if urban expected income is lower than the rural income" (Stark, 1991: 54). Stark (1991) presents some explanations for his arguments.

First, migration to urban areas is a type of risk avoidance tactic. A farmer would endure a higher level of risk per period of time emanating from stochastic variation in climatic conditions, plant diseases and attacks by pests, while migration to cities would not subject him to a similar level of risk (Stark, 1991: 42). Second, the lack of, or imperfection of financial institutions and capital markets in rural areas of LDCs also encourage people to move to the cities (Stark, 1991: 4, 50). Third, improving a family's social rank in the home community or village can be another motivation to migrate, since people can be satisfied not only from an increase in absolute income but from the improvement of their relative social rank (Stark, 1991: 87-101). Finally, families as a whole, rather than individuals, can be considered as the centre of the migration decision-making process (Stark, 1991: 5). This implies that even if the family could not increase income in the short term, the children could receive more appropriate education and eventually generate greater income in the long term. Eventually, the satisfaction for the family as a whole would be increased. In summary, Stark's arguments can be regarded as a complement to Todaro's expected income hypothesis; that is, not only disparity in income between rural and urban areas but also factors other than economic considerations can induce rural-to-urban migration.

Based on survey data from Senegal, Guilmoto (1998) finds that irrigation projects and infrastructure improvement can reduce out-migration, and that in the absence of, or incomplete marketing of, commodities, chain migration was becoming a prevailing phenomenon. In India, Skeldon's (1986) investigation shows that for interstate migration, motivations to migrate for males and females are quite different. Motivation for males to migrate to cities was principally employment, while marriage or family reasons became the justification for female migration.

2.3 Area versus individual approaches to migration studies

Migration studies can be conducted through different perspectives. In general, however, two approaches in social sciences can be distinguished. One is called the area or macro-approach, and the other is an individual or micro-approach. In the area or macro-approach, migration is regarded as a function of aggregate or area attributes (Garkovich, 1989). Such attributes may include labour market conditions at both origin and destination. The labour market condition is usually related to wage levels, unemployment rates, or welfare programs. The aggregate attributes also involve some non-economic factors, such as amenities, climatic conditions, and ethnic or racial composition. Another major feature unique to this approach is that area or aggregate data from censuses are usually employed.

On the other hand, the individual or micro approach uses individual, family or household level data available from sample surveys. The unit of analysis is the individual or the household. In this approach migration is considered as a function of individual or family characteristics (Garkovich, 1989). As with the area approach, migration studies using this perspective also investigate the influence of economic and non-economic factors on migration. The economic factors that are considered are based on human capital theory. Individuals or families consider migration as investment and, as with any other investment, they compare costs and returns. Migration is only considered rational when returns exceed costs. The notion of migration returns and costs can be dated back to Sjaastad's (1962) study. Non-economic factors considered in this perspective are related to the influences of life-cycle stages, community or kinship attachments, and personal preferences. One of the well-known studies using the notion of life cycle is Rossi's (1980) investigation of intraurban mobility triggered by varied housing needs. The influences of kinship ties and migration chains or networks are increasingly stressed in the migration studies of LDCs (Massey, 1990). The community and kinship ties, or minority status, can be formulated as a 'location-specific capital' which can both tie and attract people to a particular place (DaVanzo, 1981a).

The determinants of migration can be investigated through either a micro- or macro-approach. As mentioned in the preceding section, the former employs individual or household level data. The latter looks for explanation of migration using area data. A widespread use of the micro-approach is not possible due to the fact that this approach depends on the data from sample surveys while the use of the macro-approach for migration analysis is more common because of the easier access to census data (Mazumdar, 1987).

Pooler (1987a) summarises two approaches, multivariate linear and spatial interaction, which have been used in migration studies in geography. It is apparent that multivariate linear modelling can use either individual level data or aggregate level data. In general, the multivariate approach is often based on the social gravity notion (reviewed in the subsequent section), while using the spatial interaction approach to modelling migration flows is an extension and refinement of the early gravity models.

2.4 A brief history of modelling migration

Migration refers to "a change of usual residence by a person, family or household" (Stillwell and Congdon, 1991: 3). It is obvious that based on this definition migration involves short-distance movement such as residential or intraurban mobility, and long-distance movement such as inter-county, inter-provincial, or international migration. Of course, the definition of migration is not merely confined to this one perspective. For example, the distinction between international and internal migration may be based on whether or not a movement has crossed an international boundary.

A related term is 'spatial interaction'. Based on Haynes and Fotheringham (1984: 9), it refers to

> "any movement over space that results from a human process. It includes journey-to-work, migration, information and commodity flows, students enrollments and conference attendance, the utilisation of public and private facilities, and even the transmission of knowledge".

A consensus is usually reached that the roots of spatial interaction modelling of migration can be traced back to the work of Carey (1858, cited in Olsson, 1965). Carey introduces the concept of social gravity; that is, the interaction between two cities is directly related to the population of those cities, and inversely related to distance (Carrothers, 1956, Olsson, 1965, Pooler, 1977). Ravenstein (1885, 1889) specifically discussed migration and distance, and formulated several laws of migration. His formulation of migration can be considered as analogous to the simple gravity model, which derived its name from Newton's law of gravitational attraction (Thomas and Hugett, 1980: 132). The gravity modelling of migration means that migration flows are directly related to mass terms both at origin and at destination (such as population size), and inversely related to the distance or surrogate of distance between them (Haynes and Fotheringham, 1984: 12-13). Young (1924, cited in Carrothers, 1956) uses this gravity concept and makes some attempts to measure migration. According to Carrothers (1956), Young's work can be regarded as the application of the gravity model that was first made mathematically operabale. The social gravity model was extended into retail and trade activities by Reilly (1931, cited in Thomas and Huggett, 1980: 132). In the 1940s, gravity models were pursued by the proponents of social physics, such as Stewart (1941), Zipf (1946), and Stewart and Warntz (1958). Their formulations, such as demographic force or population potential, are directly analogous to the Newtonian formula of gravitation (Olsson, 1965: 44-48).

It was Wilson in his 1967 paper that brought the gravity models into a new era. Wilson's (1967) modelling strategy overcame some of the general deficiencies of the old type of gravity models and laid a theoretic foundation for spatial interaction models, which were derived through the entropy-maximising principle. Subsequent extensions and empirical applications of Wilson's family of models are numerous. For example, they were extended and applied to the journey-to-work in an urban context (Baxter, 1973), hospital and health services (Mayhew et al., 1986; Roy, 1987; Lowe and Sen, 1996), commodity flows (Roy and Lesse, 1985), public library facilities (Ottensmann, 1997), and to migration (Stillwell, 1978; Pooler, 1987a).

2.5 Migration and distance

In the pursuit of migration modelling through approaches ranging from the early social gravity models to the Wilson family of models, the role of distance is of essential concern. Many studies have shown that migration is related to distance (Boyle, 1995;

Dorigo and Tobler, 1983; Fik et al., 1992; Fotheringham, 1981, 1983a; Goncalves and Ulyssea-Neto, 1993; Gordon and Vickerman, 1982; Hägerstrand 1957; Isserman et al., 1985; Liaw, 1990; Long et al., 1988; Lowe and Sen, 1996; Noronha and Goodchild, 1992; Plane, 1981, 1982; Pooler, 1987a, 1988, 1992; Rose, 1975; Schwartz, 1973; Stillwell, 1978). The general observation is that number of migrant decreases as distance increases, suggesting that distance has an attenuating effect on migration. The underlying reason behind this relation is that distance constitutes a measure of costs and a proxy for information and uncertainty related to the destinations. The migration costs can be categorised into economic or non-economic costs (for example, psychic costs). Compared with migrants' expected economic returns at the destination, economic costs such as transport expenditure can be regarded as trivial (Nelson, 1959: 43-44; Schwartz, 1973: 1154; Chisholm, 1996). This may imply that with the improvement of transportation, the distance factor, as a variable of influencing migration, has become less important (Fik et al., 1992). However, distance as a proxy for uncertainty at destination in the process of migration is still in evidence. Fotheringham and O'Kelly (1989: 8) have noted that "migrants tend to minimise the uncertainty about a move by favouring closer destinations over more distant ones".

It has become a usual practice that a Pareto or exponential curve is fitted to the empirical data to reflect the impact of distance friction on migration (White and Woods, 1980: 29-30). Fitting such a curve allows the investigators to examine whether this attenuating impact is increased, constant, or reduced as distance increases, and as periods of time progress. Longer distance migrants or trip-makers are likely to perceive travel cost in a logarithmic form, implying that the frictional effect of distance on migration reduces with increases in distance (Hägerstrand, 1957;Wilson, 1971). Eldridge and Jones (1991), using an unconstrained gravity model, and the expansion method, have suggested that distance friction parameter "could vary over type of interaction, time, or setting". This contextual-dependent distance decay parameter is considered to be a result of changing technology and different potential for movement among different groups of people. Another empirical investigation using the traditional spatial interaction models by Stillwell (1991: 43) illustrates that the effect of distance on migration is less important for migrants under sixty years old. Moreover, the attenuating effect of distance on migration also changes depending upon the social context (Hägerstrand, 1957; Haynes and Fotheringham, 1984). Hägerstrand (1957: 116) has shown that the exponent of distance was more than two times greater for textile workers than for civil servants, implying that those with a higher education level were willing to travel greater distances than those having a lower education level.

Some exceptions to the above observations on the attenuating effect of distance (or inverse distance rule) on migration have been found. Ethnic and linguistic impacts on migration have been cited as an illustration of deviations from the inverse rule of distance in migration. Recent examples of such factors are related to inter-regional migration in the former Yugoslavia (Hawrylyshyn, 1977: 379-399) and in Canada (Liaw, 1990; Kaplan, 1995). The impact of information channels established between previous movers and subsequent migrants can be considered as another anomaly from the inverse distance rule (Hägerstrand, 1957: 126-132; Amrhein, 1985; Fik et al., 1992). Finally, return migration has been considered an exception to the inverse distance rule. Return migrants do not perceive distance as an obstacle for their moves, since they have first-hand and complete information on the destination, and the distance barrier is voided by the psychic benefits provided by the return to family and friends (DaVanzo, 1981b: 90-129).

2.6 Social gravity model

Prior to dealing with entropy-maximising spatial interaction models, it is necessary to define the Newtonian (or social) gravity model used in studies of migration, since it was widely employed prior to the period of Wilson's EM models in the late 1960s. The social gravity model was derived from similar ideas embedded in Newton's physical law. The social gravity model states that interaction between two places is directly related to the size of each place, such as population, and inversely related to the physical distance between them. In migration form, it can be stated as follows:

$$M_{ij} = P_i P_j / d_{ij} \tag{2.1}$$

where M_{ij} is migration from i to j, P_i and P_j population at places i and j, respectively, and d_{ij} distance between i and j. Haynes and Fotheringham (1984: 12) have pointed out that three modifications can be applied to Equation (2.1). These three modifications are: (1) the distance variable can be modified by adding an exponent, β (beta), to express whether the relation between migration and distance is directly proportional or not; (2) similar exponents, α (alpha) and δ (gamma), can also be added to the population size variables, respectively; and (3) a scale parameter or constant, k, can be applied to the whole equation. When these three changes are made, Equation (2.1) becomes:

$$M_{ij} = k \frac{P_i^{\alpha} P_j^{\delta}}{d_{ij}^{\beta}} \tag{2.2}$$

Four main deficiencies of the social gravity model are identified by Senior (1979: 175)

> "First, the model is based on a physical law and lacks an independent sociogeographical justification. Second, it is a wholly aggregate model, saying nothing of the way group interactions relate to individual interaction behaviour. Third, it is incapable of predicting interactions, which are consistent with known constraints on the number of trips leaving and/or terminating at each zone. Fourth, its forecasts tend to exaggerate changes in the amounts of spatial interaction as opportunities for that interaction change".

Wilson (1967) also points out the exaggeration error embedded in the social gravity model; that is, when the mass variables at origin and destination double, the interaction would quadruple, since the mass terms at origin and destination are multiplied.

2.7 Entropy-maximising modelling of migration

2.7.1 The concept of entropy

Wilson's 1967 seminal paper and his (1970a, 1971, 1974) subsequent research represented a new era for spatial interaction modelling of migration and other forms of spatial flows. Before we review his entropy-maximising (EM) family models, a word on the concept of entropy must be added, since this concept has been considered fundamental in the derivation of the EM models.

The concept of entropy was rooted in thermodynamics and statistical mechanics, where it is a measure to represent the degree of disorder, randomness, or uncertainty of a system with an equilibrium condition (Pooler, 1983: 154). In communication and information theory, "information is defined as the logarithm of the number of choices" (Shannon and Weaver, 1949: 10). When we say the situation is highly organised, it means that the situation "is not characterised by a large degree of randomness or of choice" (Shannon and Weaver, 1949: 13). Shannon (1949: 49-51) defines the entropy measure as follows:

$$H = -\sum_{i} p_i \ln p_i \qquad (2.3)$$

where p_i represents the probability of event i occurring, and H is termed "the entropy of the set of probabilities" (Shannon and Weaver, 1949: 51).

The concept of entropy is used to define "the amount of information contained in a probability distribution" (Batty, 1974: 2). Pooler (1983: 155) considers that "entropy is a measure of orderliness of a distribution at a point in time". He relates entropy to order, information, and uncertainty by taking population distribution as an example.

Table 2.1. Pooler's example showing the concept of entropy

Population distribution	Orderliness	Entropy	Information	Uncertainty
uniform	Disordered	high	less	more
peaked	Highly ordered	low	more	less

Table 2.1 shows Pooler's (1983: 154-155) example that the measure of entropy is linked to other concepts of information theory. Jaynes (1957) considers that the two terms, entropy and uncertainty, have a similar meaning.

Several pedagogic reviews of the concept of entropy can be found in geography, such as Gould (1972), Batty (1974), Webber (1977), Senior (1979), Thomas (1981), Batten and Roy (1982), and Pooler (1983). Although the concept of entropy originated in the physical sciences, its application to other disciplines has been widespread. A first use of the entropy concept is mainly for the descriptive purposes of socio-economic and demographic situations (Batten and Roy, 1982). The application has been extended into sociology (Coleman, 1964), demography (Keyfitz, 1977; Krishnan, 1977; Hill, 1993; Imhoff, 1994; Hill et al., 1997), archaeology (Binford, 1977), and geography (Batty, 1974; Pooler, 1983, 1992). Such a widespread application of the concept of entropy shows its advantage over other measures. Pooler (1992: 996) summarises one such advantage:

> "the entropy is a well-known nonparametric measure of the diversity, variety, or uncertainty in a distribution and, unlike variance measure of deviation around the mean, requires no assumptions about the form of the distribution".

It is well-known that some of migration measures, such as in-migration rates, net migration rates, and return migration ratio are imperfect measures, since they are "not true occurrence exposure rates" (Rogers, 1992: 790). Krishnan (1977) demonstrates that employing the entropy measure (which is used to describe the Canadian migration patterns) can overcome this difficulty. In Krishnan's (1977: 308) own words,

> "In the entropy measure, we do not need to have an estimate of the risk population. We are required to categorise the population by its mover-stayer status only. The degree of movement within the population can be known with the help of the entropy measure".

A second use of the concept of entropy is to employ it as a model-building method in the study of probability distributions (Jaynes, 1957; Pooler, 1983). As Pooler (1983: 155) points out, many geographical phenomena appear to be linked to entropy, since these phenomena "can be treated as probability distributions". Spatial interaction is one such geographical phenomenon. Wilson (1967) was the first to use the concept of entropy to estimate the unknown distribution in geography, and his approach has become known as the entropy-maximising principle. Wilson (1971) shows that the conventional gravity model, as used in spatial interaction modelling, could be derived on the basis of this principle, rather than relying on the analogy with Newtonian mechanics.

2.7.2 The entropy-maximising models

Using SIMs to estimating spatial flow patterns (such as migration), usually means that, given some known information including in- and out- migrants, and the moving distance or costs between zones, the purpose is to estimate the set of zone-to-zone migration flows. Using the concept of entropy from statistical mechanics, Wilson (1967) derives the EM based spatial interaction models. Such models can be employed to predict the amount of spatial interaction occurring between places given limited information concerning the system of interest. Suppose that the system of interest is migration with m origins and n destinations (m not necessarily equal to n). The number of migrants leaving each origin and entering each destination, respectively, can be modelled as follows:

$$M_{ij}=A_i O_i B_j D_j \exp(-\beta d_{ij}) \qquad (2.4)$$

subject to constraints:

$$\sum_{j=1}^{n} M_{ij} = O_i , \qquad (2.5)$$

$$\sum_{i=1}^{m} M_{ij} = D_j , \qquad (2.6)$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} d_{ij} = \bar{d} , \qquad (2.7)$$

where M_{ij} is the predicted number of migrants between origin and destination, d_{ij} is the distance between the regions, and $\bar{d}$ is the average distance travelled by all migrants. O_i and D_j are the total number of migrants leaving origins and entering destinations, respectively, and A_i and B_j are called balancing factors that ensure that constraints (2.5) and (2.6) are satisfied (Pooler, 1987a; Evans and Pooler, 1987). β is a parameter to reflect the relation between migration and spatial separation (Haynes and Fotheringham, 1984: 15-17; Fotheringham and O'Kelly, 1989: 10-13). The balancing factors are determined as

$$A_i = \left[\sum_{j=1}^{n} B_j \, D_j \exp(-\beta d_{ij}) \right]^{-1} \qquad (2.8)$$

$$B_j = \left[\sum_{i=1}^{m} A_i \, O_i \exp(-\beta d_{ij}) \right]^{-1} \qquad (2.9)$$

Equation (2.4) is usually referred to as the 'doubly constrained' migration model when constraints (2.5) and (2.6) are in effect. When only constraint (2.5) applies, the migration model that results is called 'production' or 'origin constrained'. When only constraint (2.6) applies, the model that results is called the 'attraction' or 'destination constrained' model.

Webber (1977: 254) points out that the entropy-maximising principle represents a rational means to build spatial interaction models subject to the constraints of the given information, "because this minimises the observer's bias".

Batten and Roy (1982: 1050) consider that the application of the entropy-maximising principle to spatial interaction model-building

> "can be viewed as a two-stage process: the first consists of the correct enumeration of the states of the system, ... , and the second includes statistical inference on the basis of partial information".

Wilson (1971) distinguishes an interaction system consisting of micro, meso, and macro states. Senior (1979) explains these three states in a pedagogic manner. Suppose the system is related to a journey-to-work situation in a city with partitioned zones. He (1979: 192) illustrates that the micro state refers to each individual commuter and his characteristics, for example, travel costs for each commuter "are recorded and identified by residential and employment zone". The meso state represents an intermediate level of aggregation and refers to only the interzonal number of commuters living in origin zones and working in destination zones, and "individual travel costs are replaced by a single interzonal cost". In other words, at this level of aggregation we are not concerned with any particular individuals or individual's costs, rather we are concerned with the aggregate number of commuters between the residential and employment zones (or a flow of commuters) and the total costs for this flow of commuters as a whole. The macro state represents a higher level of aggregation. It concerns the total number of commuter leaving each origin zone, O_i, and the total number of commuters arriving each destination zone, D_j, and the total costs for the system as a whole. The EM principle involves finding the most probable meso-state which is associated with the greatest number of micro-states, and is compatible with given constraint(s), or macro-state(s), specified in Equations (2.5) to (2.7) (Wilson and Kirby, 1975: 286-291).

Let the number of micro-states be W; then the entropy function used by Wilson to derive Equation (2.4) is as follows:

$$W = \frac{M!}{\prod_{ij} M_{ij}!} \qquad (2.10)$$

where M_{ij} is the number of trips from origin i to destination j, and M is the total number of trips. A detailed derivation of Equation (2.4) is in Wilson (1967, 1971). The EM method then allows the modeller to predict

> "the most probable, meso-level, journey-to-work interactions, which are: (i) fully consistent with any macro-level information and assumptions he wishes to take into account. ... (ii) maximally noncommittal or unbiased about micro-level behaviour for which information (*e.g.*, individual commuter, or individual travel costs, this author's note) is typically unavailable or incomplete because of system size." (Senior, 1979: 192-193).

Therefore, the EM methods launched by Wilson have dispensed with most of the deficiencies discussed in section three.

The calibrated values of A_i and B_j are not only regarded as balancing factors but also interpreted as competition-accessibility terms (Wilson, 1967; 1971: 9). Wilson (1971: 10-11) further considers that in the context of estimating shopping flows by a production-constrained model, it is more normal to regard A_i, as being "a term which represents the competition of other shopping centres for the trade of residents of zone i as perceived by shopkeepers in zone j". The interpretation of the balancing factors was facilitated by the measure of accessibility (Stewart and Warntz, 1958; Hansen, 1959; Warntz, 1964, 1965), since there is an inverse relation between balancing factors and accessibility. The measure of accessibility is dependent upon two terms, attractiveness and the travel deterrence (Wilson, 1971; Pooler, 1987b, 1995b). This may be the reason why the balancing factors are interpreted as accessibility and competition. Discussion about the balancing factors can also be found in Kirkby (1970), Cesario (1974), and Fotheringham and O'Kelly (1989). Empirical investigation of the values of A_i and B_j is included in Thomas (1977) and in Evans (1986).

Fotheringham and O'Kelly (1989: 2-4) have discussed the issue of choosing between the doubly-constrained and the singly-constrained models (production or attraction constrained) and concluded that the singly-constrained models will provide 'high-quality information' related to migration flows. The major strength of the entropy-maximising spatial interaction model is that it allows investigators to estimate the statistically most likely occurrence of place-to-place migration, M_{ij}. Such estimation is completely consistent with macro-information and constraints imposed (Senior, 1979: 192-193; Haynes and Fotheringham, 1984: 16-18). Over the past two decades, empirical applications and theoretical investigations of the EM spatial interaction models have been numerous. A review of this research can be found in Pooler (1994a).

The EM models are particularly useful in circumstances where the purpose is to allocate or distribute social services, commodity flows, and population movements in urban and social planning. In this sense, they are used essentially as allocation models. Indeed, it is due to this distributive role that the EM model has been attacked on the grounds that it has weak explanatory power. The constraints imposed on the model itself (the origin, destination, and total cost constraints) are not causes but outcomes (Hua and Porell, 1979; Hay, 1991). Hua and Porell (1979: 115) argue that in EM models the total cost is

> "simply the result rather than a real constraint. The same can be said about the other two constraints ... since the totals are simply made up of the individual trips. In short, the three constraints are not binding in a causal sense; they are *ex post* accounting identities. Hence, it is difficult to extract from them a causal explanation, which is a basic objective of theorisation in social modelling."

They further argue that due to the fact that there is "a random element" in the observed interaction data, the consistency between the predicted and the observed row and column totals cannot constitute "a logical requirement"(Hua and Porell, 1979: 106). In another paper, Hua (1980: 722) has attacked the exponential distance function of EM models, which assumes that "a homogeneous population" creates the spatial interaction. In his opinion, the distance function form should be empirically decided within the specific study context.

Although there were some concerns around EM models, their strength has been long recognised. In Wilson's own opinion, the so-called weakness of the constraints in the EM model claimed by Hay (1991) also represents a strength that reflects "reality through a set of constraints" (Wilson, 1991: 435). Batty (1991: 433) considers that the EM method launched in the Wilson's 1967 seminar paper and his subsequent research

> "should not simply be judged on what it said about the use of statistical techniques for deriving consistent accounting frameworks for urban models but on what it implied for others to research."

It seems that all the concerns raised by the above critics can be addressed. For example, prior to Hua's 1980 paper, which raised reservations about the exponential function of distance for the interaction system as a whole in the EM model, investigations of origin-specific distance decay parameters in a doubly-constrained spatial interaction model had been only undertaken by Stillwell (1978) and by Southworth (1974). Pooler's (1994b) relaxed spatial interaction modelling strategy is a straightforward solution to the concern about the "random element" between the observed and estimated interaction data.

2.7.3 Calibration of the EM spatial interaction models

Calibration of the SIM is a process of finding the parameters of the model in such a way that the model estimation fits the observed flow patterns as closely as possible (Wilson, 1974: 33). The calibration of the models usually means that we estimate the value of β in the distance or cost function (Batty and Mackie, 1972). Hyman (1969), Evans (1971), Batty and Mackie (1972), Baxter (1973), Senior (1979), and Fotheringham and O'Kelly (1989) all discuss calibration issues.

Due to the nonlinearity of SIMs, calibration against the observed data cannot be realized through the usual methods, such as regression analysis (Wilson, 1971: 9), but needs to use programs specific to it. Baxter (1973) develops a five-subroutine program to calibrate the EM models based on Hyman's (1969) method. Hyman (1969) suggests that the value of β in the negative exponential function can be estimated using a second order linear interpolation on the basis of Bayes' theorem. He indicates that the mean trip cost can be used as the reasonable statistic for such estimation.

The value of β which appears in the negative exponential or negative power function is a parameter that indicates the relation between migration and distance (Wilson, 1971). For the negative exponential function, the initial value of β is usually set equal to the negative inverse of the observed mean trip cost (Baxter, 1973). For the negative power function, the initial value of β is set to be the negative inverse of the mean value of logarithmic costs (Wilson, 1974: 320; Fotheringham, 1983a: 24).

A combination of the negative exponential and power functions leads to the negative gamma function, $f(c_{ij}) = \exp(-\beta_1 c_{ij})c_{ij}^{-\beta_2}$, and it can also be one of the cost function forms to be attempted (March, 1971; Batty and Mackie, 1972: 208). Zielinski (1979, 1980) introduces a family of quadratic gamma functions of the distance decay in the study of urban population density. Aside from travel cost (distance), introduced in Equation (2.7), two additional cost constraints, the square of and log of the travel cost, can also be introduced. When these three cost constraints are employed alone or in combination, a family of seven cost deterrence functions can be derived (Pooler, 1994a: 24-25). However, introducing additional parameters implies that more complex numerical methods will be involved. Baxter and Williams (1975) have discussed a situation where estimating two parameters in the model is required. Diplock and Openshaw (1996) discuss the calibration issues of the Goncalves and Ulyssea's (1993) hybrid SIM and of Fotheringham's (1983a) competing-destination (CD) model.

Guy (1987) shows that estimation of a production-constrained SIM can be achieved by using generalised linear modelling procedures (the GLIM computing package). Baxter and Ewing (1979) have suggested that linearising the singly-constrained interaction model can be achieved through taking logarithms and relating flows from an origin to two destinations. Experimentation with the three members of the distance function family mentioned by Batty and Mackie (1972) has shown "relatively little influence on model performance" (Baxter and Ewing, 1979: 329).

The performance of the estimated model can be gauged against the observed data by using goodness-of-fit statistics. There are three types of such statistics: information based statistics, general distance statistics, and traditional statistics (Knudsen and Fotheringham, 1986). The correlation coefficient, one of the traditional statistics, is regarded as inappropriate for evaluating the goodness-of-fit between the observed and estimated matrices (Knudsen and Fotheringham, 1986). The underlying reason is that the correlation coefficient "measures the degree of linear dependence between two random variables" (Wilson, 1976: 344). The observed and predicted matrices cannot be treated as random variables since in the SIM the constraints require at least the total number of migrants or tripmakers for the two matrices to be matched; in other words, the two matrices are not independent (Wilson, 1976: 344).

2.8 Derivation of SIMs by information minimising methods

The EM model, which is used to allocate the given number of migrants from each origin to destinations, cannot tell us what characteristics or variables cause people to move to their destinations. It lacks socio-economic variables related to origin and destination. As a result, the EM-type of migration model "typically relied on the exclusive use of distance as an explanatory variable" (Roy and Flood, 1992: 17). However, trip or migration patterns cannot be explained mainly by distance or cost matrices (Willekens, 1983). One way to remedy such deficiencies is to seek explanation of the variance of trip patterns by including a historical matrix (Willekens, 1983: 244; Roy and Flood, 1992: 33).

The information-minimising (IM) technique can incorporate prior information, w_j, which may reflect factors affecting the attractiveness of the destination such as income, housing conditions, and employment. The IM approach to spatial interaction models is closely related to the EM approach (Pooler, 1994a: 25-27, 1995a: 309). The IM approach allows the inclusion of prior information, either from empirical data or from theoretic conditions. The use of prior distribution information in migration and trip models can be traced back to the works of Fratar (1954) and Morphet (1975). Further treatment of the subject has been undertaken by Batty and March (1976), and by Batty and Sikdar (1982). For the first time, Pooler (1995a) demonstrates that such priors can be incorporated into spatial interaction model using the EM approach. Unlike previous investigations, wherein the priors are included simultaneously, his approach allows the prior probability to be parameterised and also allows such prior probability to be employed as a separation factor, replacing the traditional distance variable (Pooler, 1995a: 310). The empirical performance of such models is on a similar level with conventional models (Pooler, 1995a).

Including prior information on the attraction of destinations in the origin-constrained SIMs can be formulated by minimising the Kullback (1959) information measure. The problem is formulated to minimise

$$\sum_i \sum_j M_{ij} \ln(M_{ij} / w_j) \qquad (2.11)$$

where w_j is prior information on the attraction of the destinations, subject to the constraints (2.5) and (2.7). The result is as follows:

$$M_{ij} = A_i O_i w_j \exp(-\beta d_{ij}) \tag{2.12}$$

where

$$A_i = \left[\sum_{j=1}^{n} w_j \exp(-\beta d_{ij}) \right]^{-1} \tag{2.13}$$

The prior information may "include previously observed trips, theoretical estimates of trips or other relevant information" (Pooler, 1994a: 27). A historical (or previous) interaction matrix is often employed as the prior information when using the IM principle. For example, one of the applications by Snickars and Weibull (1977) was to forecast urban trip patterns by using the previous trip data. They showed that the models that incorporated past trip patterns performed better. Plane (1981: 47) has noted that "the inclusion of such information (the prior migration data) results in an immense improvement in forecast accuracy". Similar conclusions have been obtained by Mayhew et al. (1986) and by (Pooler, 1988). The reason for the better performance of the IM models is due to the inclusion of the prior movement probability derived from a past migration matrix, which is usually related to a present migration if the present migration system has not been greatly disturbed. The early practice of forecasting traffic flows by using an updating method, which may provide a clue to the idea of incorporating the prior information in the spatial interaction modelling methods, illustrated this advantage (Fratar, 1954). In the context of migration, the prior information is usually derived from a previously observed matrix.

Applications of such a modelling strategy can be found in Plane (1981, 1982), Pooler (1988) and others. In demography, the method of updating the migration matrix based on a fixed transition probability derived from past migration flows is called the fixed demographic method (Plane, 1982). This prior information on migration has been termed a lagged variable in econometric modelling of migration (Greenwood, 1970, 1985). Plane (1982) employs the total population at destinations and two past migration matrices as prior information. In particular, in applying two past migration matrices, Plane (1982: 455) obtains even better results. Pooler (1985) proposes that by using the IM approach, multiple prior information concerning movement between zones can be included in the model. One interesting treatment of prior information is to employ it to replace the usual spatial separation of distance (Pooler, 1995a). According to Plane (1982), the priors can be based on information other than the past migration matrix, such as employment turnover measures and changing population share at the destination, which must be related to migration. Pooler (1995a: 312) proposes that "the priors need not be based necessarily on historical information".

Webber (1979: 140) suggests use of a 'sequential approach' in the framework of the IM principle. The 'sequential approach' means that model's performance could be improved through a series of steps, wherein each step includes additional constraints.

2.9 Some other related extensions

2.9.1 Competing destination models

Another extension of EM-type models is found in the competing destination models. Empirical evidence shows that there is a spatial variation in the parameter of the distance decay function. Fotheringham (1981, 1983a) and Fotheringham and O'Kelly (1989) demonstrate that when such parameters, based on an origin-constrained SIM using data from USA, are mapped, they indicate a clear pattern over space. Even by calibrating a doubly-constrained SIM, spatial variation in the parameter still exists (Griffith and Jones, 1980). It is assumed that this variation in the parameter is influenced by spatial structure, also known as the 'configuration of origins and destinations', or 'map pattern' (Baxter, 1985; Griffith and Jones, 1980; Fik and Mulligan, 1990; Fik and Armey, 1992; Fotheringham, 1983a, 1983b, 1985, 1997; Fotheringham and O'Kelly, 1989). To account for such an effect in the SIM, Fotheringham (1983a, 1985) introduces a new variable (he terms it the "third variable"), to measure the accessibility of the destination to all other destinations, into the usual SIM. Specifically, he (1985) suggests that the general form of a SIM be

$$p_{j/i} = f(W_j, S_{ij}) \tag{2.14}$$

When the accessibility term, A_j, included into the model, it becomes

$$p_{j/i} = f(W_j, A_j, S_{ij}) \tag{2.15}$$

where f indicates that there is a functional relation between the terms in the brackets and $p_{j/i}$; $p_{j/i}$ represents the probability that a person in origin i will choose destination j; W_j indicates the attractiveness of destination j in terms of size; S_{ij} the separation of i and j; and A_j represents the relative location of destination j with respect to all other possible destinations.

Equation (2.15) is termed competing destination (CD) model. The term, A_j, in the equation (2.15) can be easily formulated following Warntz (1956, 1957), Stewart-Warntz (1958), or Hansen's (1959) accessibility measure:

$$A_j = \sum_{k(k \neq j)} \frac{w_k}{d_{jk}^{\beta}} \tag{2.16}$$

where subscript k represents all other possible destinations that are available to persons in i ; d_{jk} is the distance between j and k.

Therefore, it is clear from Equations (2.14) to (2.16) that the CD model consists of two accessibility terms, the first relates to origin and destination, and the second concerns the relative location of the destination with respect to all other destinations. Fotheringham (1983a: 19) considers the theory of competing destinations reflects a two-stage decision-making process.

> "The first stage is that individuals choose a broad region with which to interact. The second stage is that individuals then choose a specific destination from the set of destinations".

The idea of the two-stage choice process as the basic theoretic argument for the CD model was further discussed by Fotheringham and O'Kelly (1989: 67-86).

Some researchers have questioned the CD model. Gordon (1982: 18) argues that an alternative explanation is needed, since the parameter variation is in the migrants'

> " ... perceptions of distance between *pairs* of zones rather than in the sensitivity to distance (across all zones) of migrants from a particular origin".

In another paper, Gordon (1985: 59) argues that the 'map pattern' explanation for the variation in the distance decay parameter is not adequate, and more substantial explanation should be sought from "the economic assumptions of the standard spatial interaction model". Gordon (1985: 64, footnote no. 4) considers that the CD model was formulated on the basis of "trivial and arbitrary particulars" in comparison to the conventional SIM. Based on existing literature, Lo (1992) summarises two types of destination interdependence: one such interdependence results from location arrangement or spatial structure, and the other results from economic preferences toward activities at destinations. She indicates that the CD model can distinguish locational structure effects (or size and configuration) but not economic preference effects using a simulation in the context of retailing.

Reservations about the principle behind the CD model have also been raised. For example, Pooler (1994a: 30) considers that in terms of the spatial choice process, tripmakers would be concerned more about "budget constraints, past experiences, and personal taste preferences" rather than a two-stage process. In another paper, Pooler (1998: 222) further argues that a competition effect only occurs "among destinations with *similar spatial influences on origins*, regardless of their spatial proximity to one another." Plane (1993: 381) indicates that the actual spatial choice process made by would-be migrants is among "just one or two potential destinations". DaVanzo (1981a, 1983) provides another rationale. Her reasoning is that information search and collection for possible destinations are not costless. In DaVanzo's (1981a: 47) words,

> "A potential migrant will only invest in "search" as long as he or she feels the benefits outweigh the costs. This is why many potential migrants may consider only one or a few destinations".

The magnitude of the potential moving costs is directly proportional to the location-specific capital (DaVanzo, 1981a), or local human capital (Greenwood, 1985) possessed by the potential migrants. DaVanzo (1981a: 47) refers the location-specific capital to such varied things as:

> "homeownership; job-related assets such as an existing clientele (of, say, a well-regarded doctor or plumber), seniority, specific training, or a nonvested pension; knowledge of an area; friendships; and indeed any factor that "ties" a person to a particular place. Such "assets" are costly (or impossible) to replace or transfer to another locality. The potential transaction cost of replacing them or the losses in their value are cost of moving. Thus the more location-specific capital a family possesses in its current locality, the less likely the family should be to leave, other things being equal".

2.9.2 The intervening opportunities approach

One of the early variants of the social gravity models is the 'intervening opportunities' (IO) model. This approach was originated in Stouffer's (1940, 1960) two papers. Specifically, Stouffer's (1940: 846) theory is that the number of people moving to a destination

> "is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities".

It should be noted that the IO approach indirectly incorporates distance into the model in a way such that would-be trip makers rank destinations in an increasing order of physical distance away from an origin (Akwawua, 1995). The distance variable in the IO model is measured in an ordinal or ranked way, while the usual gravity model treats distance as an interval/ratio measure. The essential concern with Stouffer's approach is how the intervening opportunities are to be determined. In his own 1940 study, he considered the intervening opportunities are to be determined. In his own 1940 study, he considered the study area as a circle and measured the intervening opportunities for each partitioned circle as the number of earlier in-migrants to that partitioned circle. In his 1960 study, he revised his earlier measurement of opportunities by taking account of competing migrants.

There are also other ways to specify the intervening opportunities (Levy and Wadycki, 1974; Fields, 1979; Feder, 1980; Foot and Milne, 1984; Barber and Meline, 1988). For example, Levy and Wadycki (1974) have specified the best opportunity lying between the origin and destination as the intervening opportunities. If the concerned variable were per capita income, then the highest per capita income would be chosen as the intervening opportunity. Feder (1980) adopts a distance-weighted alternative income (much like the income potential) between origin and the alternative destinations as the intervening opportunity. The idea underlying his construction of the distance-weighted alternative income was that income levels in closer locations would have a stronger attraction effect on the would-be migrants, but distant locations with very high income may still have a significant attraction. His hypothesis was that the extent of migration between origin and destination was inversely related to such intervening opportunities. The specifications were all incorporated into a regression analysis of migration. It may be noted that the CD model discussed in the preceding section also introduces an accessibility or potential term, but it relates one destination to all other destinations.

Although Wilson (1974: 397-399) has derived the IO model [and it was also derived through EM methods (1970b)], Pooler (1994a) laments that there is not enough empirical investigation on the EM form of the IO model. Goncalves and Ulyssea-Neto

(1993) incorporate the notion of intervening opportunities into the SIM. In their approach, the opportunity index was derived from *a priori information*.

Akwawua (1995) proposes an 'intervening dominance' (ID) model, based on the ideas from the conventional IO approach and Pooler's (1992) spatial dominance theory. In the conventional IO model, destinations are ranked on the basis of nearness to origins, while in the ID approach, destinations are ranked on the basis of spatial dominance, which includes both linear distance to, and the size of, the destination. The ID model is tested against the US 1975-1980 interstate migration data, and performs well. The gravity-opportunity model developed by Goncalves and Ulyssea-Neto (1993) is considered “an important advance” (Roy, 1993: 1689). However, Roy (1993) also has expressed some concerns over the gravity-opportunity model. One such concern is that high multicollinearity between the index of the intervening opportunity and cost variables may occur in a situation where opportunity is uniformly distributed over zones. A second concern is that when trips are made toward more than one destination, the intervening opportunities may increase the trip flows between the origin and the chosen destination, which surely violates the authors' ideas.

One of the related approaches is Alonso's (1978) framework of movement. Alonso's (1978) theory of movement can be expressed as follows:

$$M_{ij} = v_i w_j D_i^{\alpha-1} C_j^{\beta-1} t_{ij} \tag{2.17}$$

where M_{ij} represents movements between classes or regions i and j, v_i is a measure of unattractiveness of class or region i, w_j is a measure of attractiveness of class or region

j, t_{ij} represents the relation term of distance between i and j, D_i is the draw or pull of the system at i, C_j is the push or competition of the system at j, $\alpha - 1$ is the movement response from i to its relation to other classes in the system, and $\beta - 1$ is the movement of response of class j to its relation to the other classes in the system. D_i and C_j can be determined as:

$$D_i = \sum_j w_j C_j^{\beta-1} t_{ij} \tag{2.18}$$

$$C_j = \sum_i v_i D_i^{\alpha-1} t_{ij} \tag{2.19}$$

As Ledent (1980, 1981) points out, the main features of Alonso's theory are that movements among regions are influenced not only by conventional terms (*i.e.*, size of origin and destination, and the distance), but also by impacts from other alternatives of the system (*i.e.*, represented here by the two terms, D_i and C_j). The calibration issues and empirical tests of Alonso's model are discussed by Ledent (1980). Treating Alonso's framework as a more general theory of movement to incorporate the existing diverse models is beyond its real value (Ledent, 1980). It is argued that Alonso's approach is "essentially equivalent" to Wilson's EM family models (Wilson, 1980: 727; Ledent, 1981: 221).

Another related approach is Tobler's (1983) alternative formulation of the SIM. Tobler's formulation can be expressed as follows:

$$M_{ij} = \frac{(k_i + k_j^{'}) P_i P_j}{d_{ij}} \tag{2.20}$$

where M_{ij} are interactions between i and j, P_i and P_j represent size of regions i and j, d_{ij} is the distance between i and j, the terms of k_i and $k_j^{'}$ are constants which have the similar normalising effects of the balancing factors in the Wilson-type model. These two terms can be determined as:

$$k_i = (2r_i - \sum_j \frac{P_j k_j^{'}}{d_{ij}}) \Big/ \sum_j \frac{P_j}{d_{ij}} \tag{2.21}$$

$$k_j^{'} = (2r_j^{'} - \sum_i \frac{P_i k_i}{d_{ji}}) \Big/ \sum_i \frac{P_i}{d_{ij}} \tag{2.22}$$

A salient feature of the Tobler model is that the multiplicative relation between the balancing factors A_i and B_j in Wilson's SIM is replaced by an additive formulation in which $k_i + k_j^{'}$, and k_i and $k_j^{'}$ are interpreted as pushes from i and pulls from j, respectively. The empirical test of the model against the US interregional migration data from 1965 to 1970 shows the model performs slightly better than the Wilson-type model. Of course, a single test of the model cannot justify its universal validity. Tobler's model is derived on the basis of minimising a quadratic objective function rather than an entropy-based function (Fotheringham and O'Kelly, 1989: 38-39). However, Wilson (1983: 705) argues that Tobler's model is based on some modification of the entropy-model, "but one that uses a different function form for the 'entropy'." Ledent (1985) introduces a more general objective function that is a synthesis of both the multiplicative and the additive approaches. He shows that the multiplicative and additive formulations can be viewed as the extremes of his own general functional form.

2.10 Summary

This chapter has concentrated mainly on entropy-maximising SIMs and some of their extensions. One of the implications of Wilson's EM methods "was in providing a framework for modelling which was rich in possibilities" (Batty, 1991: 433). Indeed, many extensions of spatial interaction modelling have been under Wilson's framework, and can be considered members of an extended Wilson family of models (Pooler, 1994a). Over the past three decades, modifications and extensions have focused on the distance function and intervening opportunities. On the other hand, the IM principle provides an approach to incorporate additional variables to improve the explanatory power of the model.

Although the method of minimum information provides a framework to incorporate additional variables into the conventional SIMs as a means of improving model performance, the literature review demonstrated that systematic investigation of the approach is rare. The present research seeks to address this issue by extending the conventional SIMs to MSIMs under the minimum information principle. The proposed MSIMs will be investigated empirically using the Chinese interprovincial migration data. It also was noted in Chapter 1 that modelling China's province-to-province migration flows has not been attempted before. Therefore, the present research can be justified both for advancing areas of spatial interaction modelling and for making contributions to Chinese migration studies. Population migration between regions is considered to relate to a variety of variables (Shaw, 1985; Long, 1988), meaning that migration process is undoubtedly multivariate. In this sense, the MSIMs can be more appropriate than the conventional SIMs in explaining and predicting China's provincial migration flows.

Chapter Three Background of China's Migration

3.1 Introduction

China is the third largest country in the world, with a territory of 9.6 million km^2 (or 3.7 million square miles), just behind the size of Canada (10 million km^2). China's population reached 1.13 billion in 1990 (China, 1991), ranking it largest in the world. Provincial units are the major administrative divisions of the country. Considerable regional diversity exists in their endowments of natural and human resources. Provinces in the western part of the country are generally larger in area, while provinces in the eastern part of China are smaller in size but larger in population. Following the opening up of over 100 treaty ports to the colonial powers in the second half of the nineteenth century, the growing concentration of population, industry, and commerce focused along the eastern part of the country (Linge and Forbes, 1990: 11-12). These regional diversities provide a firm justification for China's inter-provincial migration. Before examining China's inter-provincial migration by use of MSIMs, it is crucial to understand the background of China's migration. This chapter aims to provide such a background. Following an introduction of the history of population and migration, regional development strategies, from the founding of the People's Republic of China in 1949 to the 1980s, are discussed. Then an account of migration policies, both in the Maoist era (1949-1976) and in the reforming period from the late 1970s to 1980s, is given.

3.2 China's migration in historical perspective

Population growth in China stagnated for long periods of time in history (see Table 3.1). The stagnation was caused by natural and man-made disasters. The early stage of the demographic transition model can be best applied to the population of pre-modern China. Limited mobility is usually paralleled with the early stage of the demographic transition (Zelinsky, 1971), and this may be the case for pre-modern China. Before briefly reviewing migration in the pre-modern China, it is worth considering general facts about past population growth in China.

China's population growth was stagnant from two AD until the fourteenth century (Table 3.1). The fourteenth century was identified as the turning point for China's population growth. Prior to this point, population growth was not observed except for a few centuries, and the increase was wiped out by the Mongol invasions in the twelfth and thirteenth century (Perkins, 1969: 184). From 1368 (the year for the formal inauguration of *Ming* dynasty) until the middle of the nineteenth century, China had a period of relative peace and security. As a result, population increased six-fold, from over 65 million persons in 1400 to about 400 million in 1800. Such an increase implies that the average annual growth rate over the four centuries was 0.4-0.5 per cent. Yet even in the eighteenth century the rate did not achieve one per cent for any sustained period (Perkins, 1969: 24). It should be stressed that population growth in this period was by no means rapid in terms of modern standards, such as the magnitude of population growth of Third World countries in the 1960s and 1970s. The pattern of steady increase was halted twice, first by the warfare in the downfall of the *Ming* dynasty (1368-1644) in the seventeenth century, then by the *Taiping* Rebellion in the middle of the nineteenth century (Perkins, 1969: 184-185).

Table 3.1 Population and cultivated acreage for China, 2-1957 A.D.

Year	Population (millions)	Cultivated acreage (million *mou*)	Population to cultivated acreage ratio
(1)	(2)	(3)	(4) = (2)/(3)
2	59	571	0.103
146	47	507	0.093
976 c.a.	32	255	0.125
1393	60	522	0.115
1400	65-80	300-440	0.217-0.182
1600	120-200	400-600	0.3-0.333
1770	245-295	850-1050	0.288-0.281
1850	385-435	N/A.	N/A.
1873	325-375	1160-1260	0.280-0.298
1893	360-410	1190-1290	0.303-0.318
1913	405-455	1310-1410	0.309-0.323
1933	475-525	1420-1520	0.335-0.345
1957	632-662	1653-1703	0.382-0.389
1980	987	1490	0.662
1990	1143	1435	0.797

Notes: Cultivated acreage includes all land on which crops are grown, but excludes pasture land. 15 *mou* = 1 hectare = 2.5 acres.

Sources: Data for the period from 2 to 1393 are based on Chao (1986: 89); data between 1400 and 1957 are adapted and calculated from Perkins (1969: 16); and data for 1980 and 1990 are obtained from China (1996: 131, 142).

As in many other countries, China's population was not evenly distributed across the available cultivated land. Prior to the *T'ang* dynasty (618-906 A.D.), population concentrated on the North China Plain (provinces of Hebei, Henan, and part of Shandong). By the time of the early *Ming* dynasty, population in China was concentrated in five east-central provinces mainly along the lower Yangtze River, that is, the provinces of Jiangsu, Zhejiang, Jiangxi, Anhui, and Hubei (Perkins, 1969: 25).

The discussion above points to the general observation that the pressure of population on cultivated land was not a serious issue in pre-modern China, at least until

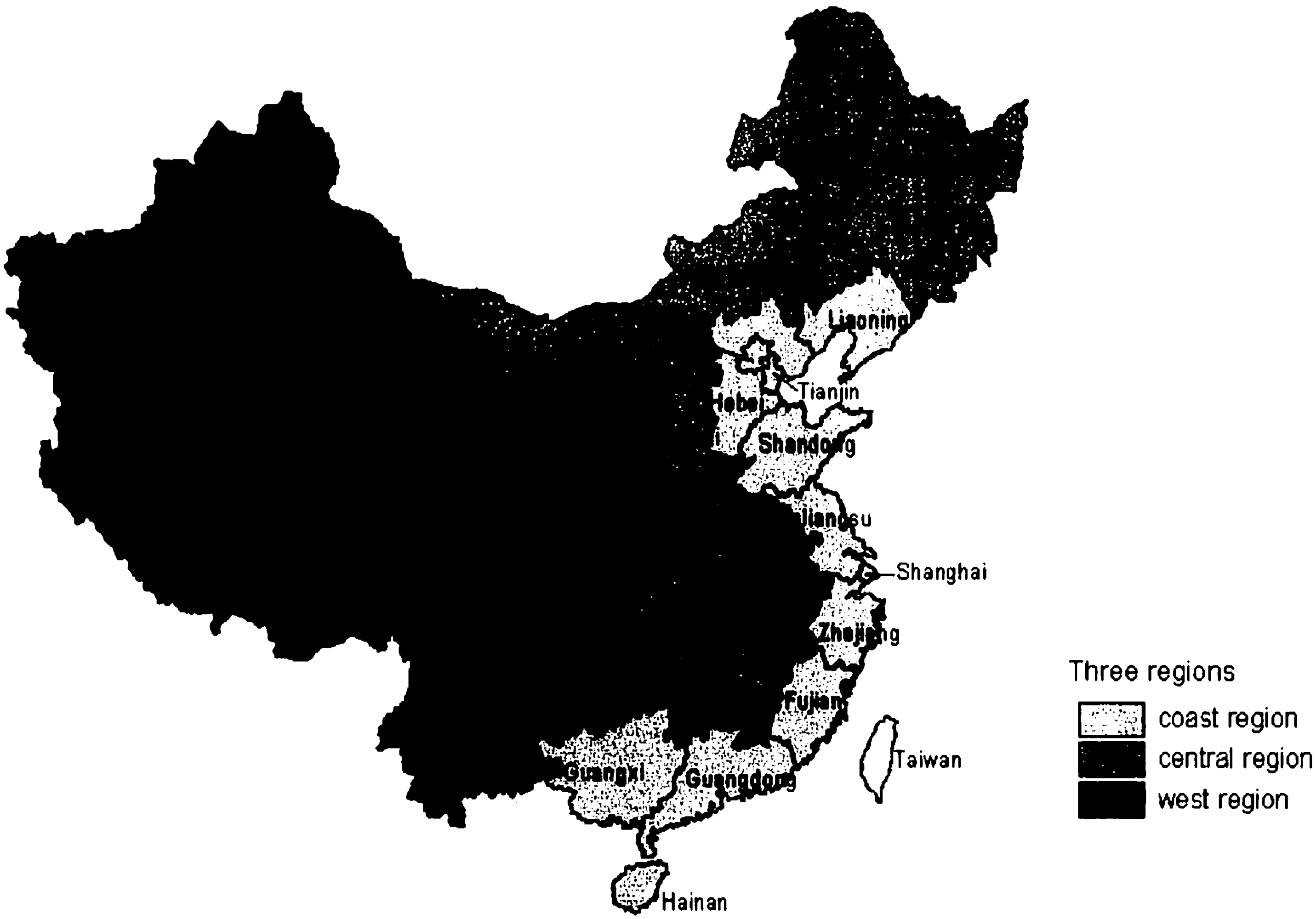

Figure 3.1 Provinces and three regions of China, 1990

Source: Alexandria digital library, 1998.

the nineteenth century (Ho, 1959: 168). Therefore, 'push' forces for migration did not surface in terms of population-to-land ratio, and in general migration levels in pre-modern China were low. As to the 'pulling' forces, such an assertion can also be substantiated by the fact that China's pre-modern economy resulted in little opportunity for any significant level of population mobility. The low level of mobility was further reinforced by the Confucian culture which undermined the migration potential of Chinese people since it instructed people to be "attached to one's native place and unwillingly to leave it"(Tu, 1996: 60).

However, the political and economic conditions in pre-modern China by no means always led to a low level of migration. In fact, a large number of people may have mobilised in some periods due to warfare, famine, and other social turmoil. Ho (1959: 136-138) categorises China's inter-regional migration into three types in the *Ming* dynasty: government-enforced, military colonisation, and voluntary migration. This categorisation may also apply to other periods in pre-modern China.

One of the salient features of Chinese history is the cyclic change of dynasties. The rise and downfall of a dynasty would lead to the restoration and reduction of China's population size. Migration became a policy measure to be used by the governments for the restoration of population to the areas where population had experienced a considerable loss. The peasant rebellions and other social turmoil often caused by corruption and mismanagement by the government prompted the downfall of the old dynasties. Such turmoil certainly brought about drastic reductions of population, in particular for the areas where heavy wars and famines prevailed. When new dynasties began, the government usually took measures to restore the population to the areas where population had been lost due to the turmoil. For example, after the downfall of the *Yuan* dynasty (1271-1368), the government of the early *Ming* dynasty made considerable efforts to move people from congested to war-devastated areas. It was reported that almost 150,000 households were moved from southern Jiangsu and northern Zhejiang to northern Anhui (Ho, 1959: 136). Migration for defence purposes was directed towards frontier regions, such as the areas along the Great Wall. The voluntary migrants were motivated mainly by economic forces. The role of this type of migration was equally as important as government-sponsored migration in the agricultural development of sparsely settled areas (Ho, 1959: 138).

Although availability of arable land was not a problem in general, for some particular regions the changing population-land relationship had a direct bearing in interregional migration in Chinese history. The provinces of Guangdong, Guangxi, and Yunnan in the southernmost regions of China were destinations for migrants only in the late *Sung* dynasty (960-1279). In the early part of *Ming* dynasty, most of the migration from the heavily populated areas (for example, the lower Yangtze river) was still moving toward Guangdong, or into central China; for example, Hunan and Hubei (Perkins, 1969: 185). During the late seventeenth and the whole of the eighteenth century, migration was directed to Sichuan and the opening-up of the Yangtze highlands (Hunan). By the first half of the nineteenth century, the pressure of population on land was increasing in the Yangtze region. From the late nineteenth century, northeast China (also called Manchuria) was the major destination for peasants from Hebei, Shandong, and Henan provinces. On the other hand, people in the southeastern part of China, such as Fujian and Guangdong, migrated abroad to destinations such as southeastern Asia and the New World (Ho, 1959: 168).

Railway networks were established in China around the turn of 20th century. The construction of railway infrastructure, and mining and agricultural development by the foreign powers of Russia and Japan in the three provinces of Northeast China (i.e., Liaoning, Jilin, and Heilongjiang) created considerable demand for labour. The labour demand was mainly supplied by the surplus workforce in the provinces of Hebei and Shandong on the North China Plain. Gottschang (1987: 461) describes the migration flows between the North China Plain and the provinces in Manchuria as follows:

> "The migration to Manchuria (Northeast China) from the North China provinces of Hebei and Shandong between 1890 and 1942 was one of the world's largest population movements in the early twentieth century. With an average annual flow of 500,000 people and a total net population transfer of over 8 million, the migration was comparable in size to the westward movement in the United States between 1880 and 1950".

Such large and sustained migration flows were motivated by economic opportunities provided by agricultural and industrial sectors at destinations, and forced by population growth, major floods, droughts, famines, and warfare at origins. Gottschang (1987) also finds that about 70 per cent of the migrants to Manchuria were not accompanied by family members. Most of them stayed at the destination for several years and eventually returned to their origins. Therefore, it seems that they practised a mobility strategy that is called "return migration".

Based on John Lossing Buck's (1937) farming sample survey conducted in China's 22 provinces (*not including* Manchuria) between 1929 and 1933, Notestein and Chiao (1937) indicate that the reasons for migration across all the 22 sampled provinces were related to the pressure of population on resources and natural calamities. In another study, Buck (1930) shows that out-migration from North China to Manchuria fell into the following three types: permanent migration of the whole family, migration of young men for at least one year and in some cases even several years, and individual migration for short periods. The first type of migration was seen only in extreme circumstances, and most migration belonged to the second and third categories. This finding is comparable with the observations made by Gottschang (1987).

In sum, migration prior to the founding of the People's Republic of China in 1949 can be attributed to two broad types of causes: the pressure of population on resources, in particular on arable land, and natural or man-made calamities. The first cause has led to migration connected with economic opportunity, and the second cause leads to forced and government-organised migration.

3.3 China's regional context of development

3.3.1 Regional divisions

The administrative division of the People's Republic of China has been organised along hierarchical lines (Figure 3.2). Three main levels in the hierarchy can be distinguished. The first level under the central government consists of three mutually exclusive categories of administrative division: province (*sheng*), autonomous region (*zi zhi qu*), and centrally administered municipality (*zhi xia shi*). The second level includes counties (autonomous counties in the autonomous regions, and counties or urban districts in the municipalities). The third level of the hierarchy is the township, formerly called "people's commune", or neighbourhood committee in cities.

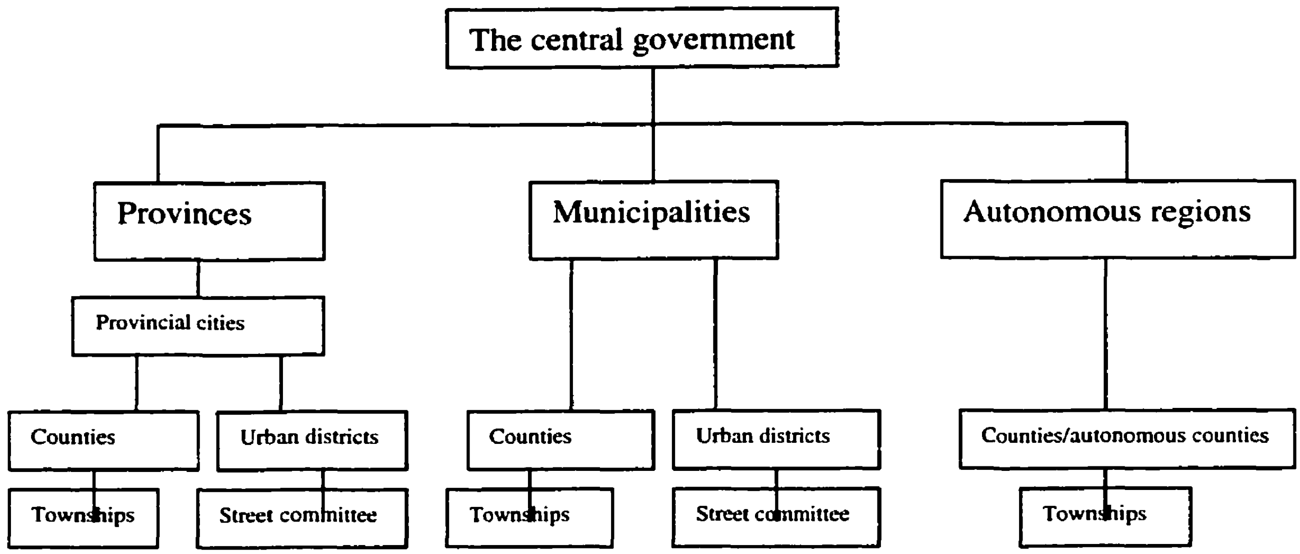

Figure 3.2 China's administrative structure, ca 1986

The administrative division of China is currently made up of 22 provinces, five autonomous regions, and three municipalities. The five autonomous regions have considerable proportions of ethnic minorities. According to the 1990 national census (China, 1991), the percentage of the ethnic groups for these five autonomous regions is: Guangxi (the Zhuang ethnic group, 33.5 per cent), Inner Mongolia (Mongol, 15.7 per cent), Ningxia (Muslin, 32.7 per cent), Tibet (Tibetan, 95.5 per cent), and Xinjiang (Urgur, 47.5 per cent). The three municipalities are Beijing, Tianjin, and Shanghai.

The five autonomous regions and the three municipalities have been treated with provincial status (Khan, et al., 1992: 1029; Yang, 1990). This convention is also followed in this thesis, and the word "province" is used to denote any one of three provincial-level units, including provinces, autonomous regions, and centrally administered municipalities. Therefore, China has 30 provincial-level units (see Figure

Table 3.2 Provincial population statistics for China in the 1990 census

ID number	Province	Abbrev.	Population	Territory (km^2)	Density (persons/km^2)
(1)	(2)	(3)	(4)	(5)	(6)
	China	PRC	1,133,682,501	9,600,000	118
1	Beijing	BJ	10,819,407	16,814	644
2	Tianjin	TJ	8,785,402	11,302	777
3	Hebei	HEB	61,082,439	187,964	325
4	Shanxi	SX	28,759,014	156,120	184
5	Inner Mongolia	IM	21,456,798	1,204,642	18
6	Liaoning	LN	39,459,697	145,803	270
7	Jilin	JL	24,658,721	188,000	132
8	Heilongjiang	HL	35,214,873	473,414	78
9	Shanghai	SH	13,341,896	6,200	2118
10	Jiangsu	JS	67,056,519	102,578	654
11	Zhejiang	ZJ	41,445,930	101,792	407
12	Anhui	AH	56,180,813	139,510	404
13	Fujian	FJ	30,048,224	121,471	248
14	Jiangxi	JX	37,710,281	166,758	226
15	Shandong	SD	84,392,827	153,126	539
16	Henan	HEN	85,509,535	166,867	512
17	Hubei	HB	53,969,210	187,467	290
18	Hunan	HN	60,659,754	210,151	286
19	Guangdong	GD	62,829,236	177,987	353
20	Guangxi	GX	42,245,765	230,512	178
21	Sichuan	SC	107,218,173	566,553	188
22	Guizhou	GZ	32,391,066	176,253	184
23	Yunnan	YN	36,972,610	392,215	94
24	Shaanxi	SN	32,882,403	204,996	160
25	Gansu	GS	22,371,141	455,099	49
26	Qinghai	QH	4,456,946	779,141	6
27	Ningxia	NX	4,655,451	66,027	90
28	Xinjiang	XJ	15,155,778	1,635,210	9
	Hainan		6,557,482	33,977	193
	Tibet		2,196,010	1,182,746	1.8

Sources: The figures for population and the population density are based on China (1991: 4-5), and the figures for territory are from Zeng (1991: 44-45).

3.1). Due to the unavailability of data sources, Hainan and Tibet are excluded from the spatial interaction modelling analysis. Therefore, only 28 provinces, as indicated by ID number ranging from 1 to 28 in Table 3.2, are included in this thesis.

One of the significant differences in administration between contemporary China and past Chinese dynasties lies in the administration of rural China. In Chinese dynasties prior to 1949, central power usually extended only down to the level of the county (*xian*), while in Communist China the central power and other levels of control have penetrated to the grassroots level of rural China. Specifically, in rural areas the township (formerly called Commune in the Maoist era), the primary division of the county and the lowest level of government is further subdivided into villages (formerly the production brigades). Each village in turn consists of 'village small groups' in some places (formerly production teams) (Oi, 1989: 4). Therefore, the township represents the authority of government below the county level. In 1986, the number of townships was estimated at about 71,521 (Oi, 1989: 5). Such an administrative penetration has considerable consequences and implications for social, economic and political activities in rural areas. For example, the national censuses can be organised effectively.

Based on political, military, and economic considerations, China has attempted different regional divisions at the level above the provincial units but below the central government during different periods of time. Each macro-region includes a varied number of provinces. Between 1949 and 1954, the central government adopted six military administrative regions for political and military reasons (Fairbank, 1992: 345). During the 1960s and the 1970s, six political-administrative regions (Northeast, North, East, Central-south, Southwest, and Northwest) were widely used. In some circumstances, a division of the country into coastal and interior regions was employed as an aid to balanced industrial development. Beginning from the seventh Five-Year Plan (1986-90), the country was divided into the *coastal*, *central* and *west* regions. The coastal region includes 12 provinces, constituting a narrow strip along China's coast. The central region consists of nine provinces, and the west region covers nine provinces (see Figures 3.2 and 3.3). Unlike previous regional divisions, the division of the country into coastal, central, and west regions in the recent reform period is based mainly on economic considerations. The coastal region is much more developed than the central region, and the central region in turn is far superior to the west region in terms of economic development.

Table 3.3 Skinner's division of China into macro-regions

Macro-regions	Provinces
North China	Hebei, Henan,Shandong, and north parts of Jiangsu and Anhui
North west China	Shanxi, Gansu, Ningxia, parts of Shaanxi and Inner Mongolia
Upper Yangtze	Sichuan, small parts of northern Guizhou and southern Gansu
Middle Yangtze	Hubei, Hunan, and Jiangxi, part of southern Shaanxi
Lower Yangtze	Southern parts of Jiangsu and Anhui, northern part of Zhejiang
Southeast coast	Fujian, southern part of Zhejiang, and small parts of eastern Guangdong
Lingnan	Most of Guangdong and Guangxi
Yun-Gui	Yunnan and most of Guizhou

Source: Skinner (1977: 211-249)

For analytical purposes, academics in China use the macro-divisions that the government has created. On the other hand, Western scholars such as Skinner (1977) have divided China into macro-regions for analytical reasons using the concept of functional regions. Skinner's work on marketing and urbanisation in late-imperial China led him to divide China into eight macro-regions (see Table 3.3), each centred around a river drainage basin and including several provinces, in whole or in part. Each macro-region has a core area and a periphery. The core area is on the water-way, with a higher population density and concentrated commerce and marketing activities; while the periphery is located in the mountainous and arid areas, and has a lower population density and less productive capacity. Although Skinner's regional framework is based on the marketing and urbanisation brought about by the western colonial powers in the latter half of the nineteenth century, it still has implications for inter-provincial migration (He, 1992).

3.3.2 Regional development strategies

Ever since the Chinese Communist Party came to power in 1949, China has had two contrasting approaches to regional development. The year 1978 is the watershed that differentiates the two approaches. The 1953-1978 period witnessed the "Maoist development strategy", which focused on a balanced development policy, in particular a biased investment strategy toward the interior. In contrast, the post-Mao Chinese leadership reversed its predecessor's approach to regional economic development. Stressing regional comparative advantage within the country, the new strategy favoured the coastal region over the interior.

The industrial system inherited from the Nationalist government in 1949 by the Communist leadership was seriously unbalanced. Over 70 per cent of the industries were located along the coast, and within the coastal region industrial production was further concentrated in a few cities (Yang, 1990: 233). To correct such an uneven distribution of industries was a major objective of the Maoist government. On the other hand, in the

Maoist era, China was isolated from the international community. The Chinese government perceived that the coast would be the most vulnerable region for military attacks from the outside world. It was with respect to these two basic considerations that the Maoist development strategy, stressing heavy industry and the interior investment policy, was conceived and carried out. Though this approach varied in degree in different sub-periods for the entire Maoist era, it dominated regional development until it faded out in the late 1970s.

Two major programs carried out during the 1960s and 1970s should be mentioned because they were specific strategies that reflected the Maoist approach to regional development: urban-to-rural youth transfer and third-front large-scale industrial construction. A brief introduction to these two programs is in order. First, the urban-to-rural youth transfer, also known as youth rustication (*shang-shan xia-xiang*), was a resettlement scheme to transfer urban graduates of secondary schools to rural and remote border areas during the Cultural Revolution (1966-1976). Three rationales were put forth for the urban youth transfer plan. First, the transfer sought to mitigate difficulties in providing urban youth with employment, as well as to achieve the objective of limiting urban growth. The second reason underlying the transfer plan was ideological. Urban youth lacked first-hand knowledge and experience of rural life. They formed some values and expectations ('bourgeois rights' in the government's opinion) which were regarded by the Chinese government of the time as unrealistic or not compatible with society. Therefore, the ideological purpose was to change the urban youths' values and attitudes. The third purpose of the transfer was that it would contribute to the development of the rural areas, in particular those of frontier regions such as Xinjiang (Northwest), Heilonjiang (Northeast), and Yunnan (Southwest) (Bernstein, 1977; White III, 1979). From the early 1960s up to the beginning of the Cultural Revolution, China dispatched 1.2 million urban youth to the countryside, whereas from 1966 to 1975, 12 million urban youths (10 times larger than the numbers prior to the Revolution) were transferred (White III, 1979: 481). Scholars in China, such as Shen and Tong (1992), considered the number of the transferred urban youths to be about 17 million. The geographical origins of the transfer were the several levels of urban centres. Urban youths from the three centrally administered municipalities (Beijing, Tianjin, and Shanghai) were sent to the rural areas of the frontier or economically backward provinces. They were involved in inter-provincial and long distance movement. On the other hand, within each province a similar principle was also applied. Therefore, short-distance movement was also involved in the transfer process. By the end of the 1970s and early 1980s, with the downfall of the radicals in the central government, the transfer plan ceased to function. Most of the youths sought to return to their urban origins (Gold, 1980).

The second program, third-front construction, refers to the large-scale heavy industrial investment for military purposes in the remote regions of northwestern and southwestern China between 1964 and 1971. Third-front industrial construction was a result of the war-economy mentality of the leadership. During the Cultural Revolution (1966-1976), fears of military invasions from the former Soviet Union and the United States were prevalent, which caused an enforced emphasis on self-sufficiency in industry. The concept of "third-front" construction was based on a defensive strategy. According to the defensive strategy of the country at the time, the coast region and Northeast China constituted the first front; the interior regions of the Southwest and Northwest (excluding

Tibet and Xinjiang) were the third front; and the region between the two was the second front. In order to prepare for possible war, large-scale heavy industries such as defence, metallurgy, machinery, and railway transport, were built in the third front regions of the interior (Yabuki, 1995: 38). The industries were either totally moved from the second front, in particular from the coast region, or newly built in the areas of the third front. The third front regions included provinces of Sichuan, Yunnan, and Guizhou in the Southwest China, the provinces of Shaanxi and Gansu in the Northwest China, and western parts of three provinces, Henan, Hubei, and Hunan in the second front (Linge and Forbes, 1990: 11; Naughton, 1988: 354). Of China's total 85 million *yuan* in basic construction investment in the period 1966-1970 (the third five year plan), investments in the third front construction made up 52.7 per cent (Yabuki, 1995: 40).

Ever since the shift of development to the coast regions after the end of the 1970s, China has stressed the importance of market forces for improving the efficiency of industrial enterprises. The awkward situation of the third front industries became clearer since the locations of these industries entailed high costs of transportation and a lack of markets. Some have now moved back to the coast, and some were reorganised for production other than that originally intended. The initiation of the program and the phasing out of it were paralleled by massive inter-provincial migration. During this program, a considerable number of workers and technical professionals were moved to the provinces of western and southwestern China from the coast, central provinces. Beginning at the end of the 1970s or early 1980s, they gradually returned to their places of origin: some returned due to the fact that plants were moved to the coast or locations near the urban centres, and some returned because of economic opportunities.

The implication for such return flows caused by these two programs is apparent since return flows of migration constitute an important part of inter-provincial migration during the 1982-1990 period covered by the present study.

Unlike the approach to regional development in the Maoist era, China's post-Mao regional development strategy has been biased towards the coast. The rationale underlying this new approach to regional development is based on the economic considerations of the post-Mao leadership. The goal of improving the efficiency of the Chinese economy has been a major consideration since the late 1970s. Therefore, the concept of regional comparative advantage embedded in a free-market system has been stressed. Coast-oriented regional development reflects such an emphasis. According to Yang (1990: 241), the new regional development strategy has four concrete components.

> "First, it assigns each region a special role, taking account of each region's factor endowments—or comparative advantage. Secondly, a series of preferential policies is granted to the coastal region, enabling it to attract most of the foreign investment, along with the advanced technology and management skills embodied in such investment. Thirdly, present central government policy towards the poorer areas has been orientated towards the more pragmatic objective of enabling the poor to feed themselves. Fourthly, the government appears to have put its faith in the promised diffusion or "trickle-down" of growth from the coastal region to other regions."

Of considerable significance in the new regional development approach is the promotion of export-oriented industries and the attraction of foreign investment to the coast region. The labour demands generated by such industries and investments have led to inter-provincial migration biased towards urban centres of the coastal region.

3.3.3 Regional inequality in development

Per capita GDP (the gross domestic product) in 1990 is used as an indicator of development, and the provincial differences in per capita GDP are shown in Figure 3.3. Average per capita GDP in 1990 for China as whole was 1808 *yuan* (*yuan* is China's currency unit; in 1990 the official exchange rate was: 4.78 *yuan* = US $ 1) (see World Bank, 1996). There are obvious differences in development levels among provinces. The most developed provinces are found along the eastern coast. Shanghai heads the list, with a per capita GDP of 5910, followed by Tianjin (3621), and Beijing (3224). These three

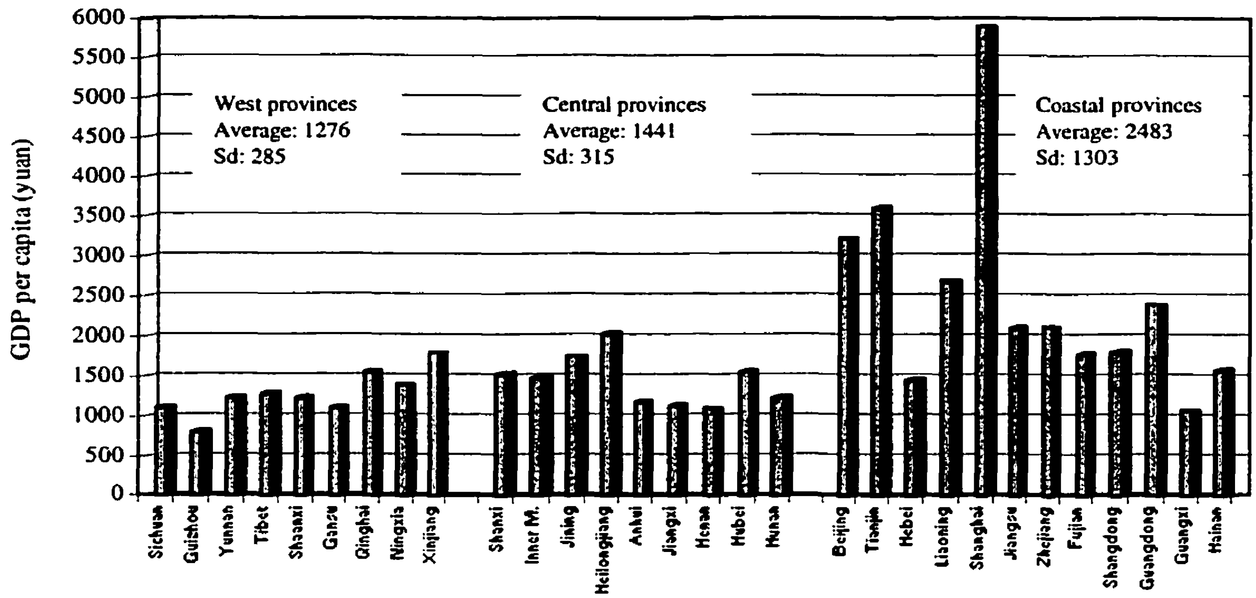

Figure 3.3 Per capita GDP (gross domestic product) for China's provinces, 1990
Source: China, 1996: 173.

centrally administered cities are old industrial centres; moreover, relative to other cities, more restrictions have been exercised over the inflow of population to these three cities.

Next are Liaoning (2698), and Guangdong (2395). Other coastal provinces, including Zhejiang, Jiangsu and Shandong, also have per capita GDP above the national average. Average per capita GDP for all coastal provinces is 2483, much higher than for the central (1441) and western (1276) regions. However, variation in per capita GDP within the 12 coastal provinces is the highest, with a standard deviation of 1303. In the coastal region, Guangxi has the lowest per capita GDP of 1066, making it one of the poorest provinces in China.

Per capita GDP levels in the central and western regions are much lower. In the poorest province of Guizhou, per capita GDP is only 810 *yuan*. Other low per capita GDP provinces are Gansu, Jiangxi, and Anhui, with per capita GDP ranging from 1099 to 1182. It is apparent in Figure 3.3 that the poorest province, Guizhou, is approximately 7.3 times lower in terms of per capita GDP than the most prosperous provincial unit, Shanghai. Although the gap is considerable, the disparity in 1977, shortly after the close of the Maoist era, was even larger. The major reason for the reduction in disparity is the fact that greater labour mobility has allowed people from interior regions to move to and work in coastal provinces, remitting earnings and increasing purchasing power at the origin (Yabuki, 1995: 86).

The above-mentioned contrast between Guizhou and Shanghai can be regarded as an extreme case of rural-urban disparity, since Guizhou has been largely a rural province. For China as a whole, the difference between urban and rural conditions was, and still is, considerable. Income per worker in urban and rural areas changed from a ratio of 3.5:1 in 1975 to 2.9:1 in 1979 (Perkins, 1984: 125). If per capita personal consumption is used as an indicator to evaluate rural-urban disparity, then personal consumption per capita in urban and rural areas ranged between a ratio of 2.85:1 in 1978 to 2.42:1 in 1990 (Chai, 1992: 739). Other sources, such as China (1996), point to a similar range of difference.

3.4 Background of China's migration policy

3.4.1 Overview of China's migration policy

Prior to economic reforms of the late 1970s, China's internal migration policy was carried out in accordance with urban and regional development plans that reflected the philosophy of the socialist planned economy. The principle of guiding China's urban development comes out of the belief that big cities have given rise to problems in areas such as housing, employment, and infrastructure, and that the number of big cities and their sizes need to be regulated. Consistent with this principle, migration was carefully restricted for the sake of social stability and to protect the benefits of urban residents. In particular, rural-to-urban migration was strictly controlled (Goldstein, 1990a). Migration restrictions were carried out through the Household Registration System (HRS). In the period before the late 1970s, some inter-provincial migration had taken place. Such population movement, however, was not based on migrants' calculations of costs and returns, but rather depended upon the socioeconomic planning strategy of the Chinese government (Liang and White, 1996). One of the more important economic strategies in the 1960s and 1970s was to develop the 'inland provinces', which mobilised considerable population with some technical skills from coastal areas into the backward inland provinces. Return migration to places of origin in the coast provinces occurred in the 1980s due to the emphasis on the open door policy (Banister, 1987). Such return migration flows may have brought some distortion to China's inter-provincial migration system.

Since the late 1970s the long-term restricted migration policy has been relaxed with the introduction of economic reforms that aimed at nurturing free-market mechanisms in the socialist economy. This policy change relieved some of the burden of rural China's population pressure, but has also facilitated urban-to-urban migration. The volume of internal migration greatly increased after the late 1970s. Migration in the post-Mao era has been motivated more by economic forces than by administrative and political forces typical of the Maoist period. This shift can be attributed to the gradual introduction of the free-market mechanism in China's economy since the late 1970s. Therefore, in the current era, the basic forces to motivate individual migration are comparable to those of other countries. The empirical relevance of the spatial interaction models for this study extend only to the period of China's economic reforms (1982-1990), since inter-provincial migration data are not available for earlier periods of time.

3.4.2 The Household Registration System (HRS) and migration

In the early years after the Chinese Communist party came to power, there was no specific policy for controlling migration. Even during the period of the First-Five-Year plan (1953-1957), the government relied largely on propaganda efforts to encourage rural people to stay in their home places (Zhang, 1988). However, the propaganda did not work as expected. Since 1956 each individual has been assigned either urban (non-agricultural) or rural (agricultural) registration status, which was the major component of the HRS (Woon, 1993: 578). According to Cheng and Selden (1996: 659), the household registration specifies:

> "All who lived in the countryside and were not state employees were classified as agricultural households (*nongye hu*) and were ineligible for state grain rations. Urban residents and all state employees were classified as urban or non-agricultural households and guaranteed grain rations."

In 1958, the Chinese government stipulated the Ordinances of Household Registration for Chinese Residence, which requires those who wished to move to urban places to have permission from the destination city (Zhang, 1988).

The distinction between agricultural and non-agricultural status was made prior to the HRS. But a full implementation of the HRS was not carried out until the end of the Great Leap Forward (an over-zealous industrial strategy pursued between 1958 and 1960, leading to economic chaos for the whole nation and famine in the countryside) (Woon, 1993: 579; Potter and Potter, 1990: 301-302). To carry out the HRS, each family had a household registration booklet, which indicated the status of the household registration. A copy of the status was kept by the commune or brigade in rural areas, and by the street committee in urban places. If there was a change in the status from rural to urban households, or migration to cities was required, permission had to be granted by the concerned authorities in the places of origin and destination (Goldstein and Goldstein, 1984: 98). Despite this, it was extremely difficult to change registration status from agricultural to non-agricultural. Such a change could only be made in a few ways. These include: (1) to pass the national exams and be admitted to a university or college, (2) to be recruited into the army and become an officer, (3) to convert status through recruitment into some special construction programs, or (4) to marry a citizen with non-agricultural status (Ma, 1992: 95). All these four ways, however, have been very difficult for peasants to achieve.

There is another possible means to change peasant status. When a city government takes over farming land to expand urban land use, peasants involved in the process may change to urban registration. State enterprises may follow the same procedure when taking over farming land from peasants (Goldstein and Goldstein, 1984: 99). Such a conversion of peasant to urban status is more likely to take place near large metropolitan areas.

Not only has migration from rural to urban areas been strictly controlled, but also population migration among urban places with different sizes has been constrained by applying the HRS. As Goldstein and Goldstein (1984) point out, migration from urban places with lower rank (defined by population size) to higher-rank urban places has been strictly controlled, but the reverse movement may be encouraged. In addition, migration from one rural area to another was also controlled during Mao's era "to ensure local self-sufficiency in food production in all parts of the country" (Woon, 1993: 579). It should be noted that control over change in status does not necessarily mean that people cannot move. However, without change in status one cannot obtain daily necessities and social services at the destination. Therefore, it is through control of the food grain and services that mobility is controlled to a maximum degree (Yang, 1993: 798).

Beginning in the early 1960s, it was stipulated, based on the HRS, that a child must take his or her status from the mother's household registration (Siu, 1990; Chan, 1996: 135). Potter and Potter (1990: 296) describe this as a "birth-ascribed stratification" system. According to Potter and Potter (1990: 304), the reason for such a status inheritance,

"may be to restrict mobility as effectively as possible. Since men are much

> more likely to shift status than women, having the child take the mother's status means that far fewer children will shift status."

It is possible, then, that children within a single family had to take different statuses since some may have been born prior to 1960 and took status under their father's registration, supposing that the father had a non-agricultural household status but the mother had not (Siu, 1990: 66). Thus, the system not only divided the country into rural and urban sectors but also differentiated family members with distinct status. As Cheng and Selden (1994: 644) point out, the HRS has served to define the urban-rural relationship, and to form the basis for "establishing identity, citizenship and proof of official status". Consequently, peasants were effectively tied to rural areas, and migration to cities was carefully controlled.

The goal of the HRS, to prevent peasants from coming to urban areas, was consistent with the overall development strategy of the Chinese government that intended to focus every possible resource on heavy industry in cities. Curtailing population migration from rural to urban areas in China may also have some roots in other socialist nations. In this regard, it may be comparable with, even much more effective than, the measures undertaken in the former Soviet Union (Clayton, 1989) and in Cuba (Gugler, 1982).

The imposition of the HRS was in line with the principles of the socialist planned economy in China. Administrative command, rather than market forces, played a key role in the distribution and price of food between the early 1950s and the late 1970s. Rationing of grain was established in all of China but was carried out more effectively in urban China. Grain and other farm products that were extracted at low prices from peasants were supplied to urban residents (Barraclough, 1991: 54; Johnson, 1988). Typically, persons registered as non-agricultural were guaranteed supplies of daily necessities at low cost, ranging from grains and edible oils to cloth and other rationed goods. They were also entitled to receive subsidies in education, medical services, jobs and retirement pensions, and housing benefits. These benefits protected the standard of living for China's urban people. On the other hand, peasants were denied any such benefits, nor were they permitted, under the HRS, to migrate from villages to urban places (Cheng and Selden, 1994; Potter and Potter, 1990).

The motivation behind the HRS was also based on the idea that China's urban population size must be compatible with the capacity of its agricultural production. The categorisation of rural and urban households through the HRS serves this purpose. Controlling urban population growth can lessen the burden of supplying grain rations and other benefits to the urban residents (Chan, 1996: 254), and avoids urban ills such as slums, massive unemployment, and crimes, which have often prevailed in less developed countries (Huang, 1990: 288).

Inasmuch as the grain supply and social services were controlled directly by the government by carrying out the HRS, China succeeded in preventing peasants from coming to cities for more than two decades. The annual growth rate of urban population in China between 1960 and the late 1970s remained as low as about one per cent, as opposed to around five per cent in other developing nations (Benziger, 1996: 541). As a result, poverty was largely confined to the countryside, leading to "a highly segmented society" that resulted in a variety of socio-economic implications (Chan, 1996: 134).

Another consequence of the implementation of the HRS was that "marriages between peasants and workers are made virtually impossible by the practical consequences of the regulation" (Potter and Potter, 1990: 305). In theory, as observed by Ma (1992: 95), marriage may be one of the avenues to change peasant status. Such a marriage might occur only when an urban worker could not find a suitable marriage partner with urban status. If a rural woman marries an urban officer, change in status for the woman would also occur. But such arrangements were rare. Thus it is clear that even though Chinese marriage law allows freedom of marriage the actual practice has been conditioned by the HRS. Based on China's 1987 One Per cent Population Survey, Ma et al. (1996: 889) have shown that the HRS, along with the shortage of urban housing, resulted in about nine per cent of Chinese young couples (under 35 and under 33 years of age for men and women, respectively) living in a separate residence from their spouses, implying about "nine million separated young couples."

Under the HRS, migrants can be identified into two types. Permanent migrants are those who have officially been allowed to change their registration from place of origin to place of destination. Temporary migrants are those who have not changed their registration, even though they may be living in places outside of their origins for some duration ranging from a few days to several years (Goldstein, 1990b: 675). The official HRS statistics on migration usually ignore all migration without change in registration status; that is, they include only those with official registration change (Banister and Taylor: 1989: 9). The discrepancy was very minor prior to the period of economic reforms because it was almost impossible for peasants to migrate to cities without a change in their household status.

3.4.3 Economic reforms and the relaxed migration policy

In the pre-reform era, China has pursued full employment as a goal of the socialist planned economy. As a result, underemployment in agriculture, and overemployment in industry and government institutions, obscured the phenomenon of unemployment that has typically prevailed in many developing countries (Banister and Taylor, 1989). Eventually, the full employment strategy may have greatly reduced the efficiency of the economy as well as labour productivity (Johnson, 1988: S229).

Following the end of Mao's regime in 1976, economic reforms were launched in the late 1970s. In rural areas, a key element of reform was the introduction of the household responsibility system, which replaced the role of the commune by individual family farming units. While farmers do not own the former commune land, they have use rights initially for a period of three to five years but subsequently for 15 years through a lease contracted between the farmer and the State (Johnson, 1988). The former commune has been abolished. Its administrative functions, albeit greatly reduced, have been assumed by township governments. Aside from meeting specified quotas for grain or farm products at government-set prices and after some payment of taxes, farmers could choose what crops they would like to grow and could sell their surplus at market rates. Agricultural sidelines flourished, and some households began to specialise in the production of certain crops or livestock. Outside of agriculture, two forms of economic organisations drove rural economic activities: township- and village-enterprises, and household-run private business. Development of the private sector in commerce and industry in urban areas has also been encouraged. The opening up of free markets in urban areas allowed peasants to sell their products directly to urban residents.

Investments from Hong Kong, Taiwan, and other countries have been attracted to China, in particular to the coastal area, as a result of the comparative advantage of the cheap labour and other benefits offered by the Chinese government.

One consequence of implementing the household responsibility system is that the past underemployment in agriculture has surfaced as an obvious issue of unemployment. The labour force in the villages is still far larger than is actually required under current conditions. The surplus labourers in rural China's villages in 1985 were at least one-third of the total labour force, representing about 100 million people who need to obtain non-farm work (Johnson, 1988). Quoting a range of estimates from 60 to 156 million surplus rural workers from Chinese sources, Banister and Taylor (1989: 4) offered a similar total of 100 million rural surplus labourers, constituting about 40 per cent of farming labour or 25 per cent of the total rural labour force. Li (1996) estimates that China currently has about 200 million people as a rural labour surplus. The *People's Daily* (May 29, 1991, quoted in Ma, 1992: 93), one of the major newspapers in China, has indicated that about 100 million rural labourers were working in the recently created rural and town industries, but still another 100 million were waiting for non-farm employment.

Banister and Taylor (1989: 5) attribute the problem of rural labour surplus to three underlying social-economic factors. First, China had invested much more in industry, in particular heavy industry, than in agricultural and service sectors, thus limiting employment creation in agriculture and services. Second, China experienced high population growth for about two and a half decades, with the rural population growth rate always higher than that of urban areas. Third, the segregation of rural areas from cities by the HRS made the countryside absorb all the added labour force due to natural increase of population.

China's approach to solving the employment problem of rural surplus labourers is to encourage them to leave their land but not their villages. The purpose of this strategy is: (1) to diversify rural labour activity into areas other than cropping, such as animal husbandry, aquaculture, and so on, (2) to promote rural industry, and (3) to loosen restrictions on service jobs, such as retail trade, transportation, repair work, etc. (Banister and Taylor, 1989: 8). However, it is impossible to absorb all the rural surplus labourers through these channels. The Chinese government has, therefore, been driven to reconsider its long-standing restrictions on rural-urban migration. In 1980, China's urban development policy could be summarised as:

> "(1) strictly limiting the size of big cities, (2) properly developing medium-sized cities, and (3) encouraging the growth of small and market and agricultural towns." [1] (Goldstein and Goldstein, 1984: 98).

In line with this urban development strategy, rural surplus labourers are encouraged to move towards small towns and small-sized cities (Banister and Taylor, 1989:10).

A significant policy change to the emerging rural surplus labour and to the increasing mobility potential was made by the State Council of China in 1984. According to this State Council's directive, <u>permanent</u> migration from villages to <u>towns</u> was officially sanctioned. The provision specified that those who could meet the following requirements should be allowed to register as town residents or with non-agricultural status. These requirements are: (1) to provide food grain and the accommodation on their

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[1] China's categorisation of city size in population is: small city (50,000 to 199,999), medium city (200,000 to 499,999), large city (500,000 to 999,999), and extra-large city (one million or more) (Goldstein, 1988).

own, and (2) to engage in some industrial or commercial activities in the market town (excluding towns that are the county seat) (Centre for Population Studies, CASS, 1986). A considerable number of rural residents have been moved to nearby towns on a temporary and permanent basis. There they can easily purchase their food grain and other daily necessities from the free markets. Rental accommodation has also been made available to the farmers (the *People's Daily*, October 22, 1984, quoted in Ma, 1992: 111). Of course, this policy from the central government, like any other policy, is subject to marked local variations in its execution (Goldstein and Goldstein, 1984: 110).

Although the Chinese government promotes the growth of small towns and cities, partly for the purpose of absorbing at least 100 million surplus labours emanating from the agricultural sector, the capital necessary for building such towns and cities comes almost entirely from rural areas. Given the limited financial capacity of the rural areas, it is obvious that all rural surplus labour cannot be absorbed through this channel (Johnson, 1988). Yet the gap in income and in living standards between rural and urban areas remains as before. Restrictions on the permanent migration of peasants to cities are still in place in order to lessen the pressure to provide urban residents with jobs, housing, low-price grain, welfare, and other facilities (Banister, 1987). On the other hand, temporary migrants (those without change in household registration status) were legally allowed to enter urban places initially in certain provinces and later for China as a whole. Meanwhile, free markets are almost ubiquitous in urban areas (Chan, 1996: 137). Considering all these factors, most of the migrants from rural areas to small towns and cities have taken up temporary residence as an alternative option (Goldstein and Goldstein, 1984).

Goldstein and Goldstein (1984: 104-105) identify four forms of such temporary migrants: (1) daily circular migrants, who were living in the outlying suburban areas, and travelling to the city to market their agricultural products; (2) peasant-workers, who obtained employment in city shops operated by townships; (3) construction workers, who worked in the urban construction projects; and (4) peasants who are engaged on their own in services or sales work in both the countryside and cities. It is noted that the daily circular migrants or commuters are very significant in linking rural places with urban areas. They usually retain the contracted farming land in the village for security but earn an income in urban places as a family strategy. Such circular migration is frequently found in other countries such as in Indonesia (Hugo, 1982).

The number of temporary migrants has increased rapidly in recent years. The number of off-farm rural labourers in urban places is estimated to be from 80 million (Li, 1997) to 100 million (*People's Daily*, May 29, 1991, quoted in Ma, 1992: 93; Whyte, 1995: 1014-1015). China's major cities have witnessed an increasing number of temporary migrants. For example, as of 1996, Beijing had 1.7 million temporary migrants, Shanghai 1.6 million, Tianjin 0.6 million, and the Pearl River Delta of Guangdong province three million (Yang, 1997). Major metropolitan areas have also seen an increasing number of enterprises, ranging from hotels to retail stores, financed and managed by peasants, and an emerging dwelling pattern based on rural places of origin (Whyte, 1995: 1014-1015).

Temporary migration has become an important route by which China transfers surplus labour to non-farm employment. This form of mobility has benefited both rural and urban places. Rural people have earned an income through this mobility strategy, while cities have also gained: menial work has been taken over by rural people and these temporary migrants have not put pressure on grain supplies in cities (Goldstein and Goldstein, 1984: 106-107). Although they may not have had a direct impact on the grain supply, they have surely added to the pressure on urban infrastructure, such as transportation, water supply, and so on.

Based on a sample survey conducted in 10 counties of China, Parish et al. (1995) found that about 24 per cent of the rural labour force was in non-farm employment in 1993, and most of them were doing manual work — typically, menial jobs. The investigation has also shown that, in prosperous coastal provinces, those who worked at non-farm jobs outside villages were daily commuters, while in interior provinces many of those working outside villages were long-distance migrants. The coast areas have a high concentration of township and village industries and attracted most of the foreign investment in China. The local residents in such places have gone to nearby towns and cities for non-farm jobs, creating a labour demand for their own farming work, while the farming work has been taken over by migrants from interior provinces (Parish et al., 1995). Thus local labour mobility in the coastal areas resulting from foreign capital or transnational companies has been causing people from interior places to move to the coastal regions. Such a pattern may be, to some extent, comparable with that in some of the Caribbean nations where long distance migration (migration to the core countries) has caused internal population movement from rural to urban places (Grosfoguel, 1995: 245-246).

During the reform period, formal rural-urban migration has also been made easier, particularly to help intellectuals and cadres to end separation from their families or to facilitate a move for a full utilisation of their professional skills (Chan, 1996: 137; Yang, 1996). This category of movement usually involves crossing inter-provincial boundaries, since during the Mao era many people moved into the interior provinces for work in the industries that had been shifted from coastal cities or in locally-built industrial complexes. It is clear that inter-provincial migrants were also motivated by the flourishing of private businesses and industries in some regions, such as the Wenzhou area of Zhejiang, mainly because they were driven to look for raw materials and markets in the whole country (Yang, 1996).

In summary, in the period of economic reform migration policies can be categorised as having three aspects. First, permanent and temporary migration to small towns is encouraged, as indicated in the directives of the State Council in 1984. Second, temporary migration to cities is permitted. Finally, migration between provinces is also made easier for those who wish to be moved, in particular those who have professional skills. All of these policy relaxations have greatly facilitated migration during China's period of economic reform.

3.5 Summary

This chapter involves an account of the background of migration in China. This background is necessary to understand contemporary migration in China. Migration in historical China resulted mainly from natural and man-made calamities; and, to a limited extent, it was caused by economic forces. Therefore, forced migration and frontier colonisation were the main types of population movement in historical China. Migration patterns and causes in the Maoist era (1949-1976) can be attributed to the regime's unique and forceful migration policy and its regional development strategies. As a result, a large number of migrants were displaced for political and military reasons, and voluntarily motivated migration was very limited and generally not allowed. One of the direct consequences of migration in the Maoist period was return migration flow, wherein past migrants have gradually returned to their places of origin. This return flow constitutes one of the characteristics of inter-provincial migrations in the reform period since the late 1970s. To quantify such return migration flows in modelling China's migration would improve the performance of any general model. This topic will occupy a subsequent chapter.

Chapter Four Data and Methodology

4.1 Introduction

In studies of migration, data sources and methodological issues are usually related. As discussed in chapter two, macro and micro approaches are used to examine migration. In the macro- analysis of migration aggregate data are employed, whereas in the micro-analysis of migration individual data are used. Recently, there has appeared an alternative to these two types of units of analysis, called multilevel analysis. In multilevel analysis, both individual data and aggregate data are used for migration studies (Newbold, 1997; Courgeau and Baccaini, 1998). The purpose of multilevel analysis is to combine the advantages of the micro- and macro-approaches, and to uncover factors underlying the migration process, since migration behaviour is not only influenced by the characteristics of individuals, but also determined by ecological factors. Due to the fact that spatial interaction modelling of migration requires data with aggregated form, the present study is a macro-level analysis, which uses areal data from China's population survey and census for spatial interaction modelling. In this chapter, the main concern focuses on data sources and methodology issues for modelling China's inter-provincial migration. The sources of migration data and investment data are discussed. A description of the selection of variables is included. Methodological issues involve the derivation and calibration of the MSIM, the model programmes, and the goodness-of-fit statistics.

4.2 Units of analysis

The definition of migration involves two critical aspects of population movement: one is the time interval within which a person moved out from his or her place of origin, and the other is the geographical boundary that the person crossed. For example, in the definition of migration for the US census, a five-year time interval and a move beyond a city or county boundary have been adopted since the 1940 census (Long, 1988). Such a definition may underestimate the level of migration since intervening movements during this time interval are ignored. There is also a limitation on presenting such migration data on a county basis because the 3,100 counties vary considerably in size and shape (Long, 1988). In spite of the limitations, this convention has been used in the US census and in other countries. Migration data derived from the census are usually available in an aggregated form due to considerations of confidentiality. Nevertheless, individual-level data are also used for migration studies.

Individuals as units of analysis in migration studies are advocated for at least two reasons. First, the motivation for migration is a result of the perceived benefits to individuals or families. As such, the investigation of reasons for migration should begin with individuals or families (Bilsborrow, 1984: 64). This perspective can be called the 'individual motivation approach' for explaining causes of migration (Skeldon, 1990: 126). The individual is viewed as the key decision-maker in the migration process. In order to explain migration patterns migrants and/or non-migrants are interviewed at the time of migration or prior to migration. Reasons why they move or stay can be elicited, and impacts of migration on the area of origin can be discerned (Skeldon, 1990; Bilsborrow, 1984). It is clear that in this approach, survey design and carefully framed questions are important for seeking explanations of migration. Incorporating one or two such questions, used to elicit records of motivation for migration into the national census in developing countries, is evident. For instance, Skeldon (1990) lists five such countries in the Asia-Pacific region having 1980 censuses. This may reflect the fact that developing countries have come to accept the idea that understanding individual decision-makers and their motivation is the key to an understanding of migration. The second reason is that the individual-level data can be fitted more easily into conventional statistical measures and models, or the methodology is already well known and well-established (Garkovich, 1989: 15; Keilman and Keyfitz, 1988: 254-255).

Disadvantages of individuals as units of analysis are several. As Skeldon (1990: 126-150) points out, the idea that an explanation of migration can be derived from individual motivation has diverted attention from broader contextual issues. The individual migration motivation and decision-making process can hardly be isolated from the migrants' surroundings or contexts. Such contexts could be related to the characters of areas of origin and destination, or linked with the macro-political and economic context of the country as whole. Referring to the migration questions in the census, Skeldon also doubts that one single question could appropriately address the complex issue of motivation for migration. He recommends that a specific sample survey can be more appropriate to seek reasons for migration. Using a migration survey, the head of family or household is usually interviewed in order to elicit reasons why it moves. Such surveys assume that the head represents all members of the family and ignores different desires that exist among the family members regarding the move. Therefore, a migration survey can distort the reality of motivation for migration (Garkovich, 1989: 15).

The unit of analysis in migration research is also directed towards the family or household. This view has been particularly emphasised by family economists and family demographers. This view is based on two assumptions. First, the migration decision influences the whole family or household and is taken by the family. It is made by the whole family, or at least by a smaller group of people within the family. The second is that the behaviour of the individual family members is interrelated, and the decision-making for migration has an interactive nature among members of the family (Garkovich, 1989; Keilman and Keyfitz, 1988).

Who should be interviewed for completing questions in the migration survey? If the head of the family or household is interviewed, different desires and intentions for the move may be overlooked as indicated in the preceding paragraph. Another fact is that this approach will clearly underestimate the level of migration in LDCs, since in many circumstances only one or two members of the family move for employment, leaving the rest of the family in the area of origin. Therefore, it seems that the usefulness of this approach may be limited to certain places or particular kinds of moves, such as urban residential mobility. In developed countries, the urban residential move is usually prompted by housing needs that are related to changes in life cycle. In such cases, movement from one location in a city to another involves the whole family rather than only specific individuals. For example, Rossi's (1980) classic study of urban residential mobility in Philadelphia is a case in point. Rossi chooses the household (defined as a group of individuals sharing the same dwelling unit) as the unit of analysis. His study indicates that information given by different individuals within the household varies little. Therefore, the interviewee can be any adult in the household, but "with preference given to male adults" (Rossi, 1980: 67).

In contrast to the units of individual, family or household in the study of migration, the geographical area unit is also employed for analysis. Use of the aggregated areal unit for migration analysis can be traced back to the work of Ravenstein (1885). He describes migration flows between rural and urban areas in the nineteenth century in Britain. One salient feature of this perspective is that migration streams or flows between origins and destinations are involved in the analysis. Such flows can be expressed as a form of a "from-to" migration table and organised in the form of a matrix. A spatial pattern can be discerned through analysing such a migration matrix. Migration flows can provide specific information on how many migrants have been attracted to, or left, a particular area (such as a province in Canada) in a given period of time. When the migration flow data are linked with the socio-economic characteristics of the area, the relative attraction or expulsion of a specific place can be evaluated, and the areal environment and government policies can be assessed. Garkovich (1989: 17) considers that "this (the flow data with economic and non-economic information, added) is the most appropriate measure of area or macro models of migration". Another reason for using the aggregated unit is that aggregating census or register data into the required level of areal unit is less expensive than collecting individual level of data by migration survey (Bilsborrow, 1984: 65). Even though using area units may overlook the role of the individual in decision-making, the migration flow data, together with the socio-economic data, can reveal areal differences in socio-economic conditions on which migration decision-making is based.

The above discussion of the three units of analysis for migration studies focuses on different aspects of the migration process. Analysis using individual, and family or household data emphasises the assumption that the individual or family can be regarded as the centre of migration decision-making, while using the aggregated areal unit for migration analysis seeks macro determinants beyond the individual or family. Skeldon (1990) argues that a significant contribution to migration theory can only be obtained by linking individual or family-level decision-making to the broader economic, social, and political environments. It is difficult, if not impossible, for a single thesis to encompass all three units of analysis. It is therefore necessary to adopt one specific unit for the investigation of migration. This thesis employs the aggregated areal unit. Specifically, China's provincial-level units are used for modelling inter-provincial migration.

4.3 The modifiable area unit problem (MAUP)

One of the main concerns when using aggregated data is the modifiable areal unit problem (MAUP). The MAUP reflects concern that the results of a statistical analysis for cross-sectional data depend upon the way in which the areal units are organized and how the areal units are spatially configured. In other words, the level of aggregation for areal units and the spatial arrangement of zones can affect the results of the analysis. The MAUP can be considered as having two different but related components: the scale effect, and the zoning effect. The scale effect refers to the fact that variation in the analytical result may be due strictly to the number of areal units used in the analysis of given data, or the level of areal aggregation. For example, in a correlation study of the relationship between population concentration and income per capita in China, a difference in such a relationship (i.e., correlation coefficient) would arise using county-level data (more than two thousand counties) and using provincial level data (30 provinces). Such a difference is called the scale effect.

The zoning effect refers to changes in the analytical results due strictly to how a given number of areal units are configured. For instance, differences can arise between the current 30 Chinese provinces and any other 30 arbitrary regions into which the 2,000 counties could be grouped. Such differences are termed the zoning effect. In other words, even with the same number of areal units, a change in boundaries for the areal units may also result in variation for the analytical results.

Figure 4.1 indicates both these effects. Suppose that the numerical values in the figure are population density expressed as persons per square kilometre, or other indicators of economic performance. It is demonstrated from the figure that the mean value varies with

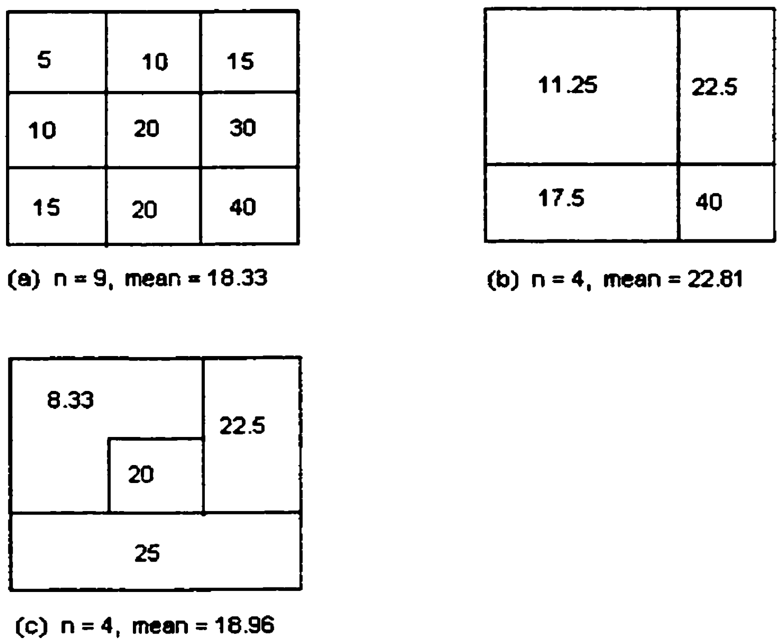

Figure 4.1 Illustration of the MAUP: scale effect - (a) to (b) or (a) to (c), and zoning effect - (b) to (c) (Amrhein, 1995: 106).

the level of aggregation (i.e., the scale effects). Specifically, when the number of areal units changes from nine to four units, illustrated from (a) to (b), or (a) to (c), the mean value changes from 18.33 to either 22.81 or 18.96. The mean value also varies with the zoning effects (see how contiguous units are grouped), indicated in (b) to (c). It is observed that even though there are four areal units for both (b) and (c), the mean value is 22.81 for (b), and 18.96 for (c). Such a difference results from a different configuration with the same number of areal units (Amrhein, 1995).

4.3.1 Two views on the MAUP

There are two general views on the MAUP: (1) the MAUP is pervasive in geographical research, (2) the extent of the MAUP depends upon specific circumstances. Using data drawn from the Los Angeles Metropolitan Region, Clark and Avery (1976) illustrate that the results from a bivariate regression model were sensitive to the level of aggregation and that there was a considerable effect of proximity aggregation on the slope coefficient of the bivariate regression model.

According to Anselin (1988), the MAUP was brought to the wider attention of geographers by Openshaw and Taylor (1979). Openshaw and Taylor's paper is a much more comprehensive study of the MAUP. Their study involves some experiments using areal data from Iowa, USA. One of the experiments is the correlation between the vote for Republican candidates in the congressional election of 1968 and the population aged 65 years old and over in 1970 (these two variables were taken as percentages) based on the data from the 99 Iowa counties. The correlation based on the data of the 99 counties is 0.3466. The 99 counties were combined into six new areal units according to different areal arrangements, producing another five correlation coefficients, which were different from that based on the 99 counties. The correlation coefficients of these five alternative combinations of the 99 counties are: (a) six functional regions 0.7128, (b) six urban/rural regions 0.8624, (c) six congressional districts 0.2651, (d) six democrat-proposed congressional districts 0.6274, and (e) six republican-proposed congressional districts 0.4823. Hence differences between the correlation coefficient at the county level and any one of the correlation coefficients of the five alternative aggregations reflect the scale effects, whereas differences in correlation coefficients among the five alternative aggregations indicate the zoning effects. Moreover, Openshaw and Taylor illustrate the limits of the zoning effects at different scales for the correlation by applying an automatic zoning algorithm. Their general observation is that as the scale decreases (or the number of areal units increases), the range of possible correlation coefficients also declines. In other words, for a series of correlation coefficients for each scale, the variance of the distribution of the correlation coefficients declines with decrease in scale (Openshaw and Taylor, 1979: 130-132).

Finally, they demonstrate that statistical results were "found to be much more elusive than initially expected" (Openshaw and Taylor, 1979: 142). Their general conclusion is that the MAUP is "much more complex, ... each areal unit problem must be treated individually" (Openshaw and Taylor, 1979: 142-143).

Fotheringham and Wong (1991) extend the MAUP into multivariate statistical models. Based on the 1980 census data of the Buffalo Metropolitan Area (the data were aggregated into 871 block groups and 271 census tracts), they estimate the parameters of both a multiple linear regression model and a multiple logit regression model. Their results show that the parameters are sensitive to variation in both scale and zoning effects.

Amrhein and Flowerdew (1992) undertake simulation experiments on the MAUP using Canadian migration data at the level of the census division. The original 260 census divisions were aggregated into 130, 65, and 10 synthetic regions to calibrate a set of Poisson regression models. The results show that aggregation effects on the parameters of estimation are not observed. Therefore, Amrhein and Flowerdew conclude that the MAUP may be associated with the choice of statistical model. In other research, Amrhein (1995) challenges the notion in the literature that the MAUP is overwhelming and pervasive in the analysis of areal data. His experimental research assumes a space consisting of 10,000 locations in which each location I s an individual. In order to illustrate the scale effects, the 10,000 individuals were aggregated into 100, 49, and 9 areal units, and to capture the zoning effects at each aggregation level, a series of randomly generated data sets were obtained. These experiments were linked to actual areal units of northwestern counties of England and sociodemographic data from the British census. Amrhein's results indicate that means and variance are not subject to the aggregation effects (scale and zoning effects), whereas the parameters and correlation statistics exhibit such effects.

The MAUP in the calibration of spatial interaction models has also been explored at different spatial scales. For example, Openshaw (1977) illustrates the effects of scale and zoning on the calibration of spatial interaction models. The MAUP was observed in the parameters estimated across the zoning systems and at three different scales. Openshaw (1977) attempts to find an optimal zoning system which approximately optimises goodness-of-fit statistics of SIMs. Batty and Sikdar (1982) indicate that a measure of spatial entropy can be decomposed into different components reflecting attributes of areal aggregation and that these attributes can be employed to evaluate variations in parameters derived from a population density model. This line of analysis was later extended into more complicated gravity models. Putman and Chung (1989) examine the MAUP in spatial interaction models with multiple parameters. They investigate five ways of aggregating the basic spatial units (BSUs) into 30 zones. The first is random aggregation (RA), and the other four are systematic aggregation procedures consisting of equal numbers of BSU for each zone, equal total area, equal population, and equal number of low-income households. Their overall conclusion is that the systematic aggregation methods produce better results in terms of parameter consistency and goodness-of-fit statistic than the RA method.

4.3.2 Proposed solutions to the MAUP

Several solutions to the MAUP have been explored. For example, Fotheringham and Wong (1991) suggest three possible approaches that may reduce the extent of MAUP. The first is to report results at different levels of aggregation scale and also with different zoning systems at the same aggregation scale. At the end of an analysis one can appreciate the extent of the MAUP and can find at which aggregation level, or with which zoning system, the results are more stable. This can lead spatial analysts to explore reasons underlying the results. The second solution is to avoid the use of areal data. The third solution is to optimise the zoning systems. However, what constitutes 'optimal' is a matter of subjective judgement. For example, Fotheringham and Wong (1991) argue that in multivariate analysis, a zoning system that may be optimal for one variable is not optimal for another. The second way of reducing the magnitude of the MAUP, as admitted also by Fotheringham and Wong themselves, is almost impossible. Census data are usually in aggregated form because of confidentiality considerations, and some data (e.g., population density) are not meaningful at all at the level of the individual.

The third approach is also explored by Openshaw (1977). In spatial interaction modelling Openshaw considers that in order to obtain the best possible results an optimal zoning system can be created using an algorithm to generate a random spatial partition. The zoning system is considered 'optimal' when it produces the best performance for the model in terms of goodness-of-fit statistics. One of the concerns arising from the optimal zoning system is that a zoning system that is optimal for one specific spatial interaction model may not necessarily be optimal for another. Another major concern is that even if some reasonably good results may be obtained using an algorithm to generate optimal zoning systems, one can question whether the optimal zoning system is meaningful in the context of the existing boundaries which are based on historical, cultural, administrative, and geographical considerations. Regarding this point, Anselin's (1988: 27) idea maybe worth citing:

> "In other words, unless there is a homogeneous spatial process underlying the data, any aggregation will tend to be misleading. Consequently, this aspect of the MAUP should be considered as a specification issue, related to the form of spatial heterogeneity, and not solely as an issue determined by the spatial organization of the data".

Research results provided by Amrhein and Flowerdew (1992), Amrhein (1995), and Batty and Sikdar (1982) indicate that an appropriate choice of model is as critical as aggregation in any modelling process based on areal data. In Amrhein's (1995) opinion, the differences in statistical results from Fotheringham and Wong (1991) cannot be strictly attributable to the MAUP, since no evaluation was made on whether a multicollinearity issue exists among the independent variables, or whether there were missing variables. This implies that a careful specification and choice of model, such as an examination of whether the data are normally distributed (Amrhein and Flowerdew, 1992: 1390), are critical before reaching a conclusion as to whether or not results are sensitive to the MAUP.

4.3.3 A related but different term: the ecological fallacy

A related term is the 'ecological fallacy', first put forth by Robinson (1950). In his seminal paper, Robinson shows that the correlation at an aggregate level differs from that between the same variables at the individual level. Specifically, Robinson demonstrates that the correlation between the proportion of people who were black and the proportion who were illiterate was 0.95 when calculated at the level of nine geographical regions in the USA, whereas the correlation between the same variables was 0.20 when calculated based on the individual level data. The conclusion is that the aggregated correlation cannot be applied to the correlation at the individual level data. It is clear that the issue of ecological fallacy in fact corresponds to the scale effect in the MAUP. In the geographical literature, reasons for the ecological fallacy were given by Openshaw (1984) and by Fotheringham and Wong (1991). As areal units are aggregated into areas larger in size, intra-areal differences are reduced, or units are more homogeneous, leading to a situation where the differences between the ecological and individual correlations reduce. Fotheringham and Wong (1991) illustrate how the causes underlying the ecological fallacy arise from the components of the formula of correlation coefficient for a bivariate case. The correlation coefficient can be calculated by dividing the covariance of x and y by the product of the standard deviation of x and y. When the aggregation level increases, the variation of the variables tends to decrease because of smoothing effects, such as that due to averaging the variables. Thus the standard deviation of x and y decreases, and the correlation coefficient will increase if the covariance between x and y remains relatively stable.

Goodman (1959) proposes a possible correction procedure that could forecast the correlation at the individual level based on a regression model between variables at the ecological level and at the individual level. This line of research is continued by Firebaugh (1978), Tranmer and Steel (1998), and by Courgeau and Baccaini (1998). Firebaugh introduces a rule for the bivariate case, which can be used to infer individual level relationships from aggregated data without bias. According to this rule, when the group mean of the independent variable has no effect on the dependent variable, with the independent variable controlled, the bias will be absent. Tranmer and Steel (1998) present a statistical model that can be used to account for the effects of aggregation on variances and correlations.

Courgeau and Baccaini (1998) suggest that multilevel analysis can be used to study the individual processes that take place in geographical space. The conceptual framework underlying this approach is that the behaviour of individuals is not only influenced by their own characteristics but is also conditioned by ecological features particular to each spatial unit. This approach involves both individual level data and areal level data, and is carried out using exponential, logit regression, and the event history model.

In commenting on the issue of the ecological fallacy, Fukurai and Alston (1992) argue that investigations undertaken at the individual level and at the ecological level are for two different purposes. In their opinion, if analysts are concerned with the beliefs and attitudes of individuals, an individual-level investigation should be carried out. However, if we are to investigate socioeconomic variation in communities or regions, areal data should be employed for analysis. Their comments echo the idea suggested by Lieberson (1985: 107):

> "The ecological correlation between spatial aggregates is not itself inherently erroneous; what is potentially fallacious is the assumption that the linkage at one level need occur at another level. In my estimation, the ecological fallacy is nothing more or less than a specific example of a widespread tendency in social research to mix up and confuse the appropriate levels of analysis".

Although the MAUP is an interesting issue in geographical modelling, the main concern of the present study is to validate the MSIM using the migration data of China. If the proposed model in this research can be successfully verified, it may provide some basis for incorporating the MAUP in further studies of Chinese migration.

4.4 Data sources for the present study

The conventional and multiple SIMs used in the present study are macro-migration models. Such models predict migration (or any other interaction) flows in aggregate form, and require aggregated data, such as province-to-province migration flow data. Whether the original data are for the individuals or for families and households, when they are used to calibrate such macro models, the data must be entered into the models in an aggregated form. Therefore, the focus of the model is on the total number of province-to-province migrants and not on individuals or families. As Akwawua (1995) indicates, the migration flow data used in spatial interaction models should have two features: (1) the migration data need to be able to indicate the flows between specific origins and specific destinations, and (2) the data should be presentable in the form of a matrix. However, for other data input into the migration models used in the present study, such as socioeconomic data, these features may not be necessary.

4.4.1 The inter-provincial migration data

The present study employs Chinese migration flow data from two major sources: The 1987 One Per Cent Population Sample Survey (referred to as the 1987 survey) data and the 1990 National Census (referred to as the 1990 census) data. These two data sets combine to record the inter-provincial migration flows in the form of a from-to table among the 28 Chinese provinces.

The 1987 survey inter-provincial migration data

The 1987 survey was undertaken by the State Statistical Bureau of China (China, 1988). The Statistical Bureau of China published the results of the survey as *Tabulations of China's One Per Cent Population Sample Survey, National Volume.* This published material also included the source questionnaire and explanatory notes for this survey. Based on this attached information, some details of this survey are revealed. The survey addressed direct and indirect questions on migration to persons living at the current place of residence with a duration of less than five years.

The survey had four questions related to migration. (1) "Is your household registration in the current place or not, or pending?" (2) "How long have you lived at the current place?" As to duration, interviewees had the choice of a 'less than one year', 'one to two years', 'two to three years', 'three to four years', and 'four to five years'. (3) "From where did you migrate?" Interviewees had the choice for answer: from which province and what is your original residence city, town, and county? (4) "Why do you migrate?" Interviewees had nine reasons from which to choose: job transfer, job assignment, manual work and commerce, education, move to relatives and friends, retirement, family migration, marriage reason, and unknown reasons.

This survey collected information about inter- and intra- provincial migration in the period from 1982 to 1987. The 1987 survey tabulated inter-provincial migrants as those who moved from cities, towns, or counties of other provinces to the place of enumeration and were living there on 1 July of 1987. It should be noted that the place of enumeration, or the current place of residence, is also classified into cities, towns, and counties. The data involve two types of migrants: (1) those who registered their official residence to the current place and; (2) those who did not, but had left their place of registration for at least six months, and had lived in the current place for five or fewer years. An inter-provincial migration matrix can be generated from this survey.

As discussed in Chapter 3, in China, particularly in the reform period, there are two types of migrants: those who moved into their current residences with changed household registration, and those who migrated to the current place but left their household of record unchanged. These two types of migrants are referred to as 'permanent' and 'temporary' migrants, respectively (Goldstein, 1990b); or 'official' and 'nonofficial' migrants (Ma, et al., 1997). The migration data from China's household registration system exclude the temporary migrants, irrespective of their duration of absence from a permanent residence. Thus, migration levels may be underestimated. On the other hand, the inclusion of all temporary movements as migrations may result in the overestimation of migration levels because some of the movements may only be the result of short visits and travel. Thus use of a fixed duration in order to include temporary migration results in a trade-off between the two extremes (Ma, et al., 1997: 712). The duration used to define 'temporary migrants' in the 1987 survey is six months. This implies that those who moved into their current cities, towns, and counties from other provinces are counted as inter-provincial migrants after having left their areas of origin for over six months.

The 1990 census inter-provincial migration data

The second data source is based on the inter-provincial migration data generated from the 1990 census. The standard time for this census was at zero hour, 1 July 1990, and was successfully completed on July 10, 1990 (China, 1993). Prior to the 1990 census, China had taken three national censuses, carried out in 1953, 1964, and 1982, respectively. The State Council of China decided that, beginning with 1990, a census would be taken every ten years (Shen, 1990: 31).

The 1990 census added two new items to the 19 questions used in the 1982 census. One of the added items was related directly to the migration issue. As in the 1987 survey, the 1990 census addressed direct questions to persons aged five years and older, including "where did you live five years ago?" and "what reasons caused your migration?" Therefore, not included were: (1) persons under five years in 1990; (2) those with intervening moves; (3) those who moved and returned in the period from July 1, 1985 to July 1, 1990; and (4) movements within a county or city. Such limitations are common among national censuses in other countries, such as the US census (Long, 1988: 8).

Regarding reasons for migration, the 1990 census followed the 1987 survey in the nine reasons specified. The respondents were required to choose only one reason from the nine. If, for some respondents, several reasons explained their migration, they were asked to give only the main reason (China. 1993: 514). As discussed in Chapter 3, under the

Chinese HRS, two types of migrants (permanent and temporary) can be identified. The 1990 census also included the temporary migrants. The duration used to define migrants was one year.

Based on the 1990 census definition, migrants were referred to as those whose current place of residence on 1 July 1990 was in a different county, city, or town compared to that as of 1 July 1985. They included: (1) all those who changed their official residence registration to the new counties or cities, and also (2) those who did not, but had left their place of origin for at least one year and had lived in the new localities for up to five years (China, 1993, vol. 4: 509, 512-513). Data on inter-provincial migration are available in the form of tabulations from the 1990 census. As for tabulations of the 1987 survey, the 1990 census distinguished between inter- and intra-provincial migrants. Inter-provincial migrants were those who moved to the place of enumeration from cities, towns, and counties in other provinces. A 28 by 28 inter-provincial migration data matrix can be derived. These migration data can further be disaggregated into total, male, and female populations. Such disaggregations create a unique opportunity to make some empirical observations regarding male and female inter-provincial migration in China through modelling with SIMs.

One concern arises from the fact that the duration used to define the temporary migrants is different between the 1987 survey and the 1990 census. The 1987 survey used six months while the 1990 census used a duration of one year. According to Tu (1996), if the 1990 census had adopted six months as the duration to define the temporary migrants, migrants would be 5.63 per cent more than those that resulted from the one year duration that was actually used for China as a whole. Applying the discrepancy of 5.63 per cent for each province does not reflect reality, since each province was likely to have a distinct discrepancy level. However, such detailed data for each province are not available. On the other hand, on the basis of experimental modelling, it is found that by adjusting migration data, using a discrepancy of 5.63 per cent for each province, the parameters of the model estimation are observed to be the same as those using unadjusted data. Therefore, the present study did not adjust the 1990 migration data.

4.4.2.Data for distance matrix

In conventional SIMs, spatial separation or distance is the only variable used for explanation (Fotheringham, 1997). There are a variety of measures for spatial separation that may be employed to calibrate the SIMs. Three general measures can be found in the existing literature, these being distance, cost, and time. These three measures can be obtained either by direct observation or by interviewing individuals regarding their perceptions of spatial separation, although the direct observed distance is the most widely used variable (Fotheringham and O'Kelly, 1989).

In previous applications of conventional SIMs to migration or mobility, inter-urban migration modelling usually employs the distance variable while modelling of intraurban movements, such as shopping trips and the journey-to-work, may use any one of the three measures. According to Fotheringham and O'Kelly (1989: 8-9), even in modelling intraurban movements physical distance is usually used as a surrogate for travel time or cost because of the difficulty involved in measuring actual time and cost. The distance measure can be obtained with minimum effort either by using some formula based on the coordinates of points (Fotheringham and O'Kelly, 1989: 8; Akwawua, 1995: 96), or by direct observation and measurement based on a map.

In calibrating a Poisson regression model using migration flow data between 30 functional regions in England and Wales in 1980 to 1981, Fotheringham and O'Kelly (1989: 98) use straight-line distance in kilometres between centroids of the functional regions as a measure of spatial separation. They emphasize that distance used is not a surrogate for migration costs, but rather a measure reflecting information decay and uncertainty. In an empirical verification of an alternative SIM using migration flow data between nine US census regions in the period of 1965-1970, Tobler (1983) uses distance in miles between centroids of the nine regions. Using centroids to obtain the physical distance is common in the calibration of migration models. However, distances can change as a result of aggregating smaller areas into larger regions (or vice versa) (Rodriguez-Bachiller, 1983). Therefore, a model calibrated using migration data may only be valid at a given level of aggregation, and cannot be used to predict migration flows at another aggregation level.

The present study uses physical distance as a measure of spatial separation, measured as the straight-line distance among the 28 Chinese provinces using the largest provincial population centre as the population "centre" of a province. In China, all provincial capital cities correspond to the largest cities. As pointed out by Akwawua (1995), the use of the provincial largest city as the centroid is based on the assumption that the largest city and its interacting surrounding areas are centres which attract and generate migration flows. One may wonder whether road distance could instead be employed as measure of spatial separation in China. Migration from one province to another in China can be undertaken through several routes (as, for example, between provinces of Guangdong and Guangxi). In such circumstances, it is difficult to choose which route is the best for the road distance. Also, in general the straight-line distance and the road distance are closely correlated.

Therefore, the use of the straight-line distance can overcome some awkward situations of selecting among several road distance candidates, and it can be obtained with reasonable effort. The unit of distance used in the present study is kilometres. The distance matrix for China's 28 provinces is included in Appendix A.

4.4.3 Investment data

In chapter one, two criteria were mentioned for selecting variables entered into the MSIMs. These are: (1) eliminating the multicollinearity problem, and (2) improving the model's performance. Based on these two criteria, two variables (average annual investment and the migrant stock) were selected. The justification for inclusion of these two variables is discussed in a following section. A description of the investment data is made first.

Capital investment determines the capacity of production of cities and regions, so that it creates opportunities for employment. In free-market circumstances, it is assumed that capital, as a factor of production, may freely flow to places, firms and sectors where maximum profits can be gained (Gertler, 1987). Therefore, regional patterns of investment can be considered as one of the major factors that influence regional economic development and regional flows of migration. In China, even though forces that determine the investment pattern may be different, particularly so prior to the economic reform of the late 1970s, it is still observed that capital investment determines productive capacity, creates labour demand, and eventually prompts inter-regional migration. For example, Fan (1995) discusses how China's investment patterns can be used to explain regional economic development. In another paper, Fan (1996) employs foreign investment as one of the two variables (another is industrial and agricultural output) to explain migration patterns in the province of

Guangdong. She concludes that foreign investment was the second most important variable to account for county patterns of migration in the province between 1985 and 1990.

The present study uses data on total investment in fixed assets. The data are compiled by the State Statistical Bureau and, as part of major statistical material officially published by China's Statistical Publishing House, entitled: *China Regional Economy: A Profile of 17 Years of Reform and Opening-Up* (China, 1996). Based on sources of finance, the total investment includes domestic loans, foreign investment, fund raising, investment from the central government's appropriation, and others. Thus the total investment data are much more comprehensive than the data on foreign investment. The data are divided into two periods: 1985-1987, and 1986-1990; the data prior to the year 1985 are not available. Due to the fact that total investment fluctuated on an annual basis, the investment data are employed as an annual average aggregate.

4.4.4 Quality of the data

Researchers in other countries may doubt whether the Chinese statistical data are reliable. Such a suspicion may be particularly strong regarding data from the period 1958-1976 (Banister, 1987: 12-13), though the statistical agency of China argues that some major economic figures in the ten chaotic years 1966-1976 can be regarded as being reliable (Li, 1984a). China set up the State Statistical Bureau in late 1952 (Banister, 1987), and attempted to build the statistical system in the subsequent five years, with the help of the former Soviet Union. However, major flaws were evident in the system. For example, prior to the late 1970s statisticians who were educated in the West were excluded from the system; some data could not be accessed in the name of national security; and modern statistical methods were seldom employed. The worst situation was in the period of the Great Leap Forward (1958-1961) and at the height of the Great Cultural Revolution (1966-1970). Comprehensive statistical work was disrupted during these two periods (Li, 1984a). In 1970, a statistical office was established under the State Planning Commission, and in 1978 the State Statistical Bureau was set up under the State Council (Li, 1984a). Since the late 1970s, in particular, with the successful completion of the 1982 national census, there has been a large increase in economic and population data released by the State Statistical Bureau. Also, the coverage of the statistics was expanded and the reliability of the data was improved (Chow, 1986). In discussing the quality of migration and investment data, quantitative investigation of the data was beyond the scope of the present study. However, based on the organisation, procedure, regulations, and methods involved in data collection, we may understand how good the data quality is. The migration data are first discussed.

The 1987 survey provides the inter-provincial migration data. The standard enumeration time of the survey was on July 1 of 1987. One per cent of the whole population was sampled at random across the country, implying that approximately 10,711,652 persons were surveyed (*Beijing Review*, 1988). The so-called one percent sample of the 1987 survey refers to the data at the national level. However, for different provinces, it was based on a stratified sampling strategy, implying that a different sampling intensity was adopted for different areas. In fact, the intensity ranged between 0.6 per cent (Sichuan) and 2.5 per cent (Ningxia) (Ma, et al., 1997). In each province, the sampling intensity for cities, towns, and counties was proportional to the respective population sizes. In order to correct the distorted migration patterns due to the different sampling intensities, different weights were applied by the State Statistical Bureau in making migration tables (Ma, et al., 1997) that are used for the present study.

The successful completion of the survey indicates that the migration data may be of reasonably good quality. Several reasons for this can be summarised. First, the migration questions incorporated into the survey were consistent with those of the international convention adopted by the western countries, such as the US census. Specifically, the geographical boundary for defining a migrant was a county or city, and the time period for defining a migrant was half a year in order to capture the temporary migrants in China (the US census usually uses a one-year limit).

Second, the 1987 survey was undertaken on the basis of the experiences of the 1982 national census and the one per thousand fertility survey in the same year. The 1982 census, also known as the third census, gained international attention because of China's large population size and included many more items than the first two censuses. The 1982 census was deemed highly successful in terms of the data reliability (Banister, 1987; Coale, 1984). The high reliability of the data from the third census was also confirmed by the one per thousand fertility survey conducted in September 1982, less than three months after the third census (Caldwell and Srinivasan, 1984). The third census did not incorporate direct migration questions. However, it identified those who were absent from their household of registration for at least one year. Incorporating this item into the census provided important information for counting temporary migrants in the 1987 survey. For the first time, the third census used computers to process data, and it also gained international assistance in the form of technical training and finance (the UN provided US$ 15.6 million) (Li, 1984b: 15). Pilot censuses and post-enumeration checks were conducted. The post-enumeration check, using sampling methods, revealed that the overcount was 0.71 per thousand, the undercount 0.56 per thousand, and the net overall count 0.15 per thousand (Li, 1983: 336-337). These indicators show that the data quality of the 1982 census reached a high level (Zeng, 1991: 8) even compared with censuses in Western countries. For example, even though the accuracy of the US census has improved since 1940, the net undercount for the US 1980 census was 1.2 per cent, and for the 1990 census was 1.8 per cent (Gibbs, 1998: 17). The U.S. net undercount in the 1990 census exhibits variations between ethnic groups (a higher undercount for blacks than for non-blacks) and among geographical regions (a far larger rate of undercount for the south and west regions) (Anderton, et al., 1997: 59-60).

Finally, the unique features of Chinese central administrative power (discussed in section 3.3.1 of Chapter 3) facilitate a strict and efficient implementation of the population census and survey. Since collectivisation in the 1950s, the State has established direct contact with individuals. In the first census, conducted in 1953, a Soviet census advisor indicated that people had no place and no incentives to evade the census authority due to the "omnipotent and omnipresent" State government (Ho, 1953: 88). Organisation of the third census was in a hierarchical manner. Specifically, a census office was set up under the State Council, and it extended into the levels of province, county, commune (township), and brigades (Li, 1984b: 9). The 1987 survey was carried out by these existing census offices at all administrative levels in China.

Migration questions were included in the 1990 census. As discussed in the previous section, the geographical boundary and the duration of time used to define a migrant is comparable with those used in the US census. The organisation, procedures, and methods for the census were almost the same as in the 1982 census. The 1990 census was acclaimed a success. In order to check the quality of the census, a sample of 173,409 persons was drawn after the 1990 census. Based on the census check, the overcount rate was 0.1 per thousand, the undercount 0.7 per thousand, and the net undercount 0.6 per thousand. The error rate for reporting sex was 0.14 per thousand, and for reporting age 3.07 per thousand. The undercount for birth was 1.03 per thousand, and for death was 4.9 per thousand (*Beijing Review*, 1990).

China's one-child policy is well implemented in cities, but it breaks down in rural areas (The Economist, 1996). In order to evade punishment due to violation of the policy, one ruse is for local authorities to report an illegal birth (birth beyond the policy quotas) as an inmigrant (Zeng, et al., 1993). If this practice were eliminated, the recorded migration level would provide a better estimate. The Chinese census authority fully realised this situation and took several appropriate measures (Shen, 1990). First, an illegal birth reported in the 1990 census can apply for formal household registration status (no longer illegal once the birth is reported). Second, local officials who did not carry out the birth control policy adequately, and concealed the truth for fear of political disgrace prior to the census, would not be punished once they reported the number of births accurately. Finally, the census officials also explained to the masses that the purpose of the census was for the government to understand demographic reality so as to furnish a scientific basis for formulating social and economic policies, rather than to aim at the birth control target.

Another concern is related to how the Chinese census authority registers the surging numbers of temporary migrants. In China, the temporary migrants are also called the 'floating population', implying that their living place is in a state of frequent change. The census office under the State Council stipulated the following regulations to guide the counting of the temporary migrants:

> "Those living in a rented house must be registered in the census area where the house is located. Those living in the dormitories or factories and enterprises, as well as in work sites must be registered by census staff (census enumerator) in charge of the census area where the units (working places) are located. Those who live in mountain areas, roadsides and self-built cottages must be registered by census staff in the census areas. Those who have no stable residence, and live on the streets, in open grounds, and under bridges should also be timely registered when they are asked by the local census staff, and be given a 'certificate card' indicating that he or she has been counted" (Shen, 1990: 32).

After these measures were taken in the 1990 census, the migration data came to reflect the general reality more accurately (Shen, 1990). The migration questions were not included for the 1990 census in Tibet, so the present study excludes Tibet from analysis.

With regard to the quality of investment data, it is useful to introduce some background on the collection of economic data. Since the late 1970s, in particular with the release of the 1982 census data, a large number of economic statistical data have been made available to the public. For example, the State Statistical Bureau has published China's Statistical Yearbook since 1982 (Chow, 1986). Western scholars showed great interest in using such statistical data, and at the same time also were concerned about the quality of the official data. According to Chow (1986), an economist at Princeton University, the quality of the official data would depend upon the circumstances in which they are collected. He gives three factors that may have some important bearing on data quality. These three factors are: (1) the quality of technical personnel; (2) the effectiveness of Chinese government control over its residents down to the "grass-roots" level; and (3) the ramifications of political pressure. For the first factor, in the early years of the 1980s, the number of people with appropriate statistical training was small. This was particularly true at provincial and county statistical bureaus. This situation has been gradually improving since the completion of the 1982 census and the one per thousand fertility survey in 1982, with technical assistance from the United Nations. Collaboration of China's Statistical Bureau with the American Statistical Association was undertaken in the middle of 1980s. The purpose of collaboration was to train Chinese personnel and to improve the statistics curriculum at major Chinese universities (Chow, 1986). As for the second factor, it is usually believed that tight and efficient control over the Chinese masses is a positive factor for the quality and collection of statistical data. Regarding the third factor, the disastrous experience of falsifying statistical data due to political intervention in the past provided bitter lessons for the government. An obvious example of such a lesson was the excess deaths of about 30 million people caused by the Great Leap Forward of 1958-61, in which falsified statistics were used for formulating economic policy (Ashton, et al., 1984; Chang and Wen, 1997). The lesson drawn from such experience by the central government was that an independent statistical reporting system is required for an objective assessment of economic performance and for making policy (Ashton, et al., 1984). Concerning the situation of China's statistical reporting in the 1980s, Chow's (1986, 194) observation may be worth quoting here:

> "It is my judgement, to be justified forthwith, that by and large Chinese statistics officials are honest. They would make an attempt to correct the data when false reporting is easily detected. My judgement concerning the honesty of Chinese statistical officials is based on personal contact, internal statistical evidence, and an announced government policy".

On December 8, 1983, China's Congress passed a "Law on Statistics of the PRC". The law mandates that honest statistical reporting at all levels of the Chinese society (and at the statistical bureau) is required, and failure to obey the law will be punished. For the first time, the law also stresses the administrative independence of statistical reporting, and condemns statistical data based on political interference as illegal (Banister, 1987; Chow, 1986). The carrying out of this law may reduce some of the influence of the political intervention, as frequently observed in the Great Leap Forward and the Cultural Revolution.

Based on the above discussion, the investment data at the provincial level may be considered a reasonable good quality. This judgement can be supported from two points of view. On the one hand, the internal evidence from the investment data used in the present study reveals consistency in the data. The investment data are broken down into several categories according to ownership (state-owned, collective-owned, and private-owned enterprises). They are also divided into categories based on the source of investment funds (such as domestic loans, foreign investment, funds-raising by local government, state appropriation, and others). A careful check indicates that the amount of investment based on ownership is consistent with that based on sources of the investment. On the other hand, from the sources of investment, it seems that there are no incentives for the provincial level of government to falsify the investment data, since most of the funds are required to pay interest, such as domestic loans, funds-raising, and foreign loans provided by the World Bank. In addition, unlike economic performance data (which are reported by local units, compiled upward first by county governments, then by provincial government, and finally by the central government), investment data are not subject to such process.

4.5 Selection of variables

Two variables, migrant stock and annual average investment, are selected for the modelling of the Chinese migration using the MSIMs in the present study. A discussion of the selection of these two variables is in order.

4.5.1 Migrant stock

Migrant stock refers to a group of people who previously moved to a destination, implying that each area of origin has a number of migrants who are already at the destination. Migrant stock is considered a major indicator of social networks, which are of pivotal importance in labour migration (Montgomery, 1991). Viewed in this way, it can constitute a social indicator that influences migration. Using the previous migrants, or migrant stock, as a variable to explain the current migration patterns can be found in regression studies of migration in the neo-classic economic approach (Greenwood, 1970; King, 1978; Waldorf, 1996; Carrington et al., 1996). It has been observed that previous migrants are positively associated with subsequent migration and are considered to be a significant factor in explanation of migration patterns (King, 1978; Fik et al., 1992).

Migrant stock also relates to the concept of chain migration. In the migration literature, the concept of chain migration covers a group of initial or pioneering migrants who first moved from the home community and are then followed by subsequent migrants, who are usually the initial migrants' relatives, friends, neighbours, and acquaintances in their origin community (Ogden, 1984: 5). The notion of chain migration is supported by the fact that information at a destination is sent back first by initial migrants, and later by all the migrants at the destination. Such information diffuses at the home community, and eventually "influences the movement of other individuals" (Ogden, 1984: 31). Emphasis on the roles of friends and relatives, who are major facilitators of the migration chain, in the distribution of migration can be found abundantly in the literature of migration (Nelson, 1959; Tilly and Brown, 1967; Massey, 1986; Bauer and Zimmermann, 1997; Guilmoto, 1998). For example, Nelson proposes two roles played by relatives and friends in the migration process: (1) a real income role, and (2) an information role. In other words, he maintains that relatives and friends play a crucial part in channelling information from destination back to origin, and serve as an income substitute when subsequent migrants arrive at the destination. In reference to the process of chain migration, Hägerstrand (1957: 131) considers that migration is "a feed-back process" and goes on to point out "migrations at any given time are *dependent* on preceding migrations". It is also commonly observed that the formal communication mechanisms in Third World countries, such as telephone and mass media, are generally not adequate, and hence relying on informal connections facilitated by migration-chain effects would have widespread importance in inter-regional migration (Brown and Stetzer, 1996).

As discussed in Chapter 3, China's migration prior to economic reforms in the late 1970s resulted mainly from political and military considerations. Two main inter-provincial migrations occurred in the period from the mid-1960s through the 1970s. The first was the sending of urban youths to the interior or frontier provinces, and the second was the migration caused by the relocation of industry from the coast to the interior provinces (the so-called 'third-front' of industrial construction, discussed in section 3.3.2 of Chapter 3). About 17 million urban youths were sent to the countryside and remote regions, and one to two million were engaged in inter-provincial migration during the height of the Cultural

Revolution in 1968-76 (Bernstein, 1977; Shen and Tong, 1992: 187). Most of these urban youth outmigrants were allowed to return to their areas of origin after 10 to 12 years (Banister, 1987). Inter-provincial migration due to the construction of the 'third-front' industries between 1964 and 1979 (Shen and Tong, 1992) was also reversed in the 1980s. To take these effects into account in modelling Chinese migration, migrant stock can be appropriate. As indicated in Figure 4.2, return migrants result from the changing political and economic situation in the 1980s. This implies that if a coastal province has a large migrant stock from an interior or frontier province, this coastal province is most likely to experience a large wave of return migration. Also, it should be noted that not every migrant to the interior and frontier regions came back to their home place, since some people married a local person, and in particular, some of the relocated industrial plants remained in the interior permanently. In such cases, the migrant stock constitutes a major facilitator to attracting subsequent migrants from the origin.

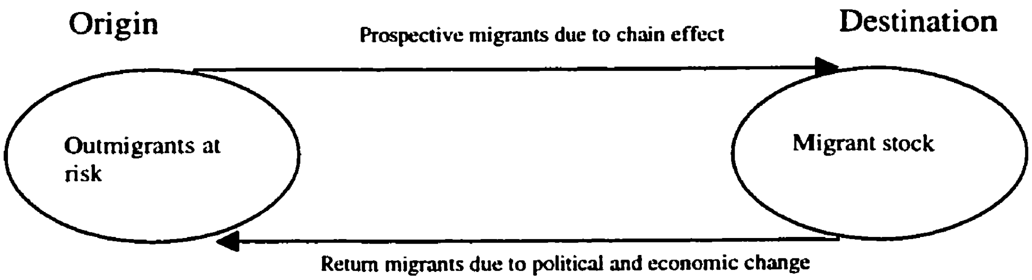

Figure 4.2 Ramifications of migrant stock in China

Therefore, return migration has particular significance in the modelling of inter-provincial migration in China when compared with a migration system in a free market economy in the developed world. It should be noted that linking migrant stock with subsequent migration is not new (though never attempted for Chinese migration data). What the present study emphasizes is that by using the concept of migrant stock one can capture some of unique features of Chinese inter-provincial migration flows due to political intervention.

The concept of return migration is defined on the basis of the current move related to the previous moves (those who migrate back to their place of birth following an initial migration) (Long, 1988: 100). The other two concepts defined on the basis of the same principle are primary and onward migration. Suppose that a group of people migrates from their region of birth *A* to destination *B*. Among this group of people, those who would stay in destination *B* are referred to as primary migrants, while those who would be disappointed with destination *B* and further migrate to an alternative destination *C*, other than their region of birth, are referred to as onward migrants (Newbold, 1997). This new definition of migration is regarded as a major conceptual advance (Long, 1988), since using these concepts, the migration process can be best explored using longitudinal data. Even for a migration system that is not disturbed by any political intervention, return migration constitutes an important inter-regional population flow. For example, return migrants account for a considerable proportion of total migrants in the US (20.9%, 1985-90) and Canada (31.2%, 1986-91) (Newbold, 1997: 183). Except for the return migration flows caused by political intervention, China's economic reform era has also witnessed a considerable number of return migrants (Li and Li, 1995). Return migrations in China are caused by the following factors: (1) political interventions, (2) retirement, (3) economic conditions better than at the destination, and (4) disappointment with life at the destination

(Shen and Tong, 1992).

The migration-chain effect has been even more conspicuous since economic reforms in the late 1970s. For example, a sampling survey conducted in the early 1990s revealed that 57 to 78 per cent of rural labour migrants obtained employment through friends and relatives at the destination (Zhang, et al., 1997: 196). This demonstrates that the migrant stock — both politically dispersed in the Cultural Revolution, and voluntarily moved to prosperous areas in the reform period — acts as an important facilitator to attract migrants.

In the present study, migrant stock is defined as the number of people who moved previously to the destinations. In order for this measure to be fully operational, it can be expressed as a probability of the total number of migrants, in the form of the following equation:

$$s_{ij} = \frac{M^{\circ}_{ij}}{\sum_{i,j} M^{\circ}_{ij}}, \qquad (i = 1, \ \ldots, n; \ \ j = 1, \ \ldots, n) \tag{4.1}$$

where s_{ij} is the probability of migrant stock size and, M°_{ij} is the number of people in the destination who moved from the origin during the period 1982-1987. Combined with the discussion in section 3.3.2 of Chapter 3, it can be noted that s_{ij} captures return migration caused by Chinese political interventions in the middle 1960s to the late 1970s. The denominator refers to the total number of migrants who previously moved to the destinations in the region or country under study. To illustrate this definition, suppose we have a regional migration system consisting of four subregions, $A, B, C,$ and D (in the form of a 4 by 4 migration matrix), A's migrant stock at B is calculated as the number of migrants that moved in the past from A to B divided by the summation of all migrants from every cell to every cell of the matrix. This definition follows the same procedure for calculating prior probability, which is derived from a past migration matrix, as an alternative for the spatial separation measure used by Pooler (1995a). Although migrant stock is also derived from a past migration matrix in this study, it will be treated not only as a complement to distance, but also as a measure that can boost the behavioural explanation for the migration system.

Using s_{ij} as a complement for traditional spatial separation can be justified on the grounds of the following three arguments. First, s_{ij} can be considered as information stock. The decision-making process for migration is based on the would-be migrant's perception of information concerning alternative destinations. If friends and relatives are already at a destination, they will send back information to their place of origin. Subsequently, the prospective migrants may make a decision to move. Numerous studies illustrate this point, such as Brown et al. (1981), Massey and Espana (1987) and Zhang, et al. (1997). Second, s_{ij} can be regarded as a proxy for economic and psychic costs. Such costs may be significantly reduced if friends and relatives are present at the destinations who may supply material help, and facilitate the search for employment, housing, etc. Finally, s_{ij} represents the volume of previous or historical migrants who had responded in the past to forces driving the migration process (Fik et al., 1992). Such past forces may exert varying influences on current and future migration via the stock of migrants in the destination (King, 1978). ***In light of the above three arguments, it will be expected that migration will be positively related to*** s_{ij}. The idea underlying this relationship is that migration is a feedback process that results in multiplying effects on the origin's population, causing more would-be migrants to follow the route of previous migration. As migrant stock increases at the destination, subsequent migrants will be attracted to the destination from the origin and the size of return flow will also be increased. However, it should be pointed out that such a process is not without limit in long-term perspective.

4.5.2 Annual average investment

One important rule for selection of variables in modelling migration is to avoid inter-correlated variables (Alonso, 1968), or multicollinearity. Based on this rule for this study, a correlation matrix is calculated among six variables. These six variables are (1) ratio of cultivated land to population in 1990, (2) per capita GDP in 1990, (3) per capita total investment in 1986-90, (4) length of railway in 1988, (5) annual average total investment in 1986-90, and (6) percentage of urban population in 1990.

Table 4.1 The correlation matrix for variables (1) to (6)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1)	1.000					
(2)	-0.269	1.000				
(3)	-0.223	0.936**	1.000			
(4)	0.518**	-0.187	-0.250	1.000		
(5)	-0.372	0.373	0.253	-0.041	1.000	
(6)	-0.019	0.841**	0.877**	0.093	0.184	1.000

Notes: Variable names are indicated in the text. ** correlation is significant at the 0.01 level (2-tailed).

If the correlation coefficients between variables are significant, one of each pair of the variables will be excluded from the models. On the basis of examination of the correlation matrix, as illustrated in Table 4.1, it is found that the correlation coefficients are highly significant among four of the pairs of variables, that is, variables (4)-(1), (3)-(2), (6)-(2), and (6)-(3). Thus, either variables (4), (3), (6) or variables (1), (2), (3) should be excluded.

Table 4.2 Model results for migration in 1985-90: percentage of migrants misallocated (*% E*)

Variable	*% E*	Beta
The conventional model	34.6339	1.1317
(1)	41.7926	1.2362
(2)	34.6340	1.1320
(3)	37.2584	1.1466
(4)	40.4040	1.2157
(5)	**27.7793**	1.1208
(6)	36.1392	1.1493

Notes: Variable names are indicated in the text. The conventional model is $M_{ij} = A_i O_i d_{ij}^{-\beta}$. The calibrated model equation for including variable is $M_{ij} = A_i O_i d_{ij}^{-\beta} h_j$, where h_j represents any one of the six variables as specified in the text, and all other terms are defined in section 4.6.1.

A second rule for including variables in the models, as mentioned in Chapter 1, is the extent to which the variables have improved the performance of the model. In this study, the model is calibrated with variables (1) to (6), and the calibrated results are shown in Table 4.2. The model satisfies both origin and cost constraints. The origin and cost constraints are indicated in Equations (4.4) and (4.11), respectively. The calculation of per cent error is indicated in Equation (4.19). Preliminary calibrations of the model with variables (1) to (6) in Table 4.2 show that only variable (5), the annual average total investment, improves the model performance by 6.85 per cent in comparison with the conventional model, and other variables offered no improvement in performance to the model. This may be as a result of the fact that all the other variables cannot be justified as having significant effects on China's inter-provincial migration. As a result, according to the second rule, variable (5) remains in the model. On the other hand, as discussed in the preceding paragraph, variable (5) also has no significant correlation with other variables. Therefore, on the basis of the correlation analysis and preliminary calibration for the six variables, it may be concluded that variable (5), the annual average total investment in 1986-90, is properly included in the model.

As previously discussed, total investment includes domestic loans, foreign investment, fund-raising, investment from the central government's appropriation, and other. Two questions are worth further discussion. The first is why the annual average of total investment is chosen rather than any specific yearly total investment, and the second is why total investment, rather than foreign investment, is chosen for its inclusion into the model.

The amount of investment in China displayed a cyclic pattern in the period prior to the economic reform, as examined by Ma and Wei (1997). An examination of total investment data in the 1980s indicates that there is a pattern of yearly fluctuation. This is because investment depends on China's own economic cycle, and foreign investors are sensitive to policy changes and political stability. Therefore, the annual average of the investment can avoid such fluctuations. Moreover, the annual average investment is in correspondence with migration in the corresponding time period under study. Specifically, the annual average investment between 1986 and 1990 (five-year average) is used for modelling migration in the period from 1985 to 1990, while the annual average investment between 1985 and 1987 (three-year average) is used for modelling migration from 1982 to 1987.

Previous investigations of China's migration, together with studies of China's regional development, have used foreign investment data for explanation. One of the obvious shortcomings of using the foreign investment data is that other investments are ignored, and therefore a distorted picture may arise. Even for the province of Guangdong, with the largest amount of the foreign investment among the provinces of China, foreign investment is not the most important variable to explain migration at the level of counties; industrial and agricultural output has a greater impact on migration (Fan, 1996). Fan's observation on the county-level migration in Guangdong may imply that the foreign investment variable is not adequate to account for migration, since it excludes other investments. Provincial distribution of foreign investment is particularly uneven in China, with foreign direct investment being concentrated in the 11 coastal provinces, and the largest share going to Guangdong. According to Kueh (1992: 658), for each dollar of foreign investment received, an average of three *yuan* (Chinese currency unit) is spent for the purpose of providing infrastructure, such as the provision of electricity, transport, and so on. This implies that the largest amount of foreign investment in coastal regions generates a corresponding internal investment, and hence creates a considerable amount of employment. It should be also noted that foreign capital borrowing from overseas is redistributed to interior provinces by the central government, since they lack foreign direct investment (Kueh, 1992).

Another factor concerning China's investment is the power of fiscal transfer by the central government. Although China decentralised its fiscal system and allowed provinces to retain a considerable amount of revenue from local economic activities in the 1980s, fiscal transfer by the central government still has an impact on overall capital flows into some interior provinces and the border regions. Guangxi, Yunnan, Guizhou, Xinjiang, Qinghai, Ningxia, Tibet and Inner Mongolia all received subsidies. The fiscal transfer is usually to alleviate poor economic conditions, but it is also politically motivated toward appeasing ethnic or religious dissatisfaction (Raiser, 1998). Still another factor is that the source of investment has diversified from state allocation to various other channels, including funds raised by investment units themselves, bank loans, state appropriation, and foreign capital. All these aspects of investment should be taken into account. The annual average total investment reflects the above factors of investments.

The annual average total investment variable, v_j, enters into the model in a probability form as this avoids effects of the units used for the variable. It is calculated as follows:

$$h_j = \frac{v_j}{\sum_i v_j}, (j = 1,... n) \tag{4.2}$$

where h_j is probability of the annual average total investment in province j. The variable is calculated for two time periods, one for the period between 1985-1987 (data prior to the year 1985 are not available), and the other for 1986-1990.

4.6 Model calibration

The purpose of calibration of the MSIM is to find parameters for the model in such a way that the predicted inter-provincial migration flows fit the observed ones as closely as possible (Wilson, 1974). In this section, derivation of the MSIM is briefly introduced, and estimation procedure and model programs are discussed.

4.6.1 Derivation of the MSIM

Wilson's (1967) EM model is reviewed in chapter two. It is repeated here for convenience. Suppose a known inter-regional migration matrix is available. This implies that outmigrants, O_i, leaving each origin, and inmigrants, D_j, arriving each destination are known. The modelling problem is to estimate the probability, p_{ij}, of a migrant moving from origin i to destination j. The EM method is to maximise the Shannon entropy (Shannon and Weaver, 1949).

$$H = -\sum_{i,j} p_{ij} \ln p_{ij} \tag{4.3}$$

subject to constraints:

$$\sum_{j=1}^{n} p_{ij} M = O_i, \tag{4.4}$$

$$\sum_{i=1}^{m} p_{ij} M = D_j, \tag{4.5}$$

$$\sum_{i,j} p_{ij} d_{ij} = \bar{d} \tag{4.6}$$

where M is total number of migrants in the whole migration matrix, d_{ij} the distance between regions, and $\bar{d}$ the average or mean distance travelled by all migrants. Equations (4.4) and (4.5) are constraints that ensure that the *predicted* O_i and D_j are consistent with the *observed* O_i and D_j. Equation (4.6) is the constraint for the mean migration distance. The result of the maximisation is

$$p_{ij} = \exp(-\lambda_i - \gamma_j - \beta d_{ij}) \qquad (4.7)$$

which assigns migrants to provinces in the least biased way, subject to the constraints (4.4) to (4.6) (where λ_i, γ_j, and β are parameters associated with constraints (4.4), (4.5), and (4.6), respectively). When p_{ij} is defined with respect to inter-regional migration in the form of $p_{ij} = M_{ij}/M$, then Equation (4.7) can be expressed in a more familiar form of

$$M_{ij} = A_i O_i B_j D_j \exp(-\beta d_{ij}) \qquad (4.8)$$

where M_{ij} is the predicted number of migrants between regions, and $M_{ij} = p_{ij}M$. The balancing factors A_i and B_j are presented in Equations (2.8) and (2.9) and not repeated here.

As discussed in Chapter 2, the EM models do not allow for additional information or variables that may affect migration between regions (for example, the level of unemployment or the number of jobs available at destinations). The IM method can overcome this deficiency. A number of researchers (Batty and March, 1977; Snickars and Weibull, 1977; Plane, 1981, 1982; Pooler, 1985, 1995a) have discussed this approach and derived spatial interaction models with inclusion of prior information. A synthesis and brief introduction of these discussions follows here.

Suppose that, in addition to the known information on migration above, further information on multiple prior probabilities related to migration is available, that is

$$\prod_k q_{ij}^{(k)} \qquad (i, j = 1, \ldots, n; k = 1, \ldots, m) \text{ known.} \qquad (4.9)$$

These multiple prior probabilities are defined based on $q_{ij} = r_{ij} / \sum_{i,j} r_{ij}$, where r_{ij} is any measure on, or between regions, which can be justified as having an effect on inter-regional migration. Minimising the Kullback (1959) information

$$I(p:q) = \sum_{i,j} p_{ij} \ln \frac{p_{ij}}{\prod_k q_{ij}^{(k)}}, \qquad (4.10)$$

subject to constraints (4.4), (4.5), (4.6), and (4.9) will produce a model that contains the multiple prior information q_{ij}. However, another adjustment is required in that constraint (4.6) has to be replaced by

$$\sum_{i,j} p_{ij} \ln d_{ij} = \overline{\ln d}, \qquad (4.11)$$

The rationale for using constraint (4.11) is that it results in an inverse power function of distance deterrence for the model that can be more appropriate for modelling inter-regional or longer distance migration (Fotheringham and O'Kelly, 1989: 12-13; Ottensmann, 1997). Such an inverse power function is employed in the present study. It is established that the mean trip length is appropriate and used as the cost constraint if the cost function is exponential ($e^{-\beta d_{ij}}$). However, the inverse power function, $d_{ij}^{-\beta}$ can be written as $e^{-\beta \ln d_{ij}}$, and thus the mean value of $\ln d_{ij}$ is the cost constraint (Wilson, 1971, 1974). A number of researchers adopt the mean value of logarithmic distance (cost) to derive or to calibrate spatial interaction models, such as Wilson (1974), Pooler (1994a, 1995a) and Fotheringham and O'Kelly (1989). When the inverse power function is used, the costs or spatial separations between regions can be defined as the logarithm of distance. This relationship is already indicated above ($e^{-\beta \ln d_{ij}} = d_{ij}^{-\beta}$). Therefore, the interpretation of the inverse power function is that distance is perceived in a logarithmic form rather than in the linear form we measure.

The result of the minimisation of (4.10), subject to constraints (4.4), (4.5), and (4.11), together with consideration of $M_{ij} = p_{ij} M$, is

$$M_{ij} = \prod_k q_{ij}^{(k)} A_i O_i B_j D_j d_{ij}^{-\beta} \tag{4.12}$$

Equation (4.12) is the multivariate spatial interaction model. It can be seen that Equation (4.12) is an estimation of migration flows which allows for inclusion of k prior probability distributions. In the present study, a production-and cost- constrained version of the MSIM is used, we have

$$M_{ij} = \prod_k q_{ij}^{(k)} A_i O_i d_{ij}^{-\beta} \tag{4.13}$$

which results when equation (4.10) is minimised subject only to constraints (4.4) and (4.11). The balancing factor A_i ensures that constraint (4.4) is satisfied, and defined as

$$A_i = \left[\sum_j \prod_k q_{ij}^{(k)} d_{ij}^{-\beta} \right]^{-1} \tag{4.14}$$

where $\prod_k q_{ij}^{(k)}$ in the present study, includes the two explanatory variables, the migrant stock and the annual average total investment, defined in Equations (4.1) and (4.2) above.

The discussion in the previous section indicated that the migrant stock, defined as the prior probability based on the past migration flow, can be regarded as playing a role in attracting subsequent migrants to destinations. Pooler (1995a) shows that the prior probability of the past migration flow has a negative relationship with distance, and that this prior can be parameterised. It can be shown that the shorter the distance from origin to distance, the larger the migrant stock.

When q_{ij} in Equation (4.13) is replaced by the two explanatory variables, Equation (4.13) becomes

$$M_{ij} = h_j s_{ij} A_i O_i d_{ij}^{-\beta} \tag{4.15}$$

where

$$A_i = \left[\sum_j h_j s_{ij} d_{ij}^{-\beta} \right]^{-1} \tag{4.16}$$

Equation (4.15) will be calibrated subject to constraints (4.4) and (4.11) and is the production- and cost-constrained MSIM used in the present study. This study also uses an origin-specific version of the production- and cost- constrained MSIM (referred to as the origin-specific MSIM) for modelling out-migration within a multi-regional framework. Such an origin-specific out-migration field model for a single province can be expressed as

$$M_{ij} = h_j s_{ij} A_i O_i d_{ij}^{-\beta_i}, (i \neq j) \tag{4.17}$$

where

$$A_i = \left[\sum_j h_j s_{ij} d_{ij}^{-\beta_i} \right]^{-1} \tag{4.18}$$

Equation (4.17) will be calibrated for each origin in China's inter-provincial migration matrix for the period 1985-90.

4.6.2 Calibration procedure

Calibration of the SIMs is reviewed in Chapter 2. Calibration of the SIMs against the observed interaction data cannot be realised through usual methods, such as regression analysis (Wilson, 1971: 9). It needs to use programs specific to it. The model calibration programs for the present study are written in Fortran 77 and based on Baxter's (1973) program; a sample of such model programs appears in Appendix B. The Baxter program is modified considerably, in four major ways:

(1) The Baxter program was written in ASA FORTRAN IV with five subroutines based on a doubly constrained EM model. It is adjusted here to fit the environment of FORTRAN 77. Also, three types of programs are written separately, corresponding to three situations: the conventional production- and cost-constrained SIMs, the production- and cost-constrained MSIMs, and the origin-specific version of the production- and cost-constrained MSIM.

(2) The Baxter program is also expanded to include an input file and an output file, so that these files can be read directly from a computer directory.

(3) The original program was devised for an urban journey-to-work illustration, and intra-zone trips were included. In this study, intra-provincial migration is excluded, and the original program is therefore changed to set the diagonal cells of the estimated migration matrix to zero.

(4) Calculation of the goodness-fit-statistic, the percentage of misallocated between the observed and the estimated migration matrices, is incorporated into the main program.

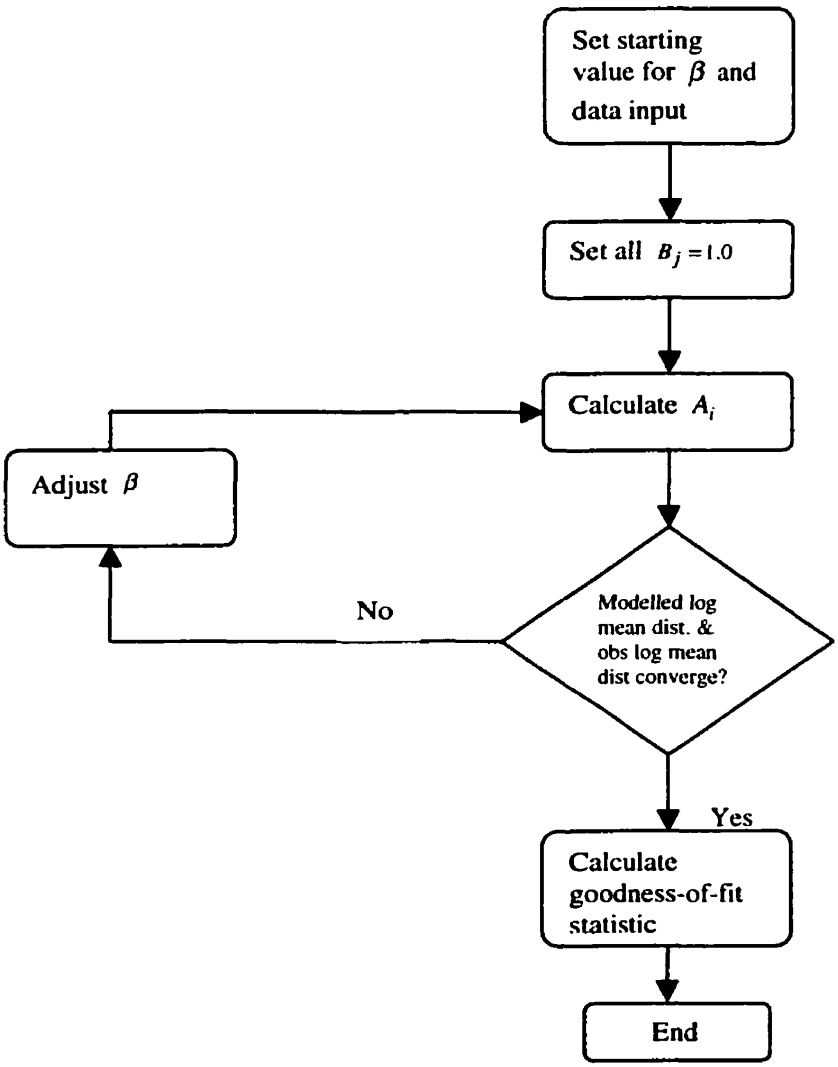

Figure 4.3 Calibration procedure for the MSIM

The calibration of a doubly constrained SIM in the transportation area was illustrated in Hyman (1969) and Evans (1971). This line of calibration was followed in the field of migration research, as in works by Stillwell (1978), Haynes and Fotheringham (1984), Evans and Pooler (1987), Pooler (1994a), and O'Kelly (1999). Hyman's method was put into operation by Baxter (1973), and the calibration methods were also discussed by Fotheringham and O'Kelly (1989), Pooler (1994a, 1995a).

To calibrate the production- and cost-constrained MSIM in Equation (4.15) is to estimate some parameter of the model to optimise goodness-of-fit statistics. This also implies that after calibration of Equation (4.15) the predicted number of out-migrants leaving each province matches the observed ones, and the estimated mean of the logarithmic migration distance is consistent with the observed one. The value for β is adjusted so that the mean of the logarithmic migration distance calibrated within the model ($\bar{d}$) is equal to the observed one ($\bar{d}_{obs}$). Therefore, iteration is required to change the value for β until the value of $\overline{\ln d}$ converges on to $\overline{\ln d_{obs}}$. An initial value for β is established (Baxter, 1973; Wilson, 1974; Brown and Masser, 1978; Pooler, 1983, 1995; Akwawua, 1995). The present study employs the negative power function (as justified in section 4.6.1), and the initial value for β is set to be the negative inverse of logarithm of the mean migration distance (Wilson, 1974: 320; Fotheringham, 1983a: 24). A method whereby the β value is altered on the basis of knowing $\bar{d}$ at the end of each iteration and $\bar{d}_{obs}$, is suggested by Hyman (1969). Hyman's method is to use a second-order linear interpolation for efficient convergence when a starting value for β is determined. It is noted that the starting value for β indicated above can provide a fast convergence so that time for computing can be saved. Other starting values also can be used and convergence still can be achieved.

Figure 4.3 illustrates the calibration procedure of the MSIM. From the model equation (4.15), all the terms, other than values for A_i and β, must be known before the matrix of migration can be predicted. The first term, h_j, is the average annual total investment, entered into the model in a form of a probability. This term reflects the attractiveness of destinations. The idea is that a large number of investments from all sources create more employment opportunities that attract migrants from other provinces. The second term is the migrant stock, s_{ij}, calculated from inter-provincial migration data for the period 1982-87. The third term is out-migrants leaving each province, O_i. The value for O_i is obtained from the known migration matrices and also used as input data. Values for distance are entered into the model in units of kilometres. Two terms, A_i and β, are results of estimation. The parameter β is an indicator of distance decay that captures the effects of physical separation on migration flows.

The value of A_i is not only regarded as a balancing factor but also interpreted as a competition-accessibility term (Wilson, 1967, 1971: 9; Senior, 1979). The measure of accessibility is dependent upon two terms, attractiveness and travel deterrence (Wilson, 1971; Pooler, 1995a). This may be why the balancing factor is interpreted as accessibility and competition. Empirical investigation of values for the balancing factor is included in Cesario (1974, 1977), Thomas (1977), Evans (1986), and Akwawua (1995). In the conventional SIM, the balancing factor A_i can be regarded having an accessibility interpretation. It is more appropriate that A_i values in the MSIMs are interpreted in terms of competition and accessibility, since values for A_i are influenced by both socioeconomic variables and distance impedance.

The calibration procedure for the origin-specific MSIM is similar to that diagrammed in Figure 4.3, but is undertaken for each province separately. Investigation of migration patterns using a zone-specific SIM was carried out by Stillwell (1978). The present study examines the origin-specific MSIM, and the objective is to compare the modelled parameters among 28 provinces and to see whether model performance can be improved. In addition, the equations used in the present study adopt a negative power function of distance, since it is considered more appropriate for analysing long distance interactions such as inter-regional migration (Wilson, 1971; Fotheringham and O'Kelly, 1989; Ottensmann, 1997).

4.6.3 Goodness-of-fit statistics

An important component in the process of modelling spatial interaction is to evaluate the model's ability to replicate known migration flows. A more accurate replication may demonstrate that the proposed model has a solid empirical basis, and can be used for prediction with confidence. On the other hand, low accuracy of the model may alert investigators to look for its causes. Such causes are usually important clues for further improvement of the model. Many goodness-of-fit statistics have been used in spatial interaction modelling. These statistics are discussed and reviewed by Wilson (1976), Knudsen and Fotheringham (1986), and Fotheringham and O'Kelly (1989). Fotheringham and O'Kelly recommend three statistics be used to evaluate the model performance: information gain, the minimum discrimination information (MDI), and the standardised root mean square (SRMS). Pooler (1987a) employs three statistics — R^2, percentage misallocated, and the root mean square error — in modelling Canadian migration. Evans and

Pooler (1987) use percentage misallocated and the phi statistic for assessment of the model performance. All such statistics involve a quantitative description of difference between the predicted and observed migration flow matrices. However, little consensus has emerged concerning the use of the goodness-of-fit statistics in the literature of spatial interaction modelling.

Following the previous convention, the present study employs the percent misallocated to assess this model's ability to replicate the known migration flows. This statistic can be calculated using the predicted and observed migration flow matrices. It takes the following form:

$$\% E = \frac{50}{M} \sum_{i,j} \left| M_{ij} - M_{ij}^{*} \right|, \tag{4.19}$$

where $\% E$ represents the percentage of misallocated migrants in the migration matrix, M is total number of migrants, and $\left| M_{ij} - M_{ij}^{*} \right|$ the absolute difference between the predicted and the observed migrant flows from origin to destination, respectively. Any calculated value for this measure indicates the percentage of migrants that would have to be redistributed to the correct provinces in order for the predicted migration matrix to match the observed matrix of migration. Based on this measure, it is possible that further exploration can be made as to which provinces, and how many migrants, are over- or under-predicted.

4.6.4 An illustration of data transformation

In this section, Equation (4.15) is employed to illustrate the data transformation in the calibration of China's inter-provincial migration in 1985-90. For convenience of presentation, Equation (4.15) is cited here, $M_{ij} = h_j s_{ij} A_i O_i d_{ij}^{-\beta}$, and is termed MSIM 3. According to Thomas and Huggett (1980), the phrase 'spatial interaction model' refers to an equation which predicts the size and direction of place-to-place flow (the dependent variable) using variables that measure the structural features of the spatial system under study (independent variables). In other words, the concept of dependent and independent variables in regression modelling can also be applied to the spatial interaction model. One of the ways to improve modelling results using a regression model is to transform data. There are two ways to transform data or variables: one is the linear transformation (such as distance in miles transformed into distance in kilometres), and the other is non-linear transformation (Hamilton, 1990). In modelling China's inter-provincial migration, the two added variables, migrant stock (s_{ij}) and annual average investment (h_j) are transformed for the purpose of improving the performance of the models. In order to reduce skewness of the data, a non-linear transformation, called a power transformation (Hamilton, 1990: 163), is employed. Specifically, let X^* represent transformed X. Then $X^* = X^q (q > 0)$, if $q > 1$ the transformation reduces negative skewness of data; if $0 > q < 1$ the transformation reduces positive skewness. When $q < 0$ the transformation would reverse the order of the original data (Hamilton, 1990).

In transforming the migrant stock and investment data for modelling China's inter-provincial migration, let $s_{ij} = s_{ij}^r$, $h_j = h_j^u$. The power transformation is followed in order to reduce the skewness of the migrant stock and investment data. The procedure is heuristically performed and is shown in Table 4.3. At each step, r changes by 0.1 until the best performance level (or the lowest possible $\% E$) for the model is obtained.

Table 4.3 Power transformation of migrant stock data, MSIM 3, for total inter-provincial migration, 1985-90

r	β	$\% E$	r	β	$\% E$
-0.2	1.3918	34.7472	0.5	0.5255	22.4052
-0.1	1.2558	32.1816	**0.6**	**0.4186**	**22.0550**
0.0	1.1240	29.8775	0.7	0.3161	22.1446
0.1	0.9961	27.7694	0.8	0.2180	22.9624
0.2	0.8723	25.8623	0.9	0.1241	24.1745
0.3	0.7525	24.3273	1.0	0.0343	25.4666
0.4	0.6369	23.1761			

Table 4.4 Power transformation of the annual investment data, MSIM 3, for total inter-provincial migration, 1985-90 (power $r = 0.6$)

u	β	$\% E$	u	β	$\% E$
-0.1	0.4198	19.3096	**0.2**	**0.4132**	**17.7558**
0.0	0.4170	18.5536	0.3	0.4122	17.8061
0.1	0.4148	18.0169	0.4	0.4117	18.0535

Table 4.3 shows the calibrated results for the model to predict province-to-province migration flows. When the power r takes the value of 0.6, the best possible performance ($\%E$) is 22.0550. On the basis of this r value, the second step is to transform the annual investment data. It is shown in Table 4.4 that when the power u takes the value of 0.2, the optimal performance with $\%E$ of 17.7558 is obtained. All other models also follow the same procedure to transform the data, and the heuristic values are indicated in Appendix C.

4.7 Summary

This chapter presents the data sources and methodology used in the present study. The MAUP, a frequently encountered concern, is first reviewed. The sources of data are described, and some major concerns associated with the Chinese inter-provincial migration data and economic data are highlighted. The main conclusion is that the migration data from the 1987 survey and the 1990 census are considered as being of good quality. The quality of the investment data is better than other economic data, such as income per capita. Two variables, migrant stock and the annual average total investment, are selected for the model. The variable of migrant stock is included in the model not only because this variable can capture migrants due to changes in economic condition but also because it reflects migrants (in particular return migrants) caused by Chinese political interventions in the middle 1960s through the late 1970s. The average annual total investment is selected based on the justifications that the investment channels are diversified in the 1980s and the generation of employment is closely related to the investment patterns.

Derivation of the MSIM is based on the information minimisation principle, and calibration issues associated with the model are discussed. The MSIM in the present study differs from the conventional SIM in that the MSIM includes the two explanatory variables, so that performance can be improved. How the variables and parameters are determined and entered into the model was discussed. Finally, a description was presented concerning the goodness-of-fit statistics.

Chapter Five Regional Patterns of Inter-provincial Migration

5.1 Introduction

Prior to the 1987 survey, few statistics on inter-provincial migration (IPM) in China were released. Part of the problem is that such data were not systematically collected. Even for the 1982 census, there was no question asked on migration. The 1987 survey and the 1990 national census filled this gap. Information on IPM from these two data sources can facilitate an assessment of IPM in China. Using the data from the1987 survey and the 1990 census, this chapter analyses regional patterns of the IPM in China. Following an overall analysis of the IPM, an examination of the spatial focusing of the IPM is undertaken. Investigation is also made on male-female differentials in the IPM flows.

5.2 Overall pattern of inter-provincial migration

With the relaxation of the internal migration policy and increasing economic prosperity in the coastal regions, China has witnessed a surging level of geographical mobility. Table 5.1 shows numbers of in- and out-migration for China's provinces. Prior to making observations based on the table, a few words should be said on how migration *rates* are calculated.

The conventional way of calculating out- and in- migration rates is to divide the number of out- and in- migrants by the population of the region under study. Suppose that the task is to calculate out- and in-migration rates for Beijing. The out- migration rate is calculated by dividing the total number of out-migrants from Beijing by its population size. The in-migration rate is obtained by dividing the total number of in-migrants to Beijing by this same population size.

Table 5.1 Inter-provincial migration, China, 1982-87 and 1985-90 (in 1,000)

	1982-1987			1985-1990		
Province	in	out	net	in	out	net
Beijing	320.9	98.9	220.0	670.8	131.2	539.6
Tianjin	131.8	47.4	84.4	243.7	72.0	171.7
Hebei	593.0	372.9	220.1	518.6	645.0	-126.4
Shanxi	164.5	181.3	-16.8	306.5	218.1	88.4
In. Mongo	167.6	204.6	-37.0	254.2	302.9	-48.7
Liaoning	312.8	230.8	82.0	540.3	294.5	245.8
Jilin	169.2	239.3	-70.1	237.1	354.9	-117.8
Heilonjiang	191.3	450.0	-258.7	367.3	606.7	-239.4
Shanghai	371.8	88.0	283.8	663.8	132.0	531.8
Jiangsu	472.7	320.6	152.1	785.6	617.8	167.8
Zhejiang	121.7	237.1	-115.4	334.5	629.2	-294.7
Anhui	163.6	250.9	-87.3	335.4	531.6	-196.2
Fujian	88.1	108.1	-20.0	250.0	231.0	19.0
Jiangxi	100.8	144.6	-43.8	223.6	291.8	-68.1
Shandong	544.5	339.0	205.5	606.2	534.2	72.0
Henan	260.1	315.3	-55.2	472.9	587.2	-114.3
Hubei	273.0	223.4	49.6	428.2	341.8	86.5
Hunan	216.3	377.2	-160.9	266.6	518.1	-251.4
Guangdong	297.3	153.8	143.5	1,181.1	188.9	992.2
Guangxi	58.9	213.1	-154.2	137.1	558.5	-421.4
Sichuan	366.6	471.8	-105.2	437.1	1,301.9	-864.8
Guizhou	114.6	122.8	-8.2	189.9	311.6	-121.7
Yunnan	94.2	183.4	-89.2	248.4	276.7	-28.3
Shaanxi	222.4	284.0	-61.6	310.4	361.5	-51.1
Gansu	98.2	189.9	-91.7	197.1	280.4	-83.3
Qinghai	29.1	100.6	-71.5	115.1	102.0	13.0
Ningxia	91.5	50.9	40.6	91.9	56.5	35.3
Xinjiang	202.0	238.8	-36.8	341.3	277.1	64.2
Total	**6,238.5**	**6,238.5**	**0**	**10,754.7**	**10,754.7**	**0**

Sources: China, 1988, 1993.

Among migration researchers it is generally known that the denominator should reflect those at risk of becoming, respectively, out- and in- migrants. Therefore, the calculation of the out-migration rate is in accordance with the notion of the at-risk population, whereas in the conventional method of calculating the in-migration rate this notion is violated. A way of overcoming this difficulty is to use the population of all the provinces other than Beijing in the migration system as the denominator for calculating the in-migration rate. However, this method is rarely employed in migration research (Plane and Rogerson, 1994), and is not pursued for the present study.

The appropriate measure of the at-risk population is the population of the region under study at the middle of the time interval (Plane and Rogerson, 1994). In the present study, out- and in- migration rates for China's provinces are calculated in the conventional way. The denominator is the middle year population at the time interval under study. Specifically, in calculating migration rates for the period between July 1,1982 and July 1, 1987, the middle of the time interval is the end of 1984. In the same way, the middle of the time interval for the period between July 1, 1985 and July 1, 1990 is the end of 1987. The population at the middle of these two time intervals is estimated based on a method of interpolation. Details of the estimation are included in Appendix D.

Table 5.1 indicates that for China as a whole (excluding Tibet), the total number of inter-provincial migrants between 1982 and 1987 was 6.24 million. Different provinces shared a varied proportion of in-and out-migrants. In terms of the percentage share of in-migrants for each province in the total number of migrants, seven provinces each had more than a five per cent share. They included Hebei (9.51 per cent), Shandong (8.73 per cent), Jiangsu (7.57 per cent), Shanghai (5.96 per cent), Sichuan (5.88 per cent), Beijing (5.14 per cent), and Liaoning (5.01 per cent). On the other hand, based on the percentage share of out-migrants, there were major out-migration flows from six provinces: Sichuan (7.56 per cent), Heilongjiang (7.21 per cent), Hunan (6.05 per cent), Hebei (5.98 per cent), Shandong (5.43 per cent), and Jiangsu (5.14 per cent). In net terms, there were ten provinces that gained most. They were Shanghai (0.284 million), Beijing (0.222 million), Hebei (0.220 million), Shandong (0.206 million), Jiangsu (0.152 million), Guangdong (0.144 million), Tianjin (0.084 million), Liaoning (0.082 million), Hubei (0.050 million), and Ningxia (0.041 million).

All of the rest of the provinces lost population through migration, or they were net exporters in 1982-87. The five major such provinces were Heilongjiang (-0.259 million), Hunan (-0.161 million), Guangxi (-0.154 million), Zhejiang (-0.115 million), and Sichuan (-0.105 million).

It is clear that all the above ten recipient provinces in 1982-87 were in the coastal region with only two minor exceptions, Ningxia and Hubei. All of the 18 provinces that were net exporters of migrants are located in the central and west regions with only one exception, Zhejiang. Therefore, the geographical pattern of inter-provincial migration in 1982-87 was a reversal of the pre-reform (prior to the end of the 1970s) pattern. Namely, migration was from the central and western regions to the coastal region. This pattern intensified in the period 1985-90.

During the period 1985-90, the total number of migrants for China as whole (28 provinces) was 10.75 million, implying 73 per cent more than the volume of migration in 1982-87 (6.24 million). Guangdong became the largest recipient of migrants, accounting for 10.98 per cent. It was followed by Jiangsu (7.30 per cent), Shanghai (6.17 per cent), Beijing (6.24 per cent), and Liaoning (5.02 per cent). In terms of out-migration in 1985-

90, Sichuan shared the largest percentage of out-migrants (12.11 per cent), followed by Hebei (6.00 per cent), Zhejiang (5.85 per cent), Jiangsu (5.74 per cent), Heilongjiang (5.64 per cent), Henan (5.46 per cent), and Guangxi (5.19 per cent). In terms of net migration, there were 13 provinces that gained population. Most of these provinces are located in the coastal region, but there were five exceptions that gained population in relatively small numbers. These five provinces were Shanxi and Hubei (in the central region) and Qinghai, Ningxia and Xingjiang (in the western region). Shanxi is China's major site of coal mining, the construction of the Three Gorges Dam is located in the west part of Hubei, and Xingjiang is the new development region for oil exploration and production. All of these provinces gained considerable amounts of investment from the central government and created channels of in-migration from other provinces during the 1985-90 period.

The five provinces that gained most in net terms in 1985-90 were Guangdong (0.992 million), Beijing (0.540 million), Shanghai (0.532 million), Liaoning (0.246 million), and Jiangsu (0.168 million). On the export side, Sichuan replaced Heilongjiang as the largest net exporter (-0.865 million), followed by Guangxi (-0.421 million), Zhejiang (-0.295 million), Hunan (-0.251 million), and Heilongjiang (-0.239 million). All the rest of the net exporters of migration were the provinces in the central and western regions. It should be noted that among the five largest net exporters, Guangxi and Zhejiang are also located in the coastal region. Guangxi is the most underdeveloped province in the 12 coast provinces. Zhejiang as a major net exporter may have to do with its own limited area of cultivated land and long tradition of having a mobile population that either searches for materials and markets for township and private industries, or moves to other provinces for employment (Yang, 1996). The general pattern of inter-provincial migration is from the central and western regions to the coastal region. In those circumstances where this general pattern is interrupted, such disruptions can be attributed to large development projects undertaken by the central government.

Guangdong became the most important destination for migration between 1985-1990, receiving almost one million net migrants from other provinces. The underlying reason for this has to do with the fact that Guangdong has become the largest recipient of foreign investment in China since the late 1970s (Kueh, 1992). Guangdong's real GDP growth in the period 1981-90, driven mainly by exports based on foreign investments, reached 16.9 per cent per annum, being the fastest in China (Perkins, 1997: 506). Employment opportunities created by foreign investment and economic growth have attracted a large number of migrants from other provinces. The largest three contributors to Guangdong's in-migration were Guangxi (34.0 per cent), Hunan (19.3 per cent), and Sichuan (13.0 per cent). These three provinces accounted for 66.3 per cent of the total migrants to Guangdong.

Inter-provincial migration rates in general illustrate a similar pattern to that discussed above. For China as a whole, the rate of inter-provincial migration in 1982-87 was 6.03 per thousand, while the corresponding figure for the period 1985-90 was 9.95 per thousand, implying a considerable increase in the level of migration. If intra-provincial migrants are included, the national rates of migration are 29.46 and 31.12 per thousand for the two time periods, respectively. However, these rates were still considerably lower than those of developed countries. For example, the national five-year period rate of inter-state migration in the USA was around 99 per thousand for the

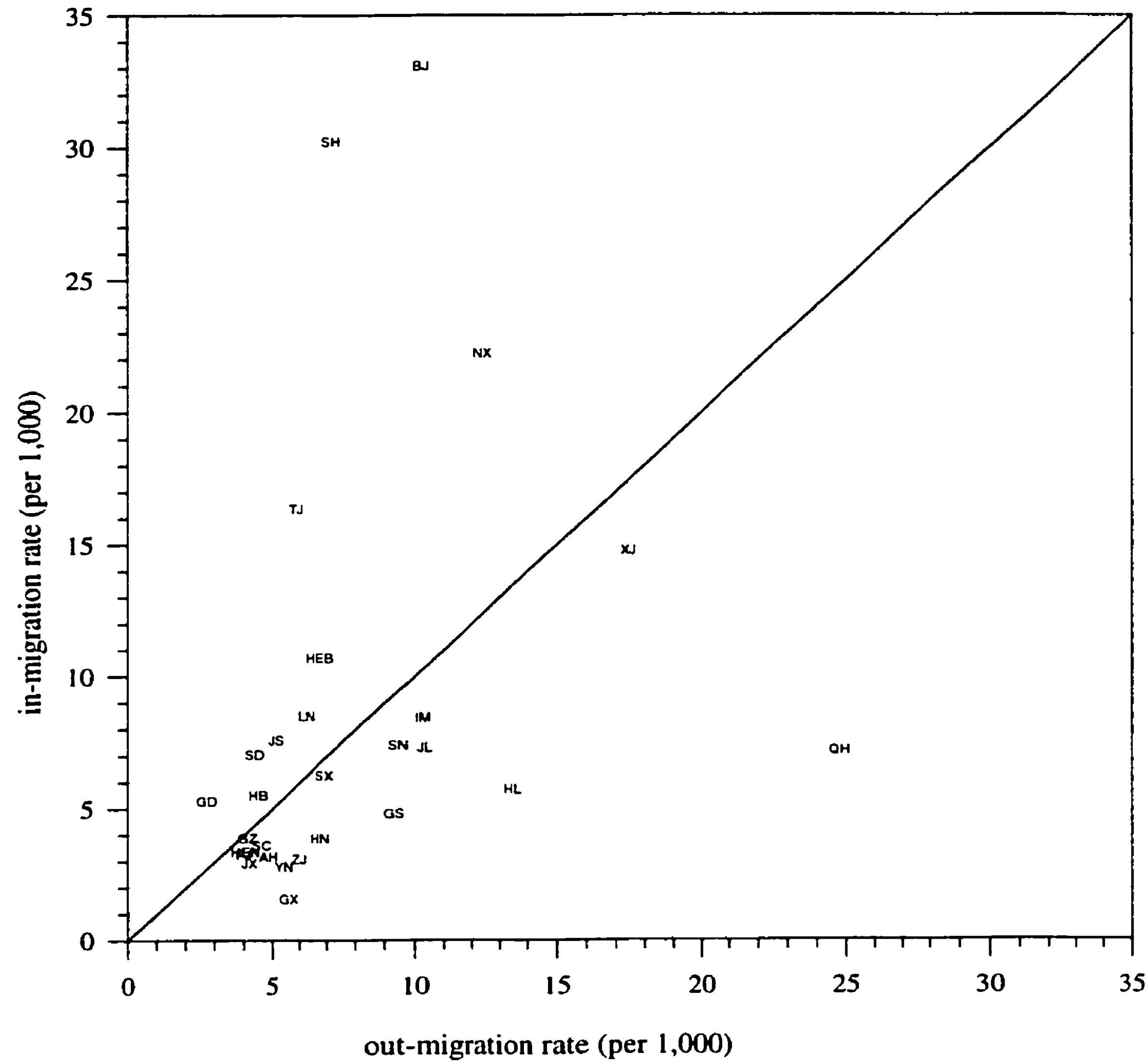

Figure 5.1 China's inter-provincial migration, 1982-87

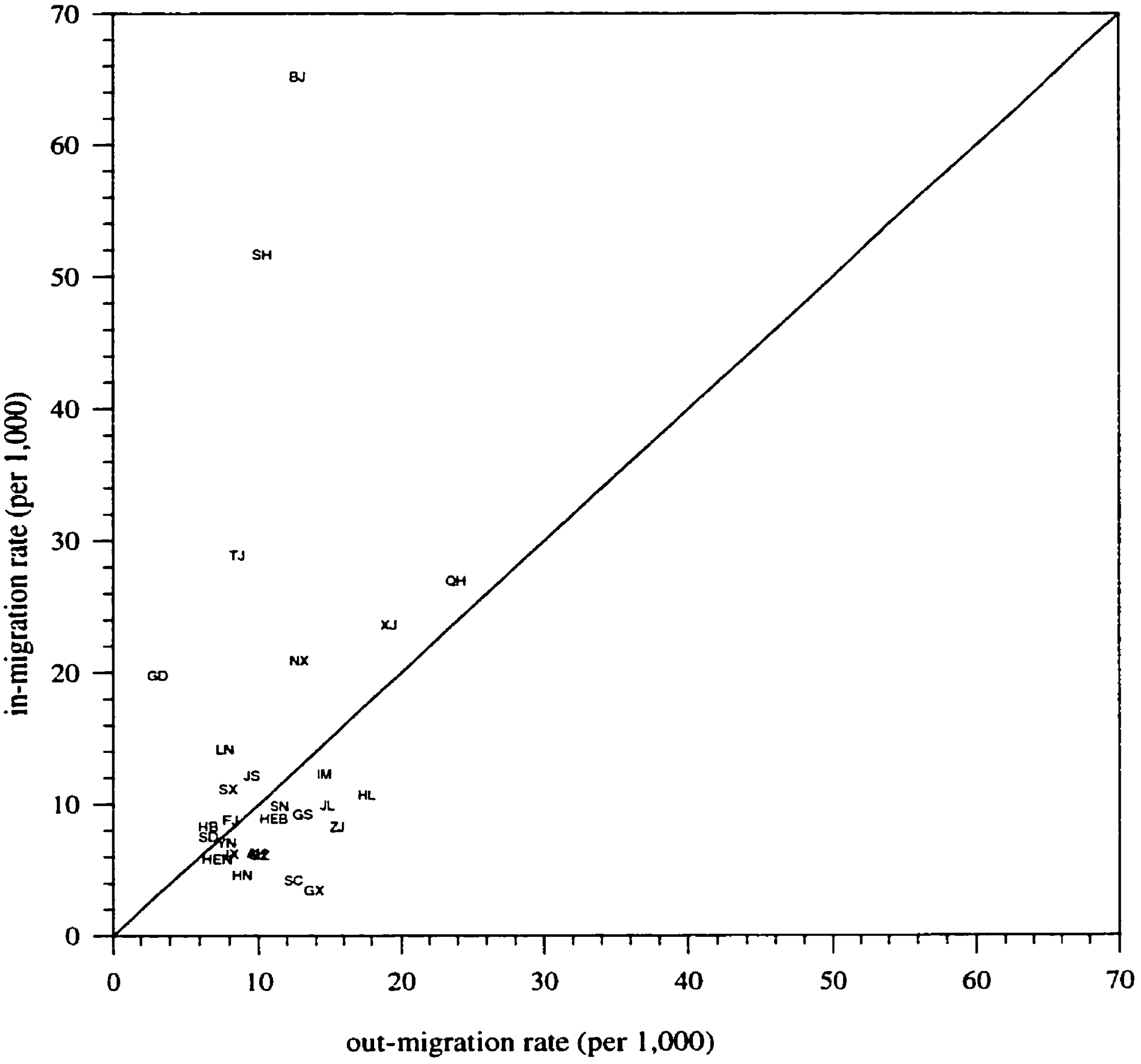

Figure 5.2 China's inter-provincial migration, 1985-90

period 1975-80 (Long, 1988: 33).

Figures 5.1 and 5.2 show a cross-plot of in- and out- migration rates for 1982-87 and 1985-90, respectively. The abbreviation for China's province names, which is specified in Table 3.2 of Chapter 3, applies to the figures. The horizontal axis represents the out-migration rate while the vertical axis represents the in-migration rate. If a province's in- and out- migration rates fall anywhere along the diagonal line in the figures, the net migration rate to this region is zero. Above and to the left of this line, in-migration rates exceed out-migration ones, so the provinces in this section of the graph correspond to provinces with net in-migration. Below and to the right of the line are provinces with net out-migration (Plane and Rogerson, 1994). It can be observed in Figures 5.1 and 5.2 that no province falls precisely along the diagonal line, implying that no province in 1982-87 and 1985-90 has a zero net migration rate. The figures point out a similar pattern that is described above in terms of provinces with net in- and out-migration. There are provinces that deviated far away from the diagonal line and with high in- and out-migration rates. They are either large metropolitan areas and prosperous provinces which attracted a considerable amount of migration (such as Beijing, Shanghai, Tianjin, and Guangdong), or provinces in China's west region with a relatively small size of population which can lead to higher migration rates. Most provinces fall around the low left corner of the figures, indicating that their migration rates are within a narrow range.

In discussing the relationship between in- and out- migration, the intuitive or common sense perspective suggests an inverse or negative relation between in- and out-migration rates (Plane and Rogerson, 1994). The underlying reason behind this relation is that economically backward or depressed regions usually result in large numbers of out-migrants and rarely attract migration to them. In actual analysis, however, the circumstances are much more complex than the intuitive perspective suggests. For example, calculations based on the data of US inter-state migration flow in 1975-76, 1976-77, and 1978-79 showed that the correlation coefficients between in- and out-migration ranged between 0.84 and 0.93 (Plane and Rogerson, 1994). This positive relation has long puzzled demographers and migration researchers, and several explanations have been offered. Rogers (1992) summarises the explanations in three arguments, namely: (1) population composition argument: a growing region with large numbers of in-migrants would also have a higher rate of out-migration, because the in-migrants are more susceptible to migrate again; (2) argument of the asymmetry of the definition for in- and out- migration rates: the population used as the denominator to calculate in-migration rates is not the at-risk population of becoming in-migrants; (3) argument of return migration: large out-migration flows from a region will create a large population living in other regions and at risk of becoming return migrants.

For Chinese inter-provincial migration, the correlation coefficients for 1982-87 and 1985-90 are found to be low (0.282 and 0.180, respectively) and are not significant at the 0.05 level. This demonstrates that neither an inverse nor a significant positive relation between in- and out-migration rate is found. Figure 5.1 shows that if only the two metropolitan provinces (Beijing and Shanghai) and three western provinces (Qinghai, Xinjiang, and Ningxia) were included, an inverse relation between in- and out-migration rates can be observed. This inverse relation did not hold for the period 1985-90, as indicated in Figure 5.2. As the second argument asserts, the positive relation has to do with the asymmetry of in- and out-migration. The present study recalculated in-migration rates based on the at-risk population (population of all of the rest of the provinces other than the province under calculation) as the denominator. The correlation coefficient between the recalculated in-migration rate and out-migration rate is found to be -0.470 (significant at the 0.05 level) for 1985-90, indicating a significant inverse relation, while the corresponding figure for 1982-87 is -0.303 and is not significant at the 0.05 level. Therefore, this inverse relation indicates that the asymmetry contributes the positive relation between in- and out-migration rates, but is still inconclusive as to whether the second argument can be firmly supported or not. The paradoxical issue of the relationship between in- and out- migration rates should be examined in a more comprehensive and contextual manner.

Table 5.2 Variance of inter-provincial migration

Period	No. of in-migrants (V_I)	No. of out-migrants (V_O)	V_I / V_O
1982-1987	2.09×10^{10}	1.28×10^{10}	1.638
1985-1990	5.58×10^{10}	6.57×10^{10}	0.848
1976-77 (US data)	9.62×10^{9}	9.65×10^{9}	0.997
	In-migration rates (V_{IR})	Out-migration rates (V_{OR})	V_{IR} / V_{OR}
1982-1987	63.48	22.55	2.815
1985-1990	200.90	19.37	10.373
1976-77 (US data)	543	373	1.46

Sources: Based on data from the 1987 survey and the 1990 census. The US data are from Plane et al. (1984).

It is also observed that there is a greater variation of in-migration rates than out-migration rates (Plane, et al., 1984; Plane and Rogerson, 1994). This observation implies that migration tends to be more spatially focused toward particular destinations than from specific origins. In other words, for a regional migration system, the effects of regional economic conditions on in- and out-migration are asymmetrical. Table 5.2 shows some statistics based on China's inter-provincial migration flows, and the US data are also used for comparison.

There are two observations that can be summarised from Table 5.2. First, in terms of numbers of migrants, the greater variation of in-migration than out-migration among China's 28 provinces is found to be inconsistent between 1982-87 and 1985-90. The US data also show a slightly smaller variation of in-migration than out-migration. Second, a consistently greater variation of in-migration rates relative to out-migration rates is evident. For the periods 1982-87 and 1985-90, the ratios of variation in in-migration rates to out-migration rates are 2.8 and 10.4 respectively. This is considerably higher than for US inter-state migration, since the ratio for US data ranged from 1.46 to 2.09 during the second half of the 1970s (Plane, et al., 1984). Hence, it may be concluded that Chinese in-migration rates have a much greater variation than out-migration rates. A more interesting observation from Table 5.2 is that using the number of migrants the ratio for 1982-87 is higher than that for 1985-90, while using the rates of migration the opposite is true.

Plane et al. (1984) put forth explanations for the greater variation of in-migration rates than out-migration rates: namely, that the difference is induced by the asymmetrical definition of in- and out-migration rates, and reinforced by the uneven distribution of regional attractiveness and of regional size, and by inter-regional spatial distance. Observations based on Chinese inter-provincial migration show that the asymmetric definition of migration rates can provide sufficient explanation, because the upper part of Table 5.2 can explain the lower part. Also, using the recalculated in-migration rates based on the at-risk population as a denominator, it is obvious that the greater variation of in-migration rates than out-migration rates would disappear completely. The conclusion is that the information in the upper section of Table 5.2 may be more meaningful than that in the lower in understanding the variation in migration across regions.

5.3 Spatial focusing of inter-provincial migration

Spatial focusing of inter-provincial migration refers to the way migrants distribute themselves across the provinces, and whether or not migrants are more spatially extensive in terms of origins than in terms of destinations. This section attempts to focus on these questions.

In any migration system, it is observed that equality of migration flows is always impossible, because various regions have different sizes of population, inequality of economies, and different distance decay effects (Plane and Mulligan, 1997). With regard to this observation, there is also no exception to China's migration system. Therefore, one would never expect all outflows from any specific origin province be of equal size. The question is why we need to evaluate spatial focusing in analysing migration. As Plane and Mulligan (1997) discuss, the purpose of such an undertaking is (1) to gauge the shifts in overall geographical patterns of flows in a migration system, and (2) to evaluate each specific province's spatial focusing of flows in terms of in- and out-migration. Furthermore, even if there is zero net migration for a specific province, it may still play a significant role in the redistribution and growth of regional population, because the specific flows of in- and out- migration may differ in their degrees of spatial concentration.

A variety of measures have been used to gauge the spatial concentration of migration. These measures include the Hoover index, the demographic effectiveness, and entropy statistics. Recently, Plane and Mulligan (1997) employed the Gini index, widely used in analysing income distribution by economists, to measure the spatial concentration of the total, in- and out- migration flows for inter-state migration in the USA. On the other hand, Rogers and Sweeney (1998) propose the coefficient of variation (CV) migration field index on the basis of a detailed evaluation of the Gini index used by Plane and Mulligan. The CV is defined as the ratio of the standard deviation to the mean in a distribution. A comparison, applying the Gini and CV to US inter-state migration data, led Rogers and Sweeney (1998: 234) to conclude that the CV provides migration analysts with "a viable, simpler, and more transparent alternative indicator of geographical concentration." High values of CV indicate more spatially focused distribution of migration flows; for low values, a more spatially extensive distribution of migration is implied. In analysing the spatial concentration of inter-provincial migration in China in the following section, the CV index is adopted.

5.3.1 The total migration flows

Based on Rogers and Sweeney's approach, the CV field indices of in- and out-migration for each of China's 28 provinces are calculated. A weighted CV of spatial concentration of migration is then adopted. Specifically, the proportion of in- and out- migrants for each province to the total number of migrants is used as weights in calculating the weighted CV for in- and out-migration. The aggregate system-wide CV (ACV) is obtained by adding these two weighted CV indices.

Table 5.3 The ACV field indices for China's and United States' internal migration

Time period	Out-migration ACV (rows)	In-migration ACV (columns)	System wide ACV (both)
China			
1982-87	1.5094	1.4521	2.9615
1985-90	1.4049	1.4527	2.8676
United States			
1985-90	1.529	1.491	3.019

Sources: China's ACV indices are calculation based on migration data from China (1988, 1993). The US data are from Rogers and Sweeney (1998).

Table 5.3 shows the ACV field indices. It appears that the spatial focus of China's IPM flows for the whole migration system decreased from 1982-87 to 1985-90. Such a decrease can be attributed to the reduction in the spatial focus of in-migration flows, because there is almost no change in the spatial focus of outflows. This observation may relate to the fact that in the last half of the 1980s potential migrants may have had more choice in terms of the possible destinations. Table 5.3 also includes the ACV indices for US inter-state migration for the period 1985-90, and shows a similar range as compared with the Chinese indices. According to Rogers and Sweeney (1998), the ACV indices for US interstate migration first increased from 2.983 in 1965-70 to 3.122 in 1975-80, and decreased to 3.019 in 1985-90.

The ACV field indices for the total migration flows do not reveal the spatiai concentration of in- and out- migration for each specific province. In order to investigate such spatial concentration of in- and out- migration flows, the CV field indices for each of the 28 provinces are calculated. This is discussed in the following section.

5.3.2 The CV indices for out- and in- migration flows

When calculating the CV indices of in- and out-migration for each province, intra-provincial migration is ignored, each province has 27 destination provinces for out migration, and each also has the same number of source provinces for in-migration. When provinces have a wide distribution of migration flows, the value of the CV indices is lower. On the other hand, when provinces have a more spatially focused distribution of migration, the value for the CV indices is higher. Table 5.4 includes the CV migration field indices for each of the 28 provinces of China for the two time periods, 1982-87 and 1985-90. Several observations can be made.

(1) In 1982-87 the high CV for out-migration flows is found to be mainly in the central region of China. Guangxi has the highest CV (2.7104), followed by Hunan (2.5233), Heilongjiang (1.9484), Jilin (1.8372), and Shanxi (1.7659), indicating that these provinces have more focused destinations for their out-migration flows.

(2) The lower values for out-migration CV are found in provinces with larger population size, or those having political dominance in the country. The lowest CV is observed in the provinces of Sichuan (0.8983), followed by Shandong (1.0727), Beijing (1.1086), and Zhejiang (1.1408).

(3) The pattern observed above is still evident in 1985-90, but in general the values for the CV decreased. For example, the CV decreased for 22 provinces, and only six provinces had an increase in the CV. In particular, six provinces (Shaanxi, Beijing, Sichuan, Zhejiang, Henan, and Hubei) have a CV of less than one, meaning that these six provinces have wide ranges of destination provinces for their out-migration flows.

Table 5.4 CV field indices for out- and in- migration, China, 1982-87 and 1985-90

	Out-migration		In-migration	
Province	1982-87	1985-90	1982-87	1985-90
Beijing	1.1086	0.8311	1.4278	1.5897
Tianjin	1.7458	1.5947	1.7848	1.9469
Hebei	1.4171	1.7756	1.5764	0.8903
Shanxi	1.7659	1.1747	1.3700	1.3062
Inner Mongolia	1.3877	1.4148	1.3089	1.3986
Liaoning	1.1458	1.1357	1.9451	1.6532
Jilin	1.8372	1.7845	2.2155	1.8160
Heilonjiang	1.9484	1.6721	2.0391	1.6703
Shanghai	2.0349	1.7376	1.7027	1.8695
Jiangsu	1.6123	1.7390	0.7234	1.0591
Zhejiang	1.1408	0.8490	0.9612	0.8950
Anhui	1.7197	1.7063	1.0426	1.0897
Fujian	1.1576	1.3830	1.3415	1.5132
Jiangxi	1.2046	1.3790	1.2879	1.3423
Shandong	1.0727	1.0104	1.3767	1.1179
Henan	1.1203	0.8694	0.7705	0.7483
Hubei	1.5971	0.9448	1.3989	1.3924
Hunan	2.5233	2.2065	1.2260	0.9935
Guangdong	1.6655	1.0696	2.0338	1.9583
Guangxi	2.7103	3.6206	1.8848	1.6674
Sichuan	0.8983	0.8385	0.8731	0.8779
Guizhou	1.3801	1.1013	1.9184	2.6928
Yunnan	1.6294	1.4255	2.2857	2.6220
Shaanxi	1.1420	0.7856	1.0614	1.0296
Gansu	1.1355	1.0221	1.3776	1.1899
Qinghai	1.2972	1.0861	1.1966	1.5402
Ningxia	1.4157	1.0756	2.9814	1.5104
Xinjiang	1.3393	1.0638	1.7581	1.9352
Mean	1.5055	1.3677	1.5311	1.4756
SD	0.4315	0.5779	0.5144	0.4887

Source: Calculations based on China (1988, 1993).

(4) For in-migration fields, the mean of the CV from 1982-87 to 1985-90 decreased. In 1982-87, there are five provinces with a value of CV more than 2.0, all located in the central and west regions of China. There are four provinces (Jiangsu,

Henan, Sichuan and Zhejiang) with CVs for in-migration less than 1.0. In 1985-90, higher and lower patterns of the CV are similar to those found in 1982-87. However, values of CV above 2.0 are only found in two provinces (Guizhou and Yunnan), while five provinces have CVs below than 1.0.

Although Table 5.4 reveals patterns of spatial focusing for specific provinces in terms of either out- or in-migration flows, it is useful to summarise the patterns by classifying the provinces into several groups. Such a classification scheme is proposed and applied to the US migration data by Roseman and McHugh (1982), Plane and Mulligan (1997), and Rogers and Sweeney (1998). A brief introduction of the scheme and its use on Chinese inter-provincial migration is left to the following section.

5.3.3 A classification of provinces based on the standardised CV

Based on an investigation of migration to and from US metropolitan areas, Roseman and McHugh (1982) show that most of the US metropolitan migration fields were not symmetrical. That is, the out-migration fields for the metropolitan areas were geographically more widespread than corresponding in-migration fields, and such metropolitan areas were termed 'outward redistributors' in terms of their role in the redistribution of the US population. Plane and Mulligan (1997) argue that a comparison of the standardised out- and in- migration field indices (z-scores based their calculated Gini indices) can help to illustrate the redistributive role that a specific region plays in the US migration system.

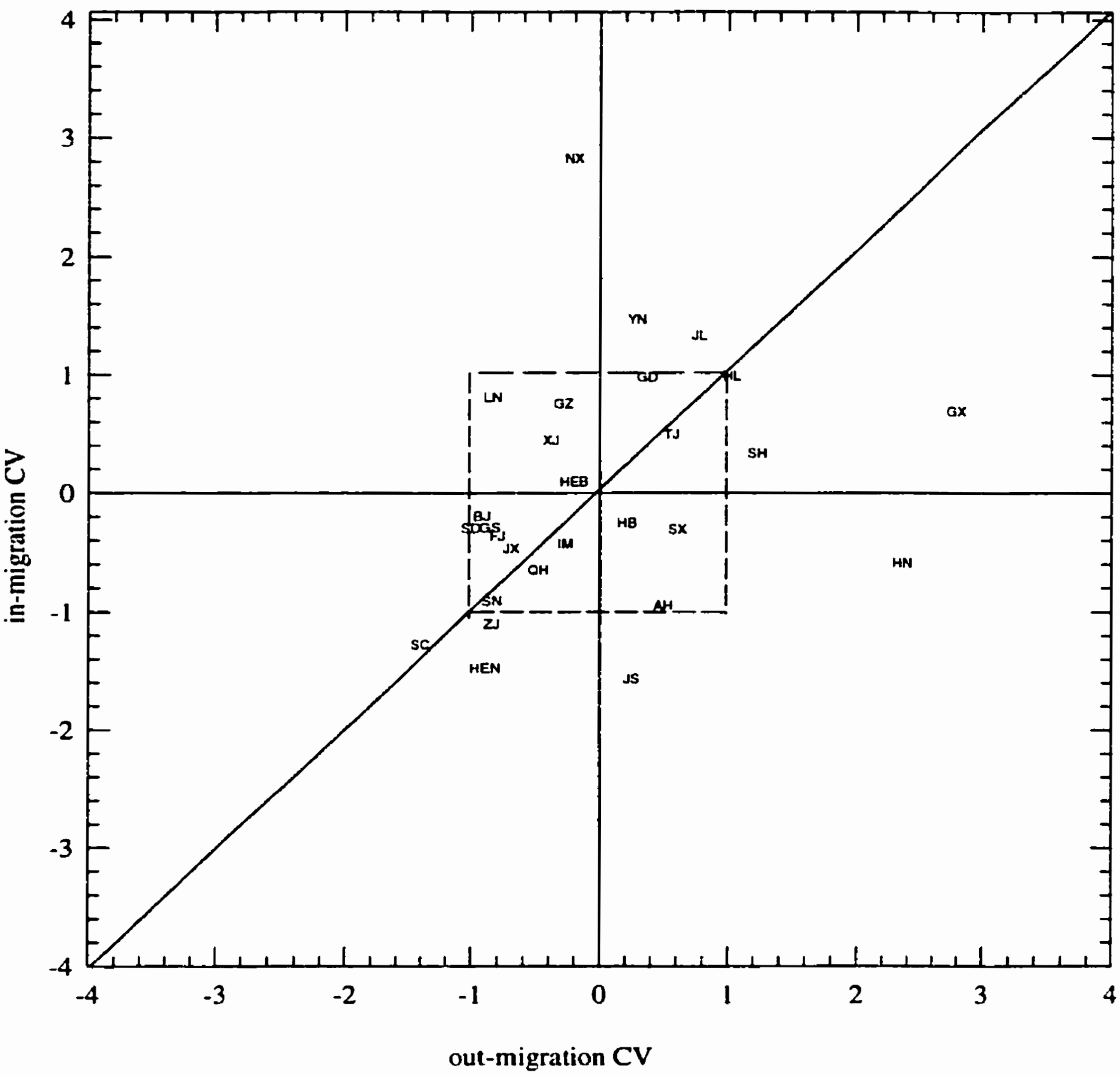

Figure 5.3 China inter-provincial migration flows, 1982-1987

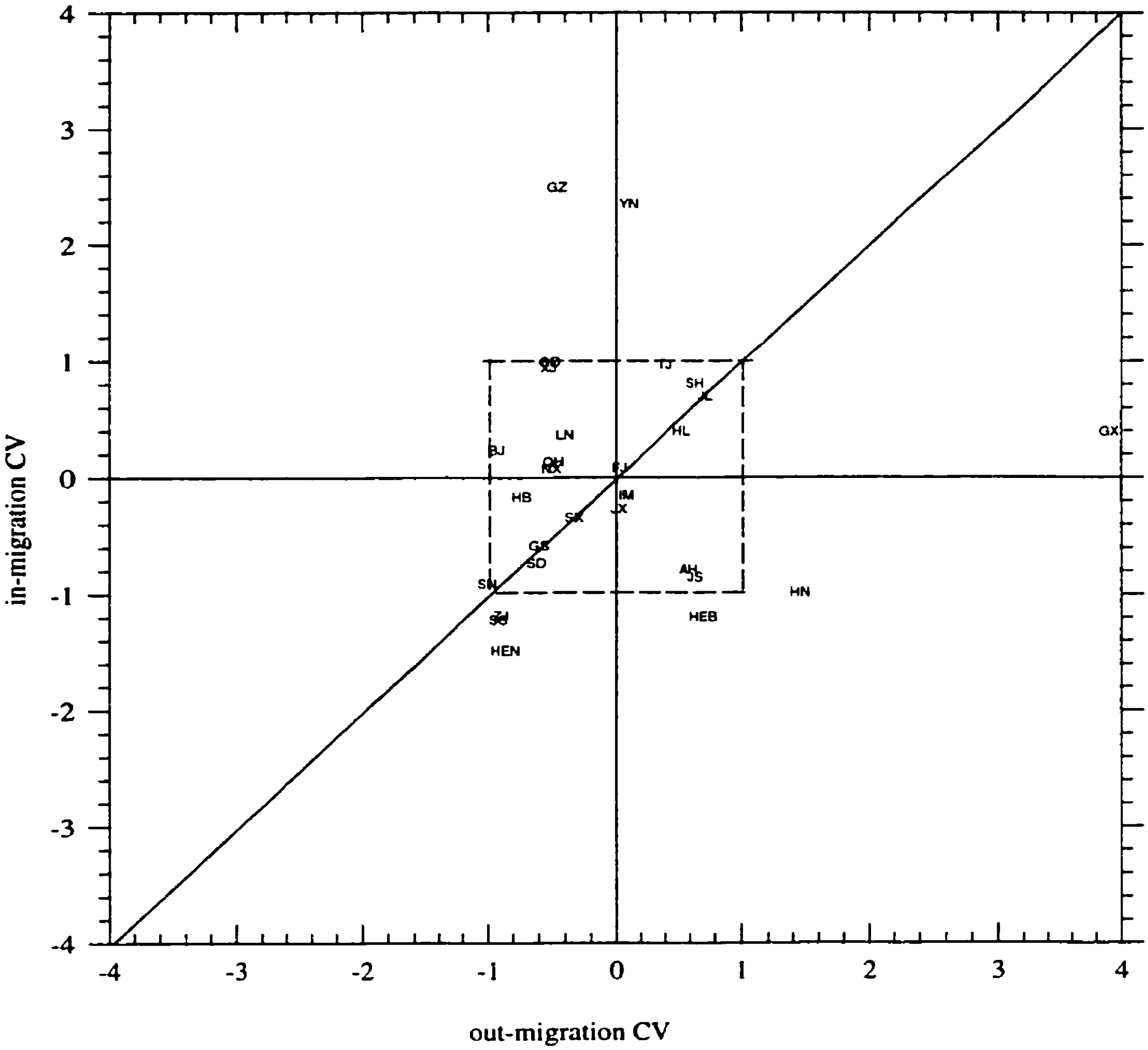

Figure 5.4 China inter-provincial migration flows, 1985-1990

Figures 5.3 and 5.4 are based on the standardised indices that are converted from the original calculated CV for out- and in-migration. In these two figures, each province is plotted with its out-migration index on the horizontal axis and the in-migration index on the vertical axis. It is argued that regions with one or both index values greater than one standard deviation above or below the mean are of particular importance in the redistribution of population in the migration system (Plane and Mulligan, 1997; Rogers and Sweeney, 1998). This is because the distribution of the standardised index values has a mean of zero and a standard deviation of one, and provinces that have index values within one standard deviation from the mean z-scores, as delimited as the concentric square, are considered not to play a significant redistributive role in the migration system.

As Figure 5.3 indicates, in 1982-87, there were 11 provinces lying outside the concentric square of one standard deviation. Provinces in the upper right quadrant have spatially focused out- and in-migration fields, implying that they send and receive migrants to and from a small number of provinces. In contrast, provinces in the lower left quadrant have spatially extensive migration fields, and they send and receive migrants to and from a large number of provinces. These two quadrants are termed 'parochial' and 'cosmopolitan', respectively (Rogers and Sweeney, 1998). Also, the figures can be divided on the diagonal line. Provinces above this line are characterised by greater in-migration than out-migration index values, implying that they send migrants to more provinces than they receive them from, and are termed 'outward redistributors'. Provinces below the diagonal line are termed 'inward redistributors', since they receive migrants from more provinces than they send them to. Provinces in the upper left and in the lower right quadrant are termed 'pure outward' and 'pure inward' redistributors, respectively. Based on these divisions, provinces outside the central square can be classified into the six categories indicated in Table 5.5.

Table 5.5 Classification of provinces based on the typology of redistributors

	1982-87	1985-90
Parochial outward	JL, YN	YN
Parochial inward	GX, HL, SH	GX
Cosmopolitan outward	SC	
Cosmopolitan inward	HEN, ZJ	HEN, SC, ZJ
Pure outward	NX	GZ
Pure inward	HN, JS	HEB, HN

The classification scheme can be further understood by examining the destination and origin flows that are reflected in one of the most cosmopolitan provinces, Sichuan, and in the most parochial province, Guangxi. The top ten destination provinces for out-migration from Sichuan were Guangdong (11.82 per cent), Yunan (9.79 per cent), Xinjiang (9.08 per cent), Guizhou (7.69 per cent), Jiangsu (7.36 per cent), Hubei (7.28 per cent), Hebei (5.92 per cent), Fujian (4.01 per cent), Henan (3.86 per cent), and Shandong (3.49 per cent). These 10 destinations account for 70 per cent of total out-migration flows from Sichuan. For in-migration flows to Sichuan, the largest 10 contributors consist of Yunan (15.74 per cent), Guizhou (9.77 per cent), Xinjiang (8.17 per cent), Hubei (6.94 per cent), Shaanxi (6.26 per cent), Hebei (4.70 per cent), Henan (4.55 per cent), Gansu (4.53 per cent), Hunan (3.43 per cent), and Liaoning (3.01 per cent). They comprise 67 per cent of the in-migration flows to Sichuan. The above list of the top 10 destination provinces for Sichuan's out-migration indicates only three are nearby or neighbouring provinces, and the rest of the 10 provinces are a long distance from Sichuan. In particular, the physical distance between Guangdong and Sichuan is about 1,215 kilometres, but Guangdong is the largest destination for Sichuan's out-migration. Therefore, the 10 destination provinces demonstrate that the effect of spatial separation on the extent of out-migration fields, albeit still visible, may not be considered important. Similar conclusions can be made regarding the provinces that contributed in-migration to Sichuan. For example, of the 10 contributors to Sichuan's in-migration flows, some are nearby provinces (Yunan, Guizhou, and Hubei), but some are located more than 2,000 kilometres away (Xinjiang and Liaoning). Xinjiang contributed 8.2 per cent to the total in-flow to Sichuan, whereas the nearby province of Hunan accounted for only 3.4 per cent.

In contrast, Guangxi — as the most parochial province — sends 93 percent of migrants to 10 provinces. Most noteworthy is the 71.86 per cent sent to its neighbour province, Guangdong. The other nine provinces are Hebei (4.31 per cent), Hunan (3.64 per cent), Fujian (2.48 per cent), Zhejiang (2.10 per cent), Jiangsu (2.08 per cent), Sichuan (1.78 per cent), Yunnan (1.55 per cent), Guizhou (1.55 per cent), and Hubei (1.34 per cent). Therefore, out migration more spatially focused. On the other hand, the 10 largest source provinces contributed 84 per cent of total in-migration to Guangxi. They are Hunan (26.6 per cent), Guangdong (22.09 pert cent), Sichuan (7.28 per cent), Guizhou (7.26 per cent), Zhejiang (4.80 per cent), Yunnan (4.79 per cent), Hubei (4.05 per cent), Jiangxi (2.81 per cent), Fujian (2.54 per cent), and Henan (2.13 per cent). This list shows that both out- and in- migration fields for Guangxi are much more focused, and that a very few provinces account for most of the total flows. Also, unlike Sichuan, the destination and source provinces for Guangxi's migration fields are generally located the south of the Yangtze River.

In the migration fields for Sichuan and Guangxi, most of the 10 largest provinces are *not only* the destinations for out-migration flows, *but also* the contributors to in-migration flows. For example, the cosmopolitan province of Sichuan has six such provinces while Guangxi has eight. This finding confirms the classic observation made by Ravenstein (1885) that each migration flow has a counterflow, and may reflect a considerable socio-economic interchange between the provinces as well.

5.4 Male – female inter-provincial migration

The classic treatment of the gender difference in migration was made by Ravenstein (1885). He noted the features of female migration as: (1) women are more mobile than men, (2) women dominate in short-distance migration but men dominate in long-distance migration, and (3) like men, women migrate based on economic motivations. Ravenstein's observations provide an important basis on which research on the gender issues of migration in the contemporary era is undertaken.

Empirical research results in the contemporary era may or may not follow exactly what Ravenstein found, because his findings were based on late 19th century British census data and today's research is based on a variety of contextual situations. The relative numbers of men and women in migration streams can be measured by sex ratios. There are three types of patterns in gender differentials in migration in less developed countries. Namely, high sex ratios are found in low income countries of Africa; female dominance (or low sex ratios) in migration in Latin America; and diverse sex ratios in migration in Asia (Hugo, 1991).

In Japan, young women often left rural areas in greater numbers than young men did in the late 1940s. The young women, typically staying in the cities for several years, either returned home for marriage upon saving enough money, or else remained in the urban places (Davis, 1966). In South Korea, it is evident that there were also more female than male migrants in the period 1961-1975 in all of rural-to-urban, rural-to-rural, urban-to-rural, and urban-to-urban migration stream (Hong Sawon, 1984). In Thailand, among the labour migrants to Bangkok in 1986-88, there were more women than men (Phongpaichit, 1993: 184). In India, except for rural-to-rural migration, all other migration flows such as urban-to-urban, urban-to-rural, and rural-to-urban movements were male dominated (Singh, 1984; Skeldon, 1986). The greater number of women than men in India's rural-to-rural migration can be attributed to the marriage custom "of village exogamy and patrilocal residence" (Singh, 1984: 82).

In investigating gender differences in China's inter-provincial migration, the sex ratio (number of males per 100 females) is used to describe the disparity. Because the sampled number of migrants for some provinces in the 1987 survey is too small to allow for a meaningful calculation of sex ratios, we only employ the 1990 census data for examining the regional patterns of male and female differences in migration. Table 5.6 shows sex ratios for out- and in-migration in 1985-90. The table illustrates the following noteworthy points.

First, out-migration sex ratios are high for the three major metropolitan areas (Bejing, Tainjin, and Shanghai) and the coastal prosperous provinces (Guangdong, Jiangsu, Fujian, and Shangdong), ranging between 286.1 and 184.7. Second, low sex ratios for out-migration are found in Inner Mongolia, two provinces (Heilongjinag and Jilin) in northeast China, and in Hunan. Particularly low sex ratios for out-migration are observed in Guangxi (61.5) and two of the southwestern provinces, Guizhou (47.5) and

Yunnan (53.3). Third, the sex ratios for in-migration for the three large metropolitan regions are lower than those for their respective out-migration flows. Finally, women dominate in-migration to the provinces of Guangdong, Hebei, Shandong, and Anhui, and relatively low sex ratios for in-migration are also found in Jiangsu, Fujian, Zhejiang, and Ningxia.

Table 5.6 Sex ratios for China's inter-provincial migration, 1985-90

Province	Out-migration	In-migration	Province	Out-migration	In-migration
Beijing	286.1	189.5	Shandong	184.7	89.4
Tianjin	185.7	131.4	Henan	167.1	138.8
Hebei	181.7	77.0	Hubei	137.6	207.0
Shanxi	168.4	172.5	Hunan	116.9	156.4
In. Mongolia	113.0	127.4	Guangdong	283.0	86.7
Liaoning	156.9	148.9	Guangxi	61.5	206.7
Jilin	114.5	160.1	Sichuan	127.0	170.1
Heilongjiang	101.3	185.7	Guizhou	47.5	232.0
Shanghai	256.8	205.8	Yunnan	53.3	279.5
Jiangsu	221.5	100.8	Shaanxi	130.9	198.8
Zhejiang	181.5	121.7	Gansu	154.1	130.8
Anhui	185.2	98.4	Qinghai	140.2	233.6
Fujian	251.3	117.2	Ningxia	143.7	119.3
Jiangxi	153.6	206.2	Xinjiang	131.4	185.8

Source: Calculation based on China (1993).

The above pattern can be explained by China's urban and regional development strategy and surging temporary migration resulting from economic reforms. For example, sex ratios both for out- and in-migration are high for the three large metropolitan regions, confirming that there has been a strict control policy for urban population growth. In out-migration flows men are dominant, because university

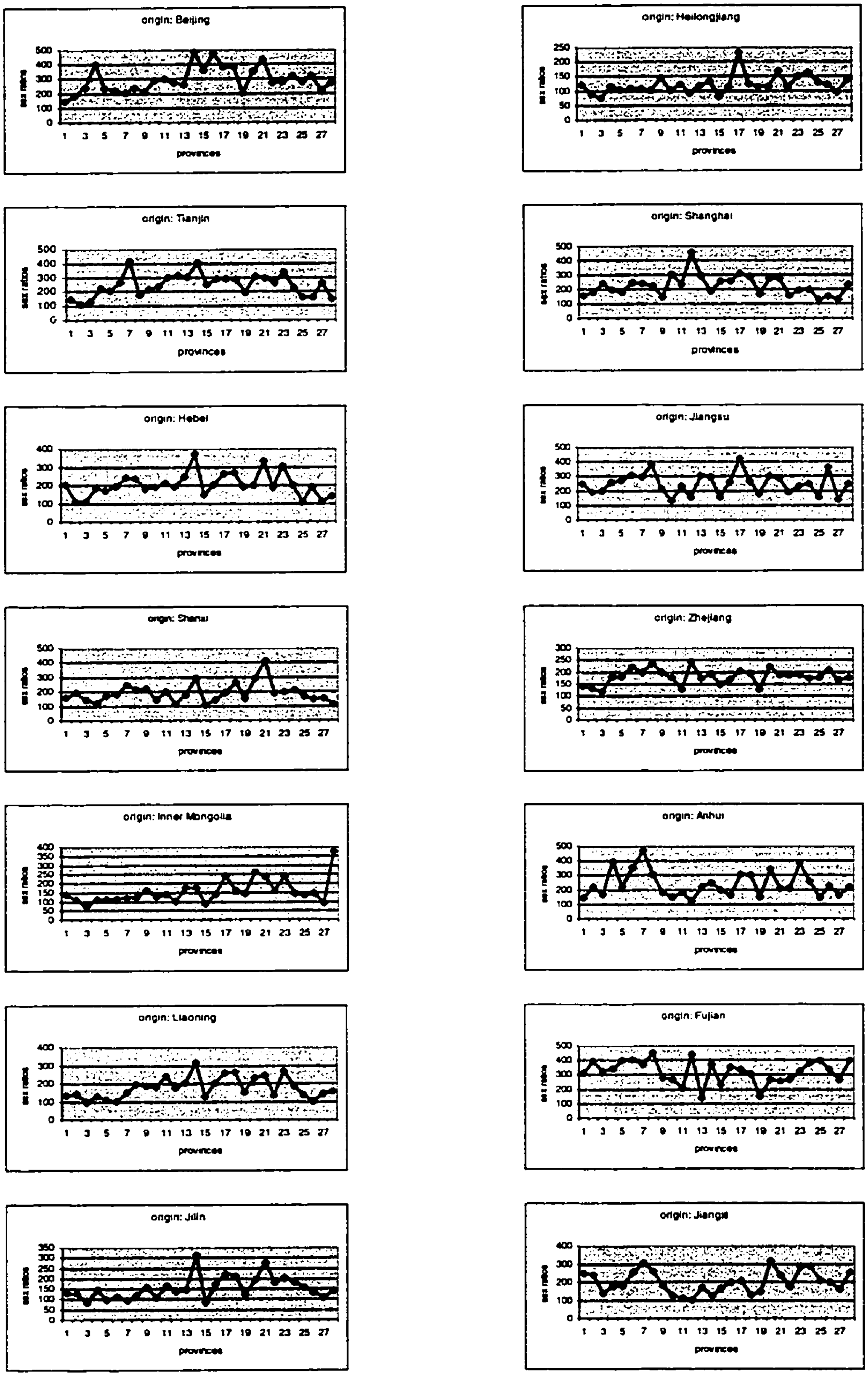

Figure 5.5 Sex ratios of out-migration, China, 1985-90
Source: China, 1993.

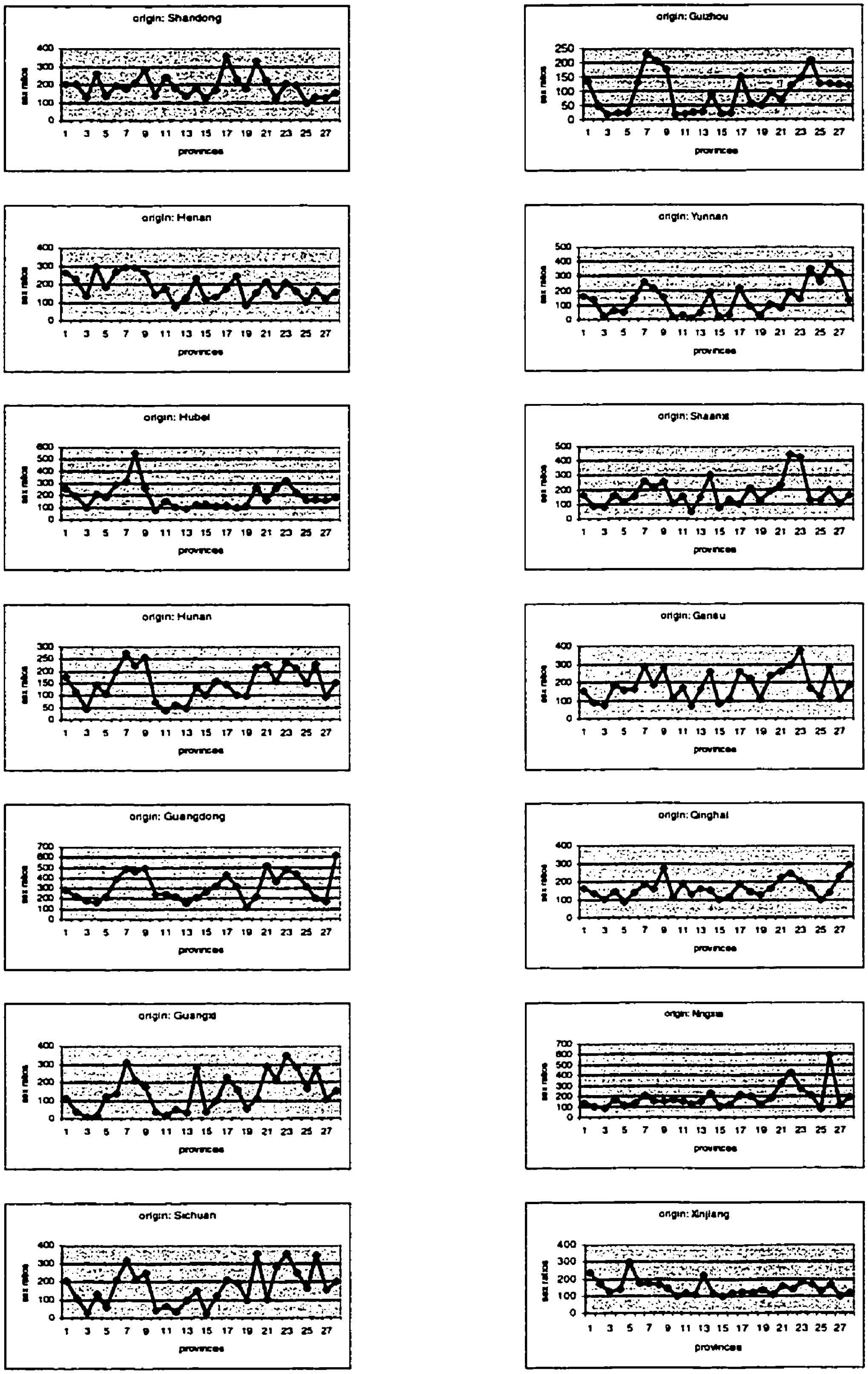

Figure 5.5 Cont.

graduates (of which males usually make up the predominant proportion) move to other provinces. The lower sex ratios for in-migration than for out-migration in these three large cities reflect the inclusion of the influx of the temporary migrants that are female. Overall, the observations made from the table are consistent with the findings by Goldstein and Goldstein (1994).

Also, it may be noted that low and extremely low sex ratios for out-migration are found in the provinces with less developed economies, while low sex ratios for in-migration are usually observed in prosperous coastal provinces. This demonstrates that women leave their poor origin provinces in large numbers for other opportunities. They constitute a major part of the temporary migration to the coastal provinces, which was highly selective of females (Goldstein and Goldstein, 1994).

Further understanding of male-female migration differentials can be gained by disaggregating the total out- or in-migration. Figure 5.5 shows the sex ratios for each province's out-migration flows to the 27 destination provinces, including intra-provincial migration for convenience of plotting the graph. Specifically, the 27 destination provinces, including each origin province (for intra-provincial migration), are represented in identification (ID) numbers from 1 to 28 by the horizontal axis, and the provincial ID numbers in Table 3.2 of Chapter 3 apply to the figure. Based on Figure 5.5, two patterns can be observed. The first pattern is that the sex ratio for every out-migration flow to the 27 destination provinces is higher than 100.0, implying that male migrants make up a large or dominant proportion. This pattern includes the three centrally administered large cities (Beijing, Tianjin, and Shanghai) and the provinces of Hebei, Shanxi, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Guangdong, and Shandong.

The second pattern is characterised by sex ratios less than 100 for out-migration to a number of destination provinces, the number of such destinations being from 6 to 15. They consist of Guizhou (15), Yunnan (12), Guangxi (9), Sichuan (7), and Hunan (6). This pattern is found in part of the southern, and the whole of southwestern, China. It is a spatial cluster that exports female migrants in large numbers mainly to the rich provinces with employment opportunities generated by foreign investments and the private business sector. Geographical distance no longer constitutes an obstacle for such migrants (Chang, 1996). Such female migration flows also are caused by marriage considerations (Fan and Huang, 1998).

5.5 Summary

This chapter discusses regional IPM patterns in China by (1) examining out- and in-migration flows in numbers and rates, (2) investigating the spatial concentration of migration, and (3) identifying the gender differential in migration. The overall pattern is that migration is primarily from the interior (including the central and west regions) to coastal regions. It is also found that the disaggregation analysis for a large country like China is useful to further understand migration patterns. In this chapter, such disaggregation analysis is undertaken by calculating CV indices of out- and in-migration flows for each province. The CV indices confirm that each province has its own migration field, and the difference lies mainly in the degrees of the spatial focus of the IPM flows. The standardised CV indices illustrate that a number of provinces play an important role in redistributing migrants in China.

Analysis of the gender differential in migration reveals that female migrants make up a predominant proportion in a number of out-migration flows, particularly from the provinces of southwestern China to the rich provinces in the coast region. This finding is significant in understanding the migration constraints for ordinary citizens in general, and for women in particular. It has been noted that the low status of women might force them to move out of their places of origin so that they can escape oppressive situations (Boserup, 1970, quoted in Guest, 1993). The large numbers of Chinese women participating in out-migration reflects the fact that they have a desire to improve their status. Moreover, female out-migration is a result of the interplay of a variety of factors and constraints. For example, rural, female out-migrants are usually faced with the constraints of low education and social status, a narrow social network, and less chance to participate in the urban labour market. Therefore, in such circumstances, migration to rural places in the coastal regions is a possible and practical route for improving status of the interior rural women, who migrate for employment, for marriage, or for both.

Chapter Six Analysis of Results

6.1 Introduction

As discussed in Chapter 1, a main objective of the present study is to estimate China's province-to-province migration flows by using MSIMs for 1982-87 and 1985-90. The modelling process involves estimation of the model parameters, which was discussed in Chapter 4, for the purpose of replicating the observed migration flows. The predicted migration matrix is then compared with the observed one for verification of the models. In modelling China's migration, a conventional SIM is also estimated, so that the performance of the MSIMs can be evaluated against the conventional SIM.

The purpose of this chapter is to analyze and discuss the modelling results. It involves first an overall analysis of the results from the MSIMs. An evaluation of the performance of the MSIMs is made against the conventional SIM. The analysis is then directed toward comparisons of MSIMs estimated between the two time periods, and between male and female migrations in 1985-90. The discussion is further related to the origin-specific MSIMs. Evaluation of the impact of the two external variables on model performance is also made. Finally, analysis of errors in prediction of the migration flows is carried out.

6.2 Results of the MSIMs

The MSIM of Equation (4.14), derived in Chapter 4, is:

$$M_{ij} = h_j s_{ij} A_i O_i d_{ij}^{-\beta} \tag{6.1}$$

In the actual modelling process, Equation (6.1) is estimated, and it is also disaggregated into the following three models for comparative purposes:

$$M_{ij} = A_i O_i d_{ij}^{-\beta} \tag{6.2}$$

$$M_{ij} = h_j A_i O_i d_{ij}^{-\beta} \tag{6.3}$$

$$M_{ij} = s_{ij} A_i O_i d_{ij}^{-\beta} \tag{6.4}$$

All the terms are introduced and defined in Chapter 4 and not repeated here. For convenience of presentation and analysis followed, Equations (6.2), (6.3), (6.4), and (6.1) are referred to as the conventional model (CM), MSIM 1, MSIM 2, and MSIM 3, respectively, where MSIM refers to multivariate spatial interaction model.

6.2.1 Overall performance, 1985-90 and 1982-87

Table 6.1 presents the modelling results for total inter-provincial migration during the period 1985-1990. Three observations can be made from this table. First, the value for beta (β) decreases from 1.1317 for the CM to 0.4132 for MSIM 3, indicating a 63.5 per cent decrease. This change illustrates that when the two variables, total investment average in 1986-90 and migrant stock of 1982-87, are included, the effect of distance impedance on inter-provincial migration appears to be lessening. This reduction may imply that a destination province with high employment opportunities will attract a considerable number of migrants. In such a circumstance, physical distance seems to be a secondary consideration for migration decision-making.

Table 6.1 Parameters of the CM and the MSIMs for total inter-provincial migration, 1985-90

Model type	CM	MSIM 1	MSIM 2	MSIM 3
Beta	1.1317	1.1208	0.2263	0.4132
% E	34.63	29.78	16.73	17.76

Second, a comparison of the beta values between MSIM 1 and MSIM 2 on the one hand, and the conventional model on the other, shows that the migrant stock variable in MSIM 2 has a much more depressing effect on the beta value than the investment variable in MSIM 1. This is an obvious confirmation that in a developing country like China past migration plays an important role in the process of inter-provincial migration in terms of overcoming the difficulty of the distance barriers.

Third, the goodness-of-fit statistic, represented by the percentage of migrants misallocated (shown as *% E* in Table 6.1), shows that the performance of the model is improved considerably from the conventional model (34. 63 per cent) to MSIM 1 (29.78 per cent) to MSIM 3 (17.76 per cent). The percentage of migrants misallocated among the cells of the migration matrix measures the per cent of the total number of predicted migrants that are allocated to incorrect cells in the migration matrix. The magnitude of this index illustrates that the conventional model correctly assigns about 65 per cent of the total number of migrants in 1985-90, whereas MSIM 3, with inclusion of the two additional variables, correctly allocates about 82 per cent of all migrants, this being a 17 percentage points improvement. This also illustrates the validity of the multivariate approach to modelling China's inter-provincial migration.

Finally, Table 6.1 also indicates that the performance of all the models with additional variables(s) is better than the conventional model. Moreover, a comparison of all the models with additional variable(s) shows that MSIM 2 performs best, albeit its performance is close to that of the MSIM 3. This observation illustrates that more variables included into the spatial interaction model do not necessarily lead to an improvement in performance.

Table 6.2 Parameters of the CM and MSIM 1, 1982-87

Model type	CM	MSIM 1
Beta	1.0851	1.0737
% E	38.60	33.91

For modelling inter-provincial migration in 1982-87, MSIMs 2 and 3 are not estimated, because the migrant stock variable is not available. Table 6.2 shows the modelling results. The table indicates that the beta value decreases, and the overall performance as measured by the percentage of migrants misallocated improves by 4.69 percentage points between the CM and MSIM 1. This again confirms the validity of the MSIM. It may be noted that the magnitude of such an improvement of the model performance can be comparable with the improvement (4.85 percentage points) between the CM and MSIM 1 for migration in 1985-90, as shown in Table 6.1.

6.2.2 Male and female migration

Table 6.3 summarizes statistics for the modelling results for both male and female inter-provincial migrants in 1985-90. It appears from the table that a difference can clearly be identified with respect to properties of the estimated model between male and female migrations. The difference can be summarized as follows.

First, for the conventional model and MSIM 1, the difference in the values of beta between male and female migrants indicates that female inter-provincial migrants are more likely to be constrained by spatial separation. However, for MSIMs 2 and 3, the values for beta for female inter-provincial migration are considerably lower than those for male migration, and this is particularly so for MSIM 2. Such a disparity in the values for beta indicates that inter-provincial female migrants are highly likely to follow their predecessors, illustrating the importance of past migrants in guiding and channeling the subsequent migrations.

Table 6.3 Parameters of the CM and the MSIMs for male and female migrations, 1985-90

Model type	CM		MSIM 1		MSIM 2		MSIM 3	
	Male	female	male	female	male	female	male	female
Beta	1.1138	1.1576	1.0836	1.1986	0.2243	0.1406	0.4081	0.3287
% E	32.83	39.50	29.59	32.08	17.55	20.62	18.39	19.79

Second, with the addition of the two variables into the model, the beta values have a general trend of decrease from the CM to MSIM 1 to MSIM 3. For example, the beta value for male migration decreases from 1.1138 for the CM to 0.4081 for MSIM 3, while the corresponding value for female migration declined from 1.1576 to 0.3287. A comparison of the beta values between MSIM 1 and MSIM 2 reveals that the two introduced variables exert a varied influence on male and female migrations.

Finally, the performance of the estimated models, measured by the percentage of migrants misallocated, is better for male migration than that female migration. However, a common feature is that performance is improved from CM to MSIM 1 to MSIM 3. It should be noted that the main purpose of the inclusion of MSIM 2 in Table 6.3 is to uncover whether the two variables have different impacts on replication of the observed migration flows, as compared to MSIM 1. Table 6.3 indicates that such varied impacts exist.

6.2.3 The balancing factor

The balancing factor of A_i for the conventional model based on the inter-provincial data in 1985-90 is shown in Table 6.4. The parameter of A_i is to ensure that the estimated out-migrants from each origin province match the observed out-migrants. In other words, its role is to satisfy the migration origin constraint, which was discussed in Chapters 1, 3, and 4. It should be noted that the estimated values for A_i in the table are based on one global total cost constraint. That is, in estimating the conventional model for inter-provincial migration in 1985-90, the estimated mean logarithmic migration distance matches the observed one, so that the cost-constraint for the model with power function is satisfied. This value is estimated to be 6.55469 km. It also should be noted that this value is a weighted mean logarithmic distance (see discussion in Chapter 4).

Table 6.4 The balancing factor (A_i) of the CM, 1985-90

Province	A_i	Province	A_i
Beijing	56.129	Shandong	61.221
Tianjin	54.439	Henan	61.260
Hebei	52.976	Hubei	61.271
Shanxi	57.603	Hunan	71.713
In. Mongolia	78.978	Guangdong	108.972
Liaoning	97.903	Guangxi	113.749
Jilin	101.054	Sichuan	98.481
Heilongjiang	122.873	Guizhou	96.004
Shanghai	68.699	Yunnan	125.429
Jiangsu	55.343	Shaanxi	75.045
Zhejiang	61.059	Gansu	81.014
Anhui	54.108	Qinghai	92.024
Fujian	95.567	Ningxia	85.253
Jiangxi	65.685	Xinjiang	253.541

Table 6.4 shows that the A_i values range from a low of 52.976 in Hebei (situated in close proximity to Beijing) to a high of 253.541 in Xinjiang (located in far northwest China), with an overall average of 85.98 and standard deviation of 39.60. Other provinces with higher A_i values are the peripheral areas, such as Heilongjiang (122.873), Yunnan (125.429), Guangxi (113.749), Guangdong (108.972), and Jilin (101.054). Other lower A_i values are found to be in the provinces with more accessible location. Such a pattern of A_i values is obviously related to migration distance, which is a reasonable approximation of accessibility for an origin province. In the conventional model estimated here, the A_i values are positively associated with the distance of inter-provincial migration from each origin province to all other provinces. Therefore, in general, the peripheral and less accessible origin provinces have high values of A_i. In contrast, centralized and more accessible provinces of origin have low values of A_i. This observation is in accordance with previous studies by Thomas (1977), Evans (1986), and Akwawua (1995), which show that A_i is in a general measure of accessibility.

6.3 Results of the origin-specific MSIMs

For convenience of analysis and presentation, the origin-specific MSIM, introduced in Equation (4.15) of Chapter 4, is referred to as OSMSIM. In estimating the OSMSIM, three specific models for each origin province, together with the origin-specific conventional model, are calibrated. Namely,

$$M_{ij} = A_i O_i d_{ij}^{-\beta_i}, (i \neq j) \qquad (6.5)$$

$$M_{ij} = h_j A_i O_i d_{ij}^{-\beta_i}, (i \neq j) \tag{6.6}$$

$$M_{ij} = s_{ij} A_i O_i d_{ij}^{-\beta_i}, (i \neq j) \tag{6.7}$$

$$M_{ij} = h_j s_{ij} A_i O_i d_{ij}^{-\beta_i}, (i \neq j) \tag{6.8}$$

All the terms and variables are defined in Chapter 4, and not repeated here. Equations (6.5), (6.6), (6.7) and (6.8) are referred to as origin-specific conventional model (OSCM), OSMSIM 1, OSMSIM 2, and OSMSIM 3, respectively.

6.3.1 Evaluation of the performance

The results of applying the goodness-of-fit statistic to the calibration of the four origin-specific models are presented in Table 6.5. Discussion of the performance is done for each model specifically, starting with the origin-specific conventional model. The second column of Table 6.5 presents the percentage of misallocated migrants by the OSCM. The lowest percentages of misallocated migrants by this model are found in Zhejiang (15.8 per cent), Shanxi (17.92 per cent), and Guangdong (19.11 per cent); while the highest percentages are in the provinces of Guangxi (58.01 per cent), Yunnan (45.53 per cent), Hunan (44.38 per cent), Heilonjiang (43.25 per cent), and Xinjiang (43.01 per cent). The overall average of the percentage of misallocated migrants is 32.29 per cent, with a standard deviation of 9.27 per cent. Therefore, even though the OSCM can replicate the inter-provincial migration flows with a certain degree of accuracy, its performance cannot be considered satisfactory by including only the distance variable. In particular, the worst performing provinces, as listed in Table 6.5, indicate that physical distance alone will not serve as an adequate variable for improving estimates inter-provincial migration flows.

Table 6.5 Percentage of inter-provincial migrants misallocated for origin-specific models (*% E*), 1985-90

Province	OSCM	OSMSIM 1	OSMSIM 2	OSMSIM 3	Decline (%)
(1)	(2)	(3)	(4)	(5)	(6)=[(2) - (5)]/(2)×100
Beijing	28.61	14.43	15.55	13.48	52.88
Tianjin	25.51	19.81	11.01	13.82	45.83
Hebei	32.98	32.77	9.97	9.90	69.98
Shanxi	17.92	13.71	9.78	11.27	37.11
In. Mongolia	38.65	34.27	13.03	13.73	64.48
Liaoning	25.26	17.03	9.65	11.97	52.61
Jilin	24.30	19.47	5.82	4.67	80.78
Heilongjiang	43.25	27.18	11.83	9.74	77.48
Shanghai	30.37	15.99	11.46	13.22	56.47
Jiangsu	35.29	29.86	13.29	13.32	62.26
Zhejiang	15.80	15.87	11.40	13.16	16.71
Anhui	27.51	22.53	12.26	11.33	58.81
Fujian	25.75	25.92	20.57	21.53	16.39
Jiangxi	37.40	28.02	18.09	17.44	53.37
Shandong	35.12	28.51	13.33	14.71	58.12
Henan	29.10	28.54	10.38	12.39	57.42
Hubei	30.76	23.13	20.52	20.47	33.45
Hunan	44.38	31.98	37.54	26.61	40.04
Guangdong	19.11	14.01	12.59	13.08	31.55
Guangxi	58.01	10.66	8.48	6.99	87.95
Sichuan	32.75	25.12	10.90	15.19	53.62
Guizhou	36.46	24.02	16.53	14.30	60.78
Yunnan	45.53	25.18	16.32	13.38	70.61
Shaanxi	23.25	18.72	14.08	13.13	43.53
Gansu	31.70	27.30	14.40	17.44	44.98
Qinghai	35.32	20.31	16.28	15.50	56.12
Ningxia	31.07	27.84	20.12	21.12	32.02
Xinjiang	43.01	26.83	17.23	15.24	64.57
Average	**32.29**	**23.18**	**14.37**	**14.22**	**59.71**
sd	**9.27**	**6.40**	**5.86**	**4.44**	**52.10**

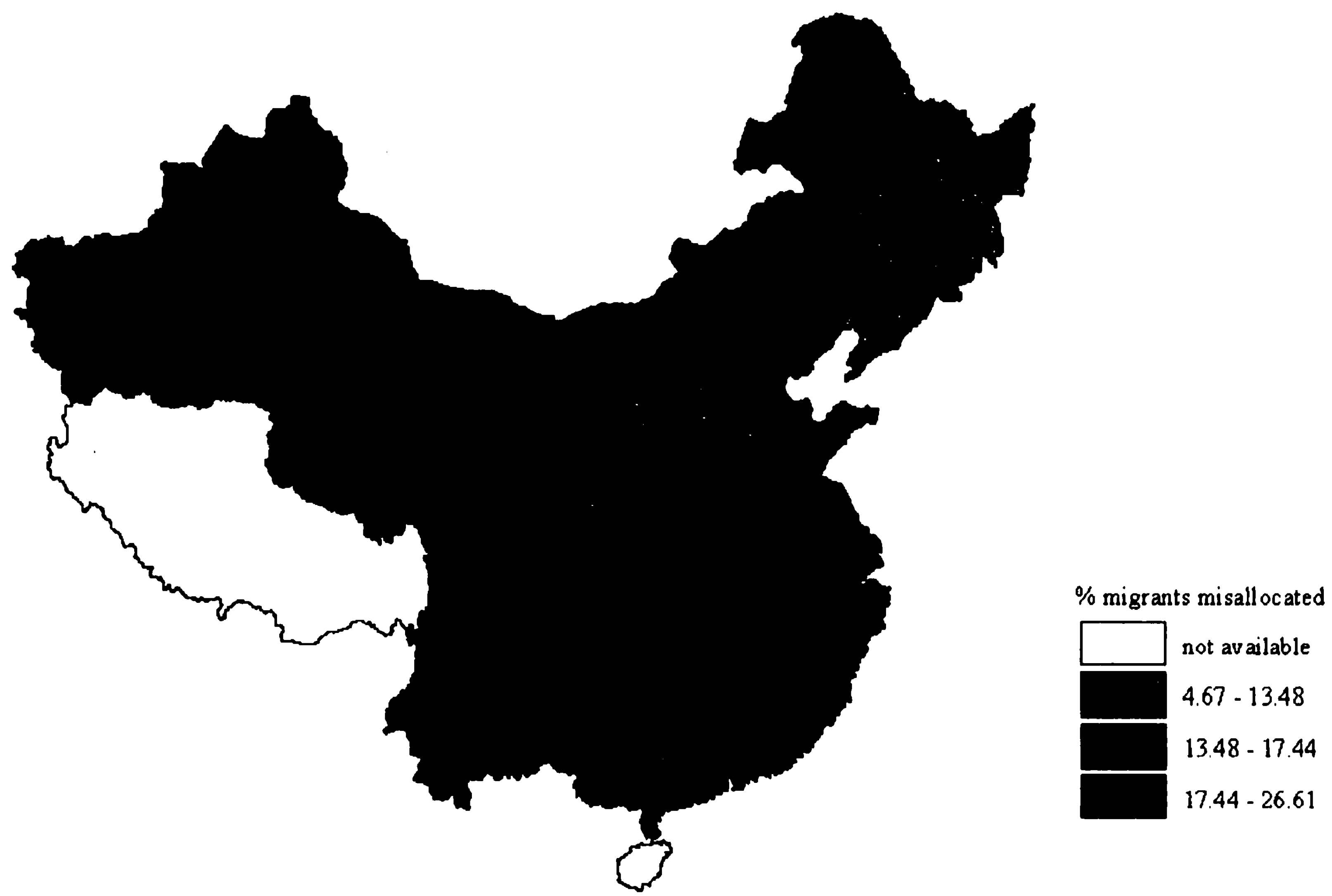

Figure 6.1 Geographical distribution of % E for OSMSIM 3, 1985-90

The performance level of OSMSIM 3 is included in the fifth column of Table 6.5. It should be noted that the average investment in 1986-90 and the migrant stock in 1982-87 are the two additional variables included in this model. Figure 6.1 shows the spatial distribution of the performance for OSMSIM 3. The distribution indicates that with the exception of Hainan and Tibet (no data available), the 28 provinces can be divided into three categories in terms of the percentage of migrants misallocated. Based on this performance index, 14 provinces (Yunnan, Guangxi, Guangdong, Zhejiang, Jiangsu, Anhui, Henan, Shaanxi, Shanxi, Hebei, Beijing, Liaoning, Jilin, and Heilongjiang) are in the range between 4.67 per cent and 13.48 per cent, and this implies that the OSMSIM 3 provides an estimation of out-migration from these 14 provinces with reasonable accuracy. Four provinces (Fujian, Hunan, Hubei, and Ningxia) have performance levels between 17.44 per cent and 26.61 per cent, and the performance for all the remaining provinces lies in between these two categories.

Comparing with the performance of OSCM in the second column of Table 6.5, it is evident that the performance of OSMSIM 3 improves on it considerably. The improvement between these two models is calculated and indicated in the sixth column of Table 6.5. Overall, the average improvement is about 60 per cent, with a reduction of the standard deviation of 52.10 per cent, illustrating that the model with these two additional variables can replicate the observed migration flows with much-improved accuracy. The sixth column of Table 6.5 shows that high improvement is found in the provinces of Guangxi (87.95), Jilin (80.78), Heilongjiang (77.48), and Yunnan (70.61). Lower improvement is found in two southeastern provinces, Fujian (16.39) and Zhejiang (16.71).

The high-improvement provinces are usually in peripheral locations. Such provinces once received migrants in large numbers from the coastal provinces, and in particular from three large cities (Beijing, Shanghai, and Tianjin) in the period prior to the late 1970s. In such circumstances, the distance variable is no longer appropriate in accounting for the inter-provincial migration flow pattern, and only migrant stock and investment variables improve the performance of the model. For example, Guangxi's out-migration flow fields can be replicated much more accurately by the model with either the investment variable or the migrant stock variable or both, rather than by the model with the conventional distance variable. This is due in part to the fact that Guangxi's out-migration field was highly focused geographically in the 1980s, as discussed in Chapter 5. Specifically, out-migration from Guangxi was mainly directed into one of its neighboring provinces, Guangdong, while Guangdong accounted for a relatively high proportion of total investment (8.7 per cent of China's total investment in 1986-90), in particular investment from foreign countries. It was to be expected that the two additional variables would improve the performance of the models considerably.

A comparison between the performance of OSMSIM 1 (the third column of Table 6.5) and OSMSIM 2 (the fourth column of Table 6.5) indicates that OSMSIM 2 replicates the observed out-migration from each origin province more accurately than OSMSIM 1. For example, the average performance level of OSMSIM 2 indicates that it allocates correctly 86 per cent of inter-provincial migrants, while the corresponding figure for OSMSIM 1 is 77 per cent. The standard deviation for these two models shows that OSMSIM 2 has a narrower range of variation around the average performance level than OSMSIM 1, confirming that in general OSMSIM 2 shows more adequate performance for each origin province. The observation therefore is that in China the migrant stock variable can be used for estimating migration flows with much more accuracy than the investment variable.

Observation of columns 2 and 3 in Table 6.5 shows that for 26 out of 28 provinces OSMSIM 1 (the model with the investment variable) outperforms OSCM (the conventional model). Only two provinces (Zhejiang and Fujian) are found to be exceptions. For example, the performance between OSCM and OSMSIM 1 for Zhejiang is 15.80 per cent versus 15.87 per cent, while the corresponding figures for Fujian are 25.75 per cent versus 25.92 per cent. Although these two provinces can be considered as exceptions, the performance difference between these two models is narrow. This implies that for these two origin provinces, the investment in all other possible destinations does not exert much influence in altering the out-migration flow pattern that is estimated by OSCM for these two provinces.

Overall, the general observation made from Table 6.5 is that the origin-specific spatial interaction modelling of China's inter-provincial migration with additional variable(s) is a valid approach to replicating the observed migration flows. The empirical models are a firm confirmation of this approach.

6.3.2 The beta values

Table 6.6 presents the beta values for all the origin-specific models for comparative purposes. The beta values for OSCM are shown in the second column of the table. It is revealed here that for the origin-specific conventional model, the beta values range from a low of 0.3324 in Sichuan to a high of 2.8233 in Guangxi. The overall average of the beta for OSCM is 1.1431 with a standard deviation of 0.5048.

Table 6.6 The beta values for origin-specific models, 1985-90

Province	OSCM	OSMSIM 1	OSMSIM 2	OSMSIM 3
(1)	(2)	(3)	(4)	(5)
Beijing	0.4824	0.4883	0.0592	0.3493
Tianjin	1.1463	1.0530	0.0424	0.4787
Hebei	1.4257	1.4167	0.0290	0.0500
Shanxi	1.2912	1.2153	0.1477	0.8423
In. Mongolia	1.2196	1.3325	0.0149	0.1802
Liaoning	1.2816	1.4686	0.3714	0.8456
Jilin	1.4092	1.2165	0.3162	0.4443
Heilongjiang	1.1207	1.2730	0.0835	0.2552
Shanghai	1.3989	1.0262	0.5707	0.8153
Jiangsu	1.0910	0.9452	0.1188	0.2132
Zhejiang	0.8125	0.7694	0.3082	0.0778
Anhui	1.4331	1.0525	0.3349	0.0625
Fujian	1.7462	1.5916	0.4637	0.9697
Jiangxi	1.3769	1.2733	0.0538	0.2948
Shandong	0.4765	0.2564	0.2401	0.1537
Henan	0.5695	0.5370	0.0177	0.0415
Hubei	0.8644	0.7485	0.2590	0.5674
Hunan	1.3590	1.9791	0.8963	1.1837
Guangdong	1.7705	1.9881	0.8697	1.6741
Guangxi	2.8233	2.5230	0.1869	0.6798
Sichuan	0.3324	1.5627	0.1040	0.3896
Guizhou	1.0630	1.2255	0.1232	0.4578
Yunnan	1.1145	1.7133	0.0352	0.8382
Shaanxi	1.2894	1.4117	0.2818	0.7643
Gansu	0.7815	1.7426	0.5386	0.7103
Qinghai	0.7788	1.6503	0.0979	1.0437
Ningxia	1.1136	1.6725	0.6075	0.8616
Xinjiang	0.4348	3.1057	0.1632	1.1591
Average	1.1431	1.3657	0.2620	0.5858
sd	0.5048	0.5984	0.2463	0.4106

The variation in the province-specific beta values may be compared with the results calculated by use of a doubly-constrained origin-specific spatial interaction model with power function to calibrate migration at the county level in Britain. In the study by Stillwell (1978), the beta value at the British county level varied from a low of 0.7924 to as high as 2.8832. The overall average and the standard deviation for British counties are 1.41 and 0.42, respectively, in comparison with values of 1.1431 and 0.5048 in the present case, meaning that the values of average and standard deviation between these two studies fall in a similar range.

Spatial variation in the values for the parameter beta of the OSCM can be observed. For example, beta values lower than the average are found in the southwestern provinces (Sichuan, Guizhou, and Yunnan), northwestern provinces (Gansu, Qinghai, Ningxia, and Xinjiang), and other three provinces (Beijing, Zhejiang, and Shandong). Beta values above the average are found mainly in the north and northeastern provinces, and in the southern provinces (Hunan, Fujian, Guangdong, and Guangxi). However, the geographical pattern of such a variation does not necessarily mean that there are no exceptions. A case in point appears in the beta values for Fujian and Zhejiang. The beta value for Fujian is recorded as 1.7462 while the corresponding figure for Zhejiang is 0.8125, although both provinces are in close proximity on the coast region. Such a contrast may only reveal that spatial behavior of inter-provincial migration for these two provinces is unique.

Figure 6.2 illustrates the origin-specific beta derived from OSCM and mean out-migration distances in kilometres (the abbreviation of the provincial names applies to the figure). In general, it is not surprising to note that out-migrants from peripheral provinces tend to migrate over longer distances (more than the overall average of 895 kilometres), whereas out-migrants from more central provinces tend to migrate over shorter distances

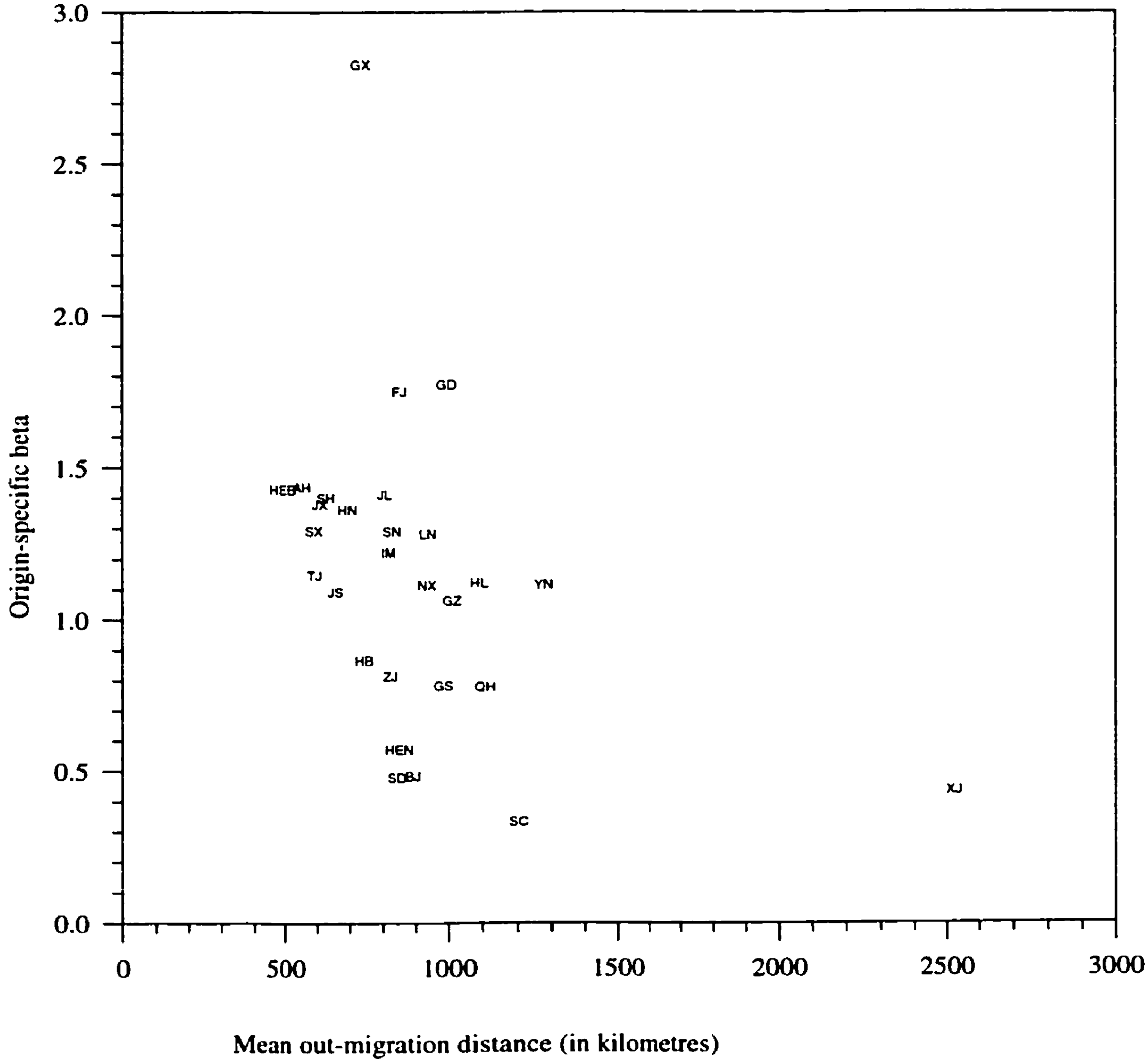

Figure 6.2 Beta values for OSCM and mean out-migration distance, 1985-90

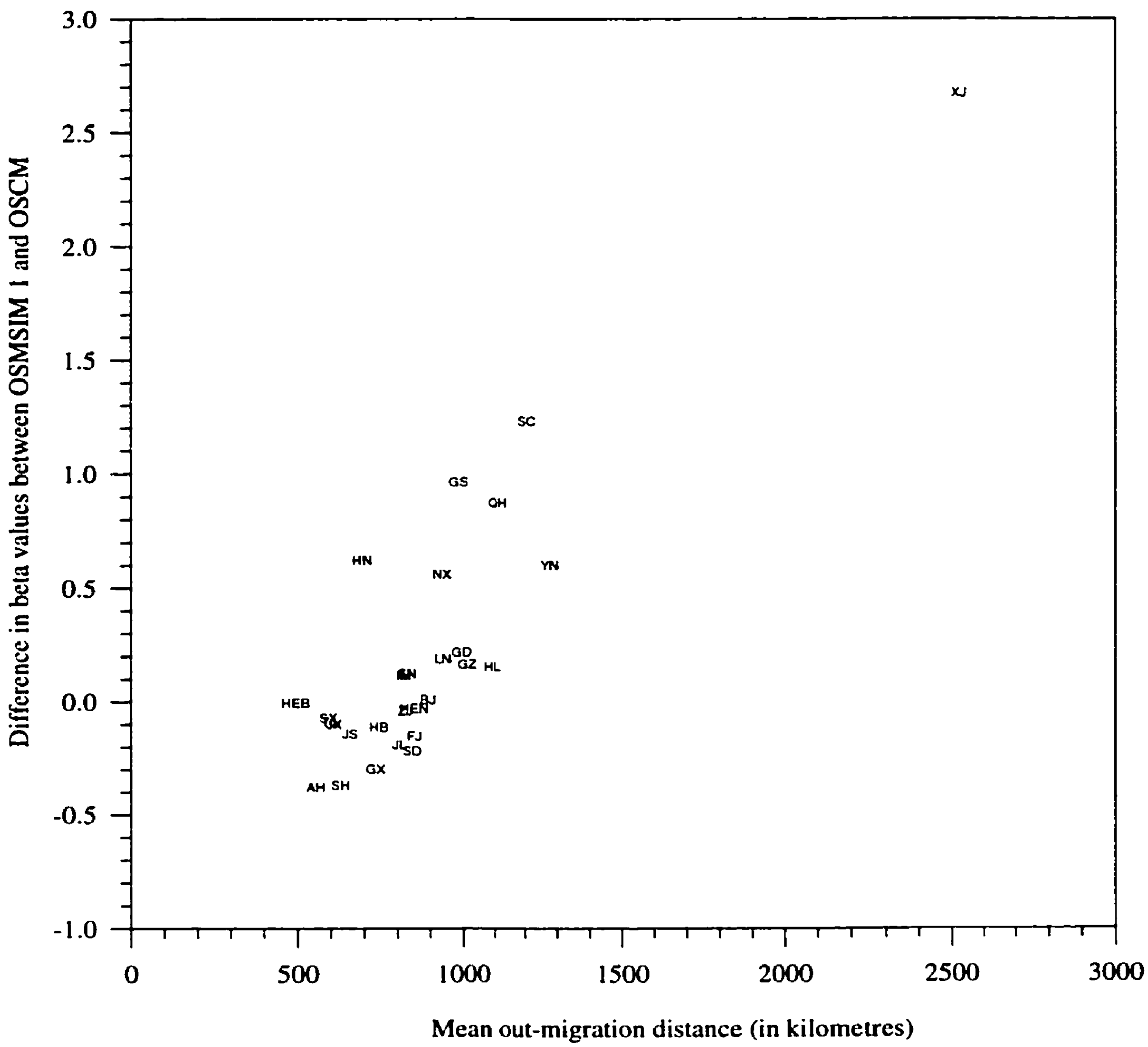

Figure 6.3 Change in beta between OSMSIM 1 and OSCM and mean out-migration distance, 1985-90

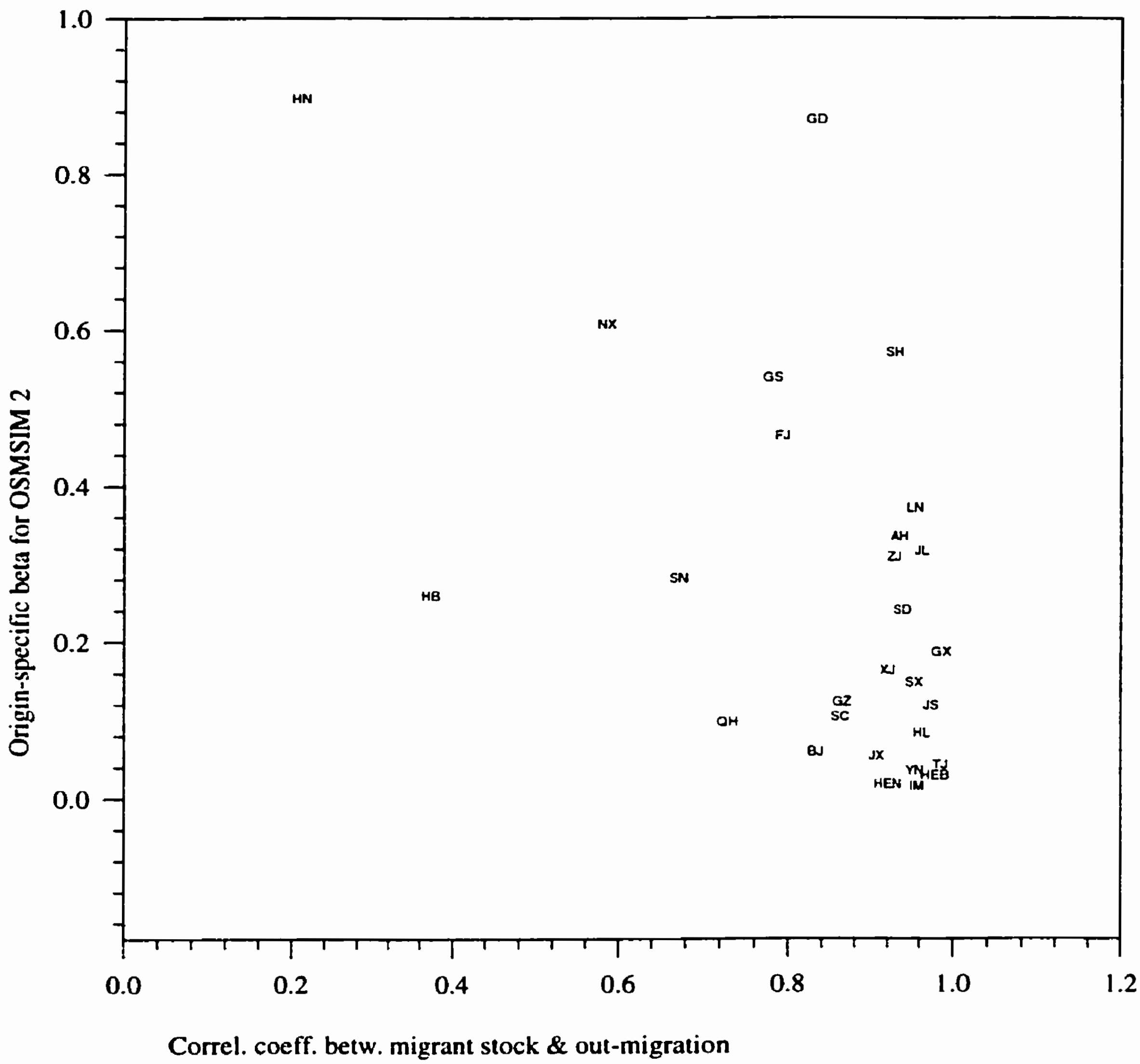

Figure 6.4 Beta for OSMSIM 2 and correl. coeff. betw. migrant stock & out-migration,1985-90

(less than 895 kilometres). This relationship can be explained by regional accessibility. However, exceptions to this relation are possible. For example, although Guangxi is peripherally located in the southwest of China, its mean migration distance is 732 kilometres, considerably lower than that of its neighbouring provinces. The reason for such an exception may be related to the spatial behavior of its out-migrants.

As discussed in Chapter 5, out-migration from Guangxi was overwhelmingly towards its eastern neighbouring province of Guangdong; migration in other directions was almost negligible. Another factor is related to the calculation of the mean migration distance itself. This measure is a *weighted* mean migration distance moved. Therefore, heavy migration towards a specific destination would exert a considerable influence on, or even distort, this measure.

In Figure 6.2, the relationship between the origin-specific beta and the mean out-migration distance can be observed to some extent. Indeed, a calculation reveals that the correlation coefficient between the spatial variation in the beta values and the spatial variation in mean out-migration distances is -0.4121, and this correlation coefficient is significant at the 99 per cent confidence level. It should be noted that in the present study the cost constraint is set to be the mean of the logarithm of the distance migrated. The correlation coefficient between the origin-specific beta and the mean of the logarithm of the distance migrated is -0.3670, and is significant at the 95 per cent confidence level. Therefore, both correlation coefficients are in accordance with the intuitive expectation that a low beta value is associated with a high mean out-migration distance moved, and vice versa (Stillwell, 1978). For example, provinces with high mean migration distance such as Xinjiang, Sichuan, Qinghai, and Gansu are associated with low beta values. The finding obtained for this case is contrasted with that calculated by Stillwell (1978). In his study, such an intuitive expectation was not evident, leading him to conclude that the pattern of variation in beta is less predictable.

It may be noted also that the negative correlation coefficient cannot be considered to be strong in the present case, so that exceptions to this relation can be found. For example, Fujian and Henan have the same mean migration distance of 850 kilometres, whereas their beta values are quite different (the beta value for Fujian is 1.7464 and that for Henan is 0.5695). A similar case is also found between Guangdong and Gansu.

Using the spatial focusing CV indices for out-migration in 1985-90 in Chapter 5 in order to calculate a correlation with the origin-specific beta values for OSCM, it is shown that the correlation coefficient between these two measures is 0.78 and is significant at the 99 per cent confidence level. This relation implies that provinces with extensive out migration fields have low beta values, and vice versa.

Results of the estimation of the origin-specific beta values for OSMSIM 1 are presented in the third column of Table 6.6. It can be noted that due to the inclusion of the investment variable in the model, the beta values have changed in comparison with those in OSCM. The beta values vary from as low as 0.2564 in Shandong to as high as 3.1057 in Xinjiang, with an overall average of 1.3657 and a standard deviation of 0.5984. In comparison with the beta values of OSCM in the second column of Table 6.6, the origin-specific beta values of OSMSIM 1 in some provinces decrease, and increase in some other provinces.

Figure 6.3 illustrates the relationship between *change* in beta values between OSMSIM 1 and OSCM and mean out-migration distances. It becomes clear from Figure

6.3 that the spatial variation in the change in the beta values shows a high correlation with the spatial variation in mean out-migration distances. This relationship is confirmed by a correlation coefficient of 0.8841, and is significant at the 99 per cent level of confidence. In other words, it implies that provinces with low mean out-migration distance are associated with decreases in beta values, while provinces with high mean out-migration distances correspond to increases in beta values. The magnitude of such decreases and increases is positively associated with the origin-specific mean out-migration distance.

The fourth column of Table 6.6 shows the calibrated beta values for OSMSIM 2. It should be noted that the migrant stock variable is included in the model. The beta values for this model range from as low as under 0.05 in provinces of Tianjin, Hebei, Inner Mongolia, Henan, and Yunnan to as high as about 0.9 in Hunan and Guangdong. The overall average is 0.2620, with a standard deviation of 0.2463, and both indices are reduced considerably as compared to those for OSCM. This demonstrates that the friction effect of distance on inter-provincial migration, on average, is greatly abated. The pattern of the beta values may be associated with the relationship between the migrant stock variable and out-migration in 1985-90. Calculation of the correlation coefficients for this relation shows that the overall average for the 28 origins is 0.8454, with a standard deviation of 0.1865. In general, it is observed from Figure 6.4 that low beta values are associated with a high correlation coefficient, and high beta values are related to low correlation coefficients. For example, the beta value of 0.0424 for Tianjin is associated with a correlation coefficient of 0.9850; and the beta value of 0.8963 for Hunan corresponds to a correlation coefficient of 0.2106. This implies that if provincial out-migration follows past migration routes closely, the distance effect will become less important.

The estimated beta values for OSMSIM 3 are illustrated in the fifth column of Table 6.6. It is observed from this column that the beta values lie in between those of OSMSIMs 1 and 2. The figures range between as low as 0.0415 in Henan province to as high as 1.6741 in Guangdong, with an overall average of 0.5858 and a standard deviation of 0.4106. Only in three other provinces are the beta values less than 0.1; and these are Hebei (0.05), Anhui (0.0625), and Zhejiang (0.0778). Also, it is illustrated in the fifth column that beta values greater than 1.0 are found only in three other provinces: Hunan (1.1837), Xinjiang (1.1591), and Qinghai (1.0437).

6.4 Impact of the variables on model performance

It is clear from the foregoing analysis that the results of applying the goodness-of-fit statistic (the percentage of misallocated migrants) to evaluate the accuracy of the model calibrations indicate that in comparison with the conventional model, each of the three models provides a much improved distribution of China's inter-provincial migration. In this section, the results of the various statistical indicators are tested for significant differences using Student's t-test. All of the models are compared in all possible pairs.

Table 6.7 illustrates the results of the calculated t-values to test significant differences in model performance (the percentage of misallocated) between the origin-specific models for inter-provincial migration, 1985-90. It is indicated in the table that all the calculated t-values, aside from the t-value between OSMSIM 2 and OSMSIM 3, are highly significant at the 0.01 level. This means that the difference in performance between the models, excluding that between OSMSIMS 2 and 3, is significant. In terms of the impact of the two entered variables, it is observed from the table the calculated t-value between OSCM and OSMSIM 1 is 5.188, while the t-value between OSCM and OSMSIM 2 is 9.979. This result indicates that the migrant stock variable exerts much more impact than the investment variable in improving the performance of the model.

Table 6.7 Results of Student's t-tests of significant differences between model performance in terms of percentage of misallocated migrants, 1985-90

Models compared	Calculated t-value	Significance (two-tailed)
OSCM & OSMSIM 1	5.188	0.000
OSCM & OSMSIM 2	9.979	0.000
OSCM & OSMSIM 3	9.522	0.000
OSMSIM 1 & OSMSIM 2	6.947	0.000
OSMSIM 1 & OSMSIM 3	7.795	0.000
OSMSIM 2 & OSMSIM 3	0.290	0.774

Table 6.8 Results of Student's t-tests of significant differences between beta values for origin-specific models, 1985-90

Models compared	Calculated t-value	Significance (two-tailed)
OSCM & OSMSIM 1	1.870	0.072
OSCM & OSMSIM 2	9.411	0.000
OSCM & OSMSIM 3	5.222	0.000
OSMSIM 1 & OSMSIM 2	10.013	0.000
OSMSIM 1 & OSMSIM 3	9.136	0.000
OSMSIM 2 & OSMSIM 3	5.364	0.000

Table 6.8 shows the results of t-tests for significant difference in values for the parameter beta between the origin-specific models. It is observed that the t-value (1.870) between OSCM and OSMSIM 1 is much lower than the t-value (9.411) between OSCM and OSMSIM 2. This illustrates that the migrant stock variable has much more impact on change in the beta values, whereas in comparison with the OSCM, the influence of the

investment variable on the beta values is found to be not significant at the 95 per cent level of confidence.

Table 6.9 Rank correlation coefficient (r_s) between the balancing factors (A_i) for total migration, 1985-90.

Models compared	r_s	Significance (two-tailed)
CM & MSIM 1	0.950	0.000
CM & MSIM 2	0.185	0.346
CM & MSIM 3	0.373	0.050
MSIM 1 & MSIM 2	0.144	0.465
MSIM 1 & MSIM 3	0.337	0.080
MSIM 2 & MSIM 3	0.963	0.000

In order to evaluate the impact of the variables further, Table 6.9 shows the calculated rank correlation coefficients between the balancing factors of the migration models for total inter-provincial migration in the period 1985-90. It is reasoned that when the impact of the variable is larger, the rank correlation between the two sets of the balancing factors arising from the two different models would tend to be smaller. It is indicated from the table that the rank correlation coefficient between the CM and MSIM 1 is 0.950, while the corresponding value between the CM and MSIM 2 is 0.185. This demonstrates that when the investment variable is entered into the model, the ranking of the balancing factors is much the same as that for the CM, whereas when including the migrant stock variable in the CM, the rank of the balancing factor changes considerably. Again, this result of the calculated rank correlation coefficients leads to the conclusion that the impact of the migrant stock variable on the model is greater than that of the investment variable.

6.5 Error analysis — residuals

The most general way of identifying errors in the model's predictions is to make a comparison between observed and predicted migration flows. Although in the above discussion, the percentage of misallocated migrants is used as goodness-of-fit statistic to evaluate the overall accuracy in prediction of the models, the prediction errors for the specific province-to-province flows cannot be uncovered by this overall statistic. Therefore, a residual analysis between the observed and predicted migration flows is undertaken for this purpose.

In geographical analysis, residual analysis has been employed to evaluate model accuracy and to seek explanations for observed patterns. An earlier example of such use can be found in the work by Thomas (1968). He discusses both absolute and relative residuals for a regression model. Researchers in the spatial interaction modelling of migration and urban journey-to-work follow this tradition (Thomas, 1977; Thomas and Huggett, 1980; Evans and Pooler, 1987; Akwawua, 1995).
For example, Thomas (1977) employs information gain to investigate errors of the model prediction. Evans and Pooler (1987) use the phi statistic to pursue such a purpose. And Akwawua (1995) demonstrates that the Shannon entropy measure can be used to evaluate the diversity of the migration flows and the spatial pattern of the prediction errors can be examined by the spatial autocorrelation test.

In this section, relative residuals are calculated for the purpose of investigating the accuracy of prediction of inter-provincial migration between specific pairs of provinces. Following the convention used by Thomas (1968) and Thomas and Huggett (1980), the relative residuals can be expressed as follows.

$$RE = (M_{ij}^{*} - M_{ij}) / M_{ij}^{*}, \tag{6.9}$$

where RE represents the relative residual, and M_{ij}^{*} and M_{ij} are the observed and predicted migration flows, respectively. It is clear from Equation (6.9) that the relative residuals are calculated as the ratio of the difference between observed and predicted flows relative to observed flows. Negative relative residuals imply over-predicted reality, while positive residuals represent under-prediction of the observed migration flows. This measure is useful in several ways. First, it can be easily calculated and interpreted. Second, the relative residuals calculated as they are for the present case can reveal particular errors in prediction for inter-provincial migrations between specified pairs of provinces. A further aspect of the relative residuals is the possibility of the mapping of this measure or the examination of the residual values for migrants either leaving or entering a particular province based on the residual matrix. The pattern of residual signs provides information on the observed attractiveness of provinces for inter-provincial migration flows. The power of such attractiveness can be found from the magnitude of the residual values.

It would be tedious and unnecessary to discuss the relative residuals associated with all the models calibrated in the present study. Rather, the relative residuals based on the CM and MSIM 3 are discussed to demonstrate to what extent the predicted flows of the models match the observed flows. Table 6.10 shows the average of the relative residuals and standard deviations for out-migration, based on the CM and MSIM 3. The average values are calculated based on all the specific residual values for a particular origin province. For example, the average value for Beijing is -0.485 based on the CM,

Table 6. 10 Average of the relative residuals and standard deviations for out-migration flows, 1985-90

Province	CM		MSIM 3	
	average	sd	average	sd
Beijing	-0.485	1.801	-0.103	0.465
Tianjin	-0.670	1.297	-0.070	0.494
Hebei	-1.210	1.693	-0.460	0.698
Shanxi	-0.818	1.822	0.020	0.704
In. Mongolia	-3.233	5.683	-0.609	0.883
Liaoning	-0.847	1.273	-0.107	0.483
Jilin	-2.357	3.283	-0.201	0.441
Heilongjiang	-3.499	5.974	-0.430	0.662
Shanghai	-1.288	1.722	-0.320	0.784
Jiangsu	-0.642	1.071	-0.299	0.769
Zhejiang	-0.029	0.550	0.065	0.374
Anhui	-1.061	1.303	-0.246	0.649
Fujian	-1.331	2.436	-0.302	0.697
Jiangxi	-2.654	6.311	-0.411	0.794
Shandong	-0.683	1.092	-0.242	0.644
Henan	-0.660	1.152	-0.183	0.445
Hubei	-1.040	2.459	-0.238	1.073
Hunan	-1.825	2.813	-0.751	2.072
Guangdong	-2.226	5.471	-0.271	0.734
Guangxi	-10.900	26.267	-1.821	1.902
Sichuan	-1.077	2.482	-0.185	0.342
Guizhou	-6.673	15.920	-0.787	1.482
Yunnan	-6.899	16.972	-0.577	1.038
Shaanxi	-0.883	1.792	-0.043	0.379
Gansu	-1.878	5.356	-0.475	1.111
Qinghai	-1.487	2.790	-0.337	1.297
Ningxia	-2.450	6.459	-0.563	1.468
Xinjiang	-2.651	4.088	-0.348	0.554

Note: the average and sd of MSIM 3 are based on Table 6.11.

and this figure is computed based on all of the 27 relative residuals for out-migration flows from Beijing to the 27 possible destination provinces. It is indicated from Table 6.10 that for the CM, for all the 28 origin provinces, the average of the relative residuals is negative, implying, on average, that out-migration flows are over-predicted. The highest average value is found in the province of Zhejiang (-0.029), whereas the lowest one is in the province of Guangxi (-10.9). It appears that change in the average relative residuals is associated with the standard deviation of the residuals. Indeed, the correlation coefficient between these two indices is found to be -0.987. Therefore, the average of the relative residuals based on the CM shows that the migration flows are poorly predicted by the model, or that spatial distance is not sufficient to explain the observed migration patterns. This corresponds with the results revealed by the goodness-of-fit statistic as discussed in Section 6.3.1.

For MSIM 3, the average values and standard deviations of the relative residuals are reduced considerably in comparison with those derived from the CM. The average values of the relative residuals based on MSIM 3 range from 0.02 (Shanxi) to -1.821 (Guangxi). Only one other province has a positive relative residual (Zhejiang). All other average values are negative. This observation demonstrates that the accuracy of the prediction of the inter-provincial flows by MSIM 3 is greatly improved. It also echoes, in general, the result revealed by the goodness-of-fit as already examined.

However, the average value of the relative residuals for out-migration flows cannot reveal the errors in prediction for inter-provincial migration between *specific pairs* of provinces. It may also not indicate both the sign and magnitude of the residuals for any specific flows. Hence, it is necessary to use other means to investigate such aspects of the relative residuals. The residual matrix can be employed to fulfill such a purpose.

Table 6.11 shows the matrix of the relative residuals based on MSIM 3 for migration flows in the period 1985-90. Several observations can be made regarding this matrix table. First, among the 756 ($756 = 28 \times 28 - 28$) specific migration flows, there

Table 6.11 Matrix of the relative residuals based on the observed and predicted inter-provincial migration flows, MSIM 3, 1985-90

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	-0.65	-0.26	-0.09	-0.82	-0.86	-0.52	0.31	0.16	-0.01	0.48	0.04	0.29	-0.05	-0.04	0.01	0.34	-0.48	0.81	0.09	0.50	-0.64	0.34	0.18	-0.63	-0.11	-1.12	-0.15
2	-0.11	0	0.22	0.05	-0.43	-0.23	0.51	0.69	-0.05	-0.55	0.21	0.24	0.29	-0.60	-0.64	-0.31	0.01	-0.60	0.40	0.40	0.34	-1.35	0.16	-0.01	0.55	-0.16	0.16	-1.16
3	0.44	0.27	0	-0.34	-0.20	0.08	-0.14	0.09	-0.95	-0.72	-0.52	-1.04	**-1.97**	-0.99	-0.52	-0.68	-0.56	-0.17	-0.07	0.26	-0.09	**-2.91**	-0.42	-0.67	0.17	-0.18	-0.77	-0.28
4	0.21	0.12	-0.42	0	-0.06	-0.03	0.47	0.43	0.55	0.04	0.40	-0.21	0.07	0.18	-0.27	-0.01	-0.57	0.01	0.34	0.55	0.45	**-3.26**	0.40	0.22	0.53	0.23	0.13	0.05
5	-0.18	-0.25	-0.08	0.23	0	0.39	0.17	0.49	-0.17	-0.79	-0.45	-0.81	**-1.67**	0.16	-0.42	-1.21	-0.30	-1.17	-0.60	-1.01	-1.10	**-3.71**	**-1.55**	-0.27	-0.17	**-2.04**	-0.66	0.11
6	0.00	-0.23	0.02	-0.44	0.40	0	0.05	0.19	-0.73	-0.45	-0.11	0.05	-0.40	-0.40	-0.10	0.13	-0.10	**-1.53**	0.23	0.44	-0.07	-0.51	-0.04	-0.17	0.61	0.74	0.46	-1.03
7	0.00	-0.39	-0.07	0.03	0.31	-0.03	0	0.13	-0.32	-0.60	-0.50	-0.07	-0.12	0.12	0.19	-0.37	-0.72	-0.61	-0.14	0.33	-0.64	-0.35	-0.41	-0.42	0.65	0.24	**-1.67**	-0.19
8	-0.06	0.16	0.23	-0.91	0.49	0.12	-0.62	0	-0.45	-0.34	-0.45	0.10	-1.06	-0.42	0.22	0.16	**-1.69**	-0.56	-0.12	0.55	-0.45	-1.19	0.27	-1.28	-0.78	**-1.63**	-0.55	**-1.78**
9	0.13	-0.57	-0.87	0.13	-0.14	-0.60	0.20	-0.85	0	-0.02	0.13	0.20	-0.06	-0.06	-0.16	-1.46	0.11	-0.48	0.60	0.05	0.30	-0.89	0.30	-1.11	**-3.42**	-0.48	-0.32	0.37
10	0.29	-0.28	-0.83	-1.40	**-2.97**	0.19	0.12	0.34	0.33	0	-0.23	-0.21	0.18	-0.26	-0.44	-0.11	-0.62	-1.97	0.44	-0.06	-0.56	-0.96	0.00	-0.21	0.33	0.43	-0.22	0.30
11	0.25	0.06	-0.24	0.30	-0.16	0.47	-0.60	0.38	-0.37	-0.51	0	-0.34	0.22	0.18	-0.17	0.11	-0.09	-0.60	0.53	-0.01	-0.36	0.41	0.10	0.39	0.60	0.70	0.58	-0.02
12	0.43	0.21	-1.78	-0.16	**-1.56**	0.47	0.06	0.20	0.19	0.16	-0.21	0	0.29	0.05	-0.15	-0.54	-0.53	-0.36	-0.40	0.03	-0.80	**-2.12**	-0.24	-0.58	-0.31	0.10	0.21	0.44
13	0.14	-0.92	**-1.72**	0.52	**-1.69**	-0.24	-0.29	0.66	-1.34	-0.61	0.22	-0.35	0	0.24	-0.05	-0.46	-0.01	-0.83	0.55	-0.04	-0.05	**-1.69**	-0.63	0.53	0.53	0.21	-0.47	-0.67
14	-0.34	0.42	**-2.27**	**-1.71**	-0.38	-0.81	0.07	-0.01	-0.27	0.08	0.28	-0.14	0.39	0	-0.12	0.15	-0.39	-0.86	0.45	-0.45	-1.11	-0.59	-0.04	**-1.59**	0.33	-0.42	**-2.53**	0.35
15	0.16	0.05	-1.04	0.06	-0.31	0.28	0.29	0.46	-0.52	-0.16	0.19	-0.26	-0.60	-0.55	0	-0.04	-0.14	-0.56	-0.07	0.47	-0.52	**-2.78**	-0.14	-0.54	0.44	-0.12	-1.04	0.21
16	0.45	0.12	-0.41	-0.17	-0.64	0.03	-0.22	0.34	-0.18	-0.22	-0.30	-0.40	-0.87	-0.50	-0.31	0	0.02	-0.53	0.41	-0.90	-0.56	-1.15	-0.50	-0.10	0.22	0.57	0.12	0.57
17	0.22	0.28	-0.45	-0.14	**-2.04**	0.31	0.18	0.67	-0.25	-0.23	0.39	-0.14	0.11	-0.40	**-4.50**	0.40	0	0.06	0.60	0.22	0.18	-0.01	0.30	0.20	0.30	-0.97	**-2.24**	0.28
18	-0.56	-0.53	**-10.9**	0.48	-0.46	**-1.69**	-0.77	0.01	-0.13	-0.28	-0.13	-0.29	-0.18	-0.06	-1.27	-0.12	-0.45	0	0.68	0.56	-0.72	-0.17	0.37	-1.10	-0.92	-0.53	**-1.90**	-0.02
19	0.28	-0.77	-1.38	-0.38	**-1.85**	-0.27	0.03	-0.37	0.30	-0.29	0.28	-0.93	0.19	0.20	-0.46	0.18	0.15	-0.44	0	0.30	-0.09	0.08	0.60	-0.12	0.62	-0.51	**-2.73**	-0.21
20	-1.25	-1.42	-0.58	**-1.55**	**-2.61**	**-2.98**	-0.80	**-2.69**	**-2.10**	-1.15	0.23	-1.17	-0.49	**-2.14**	**-1.52**	**-3.21**	-1.04	**-1.59**	0.48	0	**-2.21**	-1.45	-1.08	-0.81	**-5.14**	**-2.21**	**-9.55**	-0.95
21	-0.11	-0.42	-0.05	-0.09	-0.46	0.02	-0.05	-0.07	-0.45	0.04	0.05	-0.35	0.31	-0.72	-0.61	-0.36	-0.08	-0.51	0.50	-0.49	0	0.01	0.22	-0.31	-0.92	0.03	-0.63	0.33
22	-0.77	-0.32	0.20	-0.01	-0.89	-1.37	0.10	**-1.51**	-0.82	0.40	0.30	0.20	0.38	-0.29	0.09	0.48	-0.22	-0.15	0.35	-0.75	-0.35	0	-0.16	-1.26	**-2.57**	**-4.94**	**-5.25**	**-2.91**
23	-0.87	-0.54	-0.51	-0.46	-1.09	**-1.63**	0.41	**-1.55**	-0.52	0.20	0.41	0.27	0.02	-0.09	0.51	-0.10	-0.22	-0.17	0.24	-1.39	0.11	-0.40	0	-1.18	0.04	**-2.36**	**-4.44**	-0.85
24	-0.04	-0.92	-0.18	0.07	0.17	0.18	0.29	0.10	-0.03	-0.15	-0.24	0.08	-0.26	-0.25	-0.14	0.19	-0.69	-0.37	0.26	0.26	0.03	-0.58	0.47	0	0.35	0.56	-0.82	0.46
25	-0.28	**-2.30**	-0.34	0.33	0.27	-0.10	0.11	-0.78	-0.28	-0.17	-0.01	-0.64	0.33	-0.08	-0.54	0.03	-1.09	-0.44	0.02	**-3.92**	-0.37	**-3.75**	-0.80	-0.03	0	0.55	0.34	0.65
26	-0.40	-0.65	-0.06	**-6.22**	-0.79	-0.23	-0.62	-0.50	0.19	0.11	0.51	0.34	0.05	-0.12	0.23	0.34	0.50	-0.07	-0.04	0.41	0.08	-0.33	**-2.53**	0.11	-0.03	0	-0.31	0.58
27	0.03	**-3.94**	-0.01	-1.16	0.23	-0.60	0.42	-1.38	0.11	0.12	-0.65	0.51	-0.35	-0.49	-0.49	0.54	-0.19	-1.04	0.50	**-1.60**	-0.65	**-6.31**	-0.93	-0.13	0.33	0.69	0	0.68
28	-0.07	-0.12	-0.36	-1.30	-0.93	-0.93	0.18	-1.31	0.50	-0.05	0.07	0.04	-0.04	-1.25	0.16	0.27	0.10	-0.34	-0.82	-0.41	-0.04	**-1.50**	-0.52	0.07	0.20	-0.78	-0.55	0

Notes: (1) The numbers of the first column and first row stand for the provincial ID number as specified in Table 3.2 of Chapter 3.
(2) Large residuals are defined as those equal to or beyond -1.50, and such residuals are bolded and underlined.

are 464 specific inter-provincial flows that are over-predicted (those flows with negative signs), implying that about 61.4 per cent of total number of province-to-province flows is overestimated by MSIM 3. The remaining flows (38.6 per cent) in the matrix are underestimated by MSIM 3. It is also noteworthy that variation in the underestimated migration flows (the cells with positive values) is smaller than in overestimated ones (the cells with negative signs).

Table 6.12 Number of overestimated (negative sign) flows for province as both origin and destination, based on the residual matrix of Table 6.11, 1985-90

Province	Out-migration flow	In-migration flow	Province	Out-migration flow	In-migration flow
Beijing	15	13	Shandong	17	21
Tianjin	13	18	Henan	17	14
Hebei	21	23	Hubei	11	20
Shanxi	8	17	Hunan	22	25
In. Mongolia	21	21	Guangdong	15	8
Liaoning	15	16	Guangxi	25	12
Jilin	18	10	Sichuan	18	19
Heilongjiang	18	11	Guizhou	18	24
Shanghai	16	19	Yunnan	18	15
Jiangsu	16	19	Shaanxi	13	20
Zhejiang	12	12	Gansu	18	10
Anhui	14	16	Qinghai	15	15
Fujian	18	13	Ningxia	16	20
Jiangxi	18	20	Xinjiang	18	13

Second, the distribution of the 464 overestimated migration flows varies among the 28 provinces viewed both as origins and destinations. Table 6.12 presents a summary of this distribution. When provinces are viewed as origins (or sources of out-migration), the number of overestimated flows ranges from eight in Shanxi to 25 in Guangxi. Only in three other origins is the number of overestimated flows greater than 20; and these are the provinces of Hebei (21), Inner Mongolia (21), and Hunan (22). When provinces are viewed as destinations (or for in-migration), the number of overestimated flows varies between eight in Guangdong to 25 in Hunan. It is further found that in another four provinces the number of overestimated flows to destinations is found to be above 20. These four provinces are Guizhou (24), Hebei (23), Inner Mongolia (21), and Shandong (21).

This pattern of overestimation is associated with underestimation in the remaining flows. In other words, examination of the residual patterns can be appropriately made in the context of the whole out- or in-migration fields (Evans and Pooler, 1987). For example, there are 25 overestimated out-migration flows from Guangxi, and only two flows are underestimated. These two flows are out-migrations to Zhejiang (with the relative residual of 0.23) and to Guangdong (with the relative residual of 0.48). It appears that the underprediction for these two flows cause all other out-flows from Guangxi to be over-predicted. As discussed in Chapter 5, the province of Guangdong accounts for about 72 per cent of all out-migration from Guangxi. Guangdong is the destination that receives the largest number of migrants from all other provinces, and Guangxi is one of largest origins for sending out-migrations. These two provinces are situated in close proximity to one another. The underprediction for out-migration flows from Guangxi to Guangdong reveals that Guangdong is strongly favoured as a destination by migrants from Guangxi. On the other hand, in order to satisfy the origin and distance constraints, the underprediction for these two flows occurs at the expense of other flows being overestimated. Therefore, as the largest booming destination in China, Guangdong exerts a considerable impact on the magnitude of other flows.

Third, large overestimated flows, which are defined as the relative residuals beyond or equal to -1.50 (*bolded and underlined* in the residual matrix), are found to be mainly in-migration flows to the five provinces of Hebei, Inner Mongolia, Guizhou, Qinghai, and Ningxia. It can be observed and calculated from Table 6.11 that 65 specific flows are within this category, and the above-named five provinces account for 33 such flows. Guizhou and Ningxia each have nine such overestimated flows. Viewing provinces as origins, Guangxi has 13 such large out-migration flows.

Finally, the largest overestimated flow is found in out-migration from Hunan to Hebei, where the relative residual is -10.9. This prediction error results mainly from the migrant stock variable for this particular flow. Specifically, migration from Hunan to Hebei in 1982-87 accounted for 49.4 per cent of the total out-migration from Hunan, whereas this figure was found to be only 1.83 per cent in 1985-90. In fact, for Hunan province the correlation coefficient between out-migration in 1982-87 (used as the migrant stock) and out-migration in 1985-90 is only 0.2106. Hence, this largest overestimated flow is mainly caused by asymmetry between the migrant stock and out-migration in 1985-90. The asymmetry has to do with return migration from Hunan to Hebei, which occurred in the early 1980s. Between the mid-1960s and 1970s, coal mining in Hunan was assisted with a large number of coal workers dispatched from Hebei, and they returned to their origin in the early 1980s (Shen and Tong, 1992).

As discussed in Chapter 4, MSIM 3 includes two additional variables, investment and migrant stock. The migrant stock variable exhibits more importance in explaining the migration flows, as shown in Section 6.4. The large overestimated flows can be explained by asymmetry between migrant stock and migration in the period 1985-90.

The relative residual in the out-migration flow from Hunan to Hebei is an obvious example, already shown above. Although other large relative residuals may be involved in contextual circumstances different from the case of Hunan-to-Hebei migration, they are caused mainly by such asymmetry.

6.6 Summary

The purpose of this chapter was to present an empirical analysis and discussion of the results of the calibration of the conventional spatial interaction model and the models with the additional variable(s). Empirical verification of the models employed two inter-provincial migration data sets for China. These include the 1982-87 and 1985-90 migration flow data, consisting of two 28×28 data matrices. Constraints were applied to the models, these being the origin and cost constraints. The constraints may also be considered as calibration criteria. The cost constraint employed in the present study is matching of observed and predicted logarithmic mean migration distance. This constraint or criterion ensures optimum parameters for the models, and minimizes the differences between the observed and predicted migration flows as well.

The results of the calibration showed that all of the models with the additional variable(s) are capable of distributing migration flows with a much-improved degree of accuracy, in comparison with the conventional model based on the distance variable only. The calibration has therefore provided empirical support for the validity and utility of the multivariate approach to spatial interaction modelling of migration. However, the results obtained on the basis of this approach do not necessarily imply that including more variables in the model would result in a corresponding improvement in accuracy in the prediction of migration flows. This is evident in the performance levels between MSIMs 2 and 3. For the origin-specific models, the inclusion of the additional variable(s) into the OSCM resulted in a much-improved performance.

The errors in prediction of inter-provincial migration were examined by utilizing the relative residual measure. The results of analyzing the residuals show that the errors in prediction of migration flows by MSIM 3 were reduced significantly, in comparison with the CM. This is in accordance with the results indicated in the analysis of the goodness-of-fit statistic. It is also indicated from the relative residual matrix that Guangdong, one of the largest and economically booming provinces, exerted a considerable influence on China's inter-provincial migration flows. The largest overestimated flows (with relative residuals beyond -1.50) relate mainly to historical flows that were not followed closely by subsequent population migrations. Overall, it can be concluded that the multivariate approach to spatial interaction modelling of migration pursued in the present study is a valid one and it would be useful to apply it to the analysis of migration systems other than that of China.

Chapter Seven Summary and Conclusions

7.1 Introduction

A review of spatial interaction models in Chapter 2 indicated that the Wilson-family of SIMs in geography can be derived either through Shannon entropy or through Kullback information gain. The derivation based on the formulation of Shannon entropy is termed the EM method, while the derivation from Kullback information gain is referred to as the IM method. Both approaches can produce the SIMs, which are constrained with respect to the observed number of migrants leaving origins O_i and/or entering destinations D_j, and the mean distance travelled by all migrants $\bar{d}_{ij}$. The Shannon EM method was extended later by the Kullback IM approach and the IM principle is considered to be a generalisation of the EM method (Pooler, 1995a). In addition to the constraints as satisfied in the EM models, models derived through the IM principle can allow for inclusion of prior information that is relevant to the interaction matrix. The inclusion of prior information, which reflects forces influencing interaction flows between regions, can improve the explanatory power of the model.

This thesis focuses on the inclusion of two additional variables in the conventional spatial interaction model. Models based on this new approach are termed MSIMs, and they are empirically investigated with Chinese inter-provincial migration data. The purpose of this chapter is to summarise this new approach and the empirical results of the study and to provide concluding remarks. Possible areas for further investigation are also identified.

7.2 Spatial interaction models with additional variables

It is indicated in Chapter 2 that applications of the information minimisation in geography are not new. However, the focus of such applications was on the inclusion of an historical flow matrix into the model in order to improve the model performance (Snickers and Weibull, 1977; Plane, 1981, 1982; Pooler, 1988, 1995a). Webber (1979) suggests that a 'sequential approach' under the IM principle is appropriate in the sense that it can improve model performance through a series of steps, wherein each step includes additional information in the process of calibrating the interaction flows. Such information is not merely contained in the past interaction flow matrix, but also includes any information that is relevant to the interaction flows to be estimated between regions. Therefore, for inter-provincial migration modelling, the method of minimum information provides a way of estimating the statistically most likely form for a probability distribution of migration when prior probabilities are known and are not equally likely. The present study has successfully included two additional variables, migrant stock and annual average investment, in prior probability form, into the conventional spatial interaction models.

It should be noted that such prior probability information could be defined with respect to any measures that are relevant to the migration flows to be estimated between regions. The present study has employed two such 'priors': one is defined with respect to the amount of annual total investment of in China's provinces, and the other is defined with respect to migrants who previously moved from origin to destination provinces. The reason for the inclusion of these two defined priors is based on the two criteria discussed in Chapter 4: the model performance can be improved, and the selection of variables is made on the basis of the elimination of the multicollinearity problem.

The first prior probability considered to be relevant to the inter-provincial migration flows in 1985-90 is defined with respect to migrant stock, as derived from a past migration flow matrix (migration flows in 1982-87). This prior is considered to represent the migration chain effect. In addition to enhancing the model performance level, the purpose of including migrant stock probability into the model is to expand explanatory power of the model. Indeed, this prior probability is closely related to the 1985-90 inter-provincial migration flows in most cases. It reflects China's internal migration policies both prior to and after the late 1970s. During the 1960s and 1970s, for military and regional development considerations, inter-provincial migration flows were directed mainly from the coastal provinces (in particular the three centrally administered cities: Beijing, Tianjin, and Shanghai) to interior regions. This migration pattern was reversed at the beginning of the 1980s, and the reversed flows were continued during the whole of the 1980s. The idea is that the migrant stock derived from the 1982-87 flow data reflects such a change in inter-provincial migration flows, and it influences the migration flow patterns in the period of 1985-90, which are to be estimated by the present study. The migrant stock variable is also considered to play a significant role in providing the subsequent migrants with information, as well as economic and psychic assistance.

The second prior is defined with respect to total annual average investment in the provinces discussed in Chapter 4. The investment pattern is one of the key factors that influence internal migration in China. The investment data employed in the present study not only include foreign investments, but also consist of the investment from the central government and other channels. Investment creates employment opportunities that are a major motivation for people to migrate across a provincial boundary. Therefore, the prior probability of the investment represents the varied attractiveness of China's provinces as destinations for migration.

These two additional variables, with considerable success, represent major factors that influence China's inter-provincial migration. Origin- and cost- constrained versions of the MSIMs are calibrated in the present study. Moreover, origin-specific MSIMs, referred to as OSMSIMs, are also estimated. It should be noted that the usual cost constraint is not adopted, rather the mean of logarithmic distance migrated is employed as the cost constraint in the present study. The idea behind such a substitution is that the logarithmic distance is more appropriate for modelling longer distance migration, such as the inter-provincial migrations modelled in the present case. The calibration procedure is carried out by FORTRAN 77 programs, which are included in Appendix B.

7.3 Empirical data analysis

Preliminary analysis of the empirical data was made in Chapter 5. The purpose of such an analysis is twofold. First, it can provide insight into China's inter-provincial migration patterns; second, investigation of the empirical data is beneficial for a better appreciation of the modelling results. The empirical data analysis focuses on three aspects: the overall pattern of the inter-provincial migration, the spatial focusing of migration, and male-female migration differentials.

During the period 1985-90, the total number of migrants for China's was 10.75 million, indicating a 73 per cent increase in comparison to the total number of migrants in the period 1982-87 (6.24 million). Guangdong became the largest recipient of migrants in 1985-90, accounting for 10.98 per cent. The geographical pattern of inter-provincial migration in 1982-87 was a reversal of the pre-reform (prior to the end of the 1970s) pattern. In other words, migration was from the central and western provinces to the coastal provinces. This pattern intensified in the period 1985-90. The overall pattern of inter-provincial migration of China is in accordance with changes in migration policies and the overall development strategy of the 1980s.

The spatial focusing of inter-provincial migration is evaluated by using the coefficient of variation (CV) indices for in- and out-migration flows of each of the 28 provinces. When provinces have a wide distribution of migration flows, the value of the CV indices is lower. On the other hand, when provinces have a more spatially focused distribution of migration flows, the value for the CV indices is higher. The analysis indicates that the overall average of the CV indices for both in- and out-migration flows decreased from 1982-87 to 1985-90, illustrating a reduction of the spatial concentration of in- and out-migration flows for most provinces.

Male-female differentials in inter-provincial migration are investigated using sex ratios. There were two types of patterns based on the sex ratios of out-migration flows. In the first pattern, sex ratios for every out-migration flow to the 27 destination provinces are higher than 100, implying that male migrants make up a larger proportion of migrants. This pattern includes the three centrally administered large cities (Beijing, Tianjin, and Shanghai) and provinces of Hebei, Shanxi, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Guangdong, and Shandong.

The second pattern covers provinces with sex ratios less than 100 for out-migration to a number of destination provinces. This pattern is found in part of the south, and the whole of southwestern China. It is a spatial cluster that exports female migrants in large numbers, mainly to the rich provinces. Geographical distance no longer constitutes an obstacle for them to migrate. Such female migration flows are caused by economic and marriage considerations.

7.4 Modelling results

The MSIMs are tested using the 1982-87 and 1985-90 province-to-province migration data for the 28 provinces of China. Empirical results of the calibration are compared to results from calibration of the conventional SIM. All the models are calibrated by iterative procedures written in FORTRAN 77 that employ the mean of the logarithmic distance migrated as the calibration statistic or cost constraint. The MSIMs are first tested with total migration flow data, implying that each model is calibrated with a global beta value. The MSIMs are also tested using the out-migration flow data for each of the 28 provinces. In other words, *origin-specific* MSIMs are calibrated, and the results of this further calibration are also evaluated based on a conventional origin-specific SIM.

The analysis of the modelling results made in Chapter 6 indicated that better performance of the MSIMs is observed in comparison to the performance of the conventional model. The goodness-of-fit statistic, represented by the percentage of migrants misallocated, shows that the performance of the model is improved considerably from the conventional model (34. 63 per cent) to MSIM 1 (29.78 per cent) to MSIM 3

(17.76 per cent). In other words, this index illustrates that the conventional model correctly assigns about 65 per cent of the total number of migrants in 1985-90, whereas MSIM 3, with inclusion of the two additional variables, correctly allocates about 82 per cent of all migrants, this being a 26.2 per cent improvement. Although all the MSIMs perform better than the conventional model, this does not necessarily mean that adding yet more variables would lead to improvement in performance.

The value for beta (β) as calibrated based on the 1985-90 migration data, decreases from 1.1317 for the conventional model to 0.4132 for MSIM 3, implying a 63.5 per cent decrease. The change in beta demonstrates that the attenuating effect of distance on inter-provincial migration is partially offset by variations in migrant stock and investment. This implies that provinces with high employment opportunities and/or a large migrant stock are seen as more attractive by prospective migrants, regardless of how far away such destinations are located.

The results of calibration for the total migration flows in 1982-87, and for male and female migrations, confirm the validity of the MSIMs. Analysis of the estimation results indicates that female migrants are more likely to follow past migrants, and that the performance of the estimated models is better for male than for female migration.

Calibration for the origin-specific migration flows of 1985-90 is carried out for each of the 28 provinces of China. Results of the calibration are in agreement with the results from the modelling results for the total migration in 1985-90. Moreover, results of calibration of all the origin-specific models are improved in comparison to the results from estimating the total migration. For example, Table 7.1 indicates that when the investment variable is included in the models, the average performance of OSMSIM 1 is

23.18 per cent, while the performance level of MSIM 1 is 29.78. This illustrates that disaggregation of areal scale, or reducing the number of spatial units, can improve the performance of the models in the present case.

Table 7.1 Performance comparison between modelling of total and origin-specific migration, 1985-90

Total migration	CM	MSIM 1	MSIM 2	MSIM 3
% *E*	34.63	29.78	16.73	17.76
Origin-specific migration	OSCM	OSMSIM 1	OSMSIM 2	OSMSIM 3
% *E* (average)	32.39	23.18	14.37	14.22

Note: % *E* refers to percentage of migrants misallocated

Evaluation of the importance of the two included variables was also made on the basis of the results of calculation of both t-test and rank correlation coefficients for the origin-specific models. It is observed that the impact of the migrant stock variable on the model is more considerable than the investment variable. In addition, the errors in prediction of inter-provincial migration were examined by using the relative residual measure. The calculated relative residuals show that the errors in prediction of migration flows by the MSIM 3 were reduced significantly, in comparison with the CM. This is in accordance with the results indicated in the analysis of the goodness-of-fit statistic.

7.5 Conclusions

As discussed in Chapter 1, migration is becoming more important in the dynamics of population change of China, in comparison to birth and death rates. Therefore, modelling internal migration patterns is an immediate task for social and economic development in China. The present study is an attempt to estimate China's inter-provincial migration within the framework of multivariate spatial interaction modelling. The empirical results illustrate that this framework can replicate the observed inter-provincial migration flows with a much-improved degree of accuracy when compared with the conventional spatial interaction approach. Specifically, the modelling results and empirical data analysis presented in this thesis lead to the following conclusions.

First, using a new multivariate spatial interaction approach to estimate China's inter-provincial migration, all the resulting MSIMs produce better results than did the conventional model. In other words, all of the models with the additional variable(s) are capable of distributing migration flows with a much-improved degree of accuracy, in comparison with the conventional model with inclusion of a distance variable only. The calibration has therefore provided empirical support for the validity and utility of the multivariate approach to the spatial interaction modelling of migration. However, the results obtained on the basis of this approach do not necessarily imply that more variables included into the model would result in a corresponding improvement in model performance. This is evident in the modest change in performance levels between MSIMs 2 and 3.

Second, the empirical findings are consistent with the forces that influence China's inter-provincial migration. These forces are represented by two selected additional variables — migrant stock and total annual investment. These two variables are appropriate in that they reflect both migration policy change and economic development strategy. The successful empirical results from the calibration of the MSIMs also imply that selecting appropriate variables is crucial in calibrating migration flows within the multivariate modelling framework, because variable selection must be based on the specific country or areal contexts, on the one hand, and is also dependent upon the availability of data, on the other.

Third, a comparison of performance level between the MSIMs and OSMSIMs indicates that the calibration of origin-specific migration flows can further improve the degree of accuracy in the calibration of total migration. This undertaking is related to disaggregation of spatial interaction modelling of migration flows, and is related to the scale effect of the MAUP discussed, in Chapter 2. Specifically, the present study calibrates China's inter-provincial migration flows at two levels of scale: the national scale, with the flows among all the 28 provinces (the number of cells is 756, *i.e.*, $28 \times 28 - 28$), and the provincial scale (the number of cells is 27, *i.e.*, $1 \times 28 - 1$). At the national scale, each of the MSIMs provides only global parameters, while at the provincial level of scale, each of the OSMISMs produces local parameters. Spatial variation in the calibrated parameters can be observed based on the model calibration at the level of provincial scale. Therefore, the disaggregation of the calibration of the MSIMs is worthwhile for further modelling of migration flows. Such a disaggregation, as carried out in the present study, echoes the proposal by Fotheringham (1997) that local spatial analysis and modelling is increasingly important in revealing spatial variations in the results.

Finally, the results from the present study provide empirical support for the idea that spatial interaction migration models (based on the western countries), with additional variables, can be applied to non-western countries, in this case China. In fact, to date all theoretical models concerning population migration have been based on countries with a market economy, and thus questions can be raised as to whether such theories are relevant to countries with planned economies, or economies in transition from planned to market-based. Research on internal migration shows that migration theories are increasingly relevant to the changing socio-economic reality in China (Chang, 1996) and in the former Soviet Union (Mitchneck, 1991; Mitchneck and Plane, 1995). The present study illustrates that Chinese inter-provincial migration flows can be estimated by the MSIMs with an improved degree of accuracy. This in turn demonstrates that the multivariate approach to migration modelling fits well with China's socio-economic context, given that China has been experiencing a major transformation from a planning to a market economy since the late 1970s.

One of implications arising from the present study is that the MSIMs can be employed to provide policy and planning guides for the Chinese government. The present study suggests that heavy flows to a few specific locations in the coastal region in the long- term might be not beneficial to a balanced regional development. Therefore, if China would consider a change in its provincial migration patterns, the focused spatial investment on the coastal region should be diversified to interior provinces. A second point to be made is that the government should be fully aware of potential social impacts of regional migration flows on places of origin. Heavy out-migration flows of women from the southwest provinces of China may not only reflect unfavourable socio-economic conditions in certain areas of this region, but also result in a further worsening situation; for example, there may be a shortage of marriage partners for young men due to out-migration of females in such provinces. A final point is that information channels should be broadened for prospective migrants in order for them to have a reliable and complete assessment of destinations.

7.6 Future work

The present study accomplished its objectives. Specifically, the thesis extended the conventional spatial interaction modelling to a new, multivariate spatial interaction approach. Two additional variables were included into the model. The new approach was empirically investigated by calibrating both the MSIMs and OSMSIMs. Evaluation on model performance and on relative impact of the two additional variables was made using the goodness-of-fit statistic and rank correlation coefficient. The present study also points out pertinent avenues for further investigation. Such avenues can be summarised as follows.

First, with further releases of statistical data for China, alternative variables may be employed for further improvement in the accuracy of calibration of China's inter-provincial migration flows. Such alternative variables can be defined as priors included in the interaction models under the principle of information minimisation. In modelling China's inter-provincial migration, the method of information minimisation provides a framework for including additional variables when prior probabilities are known and are not equally likely. Although in the present study two such priors are defined and included in the interaction modelling of China's inter-provincial migration, there are some other options that are possible to define as priors. These include characteristics of origin and destination provinces, or any interaction measures between origin and destination. For example, such measures may include matrices related to commodity flows, telecommunication flows, and migrants' remittances. Selecting the alternative variables requires a reasonable amount of knowledge of the relationship between the system of inter-provincial migration and the selected variable itself. At least three steps are required in choosing alternative variables: a qualitative assessment on the relation of the alternative variables to migration, an experimental calibration of the model which includes the variables, and a decision as to whether the alternative variables have an impact on the model's performance. Cases where the effect of the selected alternative variable on inter-provincial migration can be firmly established may reveal that the quality of the data employed is in doubt. Thus, interaction modelling under the IM framework also provides a means of assessing the quality of data employed.

Second, when data quality and availability allow, the MSIM approach can be extended to the county level within a specific province. It would be interesting to see how, and to what extent, parameters of the model change in that case. In particular, as evidenced in Chinese migration, in most cases more than 70 per cent migration in 1985-90 took place within provinces instead of among them (China, 1993). Therefore, modelling migration at the county level in a province would be worthwhile and meaningful in order to investigate the disaggregated migration flows, such as male vs. female migration. It is equally appealing to examine properties of migration for other disaggregated groups of migrants, for example, different age groups of migrants.

Third, spatial interaction modelling under the information minimising principle provides a large number of avenues to model inter-provincial migration. One such avenue is to extend the present approach (MSIM) by taking into account the idea of structural spatial interaction. Parallel to the concept of structural unemployment in economics, a definition of structural spatial interaction was proposed by Pooler (1993). It refers to the condition in which a portion of spatial interaction is allowed by the minimum mean distance travelled under both origin and destination constraints. The nonstructural portion of spatial interaction can be immediately derived on the basis of the difference between the structural spatial interaction and the observed interaction. In the case of incorporating the present approach into the definition of structural spatial interaction, major significance may appear in the component of nonstructural inter-provincial migration. As a matter of fact, information channels, such as newspapers, TV, and radio, are controlled by the governments in China. Individuals rely upon such information and also information gained through personal contacts. Some migration is lured to destinations by unreliable or incomplete information, a case termed speculative migration (Silvers, 1977; O'Connell, 1997). The issue of speculative migration in China could be investigated by combining the present approach with the structural spatial interaction method, because the nonstructural portion of inter-provincial migration estimated by the MSIMs can be considered to relate closely to the amount of speculative migration. To determine a geographical pattern of speculative migration would be an interesting and useful exercise in that it could provide government planners with guidelines about how speculative migration might be reduced and how the efficiency of utilising human resources could be improved.

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APPENDICES

Appendix A: Matrix of distance in kilometres for provinces of China

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0																											
2	113	0																										
3	263	263	0																									
4	405	420	165	0																								
5	420	518	390	338	0																							
6	615	600	855	1013	975	0																						
7	855	840	1103	1245	1163	270	0																					
8	1050	1050	1305	1440	1320	510	233	0																				
9	1065	960	990	1095	1380	1200	1448	1673	0																			
10	900	795	773	855	1163	1155	1425	1650	270	0																		
11	1125	1020	998	1080	1463	1313	1575	1800	165	225	0																	
12	900	810	728	780	1103	1230	1500	1725	405	150	323	0																
13	1553	1455	1388	1440	1770	1785	2040	2265	600	660	465	660	0															
14	1245	1170	1050	1065	1395	1605	1875	2100	600	465	435	375	435	0														
15	375	278	270	413	653	788	1050	1275	735	540	765	525	1185	900	0													
16	623	578	375	353	690	1140	1410	1620	825	570	780	375	1095	705	375	0												
17	1050	975	825	810	1155	1478	1748	1980	690	450	473	315	690	270	720	465	0											
18	1328	1268	1095	1065	1395	1770	2040	2265	870	705	720	570	660	285	1005	720	285	0										
19	1875	1800	1650	1620	1950	2265	2535	2760	1200	1125	1035	1050	705	660	1530	1275	825	555	0									
20	2025	1980	1763	1695	1995	2505	2775	3000	1590	1440	1425	1320	1170	990	1725	1410	1035	750	510	0								
21	1515	1515	1260	1118	1320	2115	2355	2355	1650	1410	1530	1245	1560	1155	1365	1005	975	900	1215	938	0							
22	1725	1695	1455	1365	1635	2265	2528	2738	1530	1320	1365	1170	1253	930	1478	1125	855	645	750	435	510	0						
23	2070	2055	1815	1695	1920	2640	2895	3105	1950	1748	1800	1598	1665	1373	1860	1500	1290	1080	1080	615	630	435	0					
24	915	915	660	525	773	1500	1748	1950	1215	945	1125	810	1335	900	780	435	638	765	1275	1245	600	870	1170	0				
25	1200	1238	975	825	870	1800	2018	2190	1710	1448	1635	1305	1830	1388	1200	900	1125	1215	1665	1485	585	1065	1200	510	0			
26	1335	1388	1140	975	975	1950	2138	2295	1905	1650	1830	1515	2010	1575	1365	1080	1320	1395	1830	1605	690	1185	1260	705	195	0		
27	870	945	705	540	525	1485	1680	1838	1590	1328	1530	1215	1800	1395	960	750	1125	1275	1800	1710	885	1305	1515	525	375	465	0	
28	2400	2655	2325	2183	1995	2903	3000	3075	3255	2985	3195	2880	3420	2993	2595	2430	2730	2813	3225	2955	2025	2535	2460	2100	1605	1425	1665	0

Note: The numbers of the first column and first row stand for the provincial ID number as specified in Table 3.2 of Chapter 3.

Appendix B: A sample of model programs for estimating China's inter-provincial migration

PROGRAM MSIM 3

```
C     This is the original program with both cost and origin
C     constraints(power function)for modelling total migration
C     flows.
C
C     DIST is distance matrix,
C     H investment,
C     S migrant stock,
C     T observed migration matrix,
C     P estimated migration matrix,
C     M total number of migrants,
C     N number of provinces,
C     BETA the parameter of the distance decay of power function.
C     RMIS percentage of migrants misallocated.
C
      COMMON DIST(30,30),O(30),A(30),B(30),D(30),H(30),S(30,30),
     +T(30,30),P(30,30),M
C
      OPEN(UNIT=1,FILE='MF90FF.DAT',STATUS='OLD')
      READ(1,*)N
      DO I=1,N
      READ(1,*)O(I)
      END DO
      DO I=1,N
      READ(1,*)D(I)
      END DO
      DO I=1,N
      READ(1,*)H(I)
      END DO
      DO I=1,N
        READ(1,*)(S(I,J),J=1,N)
      END DO
      DO I=1,N
        READ(1,*)(DIST(I,J),J=1,N)
      END DO
        READ(1,*)COBS
      DO I=1,N
       READ(1,*)(T(I,J),J=1,N)
      END DO
      READ(1,*)M
      CLOSE(1)
      BETA=-0.15256
      TRIPS=0.0
      DO 1 I=1,N
1     TRIPS=TRIPS+O(I)
      DO 2 I=1,N
      O(I)=O(I)/TRIPS
```

```
2       D(I)=D(I)/TRIPS
        CALL ENT2(N,BETA,COBS)
        CALL OUT(N,BETA,COBS,TRIPS)
        STOP
        END

        SUBROUTINE ENT2 (N,BETA,COBS)
        COMMON DIST(30,30),O(30),A(30),B(30),D(30),H(30),S(30,30),
       +T(30,30),P(30,30),M
        DO 11 KK=1,10
         DO I=1,N
          A(I)=0.0
          B(I)=1.0
           DO J=1,N
            IF(I.EQ.J)THEN
             A(I)=A(I)+0.0
            ELSE
             A(I)=A(I)+H(J)*S(I,J)*DIST(I,J)**BETA
            END IF
           END DO
           A(I)=1.0/A(I)
         END DO
          C=0.0
          DO I=1,N
            DO J=1,N
              IF(I.EQ.J)THEN
               C=C+0.0
              ELSE
               C=C+O(I)*A(I)*H(J)*S(I,J)*
       +        (DIST(I,J)**BETA)*LOG(DIST(I,J))
              END IF
            END DO
          END DO
          IF(KK.EQ.1) GO TO 10
          W=C-CT
          IF(ABS(W).LT.COBS*0.000001) GO TO 12
          W=((COBS-CT)*BETA-(COBS-C)*BT)/W
          CT=C
          BT=BETA
          BETA=W
          GO TO 11
10        BT=BETA
          CT=C
          BETA=C/COBS*BETA
11      CONTINUE
12      RETURN
        END

        SUBROUTINE OUT (N,BETA,COBS,TRIPS)
        COMMON DIST(30,30),O(30),A(30),B(30),D(30),H(30),S(30,30),
       +T(30,30),P(30,30),M
        DIMENSION ITEMP(28)
```

```
C
C
C     BETA IS THE PARAMETER OF THE DECAY FUNCTION
C     TRIPS IS THE TOTAL NUMBER OF TRIPS IN THE SYSTEM
C
      OPEN(UNIT=3,FILE='OUT.DAT',STATUS='OLD')
      WRITE(3,11)BETA
      DO 1 I=1,N
      X=O(I)*TRIPS
      Y=D(I)*TRIPS
1     WRITE(3,12)I,X,A(I),B(I),Y
      WRITE(3,13)
      XMEAN=0.0
      DO 3 I=1,N
      X=TRIPS
      DO 2 J=1,N
       IF(I.EQ.J)THEN
        W=0.0
       ELSE
        W=X*O(I)*A(I)*H(J)*S(I,J)*DIST(I,J)**BETA
       END IF
      P(I,J)=W
       IF(I.EQ.J)THEN
        XMEAN=XMEAN+0.0
       ELSE
        XMEAN=XMEAN+W*LOG(DIST(I,J))
       END IF
2     ITEMP(J)=IFIX(W+0.5)
3     WRITE(3,14)I,(ITEMP(J),J=1,N)
      XMEAN=XMEAN/TRIPS
      WRITE(3,15)COBS,XMEAN
      DD=0
      DO I=1,N
      DO J=1,N
      DD=DD+ABS(P(I,J)-T(I,J))
      END DO
      END DO
      RMIS=DD*50/M
      WRITE(3,16)RMIS
      RETURN
11    FORMAT(1X,'BETA=',F10.6/1X,'CELL',7X,'ORIGIN TRIPS',8X,
     +'A VALUE',10X,'B VALUE',10X,'DEST TRIPS')
12    FORMAT(I5,F17.0,2F17.5,F17.0)
13    FORMAT(1X,'TRIP MATRIX')
14    FORMAT(1X,'FROM CELL',I6/(29I7))
15    FORMAT(1X,'OBSERVED MEAN LOG MIG DISTANCE',F10.6/
     +1X,'MODEL MEAN LOG MIG DISTANCE',F13.6)
16    FORMAT(1X,'RMIS=',F10.4)
      CLOSE(3)
      END
```

PROGRAM OSMSIM 3

```
C      This is the original program for modelling origin-specific
C      migration flows with both cost and origin
C      constraints(power function).
C
C      DIST is distance matrix,
C      H investment,
C      S migrant stock,
C      T observed migration matrix,
C      P estimated migration matrix,
C      M total number of migrants,
C      N number of provinces,
C      BETA parameter of distance decay of the power function.
C      RMIS percentage of migrants misallocated
C
       COMMON DIST(1,30),O(1),A(1),B(1),D(1),H(30),S(1,30),
      +T(1,30),P(1,30),M
C
       OPEN(UNIT=1,FILE='MGX90T.DAT',STATUS='OLD')
C
       READ(1,*)N
       DO I=1,1
        READ(1,*)O(I)
       END DO
       DO I=1,1
        READ(1,*)D(I)
       END DO
       DO J=1,N
        READ(1,*)H(J)
       END DO
       DO I=1,1
        READ(1,*)(S(I,J),J=1,N)
       END DO
       DO I=1,1
        READ(1,*)(DIST(I,J),J=1,N)
       END DO
       READ(1,*)COBS
       DO I=1,1
        READ(1,*)(T(I,J),J=1,N)
       END DO
       READ(1,*)M
       CLOSE(1)
       BETA=-0.163369
       TRIPS=0.0
       DO 1 I=1,1
1      TRIPS=TRIPS+O(I)
       DO 2 I=1,1
       O(I)=O(I)/TRIPS
2      D(I)=D(I)/TRIPS
       CALL ENT2(N,BETA,COBS)
```

```
      CALL OUT(N,BETA,COBS,TRIPS)
      STOP
      END
C
      SUBROUTINE ENT2 (N,BETA,COBS)
      COMMON DIST(1,30),O(1),A(1),B(1),D(1),H(30),S(1,30),
     +T(1,30),P(1,30),M
      DO 11 KK=1,10
       DO I=1,1
        A(I)=0.0
        B(I)=1.0
         DO J=1,N
          IF(DIST(I,J).EQ.0)THEN
           A(I)=A(I)+0.0
          ELSE
           A(I)=A(I)+H(J)*S(I,J)*DIST(I,J)**BETA
          END IF
         END DO
         A(I)=1.0/A(I)
       END DO
        C=0.0
        DO I=1,1
          DO J=1,N
            IF(DIST(I,J).EQ.0)THEN
             C=C+0.0
            ELSE
             C=C+O(I)*A(I)*H(J)*S(I,J)*
     +        (DIST(I,J)**BETA)*LOG(DIST(I,J))
            END IF
          END DO
        END DO
        IF(KK.EQ.1) GO TO 10
        W=C-CT
        IF(ABS(W).LT.COBS*0.000001) GO TO 12
        W=((COBS-CT)*BETA-(COBS-C)*BT)/W
        CT=C
        BT=BETA
        BETA=W
        GO TO 11
10      BT=BETA
        CT=C
        BETA=C/COBS*BETA
11    CONTINUE
12    RETURN
      END
C
      SUBROUTINE OUT (N,BETA,COBS,TRIPS)
      COMMON DIST(1,30),O(1),A(1),B(1),D(1),H(30),S(1,30),
     +T(1,30),P(1,30),M
      DIMENSION ITEMP(28)
C
C
```

```
C     BETA IS THE PARAMETER OF THE EXPONENTIAL DECAY FUNCTION
C     TRIPS IS THE TOTAL NUMBER OF TRIPS IN THE SYSTEM
C
      OPEN(UNIT=3,FILE='OUT.DAT',STATUS='OLD')
      WRITE(3,11)BETA
      DO 1 I=1,1
      X=O(I)*TRIPS
      Y=D(I)*TRIPS
1     WRITE(3,12)I,X,A(I),B(I),Y
      WRITE(3,13)
      XMEAN=0.0
      DO 3 I=1,1
      X=TRIPS
      DO 2 J=1,N
       IF(DIST(I,J).EQ.0)THEN
        W=0.0
       ELSE
        W=X*O(I)*A(I)*H(J)*S(I,J)*DIST(I,J)**BETA
       END IF
      P(I,J)=W
       IF(DIST(I,J).EQ.0)THEN
        XMEAN=XMEAN+0.0
       ELSE
        XMEAN=XMEAN+W*LOG(DIST(I,J))
       END IF
2     ITEMP(J)=IFIX(W+0.5)
3     WRITE(3,14)I,(ITEMP(J),J=1,N)
      XMEAN=XMEAN/TRIPS
      WRITE(3,15)COBS,XMEAN
      DD=0
      DO I=1,1
      DO J=1,N
      DD=DD+ABS(P(I,J)-T(I,J))
      END DO
      END DO
      RMIS=DD*50/M
      WRITE(3,16)RMIS
      RETURN
11    FORMAT(1X,'BETA=',F10.6/1X,'CELL',7X,'ORIGIN TRIPS',8X,
     +'A VALUE',10X,'B VALUE',10X,'DEST TRIPS')
12    FORMAT(I5,F17.0,2F17.5,F17.0)
13    FORMAT(1X,'TRIP MATRIX')
14    FORMAT(1X,'FROM CELL',I6/(29I7))
15    FORMAT(1X,'OBSERVED MEAN LOG MIG DISTANCE',F10.5/
     +1X,'MODEL MEAN LOG MIG DISTANCE',F13.5)
16    FORMAT(1X,'RMIS=',F10.4)
      CLOSE(3)
      END
```

Appendix C: Heuristical powers (r and u) applied to transform the data

(1) total migration, 1982-87 and 1985-90

Model type	MSIM 1		MSIM 2	MSIM 3
Time period	1985-90	1982-87	1985-90	1985-90
r			0.8	0.6
u	0.9	0.9		0.2

(2) male and female migration, 1985-90

Model type	MSIM 1		MSIM 2		MSIM 3	
	male	female	male	female	male	female
r			0.8	0.9	0.6	0.7
u	0.7	1.3			0.1	0.4

(3) origin-specific migration, 1985-90

Province	OSMSIM 1	OSMSIM 2	OSMSIM 3	
	u	r	u	r
Beijing	1.0	0.6	0.9	0.2
Tianjin	0.8	0.9	0.3	0.5
Hebei	0.1	1.1	0.2	1.1
Shanxi	0.4	0.6	0.3	0.2
In. Mongolia	1.3	1.0	0.2	0.8
Liaoning	1.1	0.7	0.6	0.4
Jilin	0.9	0.8	-0.2	0.7
Heilongjiang	1.4	0.8	0.5	0.7
Shanghai	1.4	0.6	1.0	0.2
Jiangsu	1.3	1.0	0.4	0.8
Zhejiang	0.1	0.5	-0.1	0.8
Anhui	0.7	0.8	0.9	0.7
Fujian	0.7	0.7	0.1	0.4
Jiangxi	1.7	1.0	0.3	0.8
Shandong	0.8	1.0	0.2	0.7
Henan	0.1	0.7	0.1	0.6
Hubei	0.8	0.6	0.6	0.2
Hunan	3.6	0.6	2.2	0.6
Guangdong	0.6	0.4	0.4	0.1
Guangxi	2.2	1.2	1.0	0.8
Sichuan	1.3	0.7	0.3	0.5
Guizhou	1.0	0.6	0.7	0.5
Yunnan	1.8	0.7	1.0	0.4
Shaanxi	0.5	0.5	0.3	0.3
Gansu	1.1	0.5	0.1	0.3
Qinghai	1.6	0.8	1.0	0.3
Ningxia	0.8	0.4	0.2	0.3
Xinjiang	1.4	0.5	0.6	0.4

Appendix D: Method of interpolation used to estimate the mid-year population

In calculating migration rates for the period between July 1,1982 and July 1, 1987, the middle of the time interval lies at the end of 1984. The middle of the time interval for the period between July 1, 1985 and July 1, 1990 is at the end of 1987. The population at the middle of these two time intervals can be estimated by using a method of interpolation. The interpolation method is based on the geometric progression growth equation, and this equation can be expressed as follows:

$$P_n = P_0(1+r)^n$$

where P_0 is the number of people in the population at the initial date, P_n is the number of people in the population at the later date, r is the annual rate of population growth, and n is the exact number of years between the initial and the later date.

Given the population data at the two dates, July 1, 1982 and July 1, 1990, for the provinces of China, the annual rate of population growth can be calculated. The population size for each province can be interpolated using the above equation. The whole estimation process can be carried out with a written computer program (*e.g.*, FORTRAN 77).

Another way to interpolate the population size is to use the exponential growth equation ($P_n = P_0 e^{rn}$) (Barclay, 1958; Crook, 1997). One wonders whether the estimation based on the equation of the geometric progression growth is significantly different from that based on the equation of exponential growth. According to Barclay (1958), in most cases where the annual rate of population growth is low (for example, in

China's provinces, it was less than two per cent), the interpolation results based on the two formulas are almost the same.