Four Essays on the Economic Development, Resource and Environmental Economics

by

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Abstract

The economic structure and household livelihood of Mongolia have been experiencing dramatic changes driven by both the socio-economic transition and the climate change in the past decades. This dissertation investigated the changes of population, livestock and cropland, and more importantly, the drivers of changing society and climate. Chapters 1 and 2 focused on population and migration. Population in Mongolia had increased from 2.1 million in 1990 to 2.9 million 2017, and dramatic re-distribution had also been taking place primarily by migration, which had been largely replacing nomadic movement. Urbanization accounted for over 80% of all migrations, mostly into Ulaanbaatar, where 70% of recent population growth was from migration. While relative wage ratio and job opportunity have been the most important drivers of migration and urbanization although demographic factors and climate matter too. Chapter 3 focused on livestock, which has been most essential to the Mongolian society and culture. I have investigated on the pastoral activities through examination of the behaviors of self-consumption, sale and the stock left for the future of the livestock using the Two-Stage Dynamic Model. The results revealed the pastoralists remain largely in the subsistence economy stage, but did respond to market factors such as prices, and debt to maximize the economic value of their livestock and their utilities. Chapter 4 focused on cropland, which has experienced significant increase in recent decades. A random effect semi-log model was applied to evaluate how socioeconomic and climate factors drive the dynamics. The relative wage, commodity prices, and policy were found significant roles on cropland expansion. Interestingly, cropland expansion was found not at the expense of livestock production. By integration the population, livestock and cropland tempo-spatially of the 4 chapters, I believed this dissertation would help us better understand and capture the essentials of the Coupled Nature and Human System (CNHS) of Mongolia.

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List of Abbreviations

UB	Ulaanbaatar
IM	Inner Mongolia
ROC	Rest of the Country
UR	Unemployment Rate
NPF	Net Population Flow
LU	Livestock Unit
MSO	Mongolia Statistical Office
IMBSS	Inner Mongolia Bureau of Statistical Service
OLS	Ordinary Least Squares
GDP	Gross Domestic Product

Chapter 1. Spatial and Temporal Migration in Mongolia during Economic Transition and Changing Climate

Abstract

This chapter reviews migration and urbanization in Mongolia during the post-1990 economic transition, focusing on migration and its influencing factors from the early 2000s to the mid-2010s using the data during 2001-2014 by the Mongolia National Labor Survey. Urbanization accounted for over 80% of all migration, mostly into the capital city Ulaanbaatar (UB), where nearly 70% of recent population growth was from migration. Married and more educated people were more likely to migrate toward urban areas and less likely to migrate to rural areas. Higher wages were a major driver for people to move to cities. Population growth of suburban areas in UB might be predominantly related to land tenure policies, at least at the beginning of the economic transition, and the favorable social welfare provided in UB. Migratory rates to both urban and rural areas increased during 2011-2014 following a severe disaster, the *dzud*, in 2010. People from the eastern region were more likely to move back to the rural area than those living in the western region, due to the fact that the East has a more favorable climate for grass growth. The results confirm the importance of climate and weather changes in migration along with several socio-economic indicators.

1. Introduction

Migration and new settlement, which are often associated with globalization, industrialization, social development, improved transportation technology and infrastructure development has been a major cause of population re-distribution in developing countries since the 1960s. Migration is an important adaptive strategy in mitigating climate change and diversifying livelihood when traditional resources become not adequately available (Gioli et al. 2014). Migration is replacing nomadism as more important pattern of population resettlement in semi-arid areas.

Although Mongolia has the lowest population density in the world but is among the highest rates of urban population in developing countries (World Bank 2018b). The population settlement has been shaped jointly by natural, geographical, socio-economic and historical factors. They were very much dependent on herding in the 1920s, but the percentage of urban population grew to 40% by the 1960s (Figure. 2.1). Urban population exceeded rural population for the first time in mid-1970s, reaching 57% in 1990 (Webster 2004). Such urban population growth was mainly driven by the rapidly expanding agriculture sector, infrastructure, and industrialization with the support and guidance of the former Soviet Union (Tsogtsaikhan 2001; Spoorenberg 2015).

Substantial changes in the socio-economic systems started in the beginning of 1990s after the collapse of the former Soviet Union. The loss of Russian influence brought freedom and democracy to Mongolian society, and people were much less restricted in settlement (Pomfret 2000; Cheng 2003). Economic growth would absorb more labor force into better-paid occupations such as mining and services. However, poverty and uneven development remained in remote rural areas and small cities because they could not benefit much from the economic boom (Bruun and Odgaard 2013).

In the beginning of 1990s, economic hardships associated with the loss of assistance from former Soviet Union led many urban residents to flee towards rural areas, where they could depend on pastoral livelihoods for their basic needs. Net urban to rural migration doubled between 1990 and 1997 (Mearns 2004). Most state-owned or public firms with low productivity/efficiency went out of business, including hospitals, schools, state-owned farms/pastures, and industrial plants. In contrast, economic livelihood in rural areas was less affected, resulting in rural areas becoming refugee camps for urban residents who could barely survive due to the loss of their way of living from the process of social wealth redistribution (Fernández-Giménez 2001; Upton 2008).

From 1993 onwards, the country found a way to recover from the chaos and declines. A market system was established (Humphrey and Skvirskaja 2009), and urban areas were able to feed more people with foreign financial support (Cheng 2003). The migratory flow turned mainly from urban-to-rural to rural-to-urban in the mid-1990s due to emerging economic opportunities for educated workers and the more balanced gender ratio in urban areas, and by 2014 the percentage of urban population reached 72.4% (World Bank 2018a). Ulaanbaatar (UB), the capital city of Mongolia, occupies a very specific primacy position in the urban hierarchy. The city concentrates about half of the total population of the country (Figure. 2.1) by 2015. Political and economic transition has also exerted a significant impact on fertility and family formation in Mongolia (Spoorenberg 2009).

Another characteristic of migration in Mongolia is the fact that a huge number of rural and poor herding families settled in peri-urban parts of UB, taking advantage of the better welfare and health care systems in UB (Lindskog 2014). Pastoral land was in semi-open access and each household was provided with specific land free, at least at the beginning of the economic transition (Kim and Dorjderem 2012; Caldieron and Miller 2013). However, in order to be near the market, they had to give up frequent cyclical pastoral movement and remain on the same pastoral land for longer, leading to overgrazing issues and land degradation (Lkhagvadorj et al. 2013; Okayasu et al. 2007). Several environmental problems, including air and water pollution, are associated with under-regulated migration to the city and the land tenure (Dore and Nagpal 2006). Residential plots in sub-urban area by private land plots was in an unplanned manner owing to the poor execution of land reform policy (Tsutsumida et al. 2015).

Migration is often associated with urbanization in developing countries. Mongolians, however, also often migrate from one rural area to another area, as pastoral resources are still very much in a state of open or semi-open access. However, they migrate to new areas for permanent settlement, unlike their former ancestors. Nomadic herders have greatly diminished (Honeychurch 2010). Evidence shows that the Mongolian Plateaus is one of the areas most threatened by dramatic climate change for hundreds of years (John et al. 2013). Considering the large territory of Mongolia and variety in climate and weather patterns from the West to the East, paired with the dramatic changes in both socio-economic factors and climate in the past two decades, Mongolia provides a good case study to analyze the role of climate change and economic transformation on migration and settlement.

2. Conceptual and empirical model

We assume the income gap between herding and non-herding sector drive the migration and new settlement. Mongolian society has a tradition of high spatial mobility in which herds were their main asset with open or semi-open pastoral resources. For simplicity's sake, we assume the cost of migration is identical and relatively small among regions compared to the significantly increased income level.

Figure 1.2 illustrates equilibrium between herding and non-herding (mostly urban jobs) and how the income gap would induce job shifting and resettlement. The grassland owned by the state allows herders to migrate across apace without much barrier: higher income from non-herding would reduce labor force in herding from H2 managing livestock L2 (per capita livestock is L2/H2) to only H1 with livestock L1 (per capita livestock L1/H1), *vice versa*. The migration between herding and non-herding will keep the relative income stable but not necessarily the same. The equilibrium is at the point of migrating would not expect to have higher income. The same principle can be applied to the migration from location to location. The overall income or quality of living standard is much determined by the non-herding sectors, which are dominant in the Mongolia's economy at present time. Relative higher price of livestock suggests higher income in herding, *vice versa*.

Uneven development drives migration, but it could either reduce or enhance poverty and uneven development, which would drive migration by spatial inequalities (Deshingkar 2006; Kanbur and Venables 2005). Growth of labor-intensive production and service in industry and agriculture sector would also facilitate migration (Dayal and Karan 2003; Tsogtsaikhan 2003). However, migration might bring greater urban-rural income inequality (Deshingkar 2006). Greater rural-urban gap in economic opportunities would induce more migrants from rural to urban areas. Some people are more adaptable to new jobs and environments. Connell et al. (1976) found that single men who were young, better educated, less risk-averse, and more achievement-oriented with better communication skills in destination areas would rather migrate toward urban areas. In Asian countries, although some migrants are unskilled, they often possess job-transferable skills that can be used in new jobs (Lipton 1980). Migration would benefit them from both continuous education experiences and some regular sources of financial support for the period immediately after migration (Schultz 1975). Caviglia-Harris et al. (2013) employed the life-cycle theory to explain why people migrate at particular ages, which could help us to better understand the scheme of those demographic impacts.

Climate change also drives migration (McLeman and Smit 2006; Tacoli 2009). Migration is an adaptation strategy against nature system challenges, including dramatic climate changes like drought and floods (Black et al. 2011; Bardsley and Hugo 2010; McLeman and Smit 2006). For example, Hassani-Mahmooei and Parris (2012) found that population movement towards areas with less droughts and floods is the main migration pattern in Bangladesh. Ocello et al. (2015) emphasized the dominant role of mobility in the adaptation process of migration. A wide variety of migration patterns were reported, ranging from short-term, temporary environmentally-related migration to permanent relocation resulting from, for example, natural disasters (Hunter 2005). Naude (2008) argued that climate change would affect and boost migration through three channels: lack of natural resources (water or land), disasters, and conflicts over natural resources. In some situations, such as natural disasters, people have little choice but to migrate (Aghazarm and Laczko 2009). By studying the link between environmental change and migration, scholars have demonstrated that the redistribution of population brought on by climate change can induce conflicts linked to food security of the hosting rural areas (McGregor 1994). Conflicts seem to be inevitable under climate driven migration (Barnett and Adger 2007; Swain 1993). The population re-allocation would also affect grazing intensity and carbon emissions, particularly in dry areas (Han et al. 2016). Meanwhile, migration could also potentially help slow the process of environmental degradation (Reuveny 2007).

The Literature on migration suggest that migration is a function of relative income from one place to another place (e.g., Harris and Todaro 1970), or relative income change from rural and urban area if the rural population is migrating into urban area, most common in developing countries (e.g., Zhao 1999). People tend to migrate to more favorable places. However, migration also comes along with costs and challenges, and is therefore path dependent. Factors that contribute to migration include environmental catastrophes, wars, increased economic opportunities in other places, and attainment of better education in cities. Generally, we could classify those factors into extreme factors (severe environmental disaster, internal conflict, etc.) that force residents to leave their location without any choice, and socio-economic factors that could be decided based on information or the rational decision-making. People have various reasons to migrate regarding their current situations. Scholars have demonstrated that socio-economic factors (demographic factors, economic well-being and social networking) and the nature (land productivity) would jointly determine migration in dryland India, especially for herding communities (Shah 2010). In Mongolia, rural households who survived based on herding seemed to be more vulnerable when there were severe disasters that would devastate their livestock. For these people, climate change would be a dominant factor for migration decision. Some would abandon herding permanently and settle down in urban areas, and there was little possibility to move back to animal husbandry in rural areas.

To summarize, migration decision-making in Mongolia is affected by socio-economic factors, climate change and inequality, particularly between rural and urban areas. For each household, current location indicates its adaptation of socio-economic conditions and natural environment (McLeman and Smit 2006). However, when environment changes, people would migrate or stay in the same location. Migrating from rural to urban area is particularly common when the economy is in the process of industrialization (e.g., Zhang and Shunfeng 2003; Phouxay and Tollefsen 2011). Demographic factors such as age, gender, education, marital status, household size, and employment status are widely studied for developing countries and proven to be key factors influencing decisions concerning migration (e.g., De Jong 2000; Yaohui Zhao 1999; Tacoli and Mabala 2010). Environmental factors such as drought also drive herders to temporarily move (in most cases just for a single season) for survival, but some of them might move back when the situation improves.

To understand migration in Mongolia, we estimate the following binary logistic model:

$$\Pr(M_{it} = 1) = \beta_0 + \beta_1 \text{lnIN}C_{it} + \beta_2 \text{P}L_{it} + \beta_3 \text{M}D_{it} + \beta_4 \text{PR}O_{it} + \beta_5 \text{Regio}n_j + \beta_6 \text{Yea}r_j$$
$$+ \beta_7 \text{lnRain}_t + \beta_8 \text{lnRain}_{t-1} + \beta_9 \text{SocioDem Variables} + \varepsilon_{it}$$

where, $M_{it} = 1$ or 0 (M_{it}=1 if the respondent moved, otherwise 0). Binary logistic models, similar to binary probit models, are widely adapted in studies on individual behavior, for example in a study of pastoral land sale or acquisition in Inner Mongolia (Zhang et al. 2017). βi are the coefficients, ε is random error. Table 1.1 presents the independent variables, the definitions and measurements. Actual income rather than the relative urban-rural income gap was used in estimation because household survey data were used.

Apart from demographic information on individuals and households, a time dummy variable $Year_j$ is used to proxy environmental change/natural disasters as well socio-economic change over years. A dummy variable $Region_j$ is also adopted to quantify how regional climate and biophysical zone affect migration. We used migration data for 2002-2006, 2006-2010, and 2010-2014 periods to ascertain how demographic, regional, and natural phenomenon such as rainfall influenced migration patterns. Given the importance of precipitation for grassland production (John et al. 2016) and stored precipitation in soil as a vital water resource (Zhao et al. 2011), we also used rainy days in the current and previous year as explanatory variables.

We hypothesized that rural herders in Mongolia who faced higher expected income or other benefits in the non-herding sector were more likely to migrate to urban areas. At the same time, urban-to-urban migration could be possible with similar driving force of better livelihood (e.g., enhanced income, higher standard of living in urban areas). Non-socioeconomic factors could also drive migration. For example, unexpected disasters could potentially induce herders to abandon grazing and seek jobs in urban areas both temporarily and permanently. Herding households from the certain regions would, however, be less likely to migrate than other parts because of relatively favorable climate for herding.

3. Data

The data was gathered from the Mongolian Statistical Yearbook for the period 1990 to 2015 and Mongolia Labor Force Survey (LFS) during 2006-2014 conducted by Mongolian Statistical Information Service (MONSIS) (Table 1.2). The main objective of the LFS was to update and expand labor force statistical baseline to capture and analyze employment pattern, and aimed at collecting a comprehensive set of data of households to estimate employment and unemployment characteristics which capture seasonal variability, location, social and economic activities consistent with International Labor Organization (ILO) methodology. The survey was conducted by the National Statistical Office of Mongolia which covers 21 *aimags* (Mongolian word meaning “tribe” or “province”), 311 *soums* (Mongolian word meaning “county”, a subdivision below *aimag*) and 9 districts of Ulaanbaatar.

Current and previous location information (urban or rural) indicated in the LFS survey would reveal the migration status and pattern. In the LFS survey, the questionnaire was designed to ask about the migration behavior in the past 5 years for respondents. As a result, we have chosen the survey of 2006, 2010, and 2014 to reveal the migration pattern change in every 5 years. We also include the information of months living at current place. Demographic data (e.g., age, employment, marital status, education and household size) were also included. Their professions (herding or non-herding) were revealed from respondents' work locations (grassland/farmland). We also used rainy days in the current and previous year from Mongolia Yearbook on *aimag* level.

Table 1.3 presents the stated reasons of migration for the 3 periods by region. For each observation point, migration and occupation change in the past 5 years were reported, based upon which we traced changes in migration pattern in different periods following Bell et al. (2015). The total sample size is around 48,000 in each year.

The total population experienced rapid growth, increasing from 2.1 million to 2.9 million, an increase of 38% over the period 1990 through 2014 in Mongolia (Figure 1.3). With a relatively stabilized rural population, it was largely urban areas that experienced increases in population. However, there were differences in population growth between sub-periods. For instance, from 1990 to 1992 urban population dramatically increased but suddenly stabilized and even experienced a slight decrease in the central region from 1993 to 1998. Since then it has sped up at 4.4% per year on average. The urbanization process in Mongolia centered on migration toward UB where about 1.3 million people, accounting for 46% of the total population in 2014.

Rural population, in contrast, was quite stable at one million during 1990 - 2014. During the period 1990 to 1998 rural population did experience an increase. However, rural population started to decline in response to economic hardship following the collapse of the former Soviet Union and ensuing socio-economic turmoil, after 1998 when the economy was improving (see

Figure 1.3). The rate or urbanization by regions varied during 1990-2014, excluding the UB, and there was a sudden increase in the rate in 2010, but it fell sharply after 2011 (Figure 1.4). We also found that the rate of migrants among all respondents were decreasing along with the years, form 7.8% in 2006, to only 3.6% in 2014 (Table 1.4.). Urban-oriented migration were the main pattern, when rural to urban migration became dominant in 2014, with a rate of 58%.

4. Results

Our estimated results on factors influencing migration of rural-to-urban and urban-to-rural are reported in Table 1.5. The dependent variables are whether or not to move towards urban areas (migrate to urban=1, otherwise=0), and whether or not to migrate towards rural areas (migrate to rural=1, otherwise=0). The results suggest that rural-to-urban migrating is more likely than urban-to-urban migrating. No differences were found about moving from either urban or rural to urban areas. It is interesting that when people migrate, they would more likely migrate out of their own province (*aimag*s), regardless of urban and rural areas.

A number of demographic factors were found to affect migration behaviors. Older people were more likely to move to rural areas and less likely to move to urban areas. Married and better educated people tended to migrate to urban regions, while there were no differences between male and female as “gender” was not significant. This could be due to the fact that both women and men have equal work opportunities. Unmarried and less educated individuals tended to migrate to rural areas. Household size is not found to be related to migration decisions. People who migrated to rural areas most likely continued to engage in grazing/herding. Overall, non-herding income (or wage) level in cities largely determined urbanization process. This is consistent with our hypothesis (Figure 1.2). We also tested some joint terms. For example, those who were previously from rural area and specified in livestock grazing would rather migrate towards urban. Married male would be more likely to migrate to urban and less likely towards rural areas.

Compared with 2001-2006, the period 2006-2010 witnessed more migration to rural, and during the period 2010-2014 more people migrated to both urban and rural areas. Compared with the West, UB attracted more migration to urban areas, and the East region attracted more people to rural but less to urban areas. This is likely due to the more favorable climate for grazing and animal husbandry in the east. We did not find rainfall in current year to be significant but more rainfall in previous year would lead to less migrating towards urban areas.

5. Discussion and conclusion

In pastoral society, natural endowments play a critical role for herder community movement. Nomadic pastoralism has proven to be a successful livelihood and mobility is widely believed to play an important role in traditional nomadic society (Fernandez-Gimenez and Febre 2006; Lattimore 1940). The less fertile arid and semi-arid pastoral land could only support a limited population on the Mongolian Plateau. As a pastoral regime, the Mongolian Empire in the 13th century was built along expanding territory rather than increasing population density or establishing permanent urban areas.

Minerals and other natural resources other than pastoral resources (livestock) started to play an important role in modern periods. Supporting a larger population required dependence on alternative livelihoods other than herding, most likely in mining industry, manufacture industry or other jobs of services in cities. In the decades since the 1960s', population grew more rapidly in urban areas than in rural areas in Mongolia. The same phenomenon has also taken place in IM and many central Asian countries with similar pastoral resources and herder's population, but a much greater proportion of the population depended on agriculture, mining, manufacturing and services. Gollin et al. (2016) found that in Mongolia, unlike in other Asian countries, high urbanization was the result of high dependence on the resource trade. That could help to explain why Mongolia has one of the highest ratios of urban population among otherwise similar Asian countries.

Mongolia had been experiencing faster urbanization after the collapse of the former Soviet Union. With a relatively stable rural population around 1 million, population grew mainly in urban areas from 1.1 million to close 2 million (Figure 1.3). This is consistent with the theoretical model developed by Yamamura et al. (2013). When the overall economy was good, people migrated from rural to urban areas for higher income. In contrast, when the overall economy was bad, people retreated to rural areas for easier survival. As income in rural area is more dependent on rural labor force, a little reduction in rural labor force because of migration to urban area resulted in an increase in rural income, thereby catching up with urban areas in income; in contrast, a little increase in rural labor force following migration from urban area would reduce rural income, preventing more migration to rural area. This explains why changes in population have largely taken place in urban areas.

Because of the most recent economic recession in Mongolia caused by a sharp drop in the prices of natural resources, former urban residents were observed to abandon urban jobs and move back to rural pastoral areas after 2015, similar to that happened in the early 1990s (Kazato 2017). The key motivating factor for migration was unemployment rather than income gap (Harris and Todaro (1970). Such a de-urbanization process had been repeatedly seen in countries that heavily depended on natural resources or agricultural products export and concentration of population in several major cities (Portes 1989; Gollin et al. 2016). The manufacturing sector, rather than the natural resource sector, could lead to stabilized urbanization (He et al. 2016; Mano and Otsuka 2000; Gollin et al. 2016).

Environmental factors are found to significantly affect migration. More precipitations in the previous year would lead to less migration towards the urban are, but it will not influence the rural-oriented migration. A greater rate of rural to urban migration in 2011-2014 after a severe disaster, the *dzud*, took place in 2010. The results are consistent with the fact that the Mongolian Plateau experienced an extreme 2009-2010 summer-winter *dzud*, which killed 8.5 million livestock, 20% of the national herd (Fernandez-Gimenez et al. 2012; Sternberg 2010). The Eastern region attracted more people to rural areas than the West as the climate is more favorable with more productive grasslands. The results are consistent with other studies which argue that climate change and natural system change were important drivers of migration in Mongolia (J. Wang et al. 2013; Batima et al. 2005; Tachiiri et al. 2008; Sternberg 2010; Park et al. 2017; Dore and Nagpal 2006). To cope with the climate and weather related disasters, weather based insurance might be helpful (Luxbacher and Goodland 2011).

Our results accord with studies that claim that inequality in standard of living increased between rural areas and urban areas (e.g., Neupert and Goldstein 1994; Bolormaa Tsogtsaikhan 2001). Higher urban wages and more job opportunities would attract more people into cities. However, path dependence and skill transferability play an important role, as not all people are able to take the advantage of greater freedom and better income in cities. Our results suggest that older, single, less educated people are at a disadvantage for high wage jobs in cities and are more likely to stay or migrate from one rural area to another. In contrast, younger, married and better educated people are more likely to move to urban areas. Education is very important for a society in transition from a pastoral to a more industrial society. Although several scholars have investigated the role of social networks on reinforcing migration (e.g., Fawcett 1989; Skeldon 1997; Haug 2008), I was unable to include any accurate or close variable indicating the "network" in this study due to limited availability of data. This could lead to future studies focusing on the social network issues.

Institutional changes have been demonstrated to play an important role in migration and urbanization continuously. In semi-arid regions, privatization could lower herder's migration tendency, while the privatization process would increase grassland productivity (Kabubo-Mariara 2003). The first and most direct effect resulted from fewer restrictions in local or state laws on mobility (e.g.,Cai and Wang 2003; Shen 2012), and closures of many state-owned firms and services, including hospitals, schools, state-owned farms/pastures, and manufacturing plants after the downfall of the former Soviet Union. Land tenure system, particularly on pastoral land, is also important in influencing migration. The land privatization process was slow paced during the early transition period, with less than 1% of land being privatized by 2003 (Shagdar 2007). While non-grazing land, like urban and cultivation land could be under private ownership, rangeland remained as public asset, meaning its privatization was strictly forbidden under current land law (Johnson et al. 2006). Prior to the 1990s, the system restricted people from migrating from one place to another, but freedom provided after 1990s likely caused a "tragedy of the commons" by incentivizing overgrazing under open access (Griffin et al. 2002).

More than 80% of new migration was towards UB, driven to get the allocated land. A lot of migrants did not end up with urban jobs but settled around the city and still partially practiced herding, causing overgrazing around the city as well as pollution and other socio-economic problems in the suburban areas of UB. Therefore, grassland tenure changes, either through privatization or community-based animal control or other alternative arrangements, are urgently needed in areas around the city so that the distribution of the rural population can be socially optimized when individuals make decisions about herding and animal husbandry settlements.

Although migration is widely considered as a risk-aversion behavior, we also observe other alternative coping strategies. For example, Addison and Brown (2014) reported the buffer effect using market and flexible price adjustment to lower loss associated with external shocks, mostly disasters, in Mongolia cashmere production. Thus, because of the well-developed market system nowadays, the adaptation method is not limited to migration. Migration will likely continue to be mainly in the form of urbanization and the growing population would bring future stress on natural resource like groundwater that could potentially break the threshold (Dore and Nagpal 2006). Migration to urban area also brings several problems (Martine 2012). Poverty, air pollution, underground water pollution (Tsogtbaatar et al. 2009), inequality, and other socio-economic problems (Dore and Nagpal 2006) have made urbanization unsustainable (Guttikunda 2008).

From a global perspective, a number of Central Asian countries have displayed similar migration and urbanization patterns. For example, in Kazakhstan, a former herding-dominant country, a booming oil industry induced the urbanization process by creating many urban jobs (Wuzhati et al. 2014). IM, another major part of the Mongolia Plateau, has also experienced rapid population growth and urbanization over the last decades (N. Lu et al. 2009). Unlike Mongolia, IM of China has more evenly distributed population across its land area: 7 out of its 12 prefectures have more than 8% of total population and is not dominated by few cities (Inner Mongolia Bureau of Statistical Service, IMBSS 2016). Migration and urbanization do generate beneficial opportunities to increase the population carrying capacity and quality of living standards for the arid regions, but also impose potential risks in response to socio-economic transformation and climate changes. Developing appropriate public policies together with market mechanism including labor market to address these problems will be important for sustainable development.

Table 1.1 Name and measurements of independent variables

Variable	Name	Measurement
Gender	Sex_i	Sex_i=1 if the respondent is male, otherwise 0
Age	Age_i	Numerical
Household size	HHZ_i	Numerical
Marriage status	MAR_i	MAR_i=1 if the respondent is married, otherwise 0
Education level	EDU_i	years of education
Professions	PRO_i	PRO_i =1 if profession is herding
Monthly income	INC_i	In 1,000 Tugs (Inflation adjusted with 2010 as base year)
Year	$Year_j$	$Year_j$=1 if it is year *j*, otherwise 0
Region	$Region_j$	$Region_j$=1 if it is region *j*, otherwise 0
Location prior to migration	PL_i	PL_i=1 if it is rural, otherwise 0
Migration direction	MD_i	MD_i=1 if migration beyond the same *aimag*
Rainy days	$Rain_t$	Rainy days per year of *aimag* level
Rainy days in the previous year	$Rain_{t-1}$	Rainy days per year of *aimag* level

Table 1.2 Statistical summary of respondents in Labor Force Surveys

Variable	Measurement	2006	2010	2014
Current location	Urban (UB/*Aimag* centers)	59%	61%	54%
Previous location	Urban (UB/*Aimag* centers)	58%	66%	77%
Months living at current place	Months	19	17	21
Gender	Male=1	0.5	0.5	0.5
Age		27.3	28	29.1
Age under 22		0.3	0.3	0.3
Age over 65		0.04	0.04	0.04
Household size		4.3	4.5	4.4
Marital status	Yes=1	0.6	0.5	0.6
Education (years)		8.7	9.1	9.8
Place of work	Grassland/farmland=1	0.3	0.5	0.6
Profession	Herding=1	0.1	0.1	0.3
Monthly income	1,000 tug	1.2	1.5	2.8
Employment in last 12 months	Yes=1	0.6	0.5	0.6
Rainy days at current year		90	114	100
Rainy days previous year		90	95	113
N		48108	47995	49368

Note: First two rows "current location" and "Previous location" indicates the percentage of both locations which are urban areas. Following rows represent the mean value of key variables.

*Because of data availability, we could only start with 2006.

Table 1.3 Proportion (%) of the population who stated reasons for migration

	Stated reasons	West	East	Khangai	Central	UB
2006	Change home place	27.3	19.3	35.8	33.1	21.9
	Moved with family	18.9	22.3	9.2	21.1	32.3
	Job offer	12.4	11.6	10.1	9.7	13.2
	To study	8.3	12.3	9.7	5.9	16.9
	To get married	2.4	1.3	7.2	3.3	2.5
	Environmental reasons	5.3	3.6	2.3	1.2	9.1
	Others	25.4	29.6	25.7	25.7	4.1
2010	Change home place	21.7	34.9	42.9	34.9	45.2
	Moved with family	16.3	3.3	21.3	12.5	10.9
	Job offer	11.0	5.9	7.7	3.3	6.1
	To study	9.1	13.0	2.1	11.3	11.3
	To get married	6.1	17.1	6.4	12.6	11.9
	Environmental reasons	1.9	7.3	2.5	3.3	4.1
	Others	33.9	18.5	17.1	22.1	10.5
2014	Change home place	36.3	39.2	40.9	32.9	35.8
	Moved with family	16.9	28.8	11.1	11.9	31.2
	Job offer	10.2	9.1	6.9	8.9	11.9
	To study	7.9	2.3	9.2	12.9	10.8
	To get married	5.0	4.7	13.3	9.4	6.3

Environmental reasons	2.4	1.1	3.1	1.2	1.3
Others	21.3	14.8	15.5	22.8	2.7

Note: For each region in 2006/2010/2014, the percentage proportion of stated reasons for migration displayed.

Table 1.4 Migration pattern change in different periods (2002-2014)

	N=3752 2006	N=2024 2010	N=1778 2014
Having migration	7.8%	4.2%	3.6%
Rural→Urban	44%	42%	58%
Rural→Rural	3%	1%	7%
Urban→Rural	11%	13%	5%
Urban→Urban	42%	37%	30%

Table 1.5 Coefficients of the estimate of the factors of migration toward urban and rural areas

	towards urban (yes=1)	towards rural (yes=1)
From urban (if migration from urban=1)	0.236***	-0.026
	(0.017)	(0.019)
Migration (beyond the same *aimag*=1)	0.133**	0.466***
	(0.022)	(0.106)
Gender	0.198	-0.397
	(0.170)	(0.255)
Age	-0.170***	0.132***
	(0.029)	(0.015)
Household size	0.234	-0.353
	(0.192)	(0.163)
Marital status	0.469**	-0.197**
	(0.111)	(0.025)
Education (years)	0.360***	-0.299**
	(0.009)	(0.023)
Profession (herding=1)	-0.177	0.353***
	(0.0165)	(0.009)
Monthly income	0.153***	-0.568***
	(0.022)	(0.026)
Previous rural * Profession	0.663*	0.375
	(0.303)	(0.239)

Male * Married	0.352**	-0.770**
	(0.106)	(0.220)
Year 2006 ((base)		
Year 2010	0.277	0.136**
	(0.191)	(0.056)
Year 2014	0.102***	0.235***
	(0.001)	(0.006)
Region_West (base)		
Region_UB	0.193***	0.276
	(0.007)	(0.153)
Region_East	-0.633**	0.255**
	(0.101)	(0.053)
Region_Central	0.355	0.064
	(0.025)	(0.023)
Region_Khangai	0.102	0.077
	(0.143)	(0.156)
Rainy days	-0.336	0.206
	(0.307)	(0.170)
Rainy days previous year	-0.069***	0.196
	(0.001)	(0.175)
Constant	-1.106***	0.765***
	(0.033)	(0.102)
R-square	0.155	0.191

Observations	125687	125687

Note: ***stands for 1% significant level; ** for 5% significance level; *10% significance level.

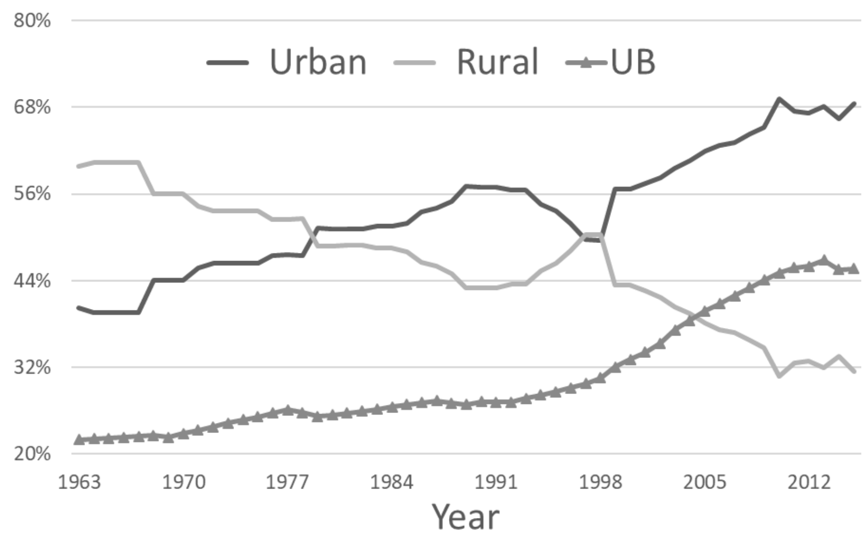

Figure 1.1 Percentage of the population living in urban area, rural area and UB (1963-2015).

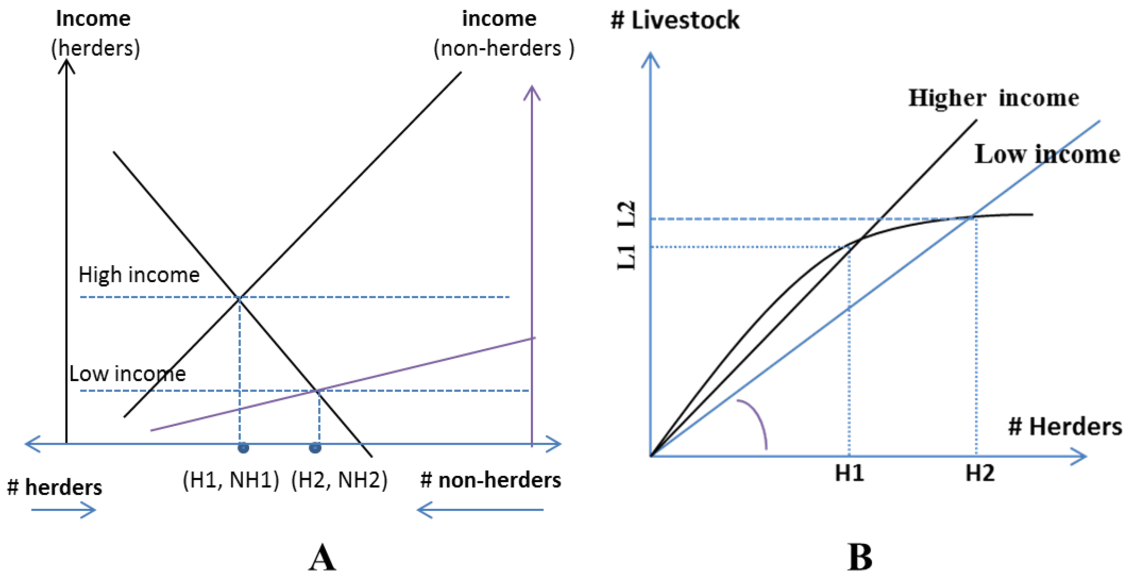

Figure 1.2 A). Equilibriums between herding/non-herding with changing relative income; **B**) The income level under open access land.

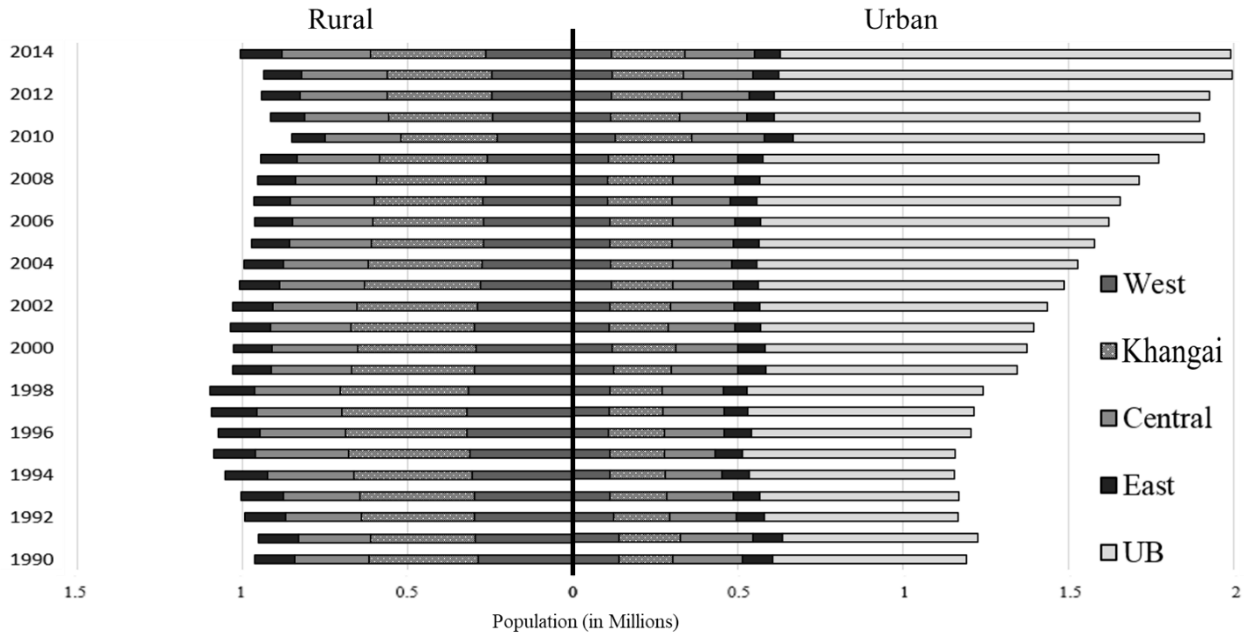

Figure 1.3 Rural and urban population change in Mongolia by regions (1990-2014)

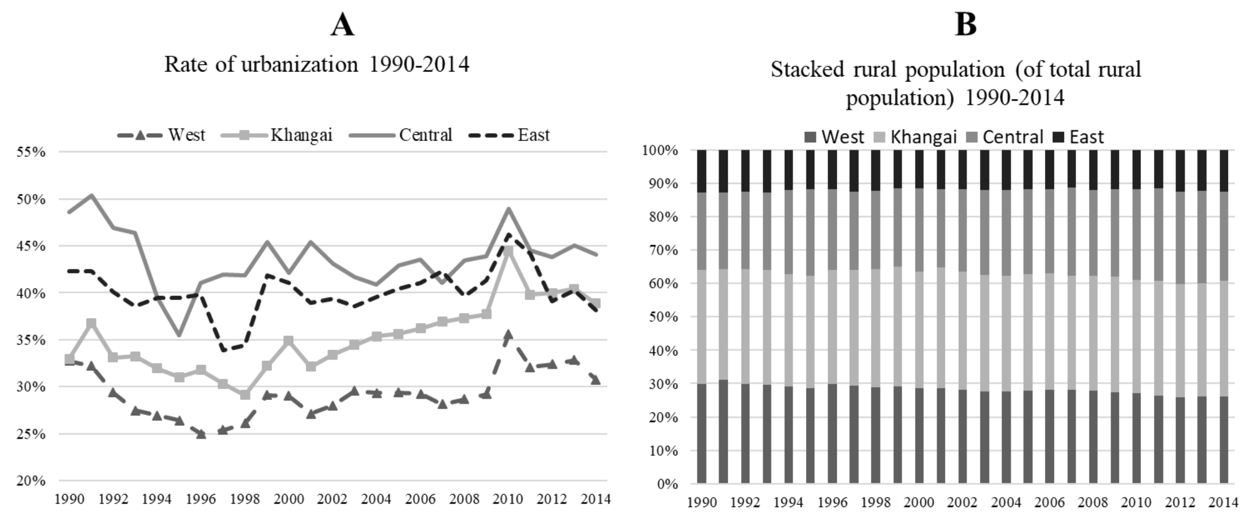

Figure 1.4 A) Urban population rates by region; **B)** Composition of total rural population by region 1990-2014

Chapter 2. Bound to Ulaanbaatar in Mongolia

Abstract

We reviewed the changes of migration to Ulaanbaatar (UB) – the capital of Mongolia –during the economic transition of 2002-2007, as well as the driving forces based on the dataset from the Mongolia National Labor Survey. We tested a hypothesis that the relative wage and unemployment between UB and the rest of the country were the primary drivers to migrate to UB. The empirical analysis confirmed that relatively higher UB wage and low unemployment rate to the rest of the country lead greater migrants towards UB. Specifically, each 1% increase in the relative wage ratio increased the odds that UB as the migration destination (hereafter, odds-UB) by 0.55% of all respondents and 0.87% of respondents from urban; each 1% increase in the relative unemployment rate ratio decreased 0.32%, 0.24%, and 0.62% in odds-UB for all respondents, respondents from urban and rural, respectively. We also found that married and more educated people were more likely to migrate toward UB. Migratory rates to UB increased during 2007-2011 following the most severe *dzud,* in 2010. The importance of climate and weather changes in migration decision was also apparent.

1. Introduction

Labor force flow from rural areas or non-metro cities to metro-city has been a major trend of population migration, primarily because of higher wages in metro-cities (Glaeser et al. 2014). Higher labor productivity and concentrated economic activities in metro-cities have led such wage differentials against other areas (Venables 2010; Rosenthal and Strange 2003). Metro-city is also preferred by highly skilled labors to maximize their income as well as enhanced life quality (e.g., better education and medical facilities) (Shapiro 2006; Jiquan Chen et al. 2018). The attraction of higher wages in metro-cities would not be offset by increased high living cost and environmental problems (Combes et al. 2008). As a result, people desire higher income with improved education seem to be "locked" in these metro-cities (Adamson et al. 2004). In the literature, the life-cycle theory has been widely used to predict the migration by age that help us to better understand demographic impacts, especially for inter-metropolitan migration (Plane and Heins 2003; Caviglia-Harris et al. 2013).

During the urbanization process in Mongolia, Ulaanbaatar (UB) as the capital city became the most dominant metro-city for the nation and the most popular migration destination. UB concentrates about half of the total population of Mongolia, accounting > 70% of the urban population (Figure 2.1) by 2017. Higher socio-economic well-being has been proposed as the key driver for migrating to UB. Fan et al. (2016) demonstrated that the in-flow rate of UB was highly correlated to the growth rate of its GDP per capita during 2000-2013. Based the household level interviews, migration towards UB appeared mainly driven by persuasion of improved life quality, more job opportunity and better education (Terbish and Rawsthorne 2016). For rural migrants who continue their livestock practice, they tend to move and settle in the peri-urban parts of UB, taking advantage of the better welfare and health care systems in UB

(Lindskog 2014; J. Chen, John, Zhang, et al. 2015). For low-income households, only few had health insurance (Lhamsuren et al. 2012). Additionally, climate and change play some roles in migration decision (Mayer 2016). For example, severe disasters (e.g., *dzuds*) and extreme climate had urged some rural herders to abandon livestock practice and seek jobs in UB after their livestock were dramatically damaged and to recover. An example is the extreme *dzud* of 2010-2011 winter that caused a record livestock mortality (Fernandez-Gimenez et al. 2012).

The population boom in UB brought several challenges to the environment and to the local community. This over-populated city had been suffering several problems as in other metro-cities. New migrants put additional pressure on the existing urban residents, leading worsening environments. Many studies had reported the problem of the pollution in air, water and soil brought from the population pressure from migrants (Kasimov et al. 2011; Sato and Lu 2002; Tsutsumida et al. 2013; Mayer 2016; Fan et al. 2016; Jiquan Chen et al. 2018). Meanwhile, the infrastructure and civil engineering system in UB fell behind the rapidly increasing population. In UB, these newly settled households could hardly find support from the surroundings due to lack of social networks, which led their life to maintain at low level (Terbish and Rawsthorne 2016). Inequality and development fluctuations among UB residents during the urbanization was also reported by Cui et al. (2019). And the welfare gap between newly settled household and local UB residents was observed (Shi 2011). Such uneven social development would undermine the sustainable economic growth in UB.

Because the urbanization process in Mongolia has been dominated by the migration towards UB, it would be helpful to focus on these UB-oriented migrants. By studying the migration pattern change and what are driving these migrants, we would better understand how socio-economic well-being would combined with the climate change, influence individuals migration decision. After reviewing the characteristics of the UB in recent decades, we propose a theoretical framework for understanding decision-making of migrants towards metro-city like UB. Based on this framework, we then examine the influencing factors of the migration through empirical analysis. We used both the national level statistical data and household survey data in micro level in recent decades.

2. Population and migration in Mongolia

Total population witnessed rapid growth, increasing from 2.1 million in 1990 to 2.9 million 2017 in Mongolia (MONSIS), yielding a 38% increase. A positive net population flow (NPF) towards UB was has been observed since 1990 while it kept negative until 2017 for rest of the country (ROC), suggesting that UB had been a preferred destination during 1990-2017 (Figure 2.2.A). The positive NPF to UB between 1989 and 2017 indicated UB was far more dominantly attractive than other regions for migrants for most periods. After 2005, there was a slowly declining positive NPF to UB and some fluctuations from 2010 to 2013, with sharp drop in 2010 and 2013. Since 2015, the NPF has been decreasing significantly. In 2017, it became negative for the first time after 1990.

During 1983-1990, ROC absorbed more migrants than UB. In 1991, the NPF of ROC was 5 times higher than that to UB. But it fell dramatically since 1992. By comparing the in-migration for UB and ROC (Figure 2.2.B), we found that UB had greater in-migrants only between 2002 and 2009. During 2016-2017, in-migrants of UB fell behind that of ROC. During 1983-2001, UB appeared less preferred for migrants. In 1992, over 70000 people moved to ROC, while the number to UB was only 13000. By comparing the NPF and in-migration during 1983-2017, we concluded that UB was the dominant migration destination in most years comparing to ROC.

When combined the NPF of UB and wage ratio (average monthly wage in UB / average monthly wage in ROC), we found that the increasing trend in wage ratio between UB and ROC was correlated to a greater NPF to UB (Figure 2.2.C). We also found that the unemployment rate (UR) ratio (UR in ROC / UR in UB), which refers to the relative job opportunity, was also correlated to the NPF to UB (Figure 2.2.D). In other words, smaller UR ratio or more job opportunity in UB is correlated higher positive NPF to UB.

3. Data

For empirical exploration of the driving forces, we used data from the Mongolian Statistical Yearbook until 2017 and Mongolia Labor Force Survey (LFS) of the Mongolian Statistical Information Service (MONSIS) during 2007-2017. The LFS data was used to update and expand labor force statistical baseline to capture and analyze employment pattern, and aimed at collecting a comprehensive set of data of households to estimate employment and unemployment characteristics which capture seasonal variability, location, social and economic activities consistent with International Labor Organization (ILO) methodology. The survey was conducted by the National Statistical Office of Mongolia, which covers 21 *aimag*s (Mongolian word meaning “tribe” or “province”), 311 *soums* (Mongolian word meaning “county”, a subdivision below *aimag*) and 9 districts of UB.

Current and previous location information (urban or rural) indicated in the LFS survey would reveal the migration status and pattern. In the LFS survey, the questionnaire was designed to ask about the migration behavior in the past 5 years for respondents, based upon which we traced changes in migration pattern in different periods following Bell et al. (2015). As a result, we have chosen the survey of 2007, 2012, and 2017 to reveal the migration pattern to UB change in every 5 years. We included monthly income from all resources calculate the monthly wage of all respondents. For the missing and inaccurate data, we used simulated value to replace, included in the appendix.

Unemployment rate (UR) and average monthly wage on *aimag* (UB) level were obtained from the Yearbook. Migration distances were originally ordinal data, which was transferred into real distances in km by categories-based reality and experiences (migrated inside the same district=5 km; from another city but within the same *aimag*=100 km; from another *aimag*=400 km; from abroad=2000 km). Demographic data (e.g., age, marital status, education and household size) were also included. We only choose respondents over age 15 when considered as labor force in Mongolia. Table 2.1 presents the independent variables, the definitions measurements, units and expected sign of all variables, along with the summary statistics.

By summarizing and analyzing the survey data, we found in 2007 and 2012, there were 10% of all respondents in the LFS survey indicated migration, and in 2017, the number was only about 5% in their past 5 years. In all years, most migrants were to UB (Table 2.2), and in 2012, the ratio ranked the highest of 70%. For these migrants to UB, we found decreasing ratio of migrants from rural areas from 2007 to 2017 and in 2017, 86% of the UB migrants were from urban.

4. Conceptual framework and empirical model

We assume people move to improve their quality of life. Quality of life depends in part on one's earning capacity. Harris and Todaro (1970) proposed that migration from a rural to an urban area is a function of relative earning capacity defined as follows:

$$\frac{dN_U}{dt} = \theta\left(\frac{W_U^e}{W_A}\right) \qquad \theta' > 0, \quad \theta(1) = 0 \tag{1}$$

where N_U is the number of permanent urban workers plus migrants, W_U^e is the expected urban wage, and W_A is the agricultural real wage. Migration is an increasing function of the expected wage ratio, and ceases only when the expected wage ratio is one (implying the gap between urban and rural wages is nil).

The incentive to migrate indicated by the expected wage gap is moderated by urban unemployment. To incorporate this factor into the model, Harris and Todaro (1970) define expected urban wage as follows:

$$W_U^e = \frac{\bar{W}_M N_M}{N_U} \qquad \frac{N_M}{N_U} \leq 1 \tag{2}$$

where N_M is the total labor (urban plus rural migrant) required to produce the manufactured good, and $\bar{W}_M$ is the fixed minimum urban wage. The minimum wage sets the upper limit on the expected wage. The upper limit obtains when urban unemployment is zero, i.e., when $\frac{N_M}{N_U} = 1$.

The effect of unemployment on migration may be seen by substituting equation (2) into equation (1) to yield:

$$\frac{dN_U}{dt} = \theta\left(\frac{\bar{W}_M}{W_A} \cdot \frac{N_M}{N_U}\right) \tag{3}$$

Migration ceases when $\frac{\bar{W}_M}{W_A} \cdot \frac{N_M}{N_U} = 1$, or when $\frac{\bar{W}_M}{W_A} = \frac{N_U}{N_M}$. Urban unemployment, i.e., $\frac{N_U}{N_M} > 1$, implies migration ceases at a higher minimum wage than when there is no unemployment. If unemployment is 10%, the minimum wage must be more than 110% of the agricultural wage to induce migration.

As explained above from the framework provided in equation (1) to (3), the migration decision towards urban or metro area is determined by the wage gap and job opportunity. Specifically, Harris and Todaro (1970) expcted that rural-urban migration is an increasing function of the urban-rural wage differential and a decreasing function of urban unemployment.

Despite these two economic factors, the impact of demographic, education and skill level, travelling distance, and natural system had been also demonstrated to be influencing (Carree and Kronenberg 2014; Pekkala 2003; Yazgi et al. 2014; Park et al. 2017). All these factors influencing the migration decision should be included in the empirical study. To test these hypotheses as they relate to Mongolia, we estimate the following binary logistic model:

$$\Pr\left(M_{UB_{it}} = 1\right) = \beta_0 + \beta_1 Wage_{R_{it}} + \beta_2 UNEMP_{R_t} + \beta_4 lnHHZ_{it} + \beta_5 Male + \beta_6 MAR_{it} + \beta_7 VTR_{it} + \beta_8 DISAB_{it} + \beta_9 lnDIST_{it} + \beta_{10} lnEDU_{it} + \beta_{11} lnAge_{it} + \beta_{12} CUR\_LOC_{it} + \beta_{13} PREV\_LOC_{it} + \beta_{14} NPP_{Rit} + \beta_{15} Year_j + e_{it}$$

where subscripts i and t are the respondents at current year, respectively. M_UB_{it}=1 if the migrated to UB, otherwise 0. Here, we only consider people who had already migrated, focusing on the differences between moving towards UB and non-UB areas. Binary logistic models, similar to binary probit models, are widely adapted in studies on individual behavior, for example in a study of pastoral land sale or acquisition in Inner Mongolia (IM) (Zhang et al. 2017). β_i are the coefficients, ε is random error, ln is the log form of variables. Beyond the full sample estimation, we also include the regression analysis for migration from urban and rural areas separately, based on which we wish to investigate the pattern differentials between former rural and urban migrants.

The hypotheses to be tested are:

$$H_N^1: \beta_1 \leq 0$$

$$H_A^1: \beta_1 > 0$$

and

$$H_N^2: \beta_2 \geq 0$$

$$H_A^2 : \beta_2 < 0$$

Harris and Todaro (1970) predicted a positive relationship between migration and relative wage. Asserting a non-negative relationship in the null means we are not prepared to accept the hypothesis unless there is strong evidence in the data to support the claim. A similar statement can be made with respect to unemployment rate.

5. Results

The model was constructed for the entire sample (Model 1) and for subsamples consisting of those who migrated from an urban area (Model 2) and from a rural area (Model 3). Most of the signs of the estimated coefficients are in line with expectations and most are significant based on the binary logistic models. The Pseudo R^2s are ~0.31 in all three models, which indicated that the model had satisfactory explanatory power for pooled cross-section data across different periods.

Our estimation are consistent with theoretical predictions. Migration to UB increases as the relative wage in UB increases, and as relative employment prospects in UB improve. The one exception is in Model 3 where the wage effect is not significant. Focusing first on Model 1, the estimated coefficient of the relative wage variable (0.354) implies an odds ratio of 1.425. The odds of migration to UB for the entire sample increase by 42% for each one unit increase in the relative wage (this number would change to 66% in Model 2). The relative wage at the sample mean is 1.32. A one unit increase from the sample mean equates to a 76% increase ((2.32-1.32)/1.32 = 0.76). Dividing 42% by 76% implies that each 1% increase in the relative wage increases the odds of migration by 0.55%. Similarly, we could calculate that in Model 2, each 1% increase in the relative wage increases the odds of migration by 0.87%. By way of comparison, the estimated coefficient of the relative employment variable (-0.373) implies an odds ratio of 0.689 in Model 1. The odds of migration to UB decreases by 45% for each one unit increase in the relative unemployment rate (UB/Local). Evaluated at the sample mean, a one unit increase in $UNEMP_R$ translates to 140% decrease ((1.71-0.71)/0.71 = 1.40). Dividing 45% by 140% implies that each 1% increase in relative unemployment decreases the odds of migration by 0.32%. Similarly, we could calculate that in Model 2 and Model 3, each 1% increase in the relative unemployment rate reduces the odds of migration by 0.24% and 0.62%, respectively. The odds of migration is inelastic to both relative wage (0.43) and unemployment (0.32), with the latter having a slightly smaller effect. The variable of relative unemployment rate are negatively significant in all models (with a coefficient of -0.373, -0.291, and -0.624 for $UNEMP_R$, respectively), indicating a one unit increase in the relative unemployment rate (UR in UB /Local UR) would lead decrease of 45%, 34%, and 87% in odds-UB for three models, respectively.

Household size measured by the number of household member influence the migration decision negatively (with a coefficient of -0.461, -0.457, and -0.618 for HHZ, respectively). Women appear a higher possibility than men in Model 1 and Model 2. Married respondents would prefer migrate to UB than others. Vocational training would also reduce the odds-UB in all models (with a coefficient of -0.857, -0.789, and -0.755 for VTR, respectively). Having disability is not significant. Grater travelling distance would decrease the odds-UB in Model 1 and Model 2, but increase that in model 3 (with a coefficient of -0.0463, -0.227 and 0.460 for $DIST$, respectively). This could also be explained that former rural residents from remote area prefer to migrate to UB, regardless of the distance, but former urban residents would lower their desire to migrate as the distance getting longer. Better educated and younger individuals would be more likely to migrate in all models.

The coefficients of CUR_LOC are positively significant and large in all models, with a value of 3.526, 4.288 and 2.762, respectively. Such finding could be explained that most people would choose UB as their migration destination if move towards urban areas, dominantly. In Model 1, we also found that people who are originally from urban areas would prefer UB to migrate (with a coefficient of 0.795 for $PREV\_LOC$). Regarding the nature factor, an increase in the relative net primary productivity (UB/Local) would increase the odds-UB for former rural residents (with a coefficient of 0.253 for NPP_R in Model 3). We also found comparing to the latest period of 2012-2017, in both the first two periods, 2002-2007 and 2007-2012, greater odds-UB had been observed.

6. Discussion and conclusion

This study explored the migration to UB under the economic transition and climate change since 1990. The findings indicate income gap from the unbalanced development between UB and non-UB areas did drive migration towards metro UB. It was also found that better job opportunity measured by relatively employment rate would also facilitate the migration to UB. Our results are consistent with other study that also claimed that work opportunities and higher wage in urban areas in Mongolia (IOM 2018). More than that, our findings suggest that demographic indicators, such as age, education level, marriage status, gender, and disability, would also play important role, as well as the impact from vocational training. Nature factors such as weather for agriculture and disaster would also influence the migration decisions.

NPF towards UB had been experiencing continuous reduction during the past 10 years, and we would expect fewer in the future. Such change could be the result of smaller income gap and more balanced rural-urban development with better implementation of social welfare and health care system, especially in the remote rural areas (Lhamsuren et al. 2012). However, UB as the largest city in Mongolia, would also be the priority migration destination for young and skilled labor force, with more job opportunities and significant income promotion.

Migration from rural to urban areas, or from less developed to developed areas, is commonly seen globally, as well as an inevitable trend brought from industrialization, modernization and marketization. Migrants would benefit from increased income and better livelihood in developed urban areas. However, some migrants would only get low skill positions because of their training and skill level, or lack of social network. These low skill jobs might reduce the wage satisfaction in the long run, which would eventually induce re-migrate or return migration (Lundholm 2012; Bürgelt et al. 2008). The return migration would always bring several social problems, like increased inequality and family tragedy. Moreover, new migrants in UB could hardly get involved into the local community with the lack of policy supports (Terbish and Rawsthorne 2016). To avoid this, better public support and guide for migrants while making the initial decision are necessary. Given the fact that migration towards urban areas, like UB, are dominantly driven by the wage gap and job opportunity, the unsustainable livelihood of new migrants would problematically undermine policies aiming at lowering the developmental inequality, like infrastructure enhancement, better healthcare and education, increase in herder income to hold the rural populations from migration.

More than 80% of new migration was towards UB in 2017. Many migrants did not end up with urban jobs, but settled around the city and still partially practiced herding, causing overgrazing around the city as well as pollution and other socio-economic problems in the suburban areas of UB. Therefore, grassland tenure changes, either though privatization or community-based animal control or other alternative arrangements, are urgently needed in areas around the city so that the distribution of the rural population can be socially optimized when individuals make decisions about herding and animal husbandry settlements.

Climate and environmental related migration often cause poverty and other related risks in urban areas (de Sherbinin et al. 2011; Cernea 2005). The same happen in Mongolia and we could not separate the coupled nature and human system in this area (J. Chen, John, Shao, et al. 2015). Natural disaster drive herders to abandon land and home and migrate to other places, likely urban areas such as e UB in Mongolia. Poverty is the most commonly seen sequence of such migration in urban areas. This would require a resistance system against the new migrant's poverty problem. Unlike the self-migrant, which would be driven by wage gap, forced migrants always need public supports in job training, health care and re-settlement, in which the government and public could contribute.

We realized the role of social networks on reinforcing migration had been widely investigated (Fawcett 1989; Skeldon 1997; Haug 2008), but ssocial network and transportation infrastructure was not included in this study due to data availability. For migrants from rural areas to UB, changing job is inevitable, from herding to non-herding jobs along with many other changes in lifestyle. During such transition process, network plays a key role for better adaptation in new jobs. What's more, according to Chi (2010), transportation infrastructure, like highway system construction and airport accessibility, is correlated to the population distribution. In Mongolia, however, road infrastructure is less developed and little formal road or highway system (Keshkamat et al. 2013), due to which most migrants took place towards UB and most of the Mongolia's population settle around the UB area potentially. This could lead to future studies combing the variable indicating network connection and transportation infrastructure.

Table 2.1 Measurements of variables and statistical summary

Variable	Label	Measurement and unit	Mean	S.D.
Migration towards UB	M_UB	migrated to UB=1, otherwise 0	0.64	0.48
Relative wage	$Wage_R$	=Average monthly wage in UB/Local monthly wage	1.32	1.12
Relative UR	$UNEMP_R$	= UR in UB /Local UR	0.72	0.93
Age	Age	Years	33.01	13.66
Household size	HHZ	the amount of household members	4.03	1.58
Gender	$Male$	=1if male, otherwise 0	0.46	0.50
Marriage status	MAR	=1 if married, otherwise 0	0.51	0.50
Vocational job training	VTR	=1 if had vocational job training, otherwise 0	0.08	0.27
Disability	$DISAB$	=1 if disabled, otherwise 0	0.04	0.19
Migration distance	$DIST$	distance to previous residency, in *km*	157.22	340.72
Education level	EDU	years of education	12.80	3.23
Current location	CUR_LOC	=1 if from urban, otherwise 0	0.92	0.27
Previous location	$PREV\_LOC$	=1 if from urban, otherwise 0	0.67	0.47
Relative Net Primary Productivity	NPP_R	annual average npp in the UB/ local annual average npp	1.147	0.456
Periods	$Year_t$	Dummy: 2002-07; 2007-2012; 2012-17 (base)		

Table 2.2 Migration pattern change in different periods

	2007	2012	2017
Total migrations	2962	3495	1415
to UB (of total migrants)	1836	2446	792
from urban (of migrations to UB)	1248	1883	681

Table 2.3 Logit model estimation on the determinants of migration to UB (odds ratios included)

	Model 1(Full Sample)		Model 2 (From Urban)		Model 3 (From Rural)	
	Estimates (SE)	Odds Ratio	Estimates (SE)	Odds Ratio	Estimates (SE)	Odds Ratio
$Wage_R$	0.354***	1.425	0.508***	1.661	0.0526	1.054
	(0.0601)		(0.0807)		(0.101)	
$UNEMP_R$	-0.373***	0.689	-0.291***	0.748	-0.624***	0.536
	(0.0659)		(0.0857)		(0.113)	
HHZ	-0.461***	0.631	-0.457***	0.633	-0.618***	0.539
	(0.0760)		(0.0969)		(0.131)	
$Male$	-0.140**	0.869	-0.217***	0.805	-0.0494	0.952
	(0.0626)		(0.0802)		(0.108)	
MAR	0.388***	1.474	0.480***	1.617	0.328**	1.388
	(0.0707)		(0.0881)		(0.129)	
VTR	-0.857***	0.424	-0.789***	0.454	-0.755***	0.470
	(0.110)		(0.135)		(0.210)	
$DISAB$	-0.0786	0.924	0.133	1.143	-0.420	0.657
	(0.162)		(0.218)		(0.266)	
$DIST$	-0.0463**	0.55	-0.227***	0.797	0.460***	1.584
	(0.0194)		(0.0231)		(0.0405)	
EDU	0.299***	1.348	0.366***	1.442	0.177***	1.194
	(0.0489)		(0.0764)		(0.0646)	
Age	-0.424***	1.529	-0.224*	1.251	-0.591***	1.806

	(0.0946)		(0.118)		(0.171)	
CUR_LOC	3.526***	33.98	4.288***	72.85	2.726***	15.27
	(0.194)		(0.408)		(0.227)	
$PREV\_LOC$	0.795***	2.214				
	(0.0716)					
NPP_R	0.0504	1.052	-0.0633	0.939	0.253*	1.288
	(0.0698)		(0.0843)		(0.133)	
$2002-2007$	0.706***	2.025	0.585***	1.795	1.030***	2.801
	(0.0885)		(0.108)		(0.178)	
$2007-2012$	0.714***	2.043	0.725***	2.064	1.029***	2.797
	(0.0832)		(0.0990)		(0.176)	
$2012-2017$ $(Base)$	-		-		-	
Constant	-3.152***	0.0428	-1.999***	0.135	-5.115***	0.00601
	(0.434)		(0.637)		(0.716)	
Pseudo R^2	0.309		0.301		0.311	
Observations	7872		5290		2582	

Standard errors (SE) in parentheses; *** p<0.01, ** p<0.05, * p<0.1

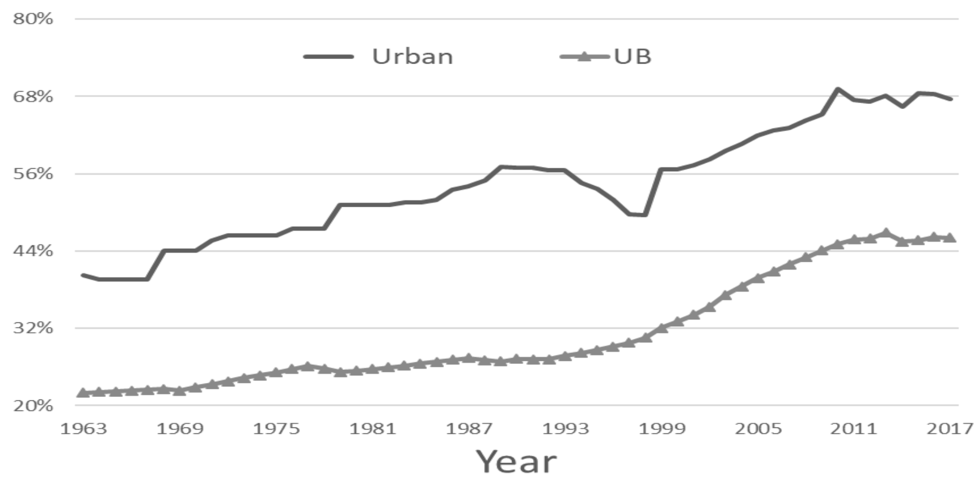

Figure 2.1 The change in percentage of urban population and UB (1963-2017) to the total national population

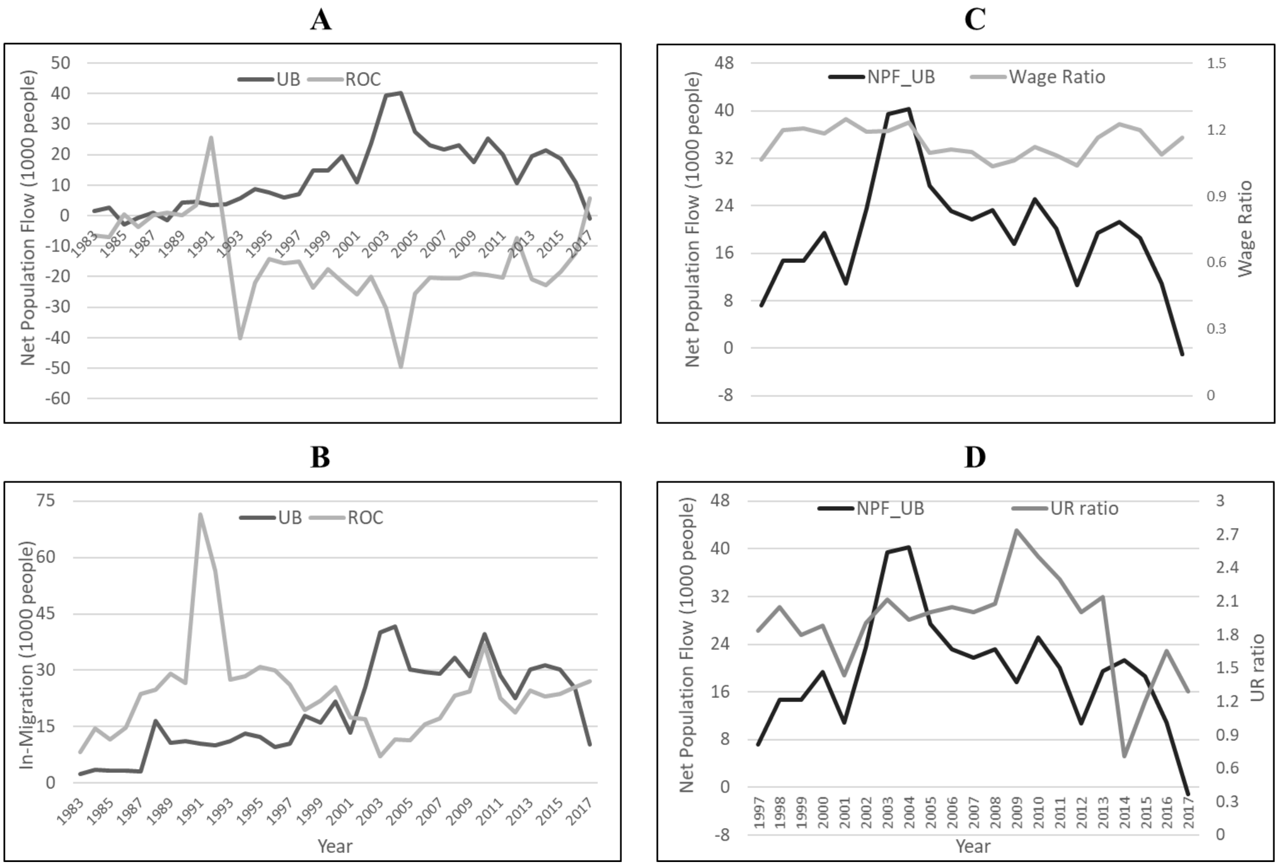

Figure 2.2 A) Net population flow (NPF, in 1000 people) in UB and rest of the country (ROC) from 1983 to 2017**; B)** In-Migration (in 1000 people) for UB and ROC**; C)** NPF of UB and wage ratio (average monthly wage in UB / average monthly wage in ROC)**; D)** NPF of UB and UR ratio (UR in UB / UR in ROC

Chapter 3. Livestock dynamics under changing economy and climate in Mongolia

Abstract

Livestock is a key variable in understanding the complex relationships of coupled natural and human systems for pastoralist societies. We used a Two-Stage Dynamic Model to examine the dynamics of livestock in terms of sales, self-consumption, and stocking in Mongolia in recent decades. While Mongolian pastoralists remain largely in the subsistence economy stage, herders do respond to market factors such as current and expected prices, substitute food prices and debt to help guide their choices and behaviors to maximize the economic value of their livestock. Our results also find that the livestock is very vulnerable to natural disasters. Providing a better capital market and livestock market could be the most essential factor to facilitate the economic transition of Mongolia from a subsistence pastoral economy to a market economy and to increase the welfare of herders in Mongolia. Improved public supports, including climate-based livestock insurance, enhancement of infrastructure animal shelter, better capital markets, increased availability of weather information, and improved winter protection, are critical components to a sustainable level of livestock production.

1. Introduction

In a nomadic pastoral society, livestock provides almost all of herders' needs, including food, shelter building materials and transportation, as well as goods to exchange for other goods and services. In studies on coupled human-nature systems, livestock has been used as the central connecting variable for understanding the underlying processes and complex relationships among the systematic drivers and functions (J. Chen, John, Shao, et al. 2015; John et al. 2016).

Mongolia is experiencing rapid societal changes. It has transitioned from a predominantly pastoral society to a mixed economy including agriculture, mining, manufacturing, and service sectors. Meanwhile, herding and animal husbandry are becoming a smaller part of the economy and national wealth (e.g., GDP). As a result, livestock is becoming less necessary for production or self-consumption, and for the whole society, livelihood strategy is appearing to be less dependent on the livestock and its associated products. However, grazing is still important to a large part of the population, especially in rural areas. For example, the grazing sector still accounts for 89% of agricultural GDP that employs 28% of the total labor force in Mongolia (National Statistical Office of Mongolia 2017).

Mongolia has been undergoing dramatic political reforms since 1990, after the collapse of the former Soviet Union. Livestock has been privatized, but pastoral land remains publicly owned, allowing open or semi-open access. Each pastoral household can make individual decisions based on its own objectives and expectations (Johnson et al. 2006). Few herders maintain traditional nomadic lifestyles, though rural households appear to be increasingly involved in modern ways of living, largely due to rapid changes in the regional and global markets, migration, and technological advancements. Herders have more freedom of choice in terms of their settlement and living strategies, such as switching from herding to other economic activities.

Mongolian herders also face challenges from dramatically changing weather and climate. The Mongolia Plateau has been identified as the most sensitive area to the changing climate (J. Chen, John, Zhang, et al. 2015; C. Shao et al. 2017). Pastoral economies are highly vulnerable to natural disasters, which can directly affect the livestock population due to a lack of necessary management facilities, especially during *dzud*s (a Mongolia term for a severe winter that leads to massive livestock loss). For example, the 2009-2010 *dzud*, which was believed to be the most devastating winter disaster in recent decades on the Mongolian Plateau, killed more than 28% of the Mongolian livestock population nationwide (Fernandez-Gimenez et al. 2015). It took more than two years for herd sizes to recover. The reality is that herders have to deal with all kinds of inevitable impacts in managing herds, not just *dzud*s, which requires improving livelihood resilience for all herder households.

Knowledge on the dynamics of livestock can help us better understand a pastoral society like Mongolia. Owning 19 equivalent sheep units per capita has been considered relatively stable throughout Mongolian nomadic history (M. Wang 2009). Such a stability of livestock per capita fits with the Malthusian Theory of Population, which describes a relationship between growth in food supply and in population, and how populations tend to outrun the food supply until they are regulated by it (Malthus 1798). Pastoral society is more vulnerable and less predictable than agricultural society, and a larger stock is needed to resist loss from natural disaster as a risk reversion (Rosenzweig and Wolpin 1993). Unlike humid regions that support equilibrium grazing systems with stable climates and predictable primary production, arid and semi-arid areas are usually characterized by non-equilibrium models of livestock-population dynamics

(Ellis and Swift 1988; Oba et al. 2000; Westoby et al. 1989). Nomadism has been adopted to respond to changing marginal environments (Davies and Hatfield 2007; Fernandez-Gimenez and Febre 2006).

Livestock dynamic analyses in general have mainly examined the business cycles of pastoral economies, and a recent study focused on biological models of livestock (e.g., Shabb et al., 2013). In a pastoral economy, the livestock dynamic is more than a business cycle. For example, natural disasters play an important role in shaping the size and quality of herds. Exploring these dynamics helps us better understand the coupled natural and human system of pastoral society and its transition to market economy. Through linking a simplified livestock growth model with economic systems, this study aims to investigate the dynamics of the livestock population at both national and household levels. We include both sale and self-consumption as part of the mechanism of the dynamics. We also explore the factors affecting the changes of livestock at the household level.

To achieve these goals, a two-period consumption-saving model was developed to quantify changes in livestock production for herder households under different socio-economic and environmental conditions, as well as to investigate how herders make decisions on livestock sale, self-consumption, and stocking. To our knowledge, there has been no other such study in Mongolia and no study in animal husbandry using the two-stage approach. This study will contribute to a better understanding of herders' behavior when the pastoral economy is in transition from a subsistence economy to a market economy and provide the pioneering work on the livestock dynamics.

2. Conceptual framework and empirical model

Livestock serves as assets (or capital), as well as products for herders. Current livestock quantity and structure directly determines the future ones. Experienced and rational herders balance their livestock between present and future use by adjusting the held assets mainly through their sale and self-consumption. In a market economy, herders will maximize their expected value of animal products subject to socio-economic factors, the market, and nature. Therefore, dynamics of livestock are jointly influenced by natural endowments and socio-economic factors (Moyo and Swanepoel 2010).

Quantitative analysis of livestock dynamic has been widely discussed in agricultural economics, such as the beef industry in the USA (e.g., Foster and Burt, 1992; Jarvis, 1974; Mathews and Short, 2001; Mundlak and Huang, 1996; Rucker et al., 1984; Schmitz, 1997). These studies focused on cow replacement and culling decisions under a breeding system that started from biological growth analyses of cattle herds. Livestock production systems in the USA and other developed countries (e.g., Australia and New Zealand), however, are highly responsive to the market. Livestock production is driven by the market and strongly associated with the business cycle to maximize profit. Because of well-developed supporting mechanisms (e.g., financial services, highly organized grazing labor and equipment), the natural system has limited influence on livestock production, compared to socio-economic systems. Jarvis (1974) called these supporting elements “capital”. Mundlak and Huang (1996) investigated cattle number changes for current and future periods and found that prices and values are the key elements for culling decision making, with technologies as vital variables for cattle production. More recently, Ge and Kinnucan (2018) also investigated the livestock dynamics, using supply and demand shifters for livestock products in a partial-equilibrium setting where the industry in question is a net exporter of livestock products. This paper makes an empirical contribution in that additional evidence is provided on the role that price plays in inventory behavior.

Livestock dynamics are in more investigated for subsistence economy in Africa. For example, Sieff (1999) found that wealthier households tended to maintain or expand their herds in Tanzania, but poor households eventually sell all livestock and stop grazing. Optimal and sustainable livestock stock rates have been explored and estimated by Weikard and Hein (2011). Tessema (2012) and Turner and Williams (2002) have emphasized the influence of the market on building sustainable pastoralism by studying the formation and the current situation of the livestock market. Other studies have explored the impact of livestock production from socio-economic factors and climate change (e.g., Nardone et al., 2010).

In semi-arid areas around the world, such as Mongolia, livestock functions as more than marketable assets in most rural households. Livestock is also considered a symbol of wealth (Murphy 2014). The changing structure and amount of livestock are major factors behind, as well an indicator of, socio-economic changes in pastoral households in Mongolia. Largely depending on the pastoral resources and fodder resources, livestock stocking has been unevenly distributed in Mongolia (Hannam 2017). Throughout the long history of the subsistence economy and nomadic pastoralism, livestock has been the interface factor between the herders and the pastoral resources (J. Chen, John, Zhang, et al. 2015).

Mongolia is in transition from a traditional pastoral society to a market economy. As the market begins playing a more and more important role, profit maximizing might become one of the key considerations for pastoralists, together with other objectives like risk reduction, signal of wealth, and food security. In addition, open access to the pastoral resources in Mongolia would potentially make herd management different than in other regions of the world, where pastoral resources are privately owned or more regulated (Crépin and Lindahl 2009). Therefore, grazing practices in Mongolia might be jointly affected by its own market structure, institutional shifts, and unpredicted climate change.

To model livestock dynamics in Mongolia, we used a two-period livestock production model for herders to maximize their discounted utility over the "present" and in the "future". The original two-stage model was developed and used in forestry (e.g., Gregorie, 1987; Packalén et al., 2009). This model could also be employed to solve production problems through resource use and stock in industries such as fisheries (J. Zhang and Smith 2011). We assume a herder household has a preference regarding present and future consumption. In present stage, a herder would choose the number for sale and self-consumption. The remaining livestock would become the initial stock for the next period. However, we assume the herder would sell and (or) self-consume all livestock by the end of the second stage. The utility is assumed to be an increasing and concave function of the consumption of goods and services. To maximize the present value or utilities of the herders' households, we have:

$$\mathrm{U} = (1-\alpha)[u(c_1) + \beta u(c_2)] + \alpha[g(x_{12}) + \beta g(x_{22})] \quad (1.0)$$

and

$$Q_1 = Q_0 - x_{11} - x_{12} \quad (1.1)$$

$$Q_2 = x_{21} + x_{22} = Q_1 + \mathrm{F}(Q_1) \quad (1.2)$$

$$\beta = (1+\rho)^{-1} \quad (1.3)$$

$$c_1 = P_1 x_{11} + m_1 - \mathrm{S} \quad (1.4)$$

$$c_2 = P_2 Q_2 + (1+r)\mathrm{S} + m_2 = P_2 Q_2 + (1+r)\{[P_1 x\}_{11} + m_1 - c_1] + m_2 \quad (1.5)$$

where U is the herder's utility; Q_0 is the initial livestock number; Q_1 is the livestock number after sale of x_{11} and self-consumption of x_{12} in the first period; Q_2 is the livestock number for the future, which is the sum of sale of x_{21} and self-consumption of x_{22} in the second period, respectively ; F (.) is the growth function for livestock; c_1 and c_2 are the present and future consumption; $\beta = (1 + \rho)^{-1}$ is herder's rate of time preference; r is the interest rate; S is the saving; $m_1$and m_2 are the non-herding income that are exogenous; g(.) is the utility function for self-consumption; α is the parameter that measures the relative utility weight between sale and self-consumption. ρ is the marginal rate of time preference. P_1 and P_2 are the constant prices in the present and the future, respectively.

To maximize the utility, we get:

$$U_{c_1} = (1 - \alpha)[u'(c_1) - (1 + r)\beta u'(c_2)] = 0 \quad (2.0)$$

$$U_{c_2} = -\frac{(1-\alpha)}{(1+r)}\beta[u'(c_1) + \beta u'(c_2)] = 0 \quad (2.1)$$

subject to:

$$U_{x_{11}} = (1 - \alpha)\{u'(c_1)P_1 + \beta u'(c_2)[(1 + r)(1 - P_1) - P_2(1 + F'(Q_1)]\} \quad (2.2)$$

$$U_{x_{12}} = (\alpha - 1)\alpha\beta P_2 u'(c_2)g'(x_{12}) \quad (2.3)$$

$$U_{x_{22}} = (1 - \alpha)\alpha\beta^2 P_2 u'(c_2)g'(x_{22}) \quad (2.4)$$

Consequently, we got the optimal condition for current sale/consuming decisions.

$$\mathrm{R}P_1 = (1 + r)\, P_1 = P_2(1 + F') \quad (2.5)$$

From the above equations for a constant price, we will get: $\mathrm{P} = P_1 = P_2$, if $\mathrm{r} = F'$. The optimal sale or consuming decision can be expressed as:

$$x_{11_{P_1}} = -\frac{R}{F''P_2} > 0;\ x_{11_{P_2}} = \frac{1+F'}{F''P_2} < 0;\ x_{11_r} = -\frac{P_1}{F''P_2} > 0;\ x_{11_{Q_0}} = 1 > 0;$$

$$x_{12_{P_1}} < 0;\ x_{12_{P_2}} > 0;\ x_{11_r} < 0;\ x_{12_{Q_0}} = 1 > 0;$$

$Q_{2_{P_1}} < 0; Q_{2_{P_1}} > 0; Q_{2_r} < 0; Q_{2_{Q_1}} > 0$

The equations above suggest that a high current price (P_1) needs to be supported by a higher interest rate (r) and a higher current sale/consumption rate. A higher future price (P_2) could reduce current sale/consumption. A greater initial stocking will lead to more sale/consumption.

For the stock in the second period, current sale/consumption changes in the opposite way of x_1 change:

$x_{21_{P_1}} = -(1 + F')x_{11_{P_1}} < 0; x_{21_{P_2}} = -(1 + F')x_{11_{P_2}} > 0; x_{21_r} = -(1 + F')x_{11_r} < 0;$

$x_{21_{Q_0}} = 0$

For decisions in the second stage, or “future”, the influences of current and future prices and interest rate have the opposite effect. However, the initial number does not influence that.

In sum, the conceptual function of current sale/consumption is:

$$x_{11} = \text{x}(P_1, P_2, r, m_1, m_2, Q_0) \qquad (3.1)$$

for expected effect = $(+, -, +, -, +, +)$, respectively for the factors.

$$x_{12} = \text{x}(P_1, P_2, r, m_1, m_2, Q_0) \qquad (3.2)$$

for expected effect = $(-, +, -, +, -, +)$, respectively for the factors.

Because of the imperfect market, herders’ decisions are determined not only by prices and initial livestock numbers but also by non-herding income (Fafchamps and Gavian, 1996).

The dynamic change can be expressed as following equation:

$$Q_t = \text{Q}(P_1, P_2, r, Q_{t-1}, Str, D, N)$$

for expected effect = $-, +, -, +, \pm, \pm, +$, respectively for the factors where D is the demographic variables (e.g., household education, labor, etc.); N is the natural endowment variables (e.g., annual precipitation, temperature, etc.); Str is the structure of livestock (i.e., the current ratios of young and female).

For Mongolian herders, two factors reflecting the market integration are vital for the livestock production model above. Market price ranks as the first. An increased demand would bring higher prices in return. Numerous previous studies have discussed the relationship between price and stock (e.g., Bailey et al., 1999; Coyle, 1992; Serra and Gil, 2012; Turner and Williams, 2002), with price in different periods jointly affecting the stock. Meuwissen et al. (2001) pointed out that the meat/milk price was the most important determinant for herders' management behavior. Ayalew et al. (2003) reported that a change in price would also affect the stock.

The second factor is interest rate, which was found to be a key one in time-sensitive industry. In financial markets, for example, a herder would only borrow money when expected rate of return exceed the interest rate from loans, especially for the small livestock business owner (Fernando 2006). Meuwissen et al. (2001) proposed that changes in interest rate should be considered an important form of risk for livestock production.

Income also directly influences a herder's decisions about the sale of livestock. It was found that lower incomes led to more sales (J. McPeak 2004). Yet there exists a balance between herding and non-herding income (Adams and Alderman 1992; Adams Jr 1994). Other demographic information like age and household size were also proposed for being included in the model (J. McPeak 2004).

Using the unbalanced OLS regression with pooled data procedure, we ran three separate regressions to estimate different dynamics for the three most important livestock species: sheep, goats, and cattle. Following our conceptual model, we used the following empirical regression models to predict the dynamics of different variables:

$$\begin{aligned}\ln(\text{Sale}) &= a_0 + a_1 ln(P_t) + a_2 ln(P_{t+1}) + a_3(\frac{Loan}{Income}) + a_4 ln(m_t) + a_5 ln(m_{t-1}) \\ &+ a_6 ln(Q_t) + a_7 P_f + a_8 Hhz_i + e_0\end{aligned}$$

$$\begin{aligned}\ln(\text{Sel}f_{Consumption}) &= b_0 + b_1 ln(P_t) + b_2 ln(P_{t+1}) + b_3(\frac{Loan}{Income}) + b_4 ln(m_t) + b_6 ln(Q_t) \\ &+ b_7 Region_i + b_8 Year + b_{10} P_f + b_{11} Hhz_i + f_0\end{aligned}$$

$$\begin{aligned}\ln(Q_t) = c_0 + c_1 ln(P_t) + c_2 ln(P_{t+1}) + c_3 \frac{Loan}{Income} + c_4 ln(Q_{t-1}) + c_5 ln(Labor) + c_6 ln(Edu) \\ + c_7 NPP + c_9 ln(m_t) + c_{10} ln(m_{t-1}) + c_{11} ln(Young) + c_{12} ln(Female) \\ + c_{13} Region_i + c_{13} Year + C_{14} Region_i \times Year + g_0\end{aligned}$$

where:

ln = natural logarithm term of variable values

Sale= quantity sold by household

$\text{Self}_{\text{Consumption}}$= quantity consumed by household itself

Q_t= livestock quantity by the end of current year

Q_{t-1}= livestock quantity by the end of previous year

Hhz_i= household size

$Region_i$= regional dummy

$Year_i$= yearly dummy

m_t= non-herding income in current year

m_{t-1}= non-herding income in previous year

Young= the amount of young livestock

Female= the amount of female livestock

NPP= Annual Net Primary Productivity (in *Aimag* level)

P_t= livestock price this year (per head)

P_{t+1}= livestock price in the coming year (per head)

P_f = price of flour

Loan/Income= ratio of amount of loan/amount of income (We used this instead interest rate to reveal the difficulty for borrowing: the higher ratio means easier to borrow, or the interest rate is lower)

3. Data

Conventional studies on livestock change at the regional/national level are mainly based on spatial and aggregated statistical data (e.g., Dietz et al., 2005; Lise et al., 2005; Rao et al., 2015). We used the Mongolian Statistical Yearbook from the Mongolian Statistical Information Service (MONSIS) to obtain the livestock price on the *aimag* (province or state) level. The yearbook covers a statistical dataset from 1990 through 2017, including major socio-economic statistics of Mongolia (e.g., livestock production, sale, and prices). We used the market price of livestock (the average sale prices per head including both male and female livestock), which was calculated based on the data from the yearbook statistics for each *aimag*.

To model herd dynamic change at household level, we used the Household Socio-Economics Survey (HSES) of 2008-2014, conducted by the National Statistical Office (NSO) of Mongolia. The survey aimed at investigating income and expenditure across Mongolia since 2003. The main objective of this survey was to update and expand the household statistical baseline to capture and analyze the livelihood across the country (in both rural and urban areas). The survey was conducted to collect a comprehensive set of data from households and estimate the socioeconomic well-being for different periods, primarily for household assets, consumption and income that covers the 21 *aimags*, 311 *soums*, and 9 districts the capital of Mongolia, Ulaanbaatar (UB). Data for demographic information (e.g., age, employment, marital status, education and household size) and livestock production, nationwide, were extracted from NSO. The NSO release HSES annually to review the change of households' socioeconomic well-being annually. In this study, we use the household survey data from 2008, 2010, 2012 and 2014 that include livestock herds and decisions about the herds.

Herding population and herder households in total have been growing along with the increased population (Table 3.1) in Mongolia but varied among regions. The total livestock size increased from 1991 to 2015, from which the sheep, goat, and cattle number change revealed a cyclical dynamic (Figure 3.1). Overall, these changes are closely related to several shocks from the environment and socioeconomic events. After the collapse of the collective farm system in 1990, the livestock population declined until 1993, when it began to recover steadily. In 2009-2010, there was a sharp drop in livestock, when nearly half of the adult sheep and goat died, likely due to the severe *dzud* (Figure 3.1.A).

With the help of new technology and government aid, livestock size recovered rapidly. The number of sheep and goats increased during 2008-2014, but the number of cattle stayed steady, with a decrease from 2012 to 2014. Meanwhile, the amount for sale exceeded self-consumption for sheep and cattle after 2010. The share of sheep for sale also increased. The consumption/sale/stock decisions of rural households differed by region and study period (Figure 3.1.B). In the West, households maintained higher stock rates, suggesting less self-consumption and fewer sales. The survey data revealed the livestock counts and self-consumption, sale and stock choices for different periods (Table 3.1). Years of education, number of laborers and household income (non-herding) also influenced behavior (Table 3.3), with increased education in herder households, non-herding income also increased, especially in UB.

4. Results

The results suggest that an anticipated increase in price led to a decrease in current sales. A higher loan-to-income ratio, reflcting the inverse effect of interest rate or more burdens of loan and debt, led to higher current sales for sheep and cattle (Table 3.4). Parameter estimates of $\mathrm{Loan/Income}$ were 0.151 and 0.996 for sheep and cattle, respectively. Assuming a high current livestock price, herders would choose to sell only goats (the parameter estimate of P_t was 0.170). A larger household population also promoted more sales. Parameter estimates of Hhz were 0.116, 0.153, and 0.268, respectively. In addition, herders reduced their self-consumption if the current price of sheep remained high (the parameter estimate of P_t in self-use was -0.364). We found a negative impact of flour price as the complement for meats: a higher flour price led to less self-consumption of livestock. Parameter estimates of P_f in the self-use model were -0.356, -0.339, and -0.336, respectively. A larger household size also increased the amount of self-consumption, as expected. Non-grazing income affected goat and cattle positively (parameter estimates of m_t were 0.265 and 0.577, respectively), but it was not statistically significant for sheep. None of the self-consumption was affected by non-grazing income. We also found more of both sale and self-consumption linked to greater herd size.

Current stock is very much dependent on the previous stage's livestock size. Anticipating a higher future price increases current stocking. Parameter estimates of P_{t+1} in the inventory model were 0.366, 0.506, and 0.337, respectively. Additionally, better environmental conditions (e.g., higher NPP) help build more stocking. Parameter estimates of NPP in the inventory model were 0.650, 0.665, and 0.255, respectively. It was demonstrated that a younger herd with more female livestock also contributes to building a larger herd.

We found time horizon and spatial differences across the years among different regions. Goat and sheep herd sizes were larger in the East region than in others, while in the Central region, cattle herd sizes were greater than in other regions. Inventory dropped significantly in 2010, and it did not recover until 2014 (2008 as base). When examining the impacts of the 2010 *dzud* for different regions, we found that the East and the Central areas suffered more than the other regions.

For goats, anticipated and current prices had contrasting impacts on sales. Parameter estimates of P_{t+1} and P_t in the sale model were -0.360 and 0.170, respectively. Current non-grazing income and household size positively influenced sales. Parameter estimates of m_t and Hhz in the sale model were 0.265 and 0.153, respectively. Higher current prices would decrease self-consumption. For inventory stock change, anticipated and current prices had opposite impacts. Parameter estimates of P_{t+1} and P_t in the inventory model were 0.506 and -0.266, respectively. With a higher NPP and no *dzud*, the inventory of goats would continue to increase. Parameter estimates of NPP and Year 2010, Year 2012, Year 2014 in the inventory model were 0.665, -0.168, -0.396, and 0.334, respectively. Predictions for cattle were similar to those for goats, with a sole difference being that current prices did not influence inventory.

5. Discussion and conclusion

Past studies of livestock dynamics have been conducted mainly from a business perspective within a market economy, like for the cattle and beef industries (e.g., Aadland, 2004; Jarvis, 1974; Rucker et al., 1984), or for purely pastoral societies (Sieff 1999). The grazing and pastoral sector in Mongolia represents a mix of business and subsistence economy, where the goals of self-consumption and profit making both exist for rural herding household. There livestock functions as capital, wealth, an approach to risk aversion, an income source, and a means to food security.

The results of this study suggest that self-consumption of livestock products is still important for herder households in Mongolia. A larger share of self-consumption revealed less commercialized activities of animal husbandry. Wang (2011) found a large proportion of meat and dairy products are self-consumed in herder households, rather than sold in the market. Still, herders do respond to market conditions: anticipating a higher price encourages herders to hold back more livestock for the future, and a higher current price leads herder to sell more at the present stage. More debt also promotes greater sales, since herders with higher levels of debt need to sell livestock for cash to pay off loans or interest. It also has been noted that the main purpose of borrowing among herder households is to purchase livestock (Attanasio et al. 2014). Household demographic factors (e.g., household size) also impacted sales and consumption, suggesting a mix of subsistence pastoral economy and the market economy.

As expected, nature and climate have profound impacts on livestock dynamics in Mongolia. More productive grassland, better fodder quality, fewer disasters, and a larger proportion of younger and female livestock lead to higher stocking. But being vulnerable to natural disasters also requires large ratios of stocking-to-sale and self-consumption and reduce the welfare of herders. Twenty million head of livestock perished in the mortality events of 2000-2002, and 2009-2010 (Rao et al. 2015). The 2010 *dzud* reduced herds across Mongolia by 20%-25% (Fernandez-Gimenez et al. 2015), confirming the vulnerability of the pastoral economy to natural environment. Inner Mongolia (IM) experienced similar natural disasters, but had a lower animal loss rate and less fluctuation in stock. Apart from the market mechanism, better public support in the IM, including climate-based livestock insurance, enhancement of infrastructure, animal shelter, weather information services and winter protection are critical to helping maintain the livestock size, particularly as we are facing the potential of more climate changes in the future. To mitigate the effects of such events on the lives of herders, international agencies such as the World Bank are taking an increasing interest in developing tailored market-based solutions like index-insurance (Rao et al. 2015).

As the Mongolian economy transforms from a subsistence-based pastoral economy to a market economy, socio-economic and institutional factors are playing more important roles than natural factors regarding managing herds, deciding how much to sell or self-consume. Comparing livestock statistics between IM and Mongolia, major policy changes in both regions appear to be responsible for the fluctuations in the livestock size. The substantial increase in livestock in the late 1980s in IM was largely the result of livestock and grassland tenure reform, while the drop in livestock around 2000 was caused by the grassland restoration policy enacted in 1998-1999. In Mongolia, the policy of reallocating rural herders into urban areas since the mid-1990s has resulted in more than half of the national population settling in the two largest cities. While sectors other than herding are growing, the population distribution, livelihoods and intuitions are less influenced by the herding sectors. The division between the pastoral economy and others or labor between herding and non-herding are affected not only by the forage available but also by opportunities to earn wages in other sectors, like mining, manufacturing and services with cities. Unlike the traditional pastoral society where herders, livestock and pastoral resources are dependent on each other, non-pastoral sectors play a more important role when the economy is in transition from agriculture to industry.

The strong dependence on livestock for self-consumption might be associated with limited market access or lower market prices of the livestock, leading to larger herds - a phenomenon observed in many pastoral societies (Johnson et al. 2006; J. G. McPeak and Barrett 2001). A higher market price encourages herders to sell more and exchange for other goods in the market. Access to markets is sometimes limited due to low population density in most parts of Mongolia where transportation infrastructure is usually poor and limited (Adrien Véron 2011; Kusano and Saizen 2013; Maytsetseg and Riichiro 2006). For example, it is not profitable to transport meat and milk to urban areas from rural Mongolian Altai, leading to supply-driven high prices in urban areas (Lkhagvadorj et al. 2013). Large holding numbers reduce the inter-annual climate variability and extend the duration of holding livestock, causing the problem of overgrazing. Goats, more than other species of livestock (sheep and cattle), damage the rangeland on the Mongolia Plateau (Werger and van Staalduinen 2006).

Efforts to enhance livestock markets and capital markets would be one of the most effective policies to promote sustainable development and foster transition from a subsistence economy to a market economy. Prompting the export of livestock products would help increase the price and promote integration into the global market. In IM, where the market is more integrated with the rest of China, the increasing market price and market integration significantly increased the welfare of the herders (Gao et al. 2015). We predict that a larger share of sale could be expected in an expanding market-oriented economy in Mongolia. Other potential reasons for changes in sale/self-consumption might be related to a change in food preference based on expanding awareness about food/health. Education on diversified food structure is encouraged by the educational system.

We hope this study will contribute to policy changes regarding the transition of Mongolia from a subsistence economy to a market economy, which is especially involved in more competitive regional and global agriculture market. As demonstrated in many studies regarding potential environmental and ecological risk factors associated with livestock and grazing, particularly the suburban areas and some fragile ecosystems, various policies like grassland use fees and even land tenure can be introduced to support sustainable development. Natural disasters in Mongolia can be devastating, and it takes several years to recover, during which problems like poverty and inequality are worsened. We recommend livestock insurance to address the fluctuation of livestock numbers in Mongolia, particularly the index-based livestock insurance system in Mongolia, that aims to help herders to recover faster when devastating disaster happened like the 2010 *dzud* (Rao et al. 2015; Skees and Enkh-Amgalan 2002; Taylor 2016). Such insurance policies might help herders optimize their livestock dynamics.

Table 3.2 Herders and herder households in Mongolia

		Total	West	Khangai	Central	East	UB
Number of herders	2012	289414	78918	119514	55098	32935	2949
	2013	285691	77137	117555	55287	32914	2798
	2014	293620	78351	121149	57348	33685	3087
	2015	297828	79220	123056	58759	34483	2310
Number of herder households	2012	207824	57560	77481	44117	23739	4927
	2013	209933	58455	77809	44854	23988	4827
	2014	213363	59513	78330	45959	24575	4986
	2015	216734	59886	79395	47011	25307	5135

Table 3.3 Data descriptive summary for all samples (standard deviation in parentheses)

		2008	2010	2012	2014
Sheep	Total #	81.8	84.8	93.7	97.7
		(35.5)	(27.7)	(44.3)	(37.5)
	of female	32.8	35.7	36.6	45.9
		(22.1)	(15.3)	(18.6)	(21.3)
	of young	28.1	19.6	30.2	37.4
		(11.5)	(9.9)	(12.3)	(9.6)
	of self-consumption	6.1	7.7	6.7	5.9
		(3.6)	(3.6)	(2.3)	(2.2)
	of sale	5.7	9.2	8.5	7.6
		(1.1)	(2.7)	(3.5)	(3.2)
	Sale amount (ppp $)	1711.4	2038.9	1149.7	1866.1
		(355.7)	(985.6)	(787.5)	(752.9)
Goats	Total #	77.4	77.4	83.7	100.2
		(35.2)	(21.7)	(22.7)	(35.7)
	of female	30.7	33.2	31.5	42.6
		(11.9)	(11.2)	(10.2)	(22.8)
	of young	24.8	14 (3.3)	25.3	33.0
		(9.6)		(15.3)	(12.3)
	of self-consumption	5.1	7.4	6.1	6.0
		(3.3)	(2.5)	(2.6)	(1.0)
	of sale	2.3	5.8	3.9	4.5
		(0.6)	(1.1)	(1.2)	(3.3)
	Sale amount (ppp $)	730.3	1105.4	407.2	1911.9
		(223.3)	(360.9)	(129.8)	(907.2)
Cattle	Total #	12.9	12.1	13.8	12.8
		(5.3)	(7.7)	(5.7)	(7.7)
	of female	4.8	4.5	5.2	6.2
		(1.1)	(2.3)	(1.5)	(2.6)

of young	3.9	2.9	4.0	4.9
	(0.6)	(0.9)	(2.3)	(3.6)
of self-consumption	0.9	0.9	0.8	0.7
	(0.1)	(0.2)	(0.3)	(0.1)
of sale	0.8	1.0	0.9	1.0
	(0.2)	(0.1)	(0.2)	(0.1)
Sale amount (ppp $)	1535.6	1779.9	831.4	2037.2
	(350.3)	(255.2)	(137.6)	(525.3)
Obs	4311	4204	4693	5992

Table 3.4 Demographic inofrmation (standard deviation in parentheses)

		2008	2010	2012	2014
Education	West	6.3	7.2	7.4	7.5
		(3.3)	(3.6)	(2.5)	(2.9)
	Khangai	6.5	7.2	7.4	7.7
		(2.7)	(1.5)	(2.2)	(2.3)
	Central	6.7	7.1	7.2	7.6
		(2.2)	(3.1)	(3.0)	(3.2)
	East	6.4	6.7	7.1	7.2
		(1.9)	(1.6)	(2.5)	(3.3)
	UB	7.2	7.9	8.0	8.0
		(1.3)	(2.3)	(2.6)	(2.9)
Labor	West	3.4	2.9	2.8	2.8
		(2.2)	(1.0)	(1.3)	(0.6)
	Khangai	4.0	3.7	3.8	3.8
		(1.3)	(0.9)	(1.2)	(1.1)
	Central	3.9	3.3	3.4	3.2
		(1.7)	(1.0)	(1.6)	(1.0)
	East	3.3	2.9	2.9	3.2
		(1.5)	(0.8)	(0.8)	(1.0)
	UB	3.2	3.3	3.4	3.2
		(1.0)	(1.1)	(1.1)	(1.3)

Non-herding	West	316.2	445.6	659.3	813.5
income		(155.2)	(223.3)	(259.4)	(223.6)
	Khangai	452.3	515.2	611.7	709.2
		(197.3)	(159.6)	(384.7)	(357.9)
	Central	293.5	417.6	559.6	550.6
		(65.3)	(252.9)	(155.9)	(256.3)
	East	368.4	405.3	402.6	411.7
		(235.3)	(133.6)	(153.2)	(99.6)
	UB	345.3	438.7	855.3	947.3
		(147.8)	(253.6)	(445.3)	(455.5)

Table 3.5 Factors influencing the dynamics and herds behaviors of livestock

	Sheep			Goat			Cattle		
	Sale	Self-Use	Inventory	Sale	Self-Use	Inventory	Sale	Self-Use	Inventory
P_{t+1}	-0.250***	0.155	0.366**	-0.360***	-0.153	0.506**	-0.780***	0.573	0.337**
	(0.001)	(0.160)	(0.150)	(0.002)	(0.089)	(0.203)	(0.100)	(0.522)	(0.123)
P_t	0.772	-0.364***	-0.355	0.170**	-0.565***	-0.266**	0.356	-0.708***	-0.179
	(0.632)	(0.019)	(0.262)	(0.082)	(0.026)	(0.115)	(0.282)	(0.036)	(0.155)
Loan/Income	0.151**	-0.355*	-0.107	0.155	-0.333	-0.562	0.996**	0.366	-0.585
	(0.026)	(0.150)	(0.122)	(0.123)	(0.250)	(0.423)	(0.383)	(0.273)	(0.377)
m_t	0.355	-0.666		0.265**	-0.456		0.577**	0.595	
	(0.266)	(-0.463)		(0.106)	(0.337)		(0.198)	(0.477)	
Q_t	0.332**	0.435**		0.365***	0.557**		0.343**	0.436**	
	(0.143)	(0.150)		(0.003)	(0.168)		(0.152)	(0.200)	
Q_{t-1}			0.985***			0.765***			0.470***
			(0.005)			(0.006)			(0.053)
P_f	0.155	-0.356***		0.266	-0.339**		0.177	-0.336***	
	(0.213)	(0.060)		(0.179)	(0.150)		(0.180)	(0.031)	
NPP			0.650***			0.665***			0.255***
			(0.055)			(0.070)			(0.020)
Hhz	0.116**	0.688***	0.355**	0.153**	0.696***	0.322	0.268**	0.433***	0.493
	(0.025)	(0.056)	(0.112)	(0.062)	(0.046)	(0.234)	(0.098)	(0.050)	(0.379)
Year 2010			-0.265**			-0.168**			-0.585***

			(0.077)			(0.055)			(0.005)
Year 2012			0.454			-0.396			0.377
			(0.339)			(0.279)			(0.281)
Year 2014			0.552**			0.334**			0.355**
			(0.201)			(0.107)			(0.102)
Female			0.155**			0.199***			0.939***
			(0.077)			(0.053)			(0.032)
Young			0.336***			0.667***			0.770***
			(0.002)			(0.050)			(0.090)
Region_West			0.355			0.253			-0.336
			(0.557)			(0.179)			(0.279)
Region_North			-0.366			-0.266			-0.326
			(0.265)			(0.190)			(0.290)
Region_Central			0.356			0.765			0.166**
			(0.299)			(0.599)			(0.072)
Region_East			0.266**			0.553*			0.110
			(0.103)			(0.250)			(0.107)
East*2010			-0.502***			-0.336***			-0.36***
			(0.006)			(0.005)			(0.004)
Cenral*2010			-0.355***			-0.490**			0.477**
			(0.050)			(0.202)			(0.020)
Constant	0.670	0.210	0.893	0.710	0.150***	0750	-0.468	0.685	0.486

	(0.535)	(0.161)	(0.755)	(0.689)	(0.050)	(0.668)	(0.336)	(0.440)	(0.353)
N	19200	19200	19200	19200	19200	19200	19200	19200	19200
R-square	0.335	0.276	0.153	0.196	0.110	0.327	0.152	0.276	0.422

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

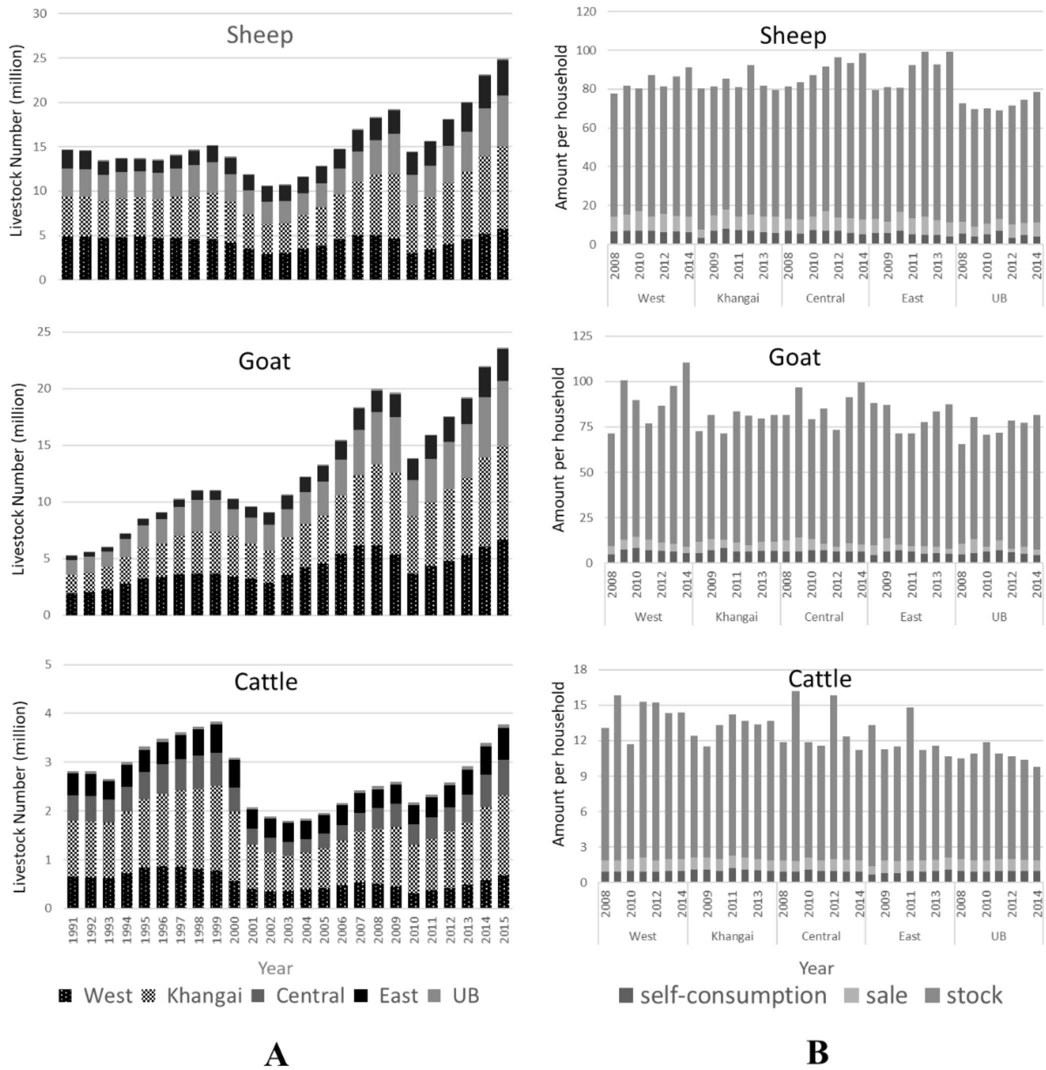

Figure 3.1 A) Historical change of livestock number from 1991 to 2015; **B)** Household consumption/sale/stock from 2008 to 2014 in Mongolia

Chapter 4. Cropland and Livestock Dynamics during Socio-Economic Transformation and Changing Climate in Mongolia

Abstract

Mongolia has witnessed unprecedented cropland changes and livestock in the recent decades. It was important to explore the dynamics and the factors. Along with an examination of historical trend, we used a random effect semi-log model to evaluate socioeconomic and climate factors in Mongolia. The results revealed that relative wage, commodity prices, and policy have significant roles on cropland and livestock. The societal transformation period after the collapse of the Former Soviet Union caused substantial fluctuation until 2008 when self-sufficient food policy was adopted in 2008, which seems responsible for the increase of cropland since then. Nonetheless, the patterns of change in cropland were not similar across the *aimags* because of their heterogeneous spatial and climatic conditions. Interestingly, cropland expansion did not adversely affect livestock production, which indicates Mongolia's traditional tenacity to pastoral practices.

1. Introduction

Land use change is affected by natural and anthropogenic factors, and in most cases, exacerbated by their interactions (Briassoulis 2000, Smith et al. 2016). Land degradation and natural disasters expedited by socioeconomic factors (Belay et al. 2017) often accelerate subsequent land use changes (Blonder et al. 2017), such as degradation of forest land (Song et al. 2018; Kubitza et al. 2018), abandonment of existing land use such as grazing (Kuemmerle et al. 2009; Liu et al. 2014; C. Lu and Fan 2013; J. Shao et al. 2015), and even relocation (Arnall 2018; Bellemare et al. 2017) or remodeling of home and dwelling places (Monge-Barrio and Gutiérrez 2018).

One of the most common forms of changes at subsistence-level in response to socio-economic transformation and natural disasters is in land use in general and cropping patterns in particular. Although cropland change is attributed to a number of factors, including, population growth., infrastructural development (Chamberlin et al. 2014), transportation costs (Headey 2016), and market access (Ulimwengu et al. 2009), the actual explanation of such expansion is country-specific. Rich and market economy like the US and Brazil have been expanding their cropland driven by food (Tilman et al. 2011) and biofuel production markets (Lark et al. 2015; Lapola et al. 2010). Poorer and more subsitantial and climate vulnerable countries like Mongolia are expanding their cropland to ensure food security for the nation (Morton et al. 2006; Butt et al. 2006).

Even though crop production has experienced historical ups and downs, it was never a dominant form of livelihoods in Mongolia (Maasri and Gelhaus 2011). During the early Qing Dynasty (1644-1912), the Manchu rulers wanted to preserve nomadic tradition. As a result, they did not allow conversion of grazing land to agricultural farming (Mearns 1993). However, begining in the late Qing Dynasty, the Manchu rulers changed their policy to one in favor of migration and land reclamation (M. Lu 1986; Ji 2010), whcih ultimately transformed Mongolia from a purely pastoral society to a mixed agro-pastoral society. In the early 1960s, the Mongolian government promoted massive crop cultivation to maintain food security (Neupert 1999). This increased agricultural land from less than 0.4% of all Mongolian land in the 1960's (McMillan 1969) to 1.2% during the Soviet Regime in 1991 (Neupert 1999). However, cropland in Mongolia experienced a large shock prompted by the collapse of the Soviet Union when large-scale croplands were abandoned in the country (Hirano and Batbileg 2013). Recently in 2008, the government intensified crop production (Priess et al. 2011) through providing massive subsidy in cultivation, inspiring farmers to adopt modern cultivation technologies and high-yield crop varieties (Schweitzerl and Priess 2009) and compensating failed cropping attempts. All these combined, Mongolia rapidly expanded crop cultivation. From 2004 to 2008, total cropland remained steady (Byambasuren and Heshmati 2010) and the country became self-sufficient in crop production in 2011 (Narangoa 2012).

A number of studies have addressed a series of issues concerning land use in Mongolia. Priess et al. (2011) addressed cropland expansion due to the “Third Campaign of Reclaiming Virgin Lands” policy adopted by Mongolian government in 2008. Another study conducted in the early 2000 claimed that population growth is likely to trigger croplands expansion and agricultural intensification (Ramankutty et al. 2002). Rasmussen and Annor-Frempong (2015) in a recent study claimed that market prices of agriculture product (including both crop and livestock) would affect crop production as well as cropland area (Rasmussen and Annor-Frempong 2015). Alexander et al. (2015) investigated the gradual changes in Mongolian food habit and concluded that changes in people's food habit would influence land demand. A comprehensive study conducted by Chen et al. (2015) concluded a number of consequences for the Mongolian Plateau due to climate change including decline of cropland productivity and subsequent land use in the rural Mongolia. Baas et al. (2012) explained that crop cultivation has a positive impact on pasture since it was likely to ensure emergency fodder supply when herd migration is necessary in winters.

However, Mongolia could have been central to more intensive scientific investigation for a number of reasons including the country's semi-arid climate, diverse land use policies under a series of unique political regimes, and cropland sprawl induced by increased food demand. These are likely to be associated with multi-faceted socioeconomic and political attributes including national policy, food security, crop price dynamics, and fodder supply. These issues have been either inadequately addressed or have never been addressed in the existing literature. The dearth of a comprehensive study combining these interconnecting issues has created the need for this study. We attempted to examine the cropland change and the livestock in Mongolia for the last 20 years and their socioeconomic and policy factors. We used acreage of land under wheat, fodder, all crops combined (which includes potato and vegetables in addition to wheat and fodder) to measure the cropland condition. We expect the results will have important policy implication for future food security in not only Mongolia but also other countries experiencing economic transformation and countries that are vulnerable to climate changes.

2. Empirical Models and Data

All households aim to maximize the net income through allocation of labor among different activities. We hypothesized that rural herders and farmers with higher expected income or other benefits in the non-rural area were more likely to migrate to urban areas for nonagricultural and pastoral jobs. Hence, the relative changes between crop cultivation and herding would also change the allocation between them. The incomes from herding and farming are expected to keep relative constant through the allocation between farming and herding. The pastureland is very much under open or semi-open access, we can assume no cost. Therefore, we can assume cropland acreage was determined jointly by agriculture product prices, wage ratio, *aimag* (Mongolian province), climate conditions, and land use policy. Following Huang and Khanna (2010), we framed the conceptual model of cropland acreage and livestock counts using equation (1):

$$M_t = f(P_t,\ W_t,\ N_t,\ S,\ I) \qquad (1)$$

where $M_t = \{A_t, L_t\}$, A_t is the cropland acreage, L_t is the *aimag* level livestock counts per year, P_t is commodity price, W_t is the average annual wage ratio between Ulaanbaatar (UB) to specific *aimag*, N_t is NPP , I is the *aimag*-level dummy, and S is the policy dummy.

We used the *aimag*-level data extracted from *Mongolia Statistical Yearbook* published by Mongolia Statistical Office (MSO). The Yearbook covers statistical data starting from 1990 on major socio-economic variables such as sales and prices of livestock and crop production. All these were measured on an annual basis. Due to the problem of data availability, we used the data that covered a period of 20 years from1997 through 2016 and included the variables livestock number (using livestock standard unit, LU), commodity price.

Definitions of variables, their units of measurements (when applicable), superscripts, and subscripts used in this study are summarized in Table 4.1. We used the sawn acreage for all crops, including wheat, potato, veggie and fodder for each *aimag* annually. Acreage for wheat (sawn area) was also included because wheat is the dominant crop for human food supply of all crops. Though for Mongolian herders, natural hay harvest is the main source of fodder supply, fodder plantation is also necessary for supplement, driven by the demand of intensive grazing and emergency fodder (Rasmussen and Annor-Frempong 2015). As a result, we also included the acreage of cultivated fodder plants (sawn area). Prices for gasoline, flour and mutton were converted to constant 2007 price in the Mongolian currency. Wage ratio was obtained from dividing monthly wage in UB by *aimag* level local monthly wage. Net Primary Productivity (NPP) was from calculated based on the measured data. We adopted the Year 2008 as the policy dummy (1997 to 2008 =0, 2009 to 2017 =1) to reveal the policy impact from the "Third Campaign of Reclaiming Virgin Lands" policy. *Aimag* dummy with regional indicator was also included.

The distribution of the 21 *aimags* across the regions has been shown in Table 4.1. UB, the capital city of Mongolia, is the dominant metro area with negligible agricultural contribution to national GDP. Thus, UB has been dropped off our analysis. Figure 4.1 shows the distribution of the *aimags* across the four regions. We also obtained the average annual percentage change in cropland acgreage for every five-year period by comparing the cropland acrage of a period to that of its preceding period starting from the year 1997 for each *aimag*.

3. Results and Discussion

3.1. Growth in the cropland acrage and livestock population

Regardless of the total size of acrage in a specific region, all four regions exhibited similiar patterns of total cropland acrage in Mongolia. Total cropland acrage in Mongolia showed a realtively continuous increasing trend since 1960 and reached its peak in 1989 with some smaller but sharp declines in 1964, 1967, 1970 and 1983 (Figure 4.2). Continued growth in corpland cover is basically attributed to the former USSR’s efforts to make it a food supplier for their command system. For the regional distribtuions, the Central region took the highest share of total acreage of corpland followed by Khangai, East, and West regions.

After 1990, with the collapse of the USSR command system, cropland area began a 16-year recession all the way down through 2006. Sharp declines were expeicned in all the regions. The change was so drastic that the East and the West regions were left with just a negligible acrage of cropland. Albeit, there was a short-term growth in the Central and Khangai regions during 2000-2002, however, it switched back to a declining trend again right after 2002. Later, the situation started to improve from 2006 and gathered further momentum in 2008 following the adoption of the “Third Crop Rehabilitation Campaign 2008”. The growth continued until 2017 in all three regions except the West (Figure 4.2).

Data from 1969 portrays that the livetsock population was relatively stable in all the regions until 1990. Later, it showed a continuously increasing trend until 1999 followed by a drastic and continuous fall until 2002. Even though the situation started to improve after that and continued to remain so until 2009, a sharp decline continued from 2009 thorugh 2010. While the ups and downs of cropland area were primarily attributed to political turmoil and policy changes, multiple and maasive declines of livetsocks were attributed to climate catastrophes. Rao et al. (2015) examined the mortality of livestock in all the *aimags* between 1955 and 2013 and reported that 20 million heads of livestock perished due to anomalous cold weather in the mortality events during 2000–2002 and 2009–2010. They also found that the mortality events had a strong linkage to preceding summer heat.

Mongolia observed significant increase of cropland cover in 2002 and 2009 with massive decline in livestock productivity in the same years. Again, both cropland and livestock sectors maintain a sharply increasing trend to the present following the enactment of milestone agriculture expansion policy in 2008. Thus, the relationship between cropland and livestock counts was inconclusive until the 2008 policy was in place. From the growth of both sectors in the last decade, it can be concluded that cropland sprawl was not in competition with livestock sector, rather both were growing concurrently. Both sectors found enough room to grow since the marginal cost of land in Mongolia is apparently zero.

3.2. Aimag-level shifts in cropland

Average rate of periodic change in cropland acreage was not homogeneous across the *aimags* in Mongolia. Figure 4.3 explains the intensity of cropland cover changes across all the *aimags* in Mongolia. It is interesting to note that the *aimags* surrounding the UB experienced the highest rate of change in cropland cover. *Aimags* in the northern part of the country had more ups and downs than those in the southern part. A temporal observation portrays that Southern *aimags* in the Khangai and West regions had significant increase in cropland cover. However, the East had tremendous decrease (< -10% per year) in cropland cover during 1997-2002. Cropland coverage showed an unprecedented contraction during 2002-2007 across all *aimags* across Mongolia except a slight increase (0-10% per year) in three southernmost *aimags* in Khangai and the western-most *aimag* in the West.

The cropland change in Mongolia showed exactly an opposite direction in the next five year period, 2007-2012. Annual average rate of cropland coverage skyrocketed in almost every *aimag* in all the regions of Mongolia in this period. The lowest rate of increase (0-10% per year) was observed in the West *aimags*. However, there was a declining trend in the southernmost *aimag* of the Khngai region. The cropland cover continued to increase but at a slower pace during 2012-2017 in most of the *aimags* except in a couple of southern *aimags*. Among the regions, the East and the Khangai showed the highest rate of cropland increase during this period.

3.3. Factors affecting agricultural land and livestock

The empirical specification for cropland acreage determination is based on equation 1. We would adopt the panel data analysis for all 21 *aimags* from 1997 to 2016. A random effect semi-log model is appropriate when non-time-variant variables (regional and policy dummy) are included. As a result, the empirical model can be specified as equation (2):

$$lnM_{it}^{j} = \beta_0 + \sum_k \beta_k lnP_{it}^{k} + \beta_4 W_{it} + \beta_5 NPP_{it} + \beta_6 S + \sum_i \beta_{6+(l,i)} I_i^l + \epsilon_{it} \qquad (2)$$

where subscripts i and t are *aimags* and current period, respectively; superscripts j denotes either different crops (wheat, fodder and all crops combined) or livestock, respectively; $k(= 1,2,3)$ denotes the commodities including gasoline, flour, and mutton, respectively; $l(= 1,2,3,4)$ denotes the regions - West, Khangai, Central, and East; and ϵ_{it} is the normally distributed error term with mean zero and constant variance.

As revealed from Table 4.2, most of the variables specified in the model were found statistically significant affecting the cropland area under one or more crops. The parameter estimates of $P_t^{gasoline}$ for A^{Fodder}, $A^{All\ crops}$, and L were -2.115, -1.253, and -0.428, respectively, which were significant at 95% confidence level. Since crop cultivation and livestock rearing are characterized with higher gasoline-related cost involvement, contraction of cropland or reduction of livestock with increase of gasoline price is intuitive. However, gasoline price did not significantly affect the extent of fodder land. Fodder cultivation in Mongolia is more of a natural management with little additional investment including fuel. Thus, fluctuation of gasoline price has hardly anything to do with the expansion of fodder land in Mongolia. Our finding is also aligned with what Mburu et al. (2014) and Huang and Khanna (2010) reported. They also claimed that fuel price is a limiting factor for the expansion of cropland acreages. In a poor and extreme climate-hit country like Mongolia, crop production is challenging and expensive, especially for the fuel-driven agriculture technology.

Although flour price, P_t^{flour}, did not have any significant impact on the acreage of any crop or fodder, it impacted livestock counts positively. The parameter estimates of this variable for the response variable L was 0.906, which was significant at 99% confidence level (Table 4.2). Apparently, flour price might not have a leverage on livestock counts, however, complementarity of the two in Mongolian food habit might get them strongly and almost equivalently linked, with the increasing demand for both wheat flour and meat product in recent decades (Bromage et al. 2018).

As expected, mutton price was found significantly and positively affecting the fodder land, and livestock counts. The parameter estimates of P_t^{mutton} were 2.099 and 0.132 for A^{Fodder} and L, respectively, which were strongly significant at 99% confidence level (Table 4.2). That is, 1% increase in mutton price was corresponding to an increase of more than 2% in fodder land and 0.132% in livestock counts. That means that higher price of mutton allured the farmers to increase the number of livestock, which in turn, required them to grow more fodder. Thus, a direct relationship of mutton price with fodder land and livestock counts is easily discernible. Similar results were also reported in other studies (Usukh et al. 2010; Mathias et al. 2010). It is interesting to note that mutton price was also positively affecting land under all the crops combined ($\beta^{P_t^{mutton}} = 0.139, P < 0.1$). While cropland expansion might be driven by land use policy, such sprawl was competitive with the fodder land or livestock rearing. Both the practices were growing side-by-side in Mongolia. Integration of crop cultivation and livestock grazing had been applied mainly in the Central region as a new form of agricultural strategy, with both the sectors intensified (Rasmussen and Annor-Frempong 2015). Such a mixed crop-livestock strategy has been proven to contribute to sustainable livelihoods in rural Mongolia (Usukh et al. 2010).

Wage ratio is one of the most important variables believed to have strong leverages on rural-urban migration (Saks and Wozniak 2011; Xiaobing Wang et al. 2011; Kemeny and Storper 2012). This is also evident in this study. Parameter estimates of W_{it}

for A^{Wheat} and A^{Fodder} were -1.669 and -2.903, respectively. A relatively higher urban (UB) wage rate compared to that in the countryside was likely to inspire rural people to migrate to UB, which was also observed by (Shi 2011). That means UB's wage rate has a negative impact on cropland acreage. Given the existing trend of increase in cropland, it can be inferred that the urban and rural wage are converging over time. Harris and Todaro (1970) also claimed that migration from rural to urban area or vice-versa is a function of wage ratio or relative wages of these places. While both forms of migration are historically evident, rural-to-urban migration is more common in the developing countries, which is mainly driven by wage ratio (Zhao,1999). However, the relationship between wage ratio and cropland acreage change is more complex in Mongolia as portrayed in Figure 4.4.

Following the fall of USSR and associated chaos, both wage ratio and cropland acreage shrunk until 2008, which is quite counter-intuitive in a normal political environment. It appears that the two sectors could come out of the political wave and started behaving intuitively after this year. Cropland area and wage ratio did not tend to progress towards the opposite directions until after 2008. The two crossed each other in 2014 and continued to maintain exact opposite patterns in subsequent years. The implication is that the wage ratio kept decreasing while the total cropland area continued to increase dramatically, with an annual average increase rate of 11.5%. Such a decreasing wage ratio across the country forced the country's work force to adopt large-scale crop production. As a result, cropland cover increased from just 192 thousand ha in 2008 to 282 thousand ha in 2009, 441 thousand ha in 2014, and more than 525 thousand ha in 2015.

As expected, climate factor measured by NPP has a significant positive impact on agricultural land expansion. The parameter estimates of NPP_{it} for A^{Wheat}, A^{Fodder} and $A^{All\ crops}$ were 1.791, 2.692, and 0.506, respectively, which were all significant at 95% confidence level (Table 4.2). However, NPP has a negative impact on livestock counts. The parameter estimates of NPP_{it} for L was -0.187, which was also significant at 95% confidence level (Table 4.2). It is quite intuitive that fertile lands are more suitable, and probably more profitable too, for crop cultivation than for livestock grazing. It can also be inferred that an increase in land productivity might make crop production more competitive to livestock rearing. However, land productivity is strongly affected by climate conditions such as rainfall and temperature. Given the existing climatic patterns in Mongolia, this shift might not be so rapid. Thus, even though cropland sprawl in Mongolia is strongly evident, crop production would take too long to override cattle grazing.

Agricultural policy has a strong momentum to change a country's land use system. This is also true for Mongolia. As our model depicts, the parameter estimates for the policy variable S were 1.001, 2.153, 0.633, and 0.260, respectively, for A^{Wheat}, A^{Fodder}, $A^{All\ crops}$, and L, which were all strongly significant at 99% confidence level (Table 4.2). That means the "Third Crop Rehabilitation Campaign 2008" policy, which aims at ensuring food security and achieving crop sufficiency in crop production (Bulag 2009), has not only boosted the country's cropland sector, it also helped grow its livestock sector. The policy came into effect in 2008 when the total cropland coverage ratio from sawn area to total area was 0.12% against 0.33% in 2017 in the country. Since the policy inspired crop production with subsidy, better technology, and even compensation for crop failing, this sector has boomed since then. This has made the country self-sufficient in 2011(Narangoa 2012; Rasmussen and Annor-Frempong 2015). It is interesting that substantial growth in agricultural land base has not adversely affected the growth of livestock sector. It is also growing with agriculture and fodder production but at a slower pace (β^S for A^{Wheat} and L were 1.002 and 0.26, respectively). Such results correspond to the argument that crop production is expected to double the present production by 2050 to face the challenge of food security with a concurrent slow growth rate of meat production (Markowitz, 2013).

Changes in the cropland, fodderland, and livestock were not homogeneous across the *aimags* in Mongolia. A number of patterns is visible in the *aimag* level land cover under wheat, fodder, and the livestock counts. While one or more of these land areas were positive in a specific aimag, the other land area or livestock counts were nagative in the same aimag. It is worth pointing out that land areas or livetsock counts under all land use types were not of the same sign in the same *aimag* excpet in *aimag* 1 of Khangai region. That is, while one or more of cropland area, or fodder land area, or all cropland area, or livestock counts were significantly increasing in a specific *aimag*, the others were decreasing in the same *aimag*. However, in the same region, most aimags had similar land use patterns.

Land area under wheat and fodder production in all five *aimags* of the West region increased; in contrast, livestock counts in all these *aimags* declined. Probably vegetable land cover also showed a negative trend making the betas for all the West *aimag* negative for land under all crops combined. Overall, wheat land and fooder land were increasing in the West as opposed to a decrease in the livestock counts. However, growth in the fodderland area with decrease of livestock counts seems counterintutive with exception that fodderand are least managed and naturally growing terrains. As stated above, the parameter estimates of $I_1^{Khangai}$ for all the three land uses except livestock rearing were significantly positive (12.59, 2.623, 0.187, respectively for A^{Wheat}, A^{Fodder}, and $A^{All\ crops}$) (Table 4.2). While wheat land cover grew significantly in all six *aimags* in the Khanagai region, fodder land increased in imags 1, 2, and 5. While land under all crops grew in *aimags* 1 and 5, there was significant reduction of land under all crops combined in *aimags* 2,3, and 6.

Livestock change showed a mixed trend in the *aimags* of the Khangai region. While livestock significantly increased in *aimags* 2 and 3, it declined in *aimags* 4,5, and 6 of the Khangai region. Central region also had mixed patterns in land use change. Wheat land sprawl was significant in *aimags* 2,5, and 6 of the Central region. While fodder land increased in *aimags* 5 and 6 with no significant decrease in any of the other *aimags* of the Central region. While combined cropland declined in all the *aimags* of the Central region, livestock counts increased in *aimags* 1, 3 and 5, and decreased in the other three *aimags* of this region. Wheat land sprawl was significnatly psoitive in all the *aimags* of the East region. However, fodder land decreased in *aimag* 1 with no significant increase in any other *aimags* of this region. Total crop land and livestock counts showed significant reduction in all the *aimags* of the East region.

Although our study doesn't strongly claim that cropland is outshining the traditional pastoral livelihoods in Mongolia, Sidahmed et al. (2008) mentioned about the grassland-cropland competition in Mongolia. An older but important study conducted immediately after the fall of USSR regime reported that not only cropland and grassland were in competition, fodder cultivation was also in competition with non-fodder cultivation, especially during the hard time right after the collapse of the communist government (Edström 1993).

Even though crop farming is not yet challenging the traditional herding, it is in rapid sprawl and increasingly becoming a dominant form of livelihood in most of the *aimags*. Given the findings in current literature, it can be touted that it will not only impact Mongolia's economy, but also its way of life, environment, and ecosystem. Especially in semi-arid areas like the Mongolia Plateau, due to its fragile ecosystem, balancing land for grazing and cultivation has been the main focus in the studies of cropland expansion in Mongolia (Kremen et al. 2007; Lambin and Meyfroidt 2011) and (Lambin and Meyfroidt 2011; Kremen et al. 2007). These studies claimed that land use change is becoming significantly vital for regional ecosystem and food security issues worldwide. Given the state of climate change, (Natsagdorj et al. 2003) have also expressed similar concerns that such alternation in land use and associated human activities would cause greater social and environmental impacts in Mongolia.

Many studies (Chuluunbat 2012; Visser and Schoenmaker 2011; Batsukh 2011) have addressed the development and current land use issues in Mongolia and predicted similar impacts of these events on its market system. Even though Spoor (1996) noticed the crisis in crop cultivation due to chaos and uncertainty in Mongolia's market mechanisms, Dixon et al. (2001) predicted that the emergence of a stable market system ultimately reduce poverty in rural Mongolia. Our study also argue that the country is moving towards a more market-based economic system with food security backed by expanding cropland. In our study, we observed that expansion of cropland is likely to augment the grazing sector since the marginal cost of land for expanding cropland is zero and the people are traditionally tenacious to herding in Mongolia. Meurs et al. (2017) also signaled similar outcomes in an effort to study the benefits of agriculture-based market scheme on grazing sector including weather insurance and sale support for herders. To sum up, our study emphasizes that the policy-backed cropland sprawl in Mongolia would reshape Mongolia's market system favorable to both agricultural farming and pastoral practices.

4. Conclusion and policy recommendation

This study, a pioneer of its kind in the context of Mongolia, provides important insights on the cropland and livestock dynamics in Mongolia where the economy is in transition from a subsistence economy to a market economy, and from a pastoral society to a mix of pastoral and agrarian society. The social economic transformation and agricultural and food policy seem most important based on results. The cropland sector shrank drastically immediately after the fall of the Soviet regime and took many years to recover. The country launched a Third Crop Rehabilitation Campaign 2008 to stimulate crop production and ensure food security for the nation. Cropland acreage is expanding following the policy and the momentum of cropland sprawl is still strong to date.

The study also concludes that cropland expansion has not been suppressive over traditional pastoral practices in Mongolia. Rather, both sectors have grown over time. However, the cropland sector was expanding at a faster rate compared to the growth rate of livestock sector. The results suggest that a relative increase in urban wage rate has a negative impact on cropland sprawl but not on livestock. Since the country is progressing towards a market-based economy, wider urban-rural wage gap might weaken the growing crop production sector in future.

The change rate of cropland cover was not homogeneous across the *aimags*. While in some *aimags* the cropland cover increased with a decrease elsewhere. This may be due to differences in local culture, climate, and soil quality. We found NPP of the soil was positively linked to the expansion of cropland in Mongolia. Thus, the differences of cropland expansion rates across the *aimags* were attributed to climate-driven varying rates of NPP in different *aimags*. Alarmingly, we found NPP had a significant negative impact on livestock counts. That means, *aimags* with relatively alluvial soil were more inclined to crop production than herding. Soil nutritional variation is an important factor on deciding the type of livelihoods especially in a subsistence society like Mongolia. Thus, it is important to produce and upgrade an agro-ecological or land use map of the country. This would help predict and monitor people's inter-regional or inter-*aimags* migration, which is quite pertinent to the nomadic nature of Mongolian society.

Even though cropland sprawl in Mongolia is gathering increasing momentum from the drive of food security and policy pushes, climatic condition of the country is quite disfavoring to it. Thus, the cropland expansion needs public support including favorable technology and supply of fuel at a reasonable cost. Our study concludes that fuel price was appreciating to the growth of neither of the cropland and livestock stock. However, mutton price was observed positively affecting the livestock counts in Mongolia. Although public support programs, like subsidy and price support, had been proven to be effective in promoting agriculture sector output, there is limited investment aiming at technological progress and R&D fund (Chuluunbaatar et al. 2017). Such challenges would potentially lower the expected agriculture expansion rate. Thus, we recommend that sufficient fuel be made available to agriculture at a reduced and subsidized price with a view to sustain the existing growth in crop production. In addition, investment on research and extension is required to explore more cost-effective crop production practices, which is also resilient to unfavorable climatic conditions.

Overall, this study will improve our understanding on how history and policy have shaped Mongolia’s agriculture and livelihoods. Detailed interpretation of the dynamics of socioeconomic factors affecting the country’s agriculture in particular and economy as whole will assist the policy makers to upgrade or amend the current crop-subsidy policy. It is also likely to contribute to policy change regarding the transition of Mongolia from a subsistence economy to a market economy, especially in the regional and global agriculture market. As has been historically recommended in many studies that switching to market-based economy from a subsistence one is often annexed to multitude of environmental and ecological risk factors, it is recommended that the government should be aware of Mongolia’s fragile ecosystem while implementing agricultural or other development activities that are repeatedly degrading to the environment. Such a balance between development and environmental stability will help make current progress sustainable.

Table 4.1 Definitions of variables and the units of measurement used in the econometric model

Variables	Definitions and units of measurement	Mean*	SD*
$A^{All\ crops}$	Cropland acreage for all crops combined (1000 ha)	4336.3	1395.9
A^{Wheat}	Acreage under wheat cultivation (1000 ha)	1452.9	6386.5
A^{Fodder}	Acreage under fodder cultivation (1000 ha)	391.9	974.5
L	Number of livestock (1000 LSU)	2732.2	1632.1
$P^{gasoline}$	Price of gasoline (tug**/liter)	763.2	150.3
P^{flour}	Price of flour (tug/kg)***	543.3	101.6
P^{mutton}	Price of mutton (tug/kg)***	2135.2	623.6
W_{it}	Wage ratio (Wage in UB/*Aimag* level local wage)	1.3	0.2
NPP	Net Primary Productivity (g/m^2/yr)	260.9	166.0
S	Policy dummy (1997 to 2008 =0, 2009 to 2017 =1)		
I_i^l	*Aimag* dummy with region l and *aimag* i		
	For $l = West$, $i = 1,2,3,4,5$ indicate the *aimags* Bayan-Ulgii, Govi-Altai, Zavkhan, Uvs, Khovd;		
	For $l = Khangai$, $i = 1,2,3,4,5,6$ indicate Arkhangai, Bayankhongor, Bulgan, Orkhon, Uvurkhangai, and Khuvsgul;		
	For $l = Central$, $i = 1,2,3,4,5,6,7$ indicate Govisumber, Darkhan-Uul, Dornogovi, Dundgovi, Umnugovi, Selenge, and Tuv****; and		
	For $l = East$, $i = 1,2,3$ indicate Dornod, Sukhbaatar, and Khentii.		

Note: *Calculated from the data available from the Mongolia Yearbook; ** Mongolian currency unit (According to the 2017 exchange rate, 1 USD= 2422 *tug*); ***Adjusted with base year 2007; **** the base *aimag* for subsequent statistical analyses.

Table 4.2 Factors affecting the cropland acreage of wheat, fodder and all crops in Mongolia during 1997-2016

	A^{Wheat}	A^{Fodder}	$A^{All\ crops}$	L
$Constant$	14.22***	5.418*	4.811***	7.859***
	(1.968)	(3.101)	(0.249)	(0.256)
$P_t^{gasoline}$	-2.115**	0.847	-1.253***	-0.428***
	(0.953)	(1.502)	(0.301)	(0.120)
P_t^{flour}	0.110	-1.731	-0.0141	0.906***
	(1.154)	(1.819)	(0.365)	(0.146)
P_t^{mutton}	-0.337	2.099***	0.139*	0.132***
	(0.233)	(0.367)	(0.0735)	(0.0294)
W_{it}	-1.669*	-2.903*	-0.217	0.118
	(0.953)	(1.501)	(0.301)	(0.120)
NPP_{it}	1.791**	2.692**	0.506**	-0.187**
	(0.750)	(1.182)	(0.237)	(0.0948)
S	1.001***	2.153***	0.633***	0.260***
	(0.278)	(0.438)	(0.0879)	(0.0352)
I_1^{West}	5.895***	6.063***	-0.652***	-0.797***
	(0.662)	(1.043)	(0.0837)	(0.0751)
I_2^{West}	11.24***	6.728***	-0.638***	-0.782***
	(0.646)	(1.018)	(0.0816)	(0.0750)
I_3^{West}	9.280***	4.823***	-0.271***	-0.416***
	(0.618)	(0.973)	(0.0781)	(0.0723)
I_4^{West}	13.55***	5.680***	-0.379***	-0.523***
	(0.613)	(0.965)	(0.0774)	(0.0733)
I_5^{West}	10.17***	5.466***	-0.458***	-0.602***
	(0.608)	(0.958)	(0.0768)	(0.0732)
$I_1^{Khangai}$	12.59***	2.623***	0.187**	0.0423
	(0.626)	(0.986)	(0.0791)	(0.0721)
$I_2^{Khangai}$	2.729***	2.431**	-0.369***	0.513***

	(0.613)	(0.966)	(0.0774)	(0.0746)
$I_3^{Khangai}$	14.91***	0.349	-0.205***	0.349***
	(0.589)	(0.928)	(0.0744)	(0.0737)
$I_4^{Khangai}$	12.01***	1.250	-0.00677	-0.151*
	(0.591)	(0.932)	(0.0747)	(0.0862)
$I_5^{Khangai}$	12.78***	3.861***	0.144*	-2.864***
	(0.625)	(0.984)	(0.0790)	(0.0738)
$I_6^{Khangai}$	14.20***	0.915	-2.719***	-1.095***
	(0.660)	(1.040)	(0.0834)	(0.0924)
$I_1^{Central}$	0.345	-1.171	-0.951***	0.701***
	(0.613)	(0.967)	(0.0775)	(0.0873)
$I_2^{Central}$	13.74***	0.709	-0.557***	-1.222***
	(0.602)	(0.949)	(0.0761)	(0.0745)
$I_3^{Central}$	0.603	-1.016	-1.078***	1.140***
	(0.614)	(0.967)	(0.0776)	(0.0732)
$I_4^{Central}$	0.210	-0.610	-0.995***	-0.144*
	(0.617)	(0.972)	(0.0779)	(0.0790)
$I_5^{Central}$	16.09***	4.439***	-2.408***	2.553***
	(0.587)	(0.925)	(0.0742)	(0.0761)
$I_6^{Central}$	15.67***	7.212***	-2.903***	-3.048***
	(0.620)	(0.977)	(0.0783)	(0.0733)
$I_7^{Central^{\theta}}$	--	--	--	--
I_1^{East}	13.54***	-1.911**	-0.640***	-0.784***
	(0.604)	(0.952)	(0.0763)	(0.0735)
I_2^{East}	8.084***	0.587	-0.293***	-0.437***
	(0.615)	(0.969)	(0.0777)	(0.0724)
I_3^{East}	14.35***	-1.406	-0.241***	-0.385***
	(0.662)	(1.042)	(0.0836)	(0.0728)

Note: ***P<0.01, **P<0.05, *P<0.1; Values in the parentheses are standard errors of means. θ: We used the *aimag Tuv* in the Central region as the base for all *aimag* dummies.

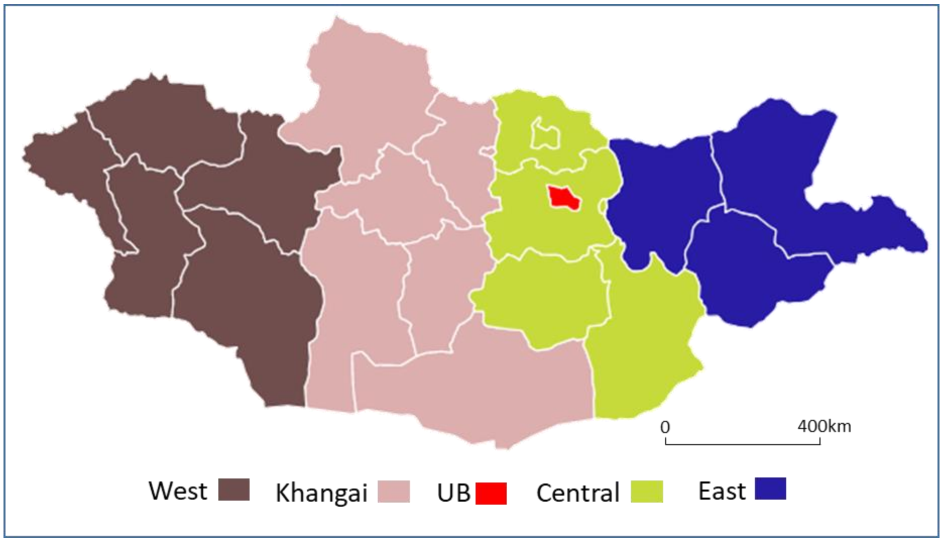

Figure 4.1 Regional distribution of *aimags* with the location of Ulaanbaatar in the Mongolian map

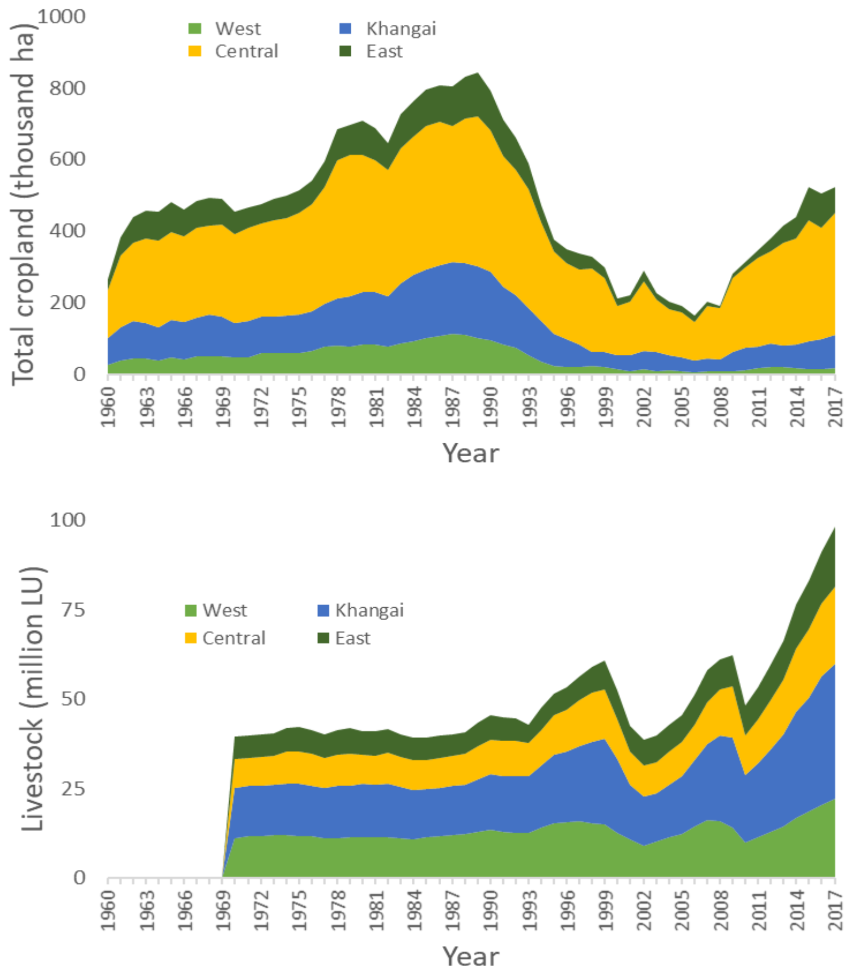

Figure 4.2 Total cropland acreage and livestock counts by regions in Mongolia from 1960 to 2017

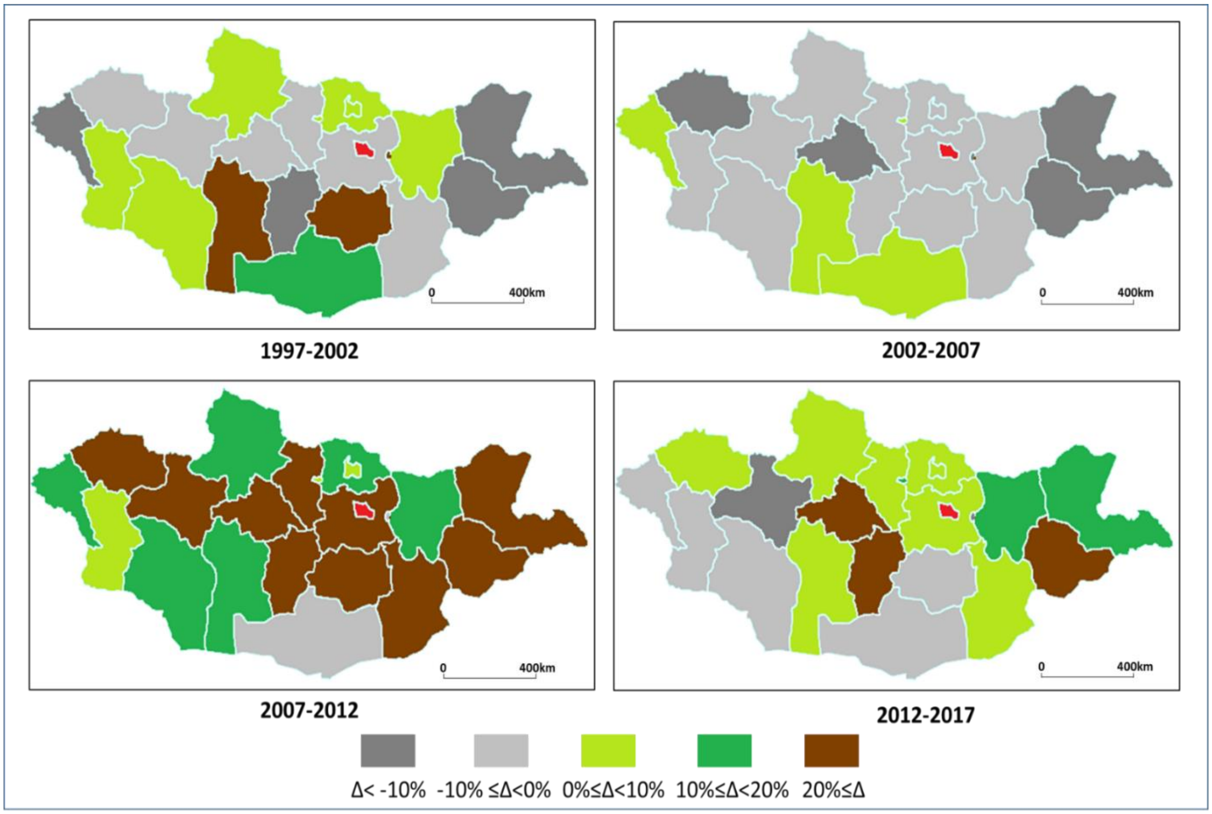

Figure 4.3 Average annual rate of cropland acgreage change (Δ) in five-year periods compared to the preceding periods from 1997 to 2017 by *aimags*

Note: Base year was 1997; the small red colored area is Ulaanbaatar, which was dropped off because it is the dominant metro area with negligible agricultural sector.

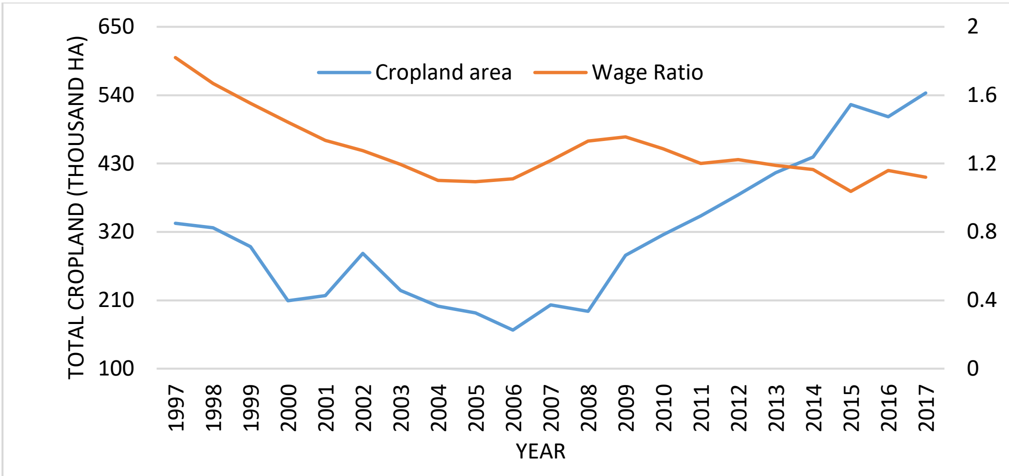

Figure 4.4 Wage ratio (monthly wage in UB/Average monthly wage of all 21 *aimags*) and total cropland change from 1997 to 2017

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