Farmer Participation, Processing, and the Rise of Dairy Production in Greater Beijing, P. R. China

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With rapid income growth, dairy production and consumption in China have increased significantly. The emergence of the dairy sector provides opportunities for farmers to participate in a high-value, potentially more lucrative enterprise. The overall goal of this paper is to analyze the major determinants of farmer participation in dairy production. Our main questions include whether or not the pace of the emergence of the dairy processing industry has affected the ability of farmers (especially small and relatively poor ones) to participate in dairy production; and whether or not it has limited the expansion of their herd size. Based on household, village, and processor surveys conducted in the Greater Beijing region, our analysis indicates that the location of dairy processing firms is one key factor that determines the participation of farmers in dairy production. Although other factors affect participation and herd size, including road access and the ability to find employment off the farm (which affects the opportunity cost of household members), the proximity to a dairy processor is shown to be one of the major factors that has encouraged the growth of dairy production for a given farmer in a specific region during the past decade. The results also show that poor, less educated farmers with relatively less access to land are not excluded from the expansion of the Greater Beijing dairy market.

La production laitière et la consommation ont augmenté considérablement en Chine, en raison de la croissance rapide du revenu. Pour les producteurs, la croissance du secteur laitier offre des occasions de se lancer dans des activités à forte valeur, potentiellement plus lucratives. L'objectif global du présent article consiste à analyser les principaux déterminants de la participation des producteurs à la production laitière. Nous nous sommes alors posé deux questions. Le rythme d'émergence de l'industrie

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de la transformation de produits laitiers influence-t-il ou non la capacité des producteurs (en particulier les petits producteurs de condition modeste) à se lancer dans la production laitière? Le rythme d'émergence de cette industrie limite-t-il ou non l'expansion de la taille de leurs troupeaux? Une analyse des enquêtes menées auprès des ménages, des villages et des transformateurs dans l'agglomération pékinoise a révélé que le lieu où se trouvent les entreprises de transformation de produits laitiers est l'un des principaux facteurs qui déterminent la participation des producteurs à la production laitière. Bien que d'autres facteurs influencent la participation des producteurs et la taille des troupeaux, notamment l'accès routier et la capacité à trouver un emploi à l'extérieur de la ferme (qui influence le coût d'opportunité/d'option des membres du ménage), la proximité d'une usine de transformation serait l'un des principaux facteurs qui ont encouragé la croissance de la production laitière, pour un producteur donné dans une région en particulier, au cours des dix dernières années. Les résultats ont également indiqué que les producteurs de condition modeste, moins instruits et ayant un accès restreint à des terres ne sont pas exclus de l'expansion du marché laitier dans l'agglomération pékinoise.

INTRODUCTION

With the nation's rapid economic growth since the early 1980s, significant changes have taken place in the composition of the diet of consumers in China. There has been a large fall in the expenditure share of staples in the typical consumer's basket and a significant increase of expenditures on nonstaples, including meat, vegetables, and fruit (Huang and Bouis 1996; Li and Wang 2000). For example, average per capita grain consumption in urban areas declined from 135 kg in 1985 to 77 kg in 2005; per capita meat consumption increased from 19 to 29 kg (NBSC 2006). Although changes in consumption patterns in rural areas were less dramatic, there were still changes in the composition of rural diets (NBSC 2006).

In examining the changes in consumption patterns of all commodities, there is no other set of commodities that has experienced as dramatic of a change as dairy products, especially recently. Prior to the mid 1990s, although incomes rose rapidly, there was only a small rise in the demand for milk and other milk products. According to China's rural and urban Household Income and Expenditure Surveys (HIES) conducted by the National Bureau of Statistics of China (NBSC), per capita milk consumption in China's cities was only 6 kg in 1982. During the decade-plus between 1982 and 1995, consumption rose slowly to only 8 kg (NBSC 2000). Annual per capita milk consumption of rural residents was nearly stagnant at about 1 kg during the 1985–95 period. Nationwide, to meet at least most of this demand, fresh milk production inside China rose gradually from 2 million tons in 1982 to 5.8 million tons in 1995 (NBSC 2000). One explanation of the slow development of the dairy industry is simply due to the fact that the growth of urban and rural consumption of milk was so slow.[1]

However, after the mid 1990s, the situation changed dramatically. During the late 1990s average urban per capita consumption of milk and milk products (in fresh milk equivalents—the unit used throughout the rest of this paper) increased quickly from 8 kg in 1995 to 13 kg in 2000. Between 2000 and 2005, per capita demand jumped to 25 kg. Over the same period (1995–2005), average rural per capita consumption of milk tripled as well, increasing from 1 to 3 kg.[2]

With the rapid rise of milk consumption, the development of the dairy industry in China accelerated.[3] The production of fresh milk increased by nearly five times from 5.8 million tons in 1995 to 28.7 million tons in 2005 (NBSC 2006). During this period of

expansion, millions of farmers began to purchase cows and produce milk. The pattern of growth of China's milk supply and demand over the past two decades—first slow and then fast—has raised interest regarding the question about what factors were underlying the changes. Understanding the determinants of production is of great interest to academics, policy makers, and the private sector. And in this vein, several specific questions have been raised. In terms of consumption, why is it that prior to the late 1990s rapid income rises and urbanization did not result in high rates of growth of milk consumption? Why did the same levels of income increases—after the mid to late 1990s—lead to a rate of increase in milk consumption in which there was a doubling of demand within a five or so year period—in both rural and urban areas? When looking at dairy production, other questions arise. What factors constrained growth in the 1980s and early 1990s? Similarly, what other factors contributed to the rapid expansion of milk production after the mid 1990s? Who has been able to participate in this emerging industry? Have poor and small farmers been excluded from the dairy industry's expansion? What are the major determinants of the participation of farmers in the milk supply business?

While these questions are not unique, previous studies in China have mainly focused on the consumption side of the dairy equation. Work by researchers in the past has shown that the demand for livestock products (including milk and milk products) are not only influenced by income and urbanization (Huang and Bouis 1996), but also by development of urban and rural food markets (Huang and Rozelle 1998; Fuller et al 2006). In other words, the absence of food markets may have constrained the growth of demand for products (all other things being equal). These studies—while not specifically on dairy demand—provide us with a clue about why dairy demand may have risen slowly at first (because markets were not well developed) and then more rapidly later (because markets had emerged). In other words, it is possible that along with income increases, improvements in marketing infrastructure and the emergence of new institutional forms (such as supermarkets and convenience stores with refrigeration facilities) as well as the steady expansion of food markets (which may have reduced restrictions on the marketing of fresh milk) have strongly influenced the consumption of fresh milk and other milk products since the late 1990s.

Moreover, supply responses may have played a critical role in the continued growth of this industry. In addition, very few prior studies have examined the expansion of dairy production in China or within the study region. Although there are a few studies that discuss some of the existing problems and policy options in dairy production, most are conceptual in nature and the findings/conclusions are largely based on anecdotes, casual observation and qualitative assessments (e.g., Ha 2004; Li and Cao 2005; Ma et al 2005).

In the same way that there have been only a few studies focusing on dairy production, even fewer have addressed the dairy processing sector. One study showed that the number of dairy processing firms in China increased sharply in recent years from 377 in 2000 to 690 in 2005 (Liu 2006). It is possible that the processing sector was one constraint in the past. The take-off of dairy demand and production at the farm level may have been facilitated by the development of dairy processing and the development of the processing market. While consistent with the facts (as presented here), previous research has never made this link. To the knowledge of the authors, no study has attempted to analyze empirically to what extent the emergence of the dairy processing sector has affected the participation of farm households in milk production.

In order to maintain a carefully collected, focused data set for an empirical study, we necessarily limited our study scope to a single region of China, Greater Beijing. Although it was requisite to ensure the quality of the data, we recognize the limitations of our work being focused on only one geographic region. The area, however, is not small. Greater Beijing includes the entire Municipality of Beijing (a province-level jurisdiction) and parts of Tianjin and Hebei. This region has experienced faster growth in terms of both dairy production and consumption than the rest of China. Although the population in these three provinces accounted for only 7.3% in China in 2007, their milk production disproportionately accounted for 17.6% (NSBC 2008).

The overall goal of this paper is to explain recent trends in the dairy industry of China by using a data set from Greater Beijing. More specifically, we seek to conduct a quantitative analysis on the determinants of the participation (that is, yes or no) and scale of participation (that is, how many cows in his/her herd) of farmers in the dairy sector. Among all of the questions, our main interest is in whether or not the emergence of the dairy processing industry over the past several years in a particular region is a key factor that has helped trigger the rapid rise in the region's dairy production. Through data analysis, we also seek to identify other factors that may be responsible for the growth in production of the Greater Beijing dairy industry.

The rest of paper is organized as follows. Section 2 introduces the data, sampling methods, and basic information regarding the surveys. Section 3 describes the basic features of dairy households in the Greater Beijing sample as well as the development of firms in the dairy processing industry. Sections 4 and 5 discuss the econometric model and reports the results of our statistical analysis. The final section concludes.

SURVEY AND DATA

Data for this study come from three field surveys designed and conducted by the authors. The first two surveys were conducted in a randomly selected set of villages and households. The third survey of all dairy processing firms in the Greater Beijing region was conducted by phone.

The dairy production data from the village and households surveys were collected as part of a larger survey effort (the Greater Beijing Horticulture and Livestock Survey), which examined the production behavior of villages and households in Greater Beijing. The authors conducted the main survey in July and August of 2005. The first round of the surveys covered 50 townships and 200 villages, and is referred to as the Village Survey in the rest of this paper.

The sample of villages in which we conducted the Village Survey was selected through a carefully designed sampling approach. With detailed maps (see Appendix Figure A1) and a compass, five concentric circles (with radii of 40, 60, 80, 100, 140 km) were drawn, centered at the geographical center of Beijing (Tian'anmen). The concentric circles were further divided into 10 wedges by drawing 10 "spokes" (140 km in length) from the center (Tian'anmen) to the edge of the outermost circle. Each wedge was defined by two spokes that created a 36° angle. The spokes cut every concentric circle into 10 arcs, creating a total of 50 arcs (see Appendix Figure A2). On every 36° arc, one randomly selected point was marked (see Appendix Figure A3). The township geographically located linearly closest to the randomly selected point was included in our sample population. In total, 50 townships

were randomly selected with the aid of a GIS mapping program that was available at the Chinese Academy of Science's Institute of Geographical Science and Natural Resource Research. Within each township, four villages were then randomly selected to create a sample population of 200 villages.

One of the main tasks of the enumerators during the Village Survey was to interview the village leader about the changes in the community's horticultural and livestock (including dairy) economy between 2000 and 2004. Among other questions, during several hour-long, sit-down questionnaire sessions with enumerators, village leaders recounted information about production trends of their village's major high-value commodities. The leaders also provided information on the most common ways that products were procured from farmers—including the types of buyers that purchased products from farmers. In total we identified eight main types of buyers. Finally, the leaders discussed the nature of the contractual arrangements—either explicit or implicit—between farmers and first-level buyers.[4] In the case of the 50 dairy villages in a subset sample population (see Household Survey selection process below) we asked the respondents to provide information about the number of cows owned by the typical dairy household, the number of dairy households, and the initial year each household entered the dairy market. Enumerators also asked village leaders about the characteristics of their communities (e.g., income per capita; cultivated land per capita; location; etc.).

A follow-up survey called the Household Survey was conducted to collect information on dairy households. This survey revisited a randomly selected set of 50 (of the 200) villages from the Village Survey. Within each selected village we visited 10 randomly selected households (further discussed below). Importantly, in the case of almost all of our variables, the aggregated averages of the answers from the household respondents were close to those provided by the village leader in the Village Survey. Hence in our study, for this study we divided all 200 villages into two groups: dairy villages (there were 25 of them) and nondairy villages (175).

Among the 25 selected dairy villages, we randomly selected dairy cow and nondairy households as follows. First, all households in each village were divided into two groups based on whether or not they owned cows. In the most common dairy villages (i.e., those with more than seven dairy producers), we randomly selected 10 households from each village, of which seven households owned dairy cows and three households did not own dairy cows. If there were less than seven dairy households in the whole village, all of the dairy households were included in our survey. In villages with more than 50 dairy households, the sample size was doubled from 10 to 20 and we surveyed 14 dairy households and six nondairy households. In the final analysis of the 25 dairy villages, we surveyed a total of 145 dairy households and 95 nondairy households. The Household Survey for the dairy households included much detail about the history of and current production of each household's dairy activities. The locations of the 25 dairy villages are shown in Figure 1.

The final survey was conducted in order to elicit information about the dairy processing sector. To collect the data, we first made a complete list of all dairy processing firms (56 firms in total) in the Greater Beijing area and included the addresses of firms from Liu (2006). We then called each of these firms. During the phone call we collected information on the date that each firm was established, the scale of production of the firm, and details on the firm's exact location. In particular, we located each of the 56 firms on

Figure 1. Map of Greater Beijing and location of villages with households that keep dairy cows

an administrative map and plotted each firm in relation to each of our 25 dairy villages. Finally, the distance (by road) between each village and the nearest dairy processing firm was computed by GIS technology. We also used the information to calculate the total daily capacity of dairy processing firms within 30 km of each dairy village.

PRODUCING AND PROCESSING DAIRY PRODUCTS

In this section, we analyze the trends of dairy participation by households in the sample villages in Greater Beijing. Additionally, we document the pattern and timing of the expansion of the dairy processing industry in the study area since the 1980s.

Dairy Production in Greater Beijing

Participation in the dairy sector at the village level has increased in Greater Beijing in recent years. Among the 200 villages, farmers kept milk cows in only 18 villages in 2000, accounting for 9% of all sample villages (Table 1, row 1). By 2004 farmers in 25 villages, an increase of seven villages (or a 37% increase), were engaged in dairy production.

The intensity of production also has increased within the dairy villages (Table 1, rows 2 to 4). Of the 240 households that were randomly sampled in the dairy villages during our survey, in 2000 only 74 households, or 37%, kept dairy cows and produced milk. By 2004, however, there were 145 households, nearly two times higher than in 2000. Using our data to estimate overall participation rates in the 25 dairy villages, we found

Table 1. Characteristics of sample villages and households in the greater Beijing region, 2000 and 2004

	2000	2004
Number of sample villages with farmers keeping dairy cows	18	25
Size of the household sample in 25 dairy villages in 2004:		
– Number of sample households	240	240
Number of households not keeping dairy cows	166	95
Number of households keeping dairy cows	74	145
– Number of households by number of dairy cows:		
$\leq$ 5 cows/household	62	101
6–10 cows/household	8	28
11–19 cows/household	2	10
$\geq$ 20 cows/household	2	6
Characteristics of households and villages:		
Share of households keeping dairy cows (%)	5.49	7.04
Average herd size of dairy cows out of dairy households	3.75	5.48
Average herd size of dairy cows out of all households	0.21	0.39
Distance from the nearest dairy processing firms $(\text{km})_{t-3}$	51.6	32.6
Daily capacity of dairy processing firms within 30 km of the villages $(\text{hundred tons})_{t-3}$	0.69	1.35
Distance from the nearest county road (km)	1.8	0.9
Percentage of off-farm employment (%)	39.8	41.2
Age of household head (years)	46.3	50.3
Education of household head (years)	6.5	6.5
Percentage of laborers in total population (%)	64.5	72.1
Per capita cultivated land (mu/person)	1.8	1.7

Notes: Among 200 villages surveyed, there were 25 villages with farmers keeping dairy cows in 2004. All data presented in Table 1 are statistics from these 25 villages. Distance of the village to the nearest dairy processing firms refers to "travel distance by road" instead of "straight-line distance." "$t-3$" means there is a lag of 3 years. All figures are weighted averages.
Data Source: Authors' survey.

that participation rates rose from 5.5 to 7.0% (row 9). In addition, the size of the average herd rose from 3.75 cows in 2000 to 5.48 cows in 2004 (row 10). Clearly the increase in the intensity of dairy production came from the entry of farmers in new villages, the entry of new farmers in existing villages, and the increase in herd size.

Questions asked in the Household Survey allow us to see that the rise in dairy production after 2000 actually appeared to accelerate when compared to the slow progress during the 1980s and 1990s (Table 2, row 1). Among the 145 dairy producers in our sample, only four households owned dairy cows and produced milk before 1990. The total number of cows in the entire sample was only 3% of the total number of cows in 2004. During the 1990s the total number of new entries into the dairy business rose gradually. Forty-one households began to produce milk between 1990 and 1999, accounting for 28% of the total number that were producing in 2004. This, of course, means that by far the majority of dairy farmers in 2004 (100 total) entered the industry between 2000 and 2004.

Table 2. Number of households keeping dairy cows and average number of cows per household in the greater Beijing region in 2004

	Timing of when households began keeping dairy cows		
	Before 1990	In 1990–99	In 2000–04
Number of households	4	41	100
- Keeping less than 5 cows	2	24	75
- Keeping 6–10 cows	1	8	19
- Keeping 11–19 cows	1	8	1
- Keeping more than 20 cows	0	1	5
Number of cows per household	7.3	6.7	5.7

Source: Authors' survey based on investigation of dairy cow households in 25 dairy villages in Greater Beijing.

Although the intensity of milk production was rising—and the average herd size was expanding, the average scale of dairy farms was still small. According to the Supplementary Household Survey, 70% of the total number of dairy households (101 of 145) owned and milked five cows or fewer in 2004 (Table 1, column 2, rows 4 and 5). Only six of all households in our sample (145 households) kept over 20 milk cows (which we call *large-scale milk producers* in this paper—column 2, row 8). Large-scale milk producers accounted for only 4% of the total number of cows in our sample.

Moreover, looking back over time, it is clear that by 2004 there was still no evident trend that herd sizes were increasing dramatically. For instance, among households who started keeping milk cows between 2000 and 2004, the average herd size scale in 2004 was only 5.7 milk cows. This level is lower than the average of those who started keeping milk cows in the 1990s (6.7 milk cows) and prior to 1990s (7.3 milk cows—Table 2, last row). Among the 100 households who started keeping milk cows between 2000 and 2004, 75 households (accounting for 75% of new milk cow households in this period) kept five or fewer milk cows (Table 2, row 2, column 5 and column 6). Even though the smaller herds of new entrants could be accounted for by the fact that they had not yet had time to build up their herds, those that had been in the dairy production business longer still did not dramatically increase their herd sizes. By the mid 2000s, the Greater Beijing's dairy production sector was growing in total production capacity, however it was still small scale and showed no immediate signs of a rapid increase of scale.

Beijing's Dairy Processing Sector

Since the 1990s, like the nation's dairy industry in general, the dairy processing sector in the Greater Beijing area has developed rapidly (Table 3). In 2005 there were 56 dairy processing enterprises in the region (row 1). Prior to 1990, however, there were only nine processors. Hence, the rate of growth of the processing sector rose at a similar rate of increase as the production sector.

Based on the daily capacities of processing firms to process fresh milk, the processing firms in Greater Beijing are mostly small to medium scale (Table 3, column 1,

Table 3. Numbers of and production capacity of dairy processing firms in the greater Beijing region in 2004

		Timing of when firms were established		
	Total	Before 1990	In 1990–99	In 2000–04
Numbers of firms	56	9	22	25
Numbers of firms by production capacity				
<100 tons/day	25	6	7	12
100–299 tons/day	16	2	8	8
300–500 tons/day	13	1	6	4
1,500–1,800 tons/day	2	0	1	1
Average daily processing capacity (tons/day)	189	94	227	190

Source: Authors' survey.

row 6). On average, the 56 processing firms in our sample were capable of processing 189 tons of milk per day, compared to a typical plant size in the United States that processes about 500–1,000 tons per day.[5] Clearly, this sector was dominated by small-scale processors.

Like dairy production, there is also no evidence that the scale of the processing sector rose sharply (Table 3, columns 2 to 4, row 6). In the case of processors established prior to 1990, the average processing capacity was 94 tons of fresh milk per day. While the daily processing capacity rose to 227 tons per day for processors established between 1990 and 1999, it fell again to 190 tons per day for processors established between 2000 and 2004.

Further disaggregation shows that the dairy processing enterprises with the smallest scale—those with less than 100 tons daily capacity—account for most of the production of plants opened before 1990. The aggregated capacity of the smallest firms account for 67% of the production capacity of all dairy processing enterprises in operation before 1990 (Table 3, rows 2 to 5). When additionally accounting for medium sized firms, the share of total capacity accounted for by small and medium sized firms was 89% before 1990. There was only one enterprise established before 1990 that had a daily processing capacity between 300 and 500 tons. This firm accounted for 11% of the production from these early emerging plants.

After 1990 the processing capacity of these enterprises expanded, but enterprises with a daily processing capacity of less than 100 tons (including newly added enterprises with a daily treatment capacity less than 100–299 tons) still accounted for more than half of total production (respectively 36% and 27% —Table 3, column 3). Moreover, for dairy processing enterprises established between 2000 and 2004, the number of firms with relatively small production capacities rose again (column 4). Among all processors established between 2000 and 2004, enterprises with daily processing capacity limits of less than 100 tons and enterprises with daily treatment capacities between 100 and 299 tons accounted for 80% of total new processing capacity.

The state has taken an active role in the expansion of these firms. Especially in the 1980s and early 1990s, the processing enterprises were mainly and initially

state owned. In most cases, these enterprises had exclusive contracts with the Beijing municipal government to procure milk from farmers and undertake fresh milk processing. Almost all supply was sold to buyers inside the Greater Beijing area. In recent years, not only are newly emerging firms mostly private, many of the original firms that were owned by the state are now privatized (Zhao 2004).

Even after privatization began in the 1990s, the government still actively supported the development of the dairy sector. General investment efforts in roads, communications, and other improvements in marketing infrastructure have accounted for substantial amounts of government investment (Luo et al 2007). Since 1988, a Ministry of Agriculture initiative (the "Vegetable Basket Project") has supported local policies that are favorable for enterprises, including dairy processing. Firms participating in major government programs are often granted land-use fee exemptions, and access to grants and loans from special funding sources.

Linkages between Dairy Farms and Processors

So is there any link between the rise of household dairy production and the emergence of dairy processors? According to our data from the household and processor surveys, it is clear that the time period in which households began to increase dairy production in the Greater Beijing area coincided with the time period in which there was an acceleration of dairy processing (Tables 2 and 3). Throughout the 1980s little activity in either dairy production or dairy processing occurred. During the 1990s, both production and processing took off—with processing growing faster in a relative sense. Finally, in the 2000s, while dairy processing continued to grow steadily, dairy production accelerated.

Looking at the data in another way, note that the development of dairy processing firms has been positively correlated with the acceleration of household milk production in 2000 and 2004 (Table 4). In examining this question we divided the 25 dairy villages into two groups. The first group contained villages in which there was a dairy processing firm within 30 km of the village in 1997 or 2001 (three years before 2000 and 2004, in which we will examine dairy production within the villages). The second group contained villages in which there was no dairy processing firm in either 1997 and 2001. We then examined the size of the average dairy herd of households in the two types of villages—those with dairy processors nearby and those without. The results demonstrate that in 2000, the size of the dairy herd in villages that were near processors was 4.5 cows per household, compared to 3.4 in villages that were not near processors (although these two-point estimates were not statistically different, see column 5). In 2004 the same pattern held; the size of the dairy herd in households of villages with processors nearby was much larger (7.7 cows per household) than those in villages that were not near processors (3.6 cows per household). In 2004, the differences in the number of cows per household were statistically significant (column 5). The same pattern holds when examining the number of households that keep dairy cows. The increase of the percentage of households that kept dairy cows between 1995 and 2005 was much greater in villages that were near processing firms.

We can also see systematic differences between the production characteristics of households that owned dairy cows and those that did not. For example, Table 5 demonstrates that households owning dairy cows, on average, lived within 35.1 km of a processing firm (row 1). At the same time, households that do not keep dairy cows lived 40.5 km away.

Table 4. Relationship between dairy households and dairy processing enterprises in 25 dairy villages in Greater Beijing, 2000 and 2004

		Villages with dairy processing firms within 30 km		Villages without dairy processing firms within 30 km		Test of statistical difference, between columns (1) and (3)
	Number of households with cows	Average number of cows per household (1)	Percentage of households with cows (%) (2)	Average number of cows per household (3)	Percentage of households with cows (%) (4)	*p*-value (5)
2000	74	4.5	2	3.4	3.8	0.3382
2004	145	7.7	9.2	3.6	3.5	0.0049**
Average	109.5	6.7	6.4	3.5	3.7	0.0024**

Notes: The numbers in the table compare the "number of cows per household" and "percentage of households with cows" in 2000 (2004) with the presence or absence of dairy processing firms with 30 km in 1997 (2001). ***, **, and * represent statistical significance at 1%, 5%, and 10%, respectively.
Source: Author's survey.

Table 5. Difference between the characteristics of sample households that keep dairy cows and sample households that do not keep dairy cows in Greater Beijing region, 2000–04

	Households that keep cows	Households that do not keep cows	Test of statistical difference (*p*-value)
Distance to nearest dairy processing firms in three years ago (km)	35.1	40.5	0.0396**
Daily processing capacity of firms within 30 km in three years ago (hundred tons)	1.6	1.1	0.0018**
Household head age (years)	43.5	45.9	0.0082**
Household head education (years)	6.8	6.6	0.3973
Percentage of labor in total population (%)	72.5	69.3	0.0994*
Percentage of off-farm labor in total labor (%)	25.7	37.6	0.0000***
Cultivated land per capita (mu/person)	2.1	1.9	0.1098
Assets per capita in 2000 (yuan/person)	10557	9759	0.3929
Distance from village to nearest road (km)	0.8	1.5	0.0337**

Source: Author's survey.
***, **, and * represent statistical significance at 1%, 5%, and 10%, respectively.

In addition, the average capacity of a processing firm was larger (160 tons) in villages that were within 30 km of a processor than those in villages that were further away (110 tons—Table 5, row 2). In both cases, the differences were statistically significant (column 3, rows 1 and 2).

Other Basic Characteristics of Dairy Households in the Region

While it appears that the nature of the emergence of dairy processing firms is correlated with the propensity of households to produce milk, there are also other fundamental differences between dairy and nondairy households (Table 5, rows 3 to 9). For example, the share of household members that had off-farm jobs was lower in dairy households (25.7%) than in nondairy households (37.6%—row 6). Cultivated land per capita, in contrast, was a bit higher for dairy households (2.1 mu vs. 1.9 mu—row 7). The distance from the village center to the nearest road was less for dairy villages (0.8 km) than nondairy villages (1.5 km). Interestingly, differences between the age, education, and demographic structure of dairy households and nondairy households were relatively small (Table 5, row 3 to 5). In the cases of all of these traits (except for education—row 4; and assets per capita—row 8), the differences are statistically significant (column 3).

From the discussion in previous sections, it is not unreasonable to believe that the rapid growth of household dairy production in recent years is closely related to the development of the dairy processing industry. In other words, there is at least some (suggestive) evidence that it is because of low production and the slow emergence of dairy processing industry that China's dairy demand was low. However, as the discussion in this section demonstrates, there are also other factors that may have been affecting household dairy production. Based on the descriptive data, it is impossible to draw conclusions on the basis of the descriptive relationships between processing and production. Therefore, in the next section the effect of the development of dairy processing on household milk production is assessed through quantitative analysis.

ECONOMETRIC MODELS AND ESTIMATION

To examine what factors determine if farmers participated in dairy production, initially we set up a probit model. To investigate how factors affect each household's herd size, a Tobit model is used.

The probit model is specified as:

$$\text{Prob}(Y_{ijt} = 1 | x_{ijt}) = \Phi(x'_{ijt}\alpha) \tag{1}$$

where Y_{ijt} (uppercase Y) is a dummy variable indicating whether the ith household living in the jth village at time period t participating ($Y_{ijt} = 1$) or not ($Y_{ijt} = 0$) in dairy production; and x_{ijt} is a vector of explanatory variables for the ith household who lived in the jth village at time t (either 2000 or 2004). The vector x_{ijt} includes $P_{j(t-3)}$, a measure of whether or not there was a dairy processor in within 30 km of village j in 1997 (when $t = 2000$) or 2001 (when $t = 2004$).[6] In an alternative specification of P, we measure it as the distance of the household from the nearest dairy processor (in kilometers). The variable, R, is included to control for the nature of the local transportation conditions, which is measured as the distance (in kilometers) from the village to the nearest road way. The symbol, H_{ijt}, is a vector of other household characteristics and includes six variables including the household's level of wealth (measured as its asset value per capita in yuan); the household head's age (in years); the education level of the household head (in years); the household's cultivated land per capita (in mu per capita); the share of household members that are in the labor force; and the share of the members of the household that

are in the labor force who have jobs in the off-farm labor market. The symbol α represents the vector of estimated parameters.

The Tobit model is a well-known econometric regression model used in the presence of censored data, but it can also be applied to corner solution responses (Wooldridge 2002).[7] In our application, we define y_{ijt} (lowercase y) as the dependent variable which represents the herd size of the household i in village j during time period t, and y^*_{ijt} as the corresponding latent variable. Under the Tobit model, the relationship between latent and observed variables for household i in village j during time period t is

$$y_{ijt} = \begin{cases} 0 & \text{if } y^*_{ijt} \leq 0 \\ y^*_{ijt} & \text{if } y^*_{ijt} > 0 \end{cases} \tag{2}$$

And the latent variable is described by

$$y^*_{ijt} = x_{ijt}\beta + \mu_{ijt} \tag{3}$$

where $\mu_{ijt} \sim N(0, \sigma^2)$. Here we chose the same set of variables, x_{ijt}, as the explanatory variables. The symbol β is a vector of the coefficients to be estimated. The main coefficient of interest is the coefficient on the variable measuring the access of the household to a dairy processor (that is the β associated with $P_{j(t-3)}$).

In our regression analysis, due to how our sample was selected, we weighted each of our observations to ensure that results are representative of the Greater Beijing region. Therefore, a sampling weight was specified for each sample observation to ensure that the contribution of the observation to the estimated coefficient corresponds with the importance of the observation in terms of share of the sample that it is representing. Specifically, the weight for ith dairy households from jth village is $W_{ij,}$ which is defined as $W_{ij} = S_j * M_j/a_{j;}$ and the weight of households without milk cows is defined as $W_{ij} = S_j*$ $(1\text{-}M_j)/b_j$, where S_j represents the share of total households in the 25 dairy villages which were in the jth village; M_j is the share of dairy households in the jth village; and a_j and b_j, respectively, represent the number of randomly sampled dairy households and nondairy households in village j. For example, in the typical village, when we chose seven dairy households out of the total number of dairy producing households and three households out of the total number of nondairy households, the value of a_j was 7 and the value of b_j was 3.

In our sample of 480 households, there are 166 households with no dairy cows in 2000 and 95 households with no dairy cows in 2004. Since the standard version of the Tobit model can not account for the different weights attached to the different observations, we needed to use a special form of the Tobit—a Weighted Tobit model. In the rest of the analysis, parameters which are estimated from a Weighted Tobit model was used (for convenience, we still use β to represent the coefficients to be estimated). To make the coefficients of the Weighted Tobit model more interpretable we needed to estimate the marginal effects for the Tobit model. The estimation was conducted using Stata and an interval regression approach that allowed us to use our p-weighted observations in estimating the Tobit model.

ESTIMATED RESULTS

The results from our empirical estimation (with coefficients reported as marginal impacts—from Equation (3)) demonstrate that our modeling efforts performed quite well (Table 6). The mathematical (positive or negative) signs of many control variables are consistent with expected values. For example, the coefficient on the age of the household head age variable was negative and highly statistically significant (row 4). Ceteris paribus, those households with younger heads were more likely participate in dairy farming. This may be the case since dairy production requires skills and strength that are more suitable to younger farmers. The sign of off-farm employment variable was also negative, and significant in both the participation and herd size equations (row 7). Since dairy farming is labor intensive, farmers who are not committed to working off the farm and/or out of the village as wage earners (or are in the nonfarm self-employed sector), clearly are more likely to enter the dairy sector. This result is similar to that in Huang et al (2007), of a negative and significant trade-off between off-farm employment and participation in the horticultural sector, another labor intensive/high-value enterprise.

The most striking result concerns the effect (or correlation) from the rise of the dairy processing sector on household decisions to participate and expand their herd size (Table 6, row 1, columns 1 and 3). The coefficients on the location of the dairy processing variables are positive and significant in the equations, regardless of the definition of the dependent variable. In Greater Beijing in 1997 (2001) if a dairy processor was already built within 30 km of the village, the probability of participating in the dairy industry in 2000 (2004) was 1.5% higher (column 1). Similarly, having a dairy processor within 30 km in 1997 (2001) is associated with an average herd size that is 2.198 cows higher in 2000 (2004). Despite the caution necessary in fully assigning causality to our results, these findings are consistent with the interpretation that the processing sector has helped to simulate the growth of the dairy sector at the farm level.

Using an alternative measure of proximity between the households to dairy processing, we find a similar result (Table 6, row 2, columns 2 and 4). When looking at participation, as the distance of a household to a processor decreases, the likelihood of participation in the dairy sector rises. According to our results, for each 10 km closer to the processor, the probability of participation increases by 1%. Similarly, as the distance to the processor declines, farm herd size rises. Access to dairy processing in the locality appears to be critical in stimulating the rise of the dairy producing sector.

After controlling for the effects of the location of the dairy processor, our results also show that access to roads (and generally better transportation) positively affects the dairy sector (Table 6, row 3). In all four equations, the sign on the coefficient of the distance from the village to the nearest paved roadway variable is negative. The point estimates of these estimated coefficients suggest that better access to roads (making the distance shorter) increases participation and raises herd size. The coefficient on the distance to road variable is statistically significant in the equations in columns 2 and 4, the models that use distance from household to dairy processor (measured in kilometers) as the proxy variable for access to dairy processing.

Significantly, whether in the results from the Probit model (determinants of participation) or the Tobit model (determinants of herd size), it is clear that China's dairy sector has excluded neither poor or uneducated households, nor those that are endowed with

Table 6. Probit and tobit analyses examining the determinants of keeping dairy cows in the Greater Beijing (what factors affect the propensity of households to keep dairy cows and how many; what factors do not)

	Probit		Tobit	
	(1)	(2)	(1)	(2)
Daily capacity of dairy processing firms within 30 km (hundred tons)	0.015 (6.08)***		2.198 (5.66)***	
Distance from the nearest dairy processing firm (km)		−0.001 (4.05)***		−0.099 (4.12)***
Distance from the nearest road (km)	−0.007 (1.51)	−0.010 (1.95)*	−0.902 (1.30)	−1.423 (1.80)*
Characteristics of households				
Household head age (years)	−0.003 (5.37)***	−0.003 (5.05)***	−0.399 (5.69)***	−0.430 (5.57)***
Household head education (years)	0.001 (0.31)	0.000 (0.22)	0.111 (0.42)	0.083 (0.30)
Ratio of labor in total population (%)	0.030 (1.32)	0.037 (1.58)	5.013 (1.50)	6.175 (1.71)*
Ratio of off-farm labor in total labor (%)	−0.064 (2.97)***	−0.068 (3.13)***	−8.717 (3.09)***	−9.733 (3.31)***
Cultivated land per capita (mu/person)	−0.002 (0.61)	−0.000 (0.12)	−0.189 (0.46)	−0.009 (0.02)
Assets per capita in 2000 (yuan/person)	0.000 (0.12)	−0.000 (0.86)	0.000 (0.18)	−0.000 (0.85)
Constant			−0.535 (0.11)	7.972 (1.45)
No. of observations	480	480	480	480

Notes: The models are estimated based on a panel data set that includes 240 farmers in 2000 and 2004. The symbols ***, **, and * represent statistically significant at the 1%, 5%, and 10% levels, respectively. When the probit model is used, the dependent variable is either one or zero.

small land holdings (Table 6, rows 5, 8, and 9). The coefficients on the household head's education variable, the household's cultivated land per capita variable and the household's asset per capita variable are all insignificantly different from zero. In other words, poor farmers, those with low levels of education and those in villages/production teams in which the household has access to relatively little land appear equally able to participate in dairy production in our Greater Beijing sample. They also have similar herd sizes. It is likely that the small scale nature of China's dairy sector is responsible for this result.

Decomposition Analysis: What Variables Really Matter

A decomposition analysis also shows the *relative importance* of the rise of the dairy processing sector in the decisions of the household's participation and herd size decisions. To show this, we decompose the change in participation rates and herd size between 2000 and 2004. In briefest terms, however, a decomposition analysis essentially estimates how much each *determining factor* (dairy processing; distance to road; rise of off-farm labor) contributes to the overall change in the dependent variables (participation/herd size). For further detail of the analysis, see the footnote of Table 7. This contribution is estimated by multiplying the marginal effects of each determining factor by the magnitude of the change in that determining factor between 2000 and 2004. The share contributed by each determining factor to the change in dairy participation (herd size) is then compared to the total change in participation (herd size), and allows us to assess which determinants are most important (or contributed the most to the observed change in participation/herd size). We use the estimates from Table 6, columns 2 and 4, for the decomposition analysis since it is in these estimated models that the coefficients of both the access to dairy processing and access to roads variables are significantly different from zero.

According to the decomposition analysis, dairy processing is the most important determinant of the rise of dairy production in Greater Beijing (Table 7, row 1). When explaining the rise in the participation of households in the dairy sector (which rose by 1.55 percentage points from 5.49 to 7.04% between 2000 and 2004—see Table 1, row 9), by far the most important factor is the rise of the processing industry. In fact, if nothing else had changed, our analysis suggests that increasing access to a dairy processor could explain 123% of the rise in dairy production. In other words had not other factors changed, participation in dairy production by households would have risen 1.91 percentage points due to better access to processors (the average distance to the processor fell by 19 km between 2000 and 2004) instead of only 1.55 percentage points (the actual rise).

The importance of the rise of the dairy processing sector is further corroborated by comparing the magnitude of the processing effect to the effect of other determinants (Table 7, columns 1 to 3, rows 2 to 4). Specifically, access to roads is also seen to positively affect participation. However, the effect of the improved road system between 2000 and 2004 (which improved access for the typical village to the nearest paved road by 0.9 km) is smaller (58%) than that of the emergence of processors (123%). So, while the rise of roads is an important factor, it is still less important than the rise of processors. The effect of increased access to off-farm employment dampened the rise in participation by households, but only by 6%. Other factors (bundled into the residual) also dampened the ability and willingness of household to participate in dairy production by 74%. If it had not been for these other factors, dairy production would have increased by more than 1% more (0.77 times 1.55). Although we can not identify these factors exactly, our

Table 7. Decomposition analysis of major factors affecting keeping dairy cows in 2000–04

	1. Participation			2. Number of cows for dairy households			Average number of cows for all households		
	Coefficient	Change in level	% change due to:	Coefficient	Change in level	% change due to:	Coefficient	Change in level	% change due to:
Explanatory variables:									
Distance from dairy processing firm (km)	−0.001	−19.0	123	−0.015	−19.0	16	−0.007	−19.0	74
Distance to highway (km)	−0.01	−0.9	58	−0.214	−0.9	11	−0.097	−0.9	49
Off-farm labor share (%)	−0.068	0.014	−6	−1.465	0.014	−1	−0.666	0.014	−5
Other factors (residuals)	na	na	−74	na	na	73	na	na	−18
Explained variable	na	0.0155	100	na	1.73	100	na	0.18	100

Notes: Coefficients in column 1 are from column 2 of Table 6 (Probit model 2); Based on β coefficients in column 4 in Table 6 (Tobit model 2), coefficients in columns 4 and 7 are estimated according to the formulas of $d1 = \partial Ey*/\partial x = \beta[1 - zf(z)/F(z) - (f(z)/F(z))^2]$ and $d2 = \partial Ey/\partial x_i = F(z)\beta$, respectively. Percentage change due to each factor is computed as: (coefficient $*$ change in level)/total change of explained variable. The total magnitude of the change over time of the dependent variable is listed in the last row. The magnitude of the changes of the explanatory and dependent variables are from Table 1.

field research suggests that there are other constraints to entering dairy production. This suggests the merits of further survey-based research to identify such factors.

Similar findings appear when decomposing the rise in herd size (Table 7). Regardless of whether we are trying to explain the increase in herd size of dairy producers (from 3.75 to 5.48 cows) or to account for the increase in the herd size of all households (from 0.21 to 0.39 cows), the emergence of the dairy processing sector is the most important determinant. It explains 16% of the rise of herd size among dairy producers (columns 4 to 6, row 1). At the same time, dairy processing explains 74% of the rise of herd size among all households (columns 7 to 9, row 1). While the contribution of the access to roads (positive contribution—row 2) and off-farm labor (negative contribution—row 3) also are measured, their relative importance are smaller than that of dairy processing.

There is one caveat that must be raised here. As discussed above, one possible factor was omitted—rising demand. While we have shown in the preceding decomposition analysis that the emergence of processing accounts for a large share of the rise of dairy production, if the emergence of processing is in part being driven by (or is correlated with rising demand), then we may be overstating the contribution of the emergence of the processing sector. If we had accounted for demand (and if demand did help explain production and was correlated with the emergence of processing), it could also be a significant share in explaining the rise of dairy production.

CONCLUSIONS AND POLICY IMPLICATIONS

This paper analyzes the effects of the emergence of dairy processing firms on the decision by farmers to own dairy cows and expand herd size in Greater Beijing. By utilizing data from surveys on the development of the dairy processing firms and the growth of the dairy cow inventories held by farmers, our study indicates that the pattern of the rise and spread of the dairy processing sector is strongly associated with the production decisions of households to increase their participation and herd sizes. Moreover, our results show that this pattern of the development in the processing sector does not exclude poor farmers. Both poor and rich farmers have been able to take advantage of opportunities to enter the dairy production sector when a dairy processing firm appears in a region near their village.

Our research results also have implications for policy. Specifically, if China is interested in further promoting dairy production, the government may need to consider playing a role in promoting a dispersed and small-scale dairy processing sector. If the new processors can enter into areas currently with no processing firms, the farmers in the area will have new opportunities to participate in dairy production and expand herd size. Such a policy would allow China to meet some (or most) of its rising demand by allowing new production to enter.

We need to remind the reader once again about the limitations of our analysis. First, the results in this study came from data only in the Greater Beijing area. To achieve our goal, we had to conduct three comprehensive surveys on our own—an effort that precluded us from covering additional other regions. While we examined all villages sampled in the region, our sampling did not discover any truly large dairy farms, though in fact, there are such large, commercial dairies in China. While we do not know why we did not find any (perhaps because there are so few), the dynamics in large commercial

farms (and dairies in other areas) quite possibly could be different than those depicted in this study.

In addition, we remind the readers that the detailed survey was conducted by our research team and unfortunately did not include questions about demand side factors. It is possible that the construction of processing plants were triggered by the rise in the demand for dairy. If so, we could be overestimating the effect of dairy processing, attributable to the omitted demand effects from the processing sector. Incorporating both sets of effects is a necessary future research endeavor.

NOTES

[1]Of course, it is possible that production constraints held back consumption. Although it is beyond the scope of this paper to test this, and we do not know if this is true or not, the work of deBrauw et al (2004) suggests that production constraints likely were not binding. Since the 1990s, China's farmers have been willing and able to move into production activities with rising prices and profitable opportunities.

[2]Per capita consumption of milk in rural and urban areas discussed in this paper is based on data from the HIES conducted by the NBSC. The data do not include milk consumption away from home. Therefore, the increase in actual per capita milk consumption is even higher than shown by the data presented here, since food consumption away home has been growing faster than food consumption at home (Ma et al 2006).

[3]Annual dairy imports accounted for only about 5% of domestic consumption over the past decade (NBSC 1998–2008).

[4]In our study, we differentiate between two types of buyers of commodities in the dairy economy. First-level buyers are those that are engaged in transactions directly with farmers. Second-level buyers are those to whom first-level buyers sell. These represent the first and second links in the marketing chain—when starting from the dairy in the village.

[5]There were 1,846 dairy processing plants in United States in 1997. In general, the capacities of milk processing firms in the United States range between 500 and 1,000 tons per day. There are, however, some individual plants that have capacities that reach as great as 5,000 tons per day (Chen and An 2002).

[6]The utilization of the index, P, lagged by three years is mainly to avoid possible influence of reverse causality and some of the other sources of endogeneity. Given this definition the interpretation of our results are measuring if the appearance of dairy processors in 1997 (2001) affected the emergence of household dairy production in 2000 (2004). We chose to use 30 km as a cutoff point because during our interviews, dairy processors told us consistently that they prefer for a number of reasons to procure milk no further than 30 km (although they sometimes do not anyhow). To test the sensitivity of our results to the choice of 30 km cutoff, in our analyses we also utilize 10 km, 15 km, and 20 km in alternative runs of the model. Although estimated coefficients on the P variable differ when different cutoff distances were used, in general, however, the major conclusions were the same. Therefore, in the rest of the paper we only report those from the model using the 30 km definition.

[7]A variable is a corner solution response if the variable is zero with a positive probability and is roughly continuously distributed over positive values. Our data are not censored data as there is no issue of data observability; y_{ijt} is an observable outcome and we are interested in features of the distribution of y, such as $E(y)$ and $P(y = 0)$. As Wooldridge points out, the standard censored Tobit model (type 1 Tobit model) can be applied to the corner solution application. See Wooldridge (2002) for more details.

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REFERENCES

Chen, G. Y. and X. N. An. 2002. The impact of dairy industry in United States on farmers' income and agriculture structure. *World Agriculture* 284 (12): 4–5.

deBrauw, A., J. K. Huang and S. Rozelle. 2004. The sequencing of reform policies in China's agricultural transition. *The Economics of Transition* 12(3): 427–65.

Fuller, F. H., J. K. Huang, H. Y. Ma and S. Rozelle. 2006. Got milk? The rapid rise of China's dairy sector and its future prospects. *Food Policy* 31: 201–15.

Ha, J. F. 2004. Restricting factors of development of Chinese dairy and corresponding countermeasures. *Gansu Agriculture* 200 (11): 83.

Huang, J. K. and H. Bouis. 1996. Structural changes in demand for food in Asia. *IFPRI's Food, Agriculture and the Environment 2020 Paper Series 11*. Washington, DC: International Food Policy Research Institute.

Huang, J. K. and S. Rozelle. 1998. Market development and food demand in rural China. *China Economic Review* 9 (1): 25–45.

Huang, J. K., Y. H. Wu and S. Rozelle. 2007. Moving off the farm and intensifying agricultural production: Linkages in China's rural labor markets. Working Paper, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing.

Li, S. L. and Z. J. Cao. 2005. Tentative discussion on problems of healthy development of Chinese cow-breeding industry in period of adjustment. *China Dairy* (3): 3–7.

Li, Z. Q. and J. M. Wang. 2000. Analysis of Chinese livestock consumption and prospects of consumer market. *Chinese Rural Economy* (7): 46–51.

Liu, C. G. 2006. *China's Dairy Industry Yearbook*. Beijing: China's Agricultural Press.

Luo, R. F., L. X. Zhang, J. K. Huang and S. Rozelle. 2007. Elections, fiscal reform and public goods provision in rural China. *Journal of Comparative Economics* 35: 583–611.

Ma, B. C., Q. Y. Zhang and Z. M. Qin. 2005. Rational analysis of development of Chinese dairy. *Heilongjiang Animal Science and Veterinary Medicine* (7): 4–6.

Ma, H. Y., J. K. Huang, F. Fuller and S. Rozelle. 2006. Getting rich and eating out: Consumption of food away from home in urban China. *Canadian Journal of Agricultural Economics* 54 (1): 101–19.

NBSC (National Bureau of Statistics of China). 1998–2008. *China Statistical Yearbook*. Beijing: China Statistics Press.

Wooldridge, J. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: MIT Press.

Zhao, J. F. 2004. Analysis of dairy structure, behavior and effect in China. Doctoral Dissertation, China's Agriculture University, Beijing.

APPENDIX

Figure A1. Location of the sample region of the Greater Beijing study. Step 1 is defining the study area

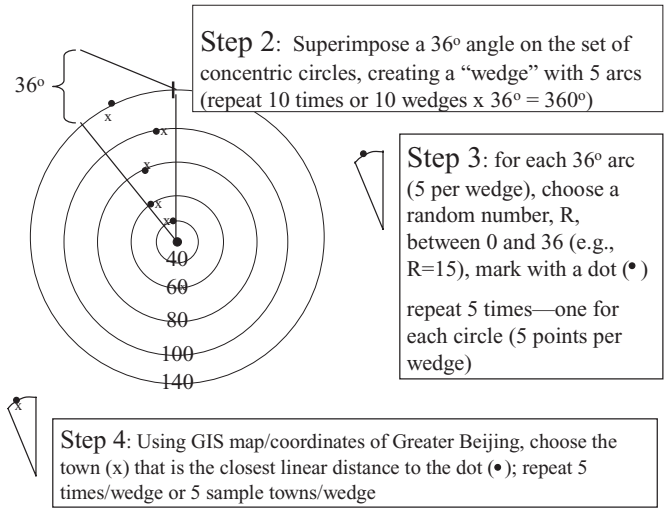
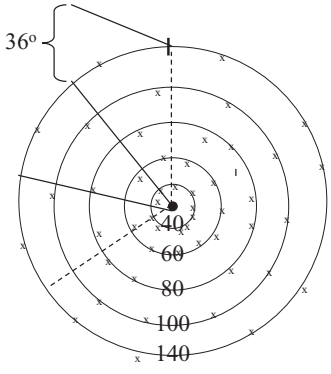


Figure A2. Steps 2 to 4 on choosing a sample for Greater Beijing study area



Step 5: Repeat selection of sample towns 10 times (once for each of 10 wedges making up the circle)

Total Town Sample Size:
5 circles x
10 towns per circle =
50 towns
(or $N_t = 50$)

Note: Population of ALL towns in each strata is used for sample weighting.

Figure A3. Fifth and final step in sample selection for Greater Beijing study area