Farmer Participation, the Dairy Industry, and the Rise of Dairy Production in China

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Abstract

With rapid income growth, dairy production and consumption in China have increased significantly. This emergence of the dairy sector will provide 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 farmers' participation in dairy production. Our main question is whether or not the pace of the emergence of the dairy processing industry has affected the ability of farmers 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 shows that the location of dairy processing firms is one of the key factors that determines the participation of farmers in dairy production. Although other factors affect participation and herd size—for example, access to roads and the ability to get a job off the farm (which affects the opportunity cost of household members)—access to dairy processors is shown to be the major factor that has encouraged the growth of dairy production over the past decade. The results also show that poor, less educated farmers with relatively less access to land are not excluded from the rapid expansion of the Greater Beijing dairy market.

Keywords: China, dairy processing, dairy production.

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With China's rapid economic growth and rising incomes since the early 1980s, significant changes have taken place in the structure of the nation's diet. There has been a large fall in the expenditure share of staple food in the typical consumer's basket and a significant increase in expenditures on non-staples, 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 kilograms in 1985 to 77 kilograms in 2005 while per capita meat consumption increased from 19 kilograms to 29 kilograms (NBSC, 2006). Although changes in consumption patterns in rural areas were less dramatic, there still were changes in the structure of the diets of those living in rural area (NBSC, 2006).

In examining the changes in consumption patterns of all commodities, there is no other commodity that has experienced as great a change as have dairy products—especially recently. Prior to the mid-1990s, although income rose rapidly, there was only a small rise in the demand for milk and 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 kilograms in 1982. During the decade-plus between 1982 and 1995, consumption rose slowly, to only 8 kilograms (NBSC, 2000). Annual per capita milk consumption of rural residents was nearly stagnant at about 1 kilogram during the period of 1985-1995. Nationwide, to meet at least part (most) of this demand, fresh milk production rose gradually, from 2 million tons in 1982 to 5.8 million tons in 1995 (NBSC, 2000). One explanation for the slow development of the

dairy industry is simply that the growth of urban and rural consumption of milk was so slow.[1]

The situation changed dramatically, however, after the mid-1990s. During the late 1990s, average per capita consumption of milk and milk products (in fresh milk equivalents—the unit used throughout the rest of this paper) in urban areas rapidly increased from 8 kilograms in 1995 to 13 kilograms in 2000. Between 2000 and 2005, per capita demand jumped to 25 kilograms. Over the same period, average per capita consumption of milk in rural areas increased from 1 kilogram to 3 kilograms.

As milk consumption was rising rapidly, the development of the dairy industry in China accelerated. 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 rapid expansion, millions of farmers began to purchase cows and produce milk. The pattern of growth of China's milk supply and demand—slow and then fast—over the past two decades has raised the interest of academics, policymakers and the private sector in what caused the change. Several questions have been raised in this regard; for instance, in terms of consumption, why is it that prior to the late 1990s, a rapid income increase 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 three- to four-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? In the same vein, what other factors contributed

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

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 industrial expansion? What are the major determinants of the participation of farmers in the milk supply business?

While these questions are not unique, previous studies 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) is not only influenced by income and urbanization (Huang and Bouis, 1996) but also by development of urban and rural food (consumption) markets (Huang and Rozelle, 1998; Fuller et al., 2004 and 2006). In other words, the absence of markets can constrain the growth of demand for a product with all other things 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 (after markets 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 may have played a critical role in the changes in demand. Previous studies, however, rarely have looked at issues related to dairy production. There is a distinct lacuna of studies that examine the factors that have affected the participation of farmers in the dairy production. Although there are a few studies that discuss some of the existing problems and policy options in dairy production, most of

them are conceptual in nature, and the findings/conclusions are largely based on anecdotes, casual observations and qualitative assessments (for example, Li and Cao, 2005; Ma et al., 2005; Ha, 2004).

While studies on dairy production in China are limited, even fewer have been conducted on dairy processing. One study showed that the number of dairy processing firms in China has increased sharply in recent years, from 377 in 2000 to 690 in 2005. It is possible that the processing sector has been one of the constraints in the past. The takeoff of dairy demand and production at farms may have been facilitated by the development of dairy processing and the processing market. While consistent with the facts (as seen here), previous studies have never made this link. To the authors' knowledge, no literature has attempted to analyze empirically to what extent the emergence of the dairy processing sector affects the participation of the household in milk production.

Does the dairy processing industry affect scale of household production? Who has gained more from the rapid expansion of the dairy processing sector? While these questions are interesting, they are not easy to answer. It is impossible to use simple correlations among the aggregated number of dairy processing firms, milk supplies at the farm level and milk consumed by urban and rural residents to assess causality. There are many factors to take into account, such as policies, the nature of infrastructure, and prices that affect processing, supply and demand. In addition, a number of unobserved factors may also affect each component of the dairy industry. When unobserved factors (e.g., expectations of future growth; expectations of future milk demand; changes in the preferences of consumers) are important and not counted, using standard statistical methods (e.g., Ordinary Least Squares regression analysis), identifying net relationships is unreliable because results may be biased. Therefore, to

have a better understanding of the impact of dairy processing development on household milk production, it is essential to have a dataset that can be used in conjunction with reliable statistical methods to clearly identify the relationship between processing and participation by farmers in the dairy industry. The results of this kind of analysis could also provide useful input for industry and policymakers in China to help them to make decisions about the allocation of investments into processing and dairy production as well as effective policies and regulations.

The overall goal of this paper is to help explain recent trends in the dairy industry in China. 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) of farmers in the dairy sector. Among all of the questions, one of the main ones that we are interested in is if the emergence of the dairy processing industry is one of the factors that triggered the rapid rise in dairy production during the past several years. Or which came first, the cows or the processors? Were some other factors responsible?

The rest of paper is organized as follows. Section 2 introduces the data, sampling methods and basic information about 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. Section 4 discusses the econometric model and reports the results of our statistical analysis. The final section concludes.

Survey and Data

Data for this study come from the authors' three field surveys. The first two surveys were conducted in a set of villages and households that were sampled

spatially. The third survey was of all dairy processing firms in the Greater Beijing region and was conducted by telephone.

The dairy production data from the village and household surveys were collected as part of a larger survey of villages/households in Greater Beijing—called the Greater Beijing Horticulture and Livestock Survey. The main survey was conducted by the authors in July and August of 2005. The first round of the survey covered 50 townships and 200 villages, and in the rest of the paper we call this the Village Survey.

To choose the sample of the Village Survey, a carefully designed approach was taken. We began the sampling with a set of detailed administrative maps of Beijing Municipality and Hebei Province. We then took a compass, stuck the needle end into the point representing Tian'anmen (the geographical center of Beijing) and traced out five concentric rings, including circles with radii of 40, 60, 80, 100 and 140 kilometers. Next, we divided the concentric circles into 10 wedges by drawing what appeared to be 10 spokes from the center of the hub (Tian'anmen) to the edge of the outer circle. Each spoke had a length of 140 kilometers. Each wedge was defined by the two spokes that created an angle of 36 degrees, and the spokes cut each concentric circle into 10 arcs that were each 36 degrees. Hence, in total there were 50 arcs (5 circles times 10 wedges). The next step was to randomly choose the township that was linearly closest to the point on each arc. This was done with the aid of the GIS (geographical information systems) mapping program that was available at the Chinese Academy of Science's Institute of Geographical Science and Natural Resource Research. In total 50 townships were sampled. In each township, four villages were then randomly selected.

One of the main tasks of enumerators during the Village Survey was to interview the village leader about the changes in the community's horticultural/livestock (including dairy) economy between 2000 and 2004. Among other things, during several hour-long, sit-down questionnaire sessions with enumerators, village leaders recounted information about production trends of their village's major commodities. The leaders also provided information on the most common ways that products were procured from farmers—including the type of buyer that purchased product from farmers. In total we identified eight main types of buyers. Finally, we also asked leaders to tell us the nature of the contractual arrangement—either explicit or implicit—between farmers and first-level buyers.[2] In the case of dairy villages (see below for definition) we asked the respondents to provide information about the number of cows for the typical dairy household, the number of households and the timing of when they entered the market. Enumerators also asked village leaders about the characteristics of their communities (for example, income per capita; cultivated land per capita; location).

A follow-up survey called the Household Survey was conducted to collect information on dairy households. This survey re-visited a randomly selected set of 50 (of the 200) villages from the Village Survey. Within each Household Survey we visited 10 randomly selected households (discussed below for dairy villages). Importantly, in the case of almost all of our variables, the aggregated average of the answers of the household was close to that provided by the village leader in the Village Survey. At the very least, the trends over time were the same.

[2] 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. The second buyers are those to whom first-level buyers sell. This represents the first and second link in the marketing chains when starting from the dairy.

Because of our interest in dairy production, after the Household Survey's villages were chosen, we also returned to the rest of the villages that had dairy production (this included those that had been randomly selected as part of the 50 and all other villages that reported having farmers who owned dairy cows). The household-level data in the dairy villages from the Household Survey were used to supplement the village-level data from the Village Survey. Hence, for this study, we divided all 200 villages into two groups, dairy villages (there were 25 of them) and non-dairy villages (175).

After the 25 sample dairy villages were chosen, we randomly selected cow and no-cow households as follows. First, all households in each village were divided into two groups based on whether or not they raised cows. In the most common dairy village (i.e., those having more than seven dairy producers), we randomly selected ten households from each village, of which seven households had dairy cows and three households did not have dairy cows. If there were fewer than seven dairy households in the whole village, all of the dairy households were included in our survey. In villages where there were more than 50 dairy households, the sample size was doubled from 10 to 20 and we surveyed 14 dairy households and 6 non-dairy households. In the final analysis, in the 25 dairy villages, we surveyed a total of 145 dairy households and 95 non-dairy households. The household survey for the dairy households covered a large number of details about the history and current production of each household's dairy activities.

The final survey was done to elicit information about the dairy processing sector. To collect the data, we first made a complete list of the dairy processing firms in Beijing. In total, there were 56 firms. The addresses of the firms in the Greater Beijing Area came from Liu (2004). We called each of these firms and collected

information on the dates that each firm was established, its scale of production and the exact details of its location. Then we located each of the 56 firms on an administrative map and plotted them in relation to each of our 25 dairy villages. Finally, we used GIS technology to compute the distance (by road) between each village and the nearest dairy processing firm. We also used the information to calculate the total daily capacity of dairy processing in the firms within 30 kilometers of each village.

Producing and Processing Dairy Products

In this section, we analyze the trend of dairy participation by households in the sample villages in Greater Beijing. Then 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 in only 18 villages raised milk cows in 2000, accounting for 9 percent of all villages (Table 1, row 1). By 2004, farmers in 25 villages were engaged in dairy production, an increase of seven villages (or 37 percent increase).

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 percent, were producing milk. By 2004, however, there were 140, almost double that of 2000. Using our data to estimate overall participation rates in the 25 dairy villages, we found that the participation rates rose from 5.5 to 7.0 percent (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

rise 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 allowed us to see that the rise in dairy production after 2000 actually appeared to be accelerating 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 were producing milk before 1990. The total number of cows in the entire sample was only 3 percent 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 percent of the total number that were producing in 2004. This, of course, means that a majority of dairy farmers in 2004 (100 of them) entered between 2000 and 2004.

Although the intensity of milk production was rising—and the average herd size was expanding—the scale of farms was still small. According to our intensive household survey, 70 percent of the total number of dairy households (101/145) owned and milked five or fewer cows in 2004 (Table 1, column 2, rows 4 and 5). Only six of all households in our sample (145 households) were raising 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 percent of the total number of cows in our sample.

Moreover, looking back over time, it is clear that by 2004 there still was not an evident trend that herd size was increasing. For instance, among households who started breeding milk cows between 2000 and 2004, the average herd size in 2004 was only 5.7 milk cows. This level is lower than the average of those who started breeding in the 1990s (6.7 milk cows) and prior to the 1990s (7.3 milk cows) (Table 2, last row).

Among the 100 households who started breeding milk cows from 2000 to 2004, 75 households (accounting for 75 percent of new milk cow households in this period) bred five or fewer milk cows (Table 2 row 2, column 5 and column 6). Even though the reason that new entrants had smaller herds was they had not yet had time to build up their herds, those who had been in the dairy production business longer still were not increasing their herd sizes dramatically. The most accurate description of Greater Beijing's dairy production sector by the mid-2000s is that, while growing in its total production capacity, it was small in scale and there were no immediate signs of a rapid increase.

Beijing's Dairy Processing Sector

Ever 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). Presently, there are 56 dairy processing enterprises in the region (row 1). Prior to 1990, however, there were only nine processors. The growth of the processing sector is rising at a rate similar to that of the production sector.

Judging from the daily capacities to process fresh milk, the processing firms in Greater Beijing are mostly small to medium in scale (Table 3, column 1, row 6). On average, the 56 processing firms in our sample were capable of processing 189 tons of milk per day, compared to 500-1,000 tons per day in the U.S.[3] Clearly this is a sector with small-scale processors.

As in dairy production, there is also no evidence that the scale in the processing sector was rising (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

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

fresh milk per day. While the daily processing capacity had risen in the case of processors established between 1990 and 1999 to 227 tons per day, 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—accounted for most of the production of those plants that opened before 1990. The smallest firms accounted for 67 percent of the total dairy processing enterprises of these firms (Table 3, rows 2 to 5). The number rose to 89 percent of the total dairy processing enterprise when smaller medium-sized enterprises (those with production capacity of between 100 to 299 tons per day) were added to small-sized processors. There was only one enterprise started before the 1990s that had a daily treatment scale between 300 and 500 tons, and it accounted for 11 percent of production from these early emerging plants.

After 1990 the processing capacity of these enterprises expanded, but enterprises with a daily treatment scale of less than 100 tons and newly added enterprises with a daily treatment scale of less than 100–299 tons still accounted for more than half of production (respectively 36 and 27 percent—Table 3, column 3). Moreover, for dairy processing enterprises starting between 2000 and 2004, the number of firms with a smaller production capacity had risen again (column 4). Among all processors starting between 2000 and 2004, enterprises with daily capacity limits of less than 100 tons and between 100 and 299 tons accounted for 80 percent of the 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 (originally) state-owned. In most of the 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 the newly emerging firms mostly private but also many of the original firms that were owned by the state have been privatized (Zhao, 2004).

Even after the nature of ownership began to change in the 1990s, the government still took actions to support the development of the sector. General investment efforts into roads, communications and other improvements in the marketing infrastructure absorbed large volumes of government investment (Luo et al., 2006). Since 1988, the government has also pushed an investment effort called the "Vegetable Basket Project." Implemented by the Ministry of Agriculture, enterprises, including those in dairy processing, have been able to enjoy various preferential policies of local governments. Firms participating in major government programs are often granted land-use fee exemptions and get access to grants and loans from special funding sources (Beijing Rural Work Committee, 2001).

Linkages between Farm and Processor

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 in Tables 2 and 3, 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 (Table 2 and Table 3). In the 1980s there was little activity in either dairy production or dairy processing. 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, dairy production accelerated.

Looking at the data in another way, we can see even more clearly that the development of dairy processing firms was positively correlated with the expansion of household milk production (Table 4). To examine this question, we first divided the 25 dairy villages into two groups. The first group contained villages in which there was a dairy processing firm within 30 kilometers of the village with a lag of three years (i.e., in 1997 or 2001). The second group contained villages in which there was no dairy processing firm in either 1997 or 2001 (three years before the period in which we will examine dairy production within the villages). 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 demonstrated that in 2000 the sizes of dairy herds in villages that were near processors were 4.5 larger than the sizes of herds in villages that were not near processors (3.4). In 2004 the same pattern held; the sizes of dairy herds in villages with processors nearby were much larger (7.7) than those in villages that were not near processors (3.6). The same pattern held with respect to the number of households that raised dairy cows. The increase of the percentage of household that raised 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 with dairy cows and those without. For example, Table 5 demonstrates that households with cows, on average, lived within 35.1 kilometers of a processing firm (row 1). At the same time, households without cows lived 40.5 kilometers away. In addition, the capacities of processing firms were larger (160 tons) in villages that were within 30 kilometers of a processor than those of firms in villages that were further away (110 tons—Table 5, row 2).

Other Basic Characteristics of Milk Cow Households

While it appears that the nature of the emergence of the dairy processing firm is correlated with the propensity of households to produce milk, there are also other fundamental differences between dairy and non-dairy 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 percent) than in non-dairy households (37.6 percent—row 6). Cultivated land per capita, in contrast, was a bit higher for dairy households (2.1 mu versus 1.9 mu—row 7). The distance from the village center to the nearest road was more favorable for dairy villages (0.8 kilometers) than for non-dairy villages (1.5 kilometers). Interestingly, differences between the age, education, and demographic structure of dairy households and non-dairy households were relatively small (Table 5, row 3 to 5).

Judging from the discussion in the sections above, it is not unreasonable to believe that the rapid growth of household dairy production in recent years is closely related with the development of the dairy processing industry. In other words, there is at least some evidence that because of low production and the slow emergence of the dairy industry, China's dairy demand was low. However, as the discussion in this section demonstrates, there are also other factors that may have affected household dairy production. Therefore, based on the descriptive data, it is impossible to draw conclusions about the relationships between processing and production. Therefore, a quantitative analysis of the influence of the development of dairy processing on household milk production is needed.

Econometric Models and Estimation

To examine what factors determine whether or not farmers participate in dairy production, first a probit model was set up. Then, to investigate how factors affect a household's herd size, a Tobit model was used.

The probit model was set up as

$$\Pr ob(Y_{ijt} = 1 \mid x_{ijt}) = \Phi(x_{ijt}'\alpha)$$

where Y_{ijt} (capital Y) is a dummy variable indicating whether the i^{th} household living in the j^{th} village at time period t participated (Y_{ijt}=1) or not ((Y_{ijt}=0); and x_{ijt} is a vector of explanatory variables for the i^{th} household who lived in the j^{th} 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 within 30 kilometers of village j in 1997 (when t=2000) or 2001 (when t=2004).[4] 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 roadway. 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 per

[4] 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 precise interpretation of our results are measuring whether the appearance of dairy processors in 1997 (2001) affected the emergence of household dairy production in 2000 (2004). We have chosen to use 30 kilometers 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 kilometers (although they often do). To test the sensitivity of our results to the choice of a 30 kilometer cutoff, in our analyses we also utilize 10 km, 15 km and 20 kilometers in alternative runs of the model. Although estimated coefficients on the P variable differ when different cutoff distances are used, in general the major conclusions are the same. Therefore, in the rest of the paper we only report those results from the model using the 30 kilometer definition.

capita in yuan); householder's age (in years); education level (in years); cultivated land per capita (in mu per capita); share of household members that are in the labor force; and share of household members that are in the labor force that have jobs in the off-farm labor market. α are estimated parameters.

The Tobit model is a well-known econometric regression model used in the presence of censored data. Define y_{ijt} (small case y) as the censored 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

$$y_{ijt} = \begin{cases} 0 \text{ if } y^*_{ijt} \le 0 \\ y^*_{ijt} \text{ if } y^*_{ijt} > 0 \end{cases}$$

And the latent variable is described by

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

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 matrix 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).

In regression analysis, because of the way that we chose our sample, we want to weight each of our observations to make sure that we have results that are representative of the Greater Beijing region. Therefore, we need to specify a sampling weight for each sample observation to make the contribution of the observation to the estimated coefficient correspond with the importance of the observations in terms of the share of the sample that it is representing. Specifically, the weight for i^{th} dairy households from j^{th} 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 $W_{ij} = S_j^* (1-M_j)/b_j$, where S_j represents the share of total households in the 25 dairy villages that were in the j^{th} village; M_j is the share of dairy households in the j^{th} village; and a_j and b_j, respectively, represent the number of randomly sampled dairy households and non-dairy 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 non-dairy 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 zero dairy cows in 2000 and 95 households with zero dairy cows in 2004. Since the standard version of the Tobit model cannot account for the different weights attached to the different observations, we need to use a special form of the Tobit—a Weighted Tobit model. In the rest of the analysis, parameters that are estimated from a Weighted Tobit model will be 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 need to estimate marginal effects in the Tobit model. The estimation was conducted using Stata and an interval regression approach that allows us to use our p-weighted observations in estimating the Tobit model.

Estimation Results

The results from our empirical estimation (with coefficients reported as marginal impacts—equation 3) demonstrate that our modeling efforts performed quite well (Table 6). The signs of many of the control variables were consistent with expectations. For example, the coefficient on the variable for the age of the household head was negative and highly statistically significant (row 4). Ceteris paribus, those households with younger people heading them were more likely to have been

participating in dairy farming. This may be so since dairying is an activity that requires skills and strength more suitable to younger farmers. The sign on the 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 that are not committed to working off the farm and/or outside of the village as wage earners or as self-employed individuals clearly are more likely to enter the dairy sector. This result was similar to results found in Huang et al. (2007), which found that there was a negative and significant trade-off between off-farm employment and participation in the horticultural sector, another labor-intensive enterprise.

The most striking result—and important, given our objective—was seen by examining the effect of the rise of dairy processing on the decision of households 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 were positive and significant in the equations, regardless of the definition of the dependent variable. In Greater Beijing in 1997 (2001), if there was already a dairy processor that was built within 30 kilometers of the village, the probability of participating in the dairy industry in 2000 (2004) rose by 1.5 percent (column 1). Likewise, having a dairy processor within 30 kilometers in 1997 (2001) increased the average herd size by 2.198 cows in 2000 (2004). The role of processing in stimulating the dairy sector is clear from this analysis.

Using the alternative measure of proximity of the households to dairy processing, we found a similar result (Table 6, row 2, columns 2 and 4). When looking at participation, as the distance of a household to a processor fell, the likelihood of participation in the dairy sector rose. According to our results, for each 10 kilometers closer, the probability of participation increased by 1 percent. Similarly,

as the distance to the processor declined, the herd size rose. Access to dairy processing in the locality has been critical to the rise of the dairy producing sector.

While less strong, (and after controlling for the effects of the location of the dairy processor), our results also showed that access to roads (and generally better transportation) positively affected the dairy sector (Table 6, row 3). In all four equations, the sign on the coefficient of the variable for distance from the village to the nearest paved roadway was negative. The point estimates of these estimated coefficients suggest that better access to roads (making the distance shorter) increased participation and increased herd size. The coefficient on the variable for distance to road was statistically significant in the equations in columns 2 and 4, the models that used the distance from household to dairy processor (measured in kilometers) as the proxy for the 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 was clear that the nature of China's dairy sector was not excluding poor or uneducated households or those that are endowed with small land holdings (Table 6, rows 5, 8 and 9). The coefficients on the variable for household head's education, the variable for household's cultivated land per capita and the variable for household's asset per capita were 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 had been allocated little land were equally able to participate in dairy production (and 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 showed the *relative importance* of the rise of the dairy processing sector in the household's participation and herd size decisions. To show this, we decomposed the change in participation rates and herd size between 2000 and 2004. The analysis, which is described in detail in the footnote to Table 7, essentially estimated how much each factor (dairy processing; distance to road; rise of off-farm labor) contributed to the overall change in the dependent variables (participation/herd size) by multiplying the estimated 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) was then compared to the total change in participation (herd size), and we were able to assess which determinants were most important. We used the estimates from Table 6, columns 2 and 4, since it was in these estimated models that the coefficients of both the variable for access to dairy processing and the variable for access to roads were significantly different from zero.

According to the decomposition analysis, dairy processing was 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 percent between 2000 and 2004—see Table 1, row 9), by far the most important factor was the rise of the processing industry. In fact, if nothing else had changed, our analysis suggested that increasing access to dairy processors could explain 123 percent of the rise in dairy production. In other words, had no other factors changed, participation in dairy production by households would have risen 1.91 percentage points because of better

access to processors (the average distance to the processor fell by 19 kilometers between 2000 and 2004) instead of only 1.55 percentage points.

The relative importance of the rise of the dairy processing sector was reinforced when 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 was 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 kilometers) was smaller (58 percent) than that of the emergence of processors (123 percent). So, while the rise of roads was an important factor, it was 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 percent. Other factors (bundled into the residual) also dampened the ability/willingness of households to participate in dairy production by 74 percent. If it had not been for these other factors, dairy production would have increased by upwards of 1 percent more (0.77 times 1.55). Although we cannot identify exactly what these factors are, our field research suggests that there were other constraints to entering dairy production. This suggests that further survey-based research would be merited to identify such factors.

Similar findings appeared when decomposing the rise in herd size (Table 7). Regardless of whether we were trying to explain the increase in herd size of dairy producers (from 3.75 to 5.48 cows) or whether we were trying to explain the increase in the herd size of all households (from 0.21 to 0.39 cows), the emergence of dairy processing was the most important determinant. It explained 16 percent of the rise of herd size among dairy producers (columns 4 to 6, row 1). Dairy processing explained 74 percent 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 was measured, their relative importance was smaller than that of dairy processing.

Conclusions and Policy Implications

This paper mainly analyzes the impact of the emergence of the dairy processing industry on the decision of households to raise dairy cows and expand herd size in Greater Beijing. By utilizing statistical data from surveys on the development of the dairy processing industry and the growth of the dairy cow inventories held by farmers, our study shows that the pattern of the rise and spread of the dairy processing sector has an important effect on the production decisions of households. While we show that many factors affect the decision to participate in the production sector and expand herd size, the results indicate that the development of the dairy processing industry is the most important factor that stimulates local farmers to enter the dairy production sector. Moreover, our results show that this pattern of the development of the processing sector does not exclude poor farmers. Both poor and rich farmers are able to take advantage of opportunities to enter the dairy production sector when a dairy processing firm appears in the area 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 that do not have processing firms, the farmers in the area, including poor farmers, 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 demand and do so with the help of small, relatively poor domestic producers.

While the goals of the paper were ambitious and the findings of interest, we need to remind the reader of the limits of our analysis. First, the results in this study are based on data that comes only from the Greater Beijing area. To achieve our goal we had to conduct three comprehensive surveys on our own—an effort that precluded us from moving into other regions. While we examined all producers in the region, our sampling methods did not discover any truly large dairies. In fact, there are such large commercial dairies in China. Our sampling approach, however, did not find any of them. While we do not know why we did not find any (perhaps because there are so few), the dynamics in large commercial firms (and dairies in other areas) quite possibly could be quite different from those reported in this study.

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Table 1. Characteristics of Sample Villages and Households in Greater Beijing.

	2000	2004
Number of sample villages with milk cows	18	25
Household samples in 25 villages with cows in 2004:		
-- Number of sample households	240	240
Number of households without cows	166	95
Number of households with cows	74	145
-- Number of households by cows numbers:		
≤ 5 cows/households	62	101
6-10 cows/households	8	28
11-19 cows/households	2	10
≥ 20 cows/households	2	6
Characteristics of households and villages:		
Share of households raising cow (%)	5.49	7.04
Average cow numbers per household with cows	3.75	5.48
Average cow numbers per household for all households	0.21	0.39
Distance from the nearest dairy processing firms $(km)_{t-3}$	51.6	32.6
Daily capacity of dairy processing firms within 30 km of the villages (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 labor in total populations (%)	64.5	72.1
Per capita cultivated land (Mu/person)	1.8	1.7

Note: Among 200 villages surveyed, there were 25 villages with milk cows in 2004. All data presented in Table 1 are statistics in 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 to lag for 3 years. All figures are weighted averages.

Data source: Author's Survey.

Table 2. Number of Households with Milk Cows and Average Number of Cows per Household in Greater Beijing in 2004.

	Households started raising cows:		
	Before 1990	In 1990-1999	In 2000-2004
Number of households	4	41	100
- with less than 5 cows	2	24	75
- with 6-10 cows	1	8	19
- with 11-19 cows	1	8	1
- with more than 20 cows	0	1	5
Number of cows per household	7.3	6.7	5.7

Source：Author's survey based on investigation of milk cow households in 25 milk cow villages in Greater Beijing.

Table 3. Numbers and Production Capacity of Dairy Processing Firms in the Greater Beijing in 2004.

	Total	Firms established:		
		Before 1990	In1990-1999	In 2000-2004
Numbers of firms	56	9	22	25
Numbers of firms by production capacities				
<100 ton/day	25	6	7	12
100-299 ton/day	16	2	8	8
300-500 ton/day	13	1	6	4
1500-1800 ton/day	2	0	1	1
Average daily processing capacities (ton/day)	189	94	227	190

Source: Author's survey.

Table 4. Relationship Between Milk-Cow-Breeding Households and Dairy Processing Enterprises of 25 Milk-Cow-Breeding Villages in Greater Beijing.

	Number of households with cows	Villages with dairy processing firms Within 30 km in 3 years ago		Villages without dairy processing firms within 30 km in 3 years ago	
		Average number of cows per household	Percentage of households with cow (%)	Average number of cows per household	Percentage of households with cow (%)
2000	74	4.5	2.0	3.4	3.8
2004	145	7.7	9.2	3.6	3.5
Average	109.5	6.7	6.4	3.5	3.7

Source：Author's survey.

Table 5. Characteristics of Households With and Without Cows in 2000–2004.

	Households with cow	Households without cows
Distance to nearest dairy processing firms 3 years ago (km)	35.1	40.5
Daily processing capacity of firms within 30 km 3 years ago (hundred tons)	1.6	1.1
Household head age (years)	43.5	45.9
Household head education (years)	6.8	6.6
Percentage of labor in total populations (%)	72.5	69.3
Percentage of off-farm labor in total labor (%)	25.7	37.6
Cultivated land per capita (mu/person)	2.1	1.9
Assets per capita in 2000 (yuan/person)	10557	9759
Distance from village to nearest road way (km)	0.8	1.5

Table 6. Determinants of Raising Cows in Greater Beijing.

	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 way (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 populations (%)	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

Note: The models are estimated based on panel data of 240 farmers in 2000 and 2004. ***, ** and * represent statistically significant at 1%, 5% and 10%, respectively. When probit model is used, dependent variable is one or zero.

Table 7. Decomposition Analysis of Major Factors Affecting Raising Milk Cows in 2000–2004.

	1. Participation			2. Number of cows for cow households			Average number of cows for all households		
	Coeffi-cient	Change in level	% change due to:	Coeffi-cient	Change in level	% change due to:	Coeffi-cient	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

Note: 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 $d2 = \partial Ey/\partial x_t = F(z)\beta$, respectively. Percentage change due to each factor is computed as (coefficient*change in level)/total change of explained variable. Total changing data of explained variable is listed in the last row. Changing data of explanatory variables and explained variables are from Table 1.