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Supply Chain Issues in China's Milk Adulteration Incident¹

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Abstract

China's melamine milk adulteration crisis highlights the challenges that arise as large well-capitalized companies procure raw materials from a diffused supply chain of scattered small farmers and milk collection stations. As milk prices climbed sharply in 2007 and companies branched out into new territories, intense competition for raw milk supplies strengthened incentives to water down and adulterate milk. Effective food safety measures must account for incentives, the distribution of market power in the supply chain and market dynamics.

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Introduction

Until 2008, the dairy industry seemed to be a bright spot in Chinese agriculture. Milk output grew four-fold from 2000 to 2007, and the sector seemed to have found innovative ways to integrate scattered small-scale farmers into modern supply chains. But the industry's profile changed in September 2008 when infant formula sold by the most prominent dairy companies was found to contain melamine, an industrial chemical high in nitrogen introduced to artificially raise the protein content in testing. Investigations revealed that melamine, urea, vegetable protein, and other "protein powders" were routinely added to raw milk, a practice that had been an open secret in the industry for some time (Barboza and Barrioneuvo). The source of adulteration could not be precisely established, but blame was generally placed on operators of village milk supply stations, traders and truck drivers who delivered milk to processing plants.

The milk powder incident exposes some of the stresses created by the industry's rapid growth. Hundreds of companies had to develop supply chains to procure large quantities of milk. Most companies have modern processing plants with internationally-recognized safety management systems in place, but they rely on supply chains that include a network of traders, village milk supply stations and over 2 million small farmers in some of China's most remote and least-developed regions. The reliance on small-scale independent farmers and traders reduces costs and increases flexibility, but sacrifices control over monitoring, quality assurance, and standardization of products (Lohmar et al.). As milk and feed prices soared in 2007, intense competition among companies for limited raw milk supplies increased incentives to water down and adulterate milk.

The complex web of factors behind the melamine incident should be studied carefully in order to better understand its causes, and to gain a better understanding of China's agri-food development and food safety challenges. This paper describes how dairy companies built supply chains based on small farms and milk collection stations and how a scramble for raw milk supplies may have contributed to the melamine incident. Our discussion is based on a variety of published and unpublished data and an extensive review of industry reports and news articles. The paper

provides background for further investigations and explorations that will lead to a deeper understanding of the problems and effective long-term strategies and measures.

Dairy Companies Branch Out Geographically

Historically, low consumption of milk in China reflected the scarcity of pasture, hay and cattle in the densely-populated regions of central and eastern China. During the decades of centrally-planned economy (roughly 1958-78), city milk supplies came from state-owned and collective farms on the outskirts of metropolitan areas. Milk was consumed mainly by infants and elderly people, and per capita consumption remained low until the 1990s.

Several factors converged in the late 1990s to fuel growth in China's dairy sector (Fuller, et al; Hu et al.):

- Urban households sought to diversify their diets as their incomes rose.
- Subsidies for milk consumed in school cafeterias were introduced in 2001 to address nutrition concerns.
- Rapid development of modern retail--supermarkets, hypermarkets, and convenience stores—that became the main marketing channel for dairy products.
- Introduction of UHT (ultra-high temperature) technology allowed interregional transport and extended shelf-life of fluid milk products.
- Domestic and overseas investments in the dairy industry created a cadre of well-funded dairy companies.
- Local officials seeking rural development opportunities in remote regions encouraged companies to develop supply networks among small farmers.

Milk production rose from just over 1 million metric tons in 1980 to over 35 million metric tons in 2007. China's 11th 5-year plan set ambitious targets for milk production of 57.3 mmt in 2020.

Geography plays a key role in China's dairy industry. Milk production is concentrated in northern and western China, where grasslands are plentiful, cool temperatures are conducive to

dairy production, and pastoral ethnic minorities have historically produced milk.² But these regions were not engaged in commercial supply chains until the emergence of UHT milk facilitated long-distance milk trade. Under central planning, fresh milk was supplied to cities mainly by State- and collective-owned farms on the outskirts of cities. Some of the commercial milk companies evolved from the earlier centrally-planned city milk-marketing bureaus. Other companies were established through a combination of private equity, local government sponsorship, capital raised through stock market listings, and foreign investment.

The recent development of the dairy industry has been characterized by hundreds of dairy companies branching out geographically from their home province or city to gain greater retail market share and to expand their milk supply base. In 2006, four big dairy companies—Yili, Mengniu, Sanlu, and Bright—accounted for nearly half of dairy sales in 2006 (fig.1). More than 700 companies split the other half of dairy sales. Some companies with small national market shares are still dominant in their home city or province. Bright Group (Guangming), the early leader in the industry, began as a state-owned milk supplier for Shanghai. Two other companies have emerged from Inner Mongolia. Yili, now China's largest dairy company, began in the 1980s as a local food processing company in Inner Mongolia, and Mengniu was established in 1999 when a group from Yili formed its own company. Other major players are identified with a specific home base. Wandashan is based in Heilongjiang and Sanlu is based in Hebei, both northern agricultural provinces with abundant feed resources. Several provincial and city governments in northern China made the dairy sector a focus of local economic development.

There is fierce competition among companies as they branch out to new regions and products and battle for national market share. Yili and Mengniu expanded aggressively after receiving infusions of capital from listing on the Shanghai and Hong Kong stock exchanges. Bright was the largest dairy company in 2003, but it has now fallen to fourth-largest as other companies expanded aggressively. With a strategy of “utilizing nationwide resources to serve a national market,” Bright is pushing fresh milk capacity into other markets by opening local plants all over the country, including the home bases of its competitors in North China. Mengniu and Yili are

² Dual-purpose cattle raised for milk and meat are central to the traditional diet of Tibetan, Mongol, and Uighur ethnic minorities in Tibet, western Sichuan, Inner Mongolia, and Xinjiang regions.

attempting to broaden market penetration of UHT fluid milk in other cities. Many of the companies have sought to develop supply networks in the northern provinces that have relatively abundant feed resources and low production costs.

Supplier Networks of Small Farms

The boom in production came by sourcing raw milk from small farms in China's northern hinterland. The capacity of dairy processors to expand raw milk output near cities was constrained by rising competition for land and labor and lack of feed resources in peri-urban areas. Northern provinces have abundant land occupied by small farmers eager to supply milk that yields a regular monthly stream of cash income. Small farmers produce at relatively low cost because they can utilize self-produced grain and forage gathered with unpaid family labor. With fierce competition and pressure to cut costs, companies ventured deep into rural China to procure milk from millions of scattered small farmers raising 1 to 20 cows. Three regions have been main centers of growth in dairy production: Inner Mongolia, Heilongjiang and Hebei Province. In 2006, these three regions accounted for 52% of China's milk production, up from 16% in 1995.

The Sanlu Company devised the small-farm procurement strategy in Hebei Province during the 1980s, providing cows and technical advice to farmers who paid off loans in milk. In some villages a piece of land is set aside as a "dairy production zone" (*yangzhi xiaoqu*) where cows are centrally housed and milked. Local governments provided land and other support for establishing supply chains, including the building of milk supply stations and logistics centers to collect milk from small farmers. Other companies adopted this small-farm supplier model. Some companies signed contracts with farmers that specified the sale price for raw milk.³

In 2006, dairy industry statistics estimate that about 60 percent of milk was produced by farms with 20 or fewer cows, including 35 percent produced by farms with 1-5 cows (fig.2). Large farms with over 500 cows account for a significant 9-percent share of production but small

³ Regression analysis of 180 small dairy farms in Inner Mongolia by Zhu found that farms with a marketing contract had significantly higher net income than other farms.

farmers are clearly the dominant suppliers of raw milk. Data from China's 2nd agricultural census shows that 87 percent of dairy cattle were held by nearly 2.8 million household-operated farms in 2006. A significant share of cattle is held by nonhousehold farms--enterprises, state farms, collectives, and institutional farms—which account for 13 percent of dairy cattle. The average number of dairy cattle held by household dairy farms was 5 head (compared with 336 for nonhousehold farms).

The low costs of small producers keep most production on small scale farms. When asked why his Shanghai-based company sourced milk in Heilongjiang, the CEO of Bright Dairy said that the company cut costs by 10-20% by procuring milk from areas where feed resources are more abundant (Sohu.com). Li et al. found that the highest milk prices were paid to large farms, followed by village production zones, and backyard farms were paid the lowest price. According to data from production cost surveys conducted by the National Development and Reform Commission (NDRC), unit production costs of large scale farms were about 20 percent higher than those of small-scale and “backyard” farms. In 2006, the average unit production cost of milk calculated from NDRC data was highest on large-scale farms at 1.94 yuan/kg and lowest on small-scale farms at 1.53 yuan/kg (fig.3). “Backyard” farms had cost of 1.64 yuan/kg., slightly above the average for small-scale farms.⁴ The average unit price (value of milk per kg) reflects differences in costs. The unit price paid to large scale farms is about 15 percent higher than the unit price paid to small-scale farms.

The difference in cost in the NDRC data comes mainly from two components: fodder and hired labor. “Backyard” and small-scale farms engage family laborers to collect wild grasses, crop residues from their fields, and other inexpensive sources of fodder; larger scale farms have to purchase fodder at market prices (Zhu Juan). Consequently, the “backyard” and small-scale farm fodder component of milk unit costs is about half that of medium- and large-scale farms. Interestingly, the cost of concentrate feed (grains and commercial feeds) is similar for farms of all scales. Small-scale and “backyard” farms almost exclusively use (unpaid) family labor for which there is no cash outlay. Medium- and large-scale farms use hired labor which does require

⁴ The National Development and Reform Commission does not publish standard errors for their cost of production estimates, so there is no way to assess whether the differences are statistically significant.

cash payment. Hired labor cost per kg of milk output averaged 0.19 yuan/kg for medium- and large-scale farms, 0.07 yuan/kg for small-scale farms, and was negligible for “backyard” farms.

Initially, dairy companies sent milk trucks to collect raw milk from villages, but later companies built milk supply stations in central locations to collect milk. Some stations have milking facilities while others collect milk from individual farmers or village milking facilities.

Anecdotal reports in 2008 indicate that a variety of marketing arrangements now exist, including modern vertically-integrated farms, village milking facilities, and farmers milking their own cows using buckets. Zhang et al. (April 2008) reported that over half of milking was mechanized, but milking by hand was still prevalent in most parts of the country. Sometimes there are two levels of stations: intermediary milk stations consolidate milk from village stations before sending it to the processor. Zhang et al. (July 2008) reported that a county in Hebei Province had 92,000 dairy cows, 154 milking facilities, and 210 milk stations.

In order to cut costs, some companies turned the milk stations over to be operated by hired managers instead of managing them directly. Zhang et al. (April 2008) reported that 55% of milk stations are individually owned, 23% were located in animal husbandry zones, 16% of were directly operated by companies, and 7% had other types of ownership. Li et al.’s survey of Heilongjiang in 2008 found that some milk stations were built by the operator and others were joint ventures in which the milking equipment and tanks were supplied by the processing company while the building and other equipment were provided by the operator. Independent station managers are under pressure to recover large investments in facilities and equipment and to maintain cash flow from milk procurement. Li et al. report that milk station costs include construction, equipment, maintenance, water and utilities, fuel, water treatment, and labor. News reports indicate the cost of building a milk station is in the range of 500,000 to 1 million yuan.

Li et al.’s 2008 survey found that milk prices for both independently-operated and jointly-operated stations were set by the processors. The station received a set fee of 0.17 yuan/kg that was independent of the milk price. The Zhang et al. (July 2008) study in Hebei found that few lower-level stations had contracts or firm agreements with processors. Intermediate stations had contracts that specified milk payments and quality standards. Zhang et al. (July 2008) reported

that the profit for lower-level milk stations was generally 0.1 yuan/kg, and the profit for intermediate stations was .04-.05 yuan/kg. (the volume handled by intermediate stations was much larger.)

A tangled network of traders, agents, and truck drivers sprang up as intermediaries between the milk station and the processor. Xu describes a pyramid-like structure of agents that procure milk from village milking stations and pass it to a higher-level trader who consolidates the milk and transports it to a processing plant. Xu also describes geographic fiefdoms ruled by “the law of the jungle,” illustrated with an incident in which traders from another county were physically assaulted when they came to a county in Shaanxi province to procure milk.

Supply Chain Cost-Price Squeeze

The competition was fierce at all stages of the supply chain, and the market dynamics at different levels were at times out of sync. Rapid expansion and fierce competition in consumer markets pushed down retail prices in the early 2000s. Lower prices were transmitted back to the raw milk stage of the chain, inducing farmers to cull cows in 2005-06. The reduced production capacity set the stage for a rapid increase in prices during 2007-08 when demand growth picked up and rising international milk and feed prices were transmitted to China. Retail prices shot up in the second half of 2007. With robust demand, companies competed for scarce milk supplies.

The industry’s rapid expansion during 2003-06 set the stage for crisis in 2007-08. China’s milk output increased about 150% during that period, and the rapid increase in supply kept milk prices from rising despite surging demand. The retail price fluctuated around 4.8 yuan/kg in 2003 and fell to 4.24 yuan/kg in 2006 (fig.4). Gong describes how intensified competition during 2005 led to price-cutting. By one estimate, the industry’s excess processing capacity was 30% in 2002 (Fang Yousheng, 2003). The National Development and Reform Commission’s (NDRC, 2008) dairy development plan noted excess capacity and “blind expansion” as problems in the industry. In contrast to stagnant or declining domestic product prices, the average unit value of imported milk products was rising during this period.

Downward pressure on prices was transmitted back through the supply chain to farmers. The NDRC cost of production surveys show that the average milk price received by small farmers remained nearly constant from 2002 to 2006, fluctuating between 1.75 and 1.80 yuan/kg, while the unit cost of production materials (primarily feed) rose (fig.5). News reports indicate the farm price fell as low as 1.2-1.4 yuan/kg in 2006, inducing many farmers to slaughter their cattle that year. News reports describe widespread abandonment of dairy production in villages due to poor profits (Yangzhi Net; Xu).

In 2007, international milk and grain prices began rising at the same time China's economic growth accelerated (GDP growth was 13% in 2007). A rapid rise in the price of imported milk products in early 2007 was followed by a sharp increase in domestic milk prices in the second half of that year, and imports fell. Chinese companies typically sell their products mainly in the domestic market, but they began ramping up export sales to take advantage of high international prices, adding to the demand for milk.⁵ According to China customs statistics, China's exports of milk products doubled in 2007. Moreover, feed costs were rising, and production in northern China was in its seasonal low during the winter months. Milk demand continued growing, and retail prices rose steadily in late 2007.

Companies competed to buy milk from a limited pool of producers in a "scramble for milk" that caused prices to shoot up during August 2007-January 2008. Gong notes that Sanlu at first had a near monopsony as a milk purchaser in Hebei Province, but as more companies entered the market processing capacity in the province grew beyond the province's supply of raw milk. Fuller, et al. (in an earlier period) described how processors competed for existing farm supplier networks as they sought to utilize newly built plants. Zhang et al. (July 2008) noted that there was fierce competition among milk stations for control of milk supplies and recommended greater government supervision to prevent competition from getting out of hand (this was before the melamine crisis came to light). The county they studied was near the home base of Sanlu Company, but Yili, Mengniu, and other companies also operated distribution centers and procured milk in the county.

⁵ In a report on the January 2008 "China Dairy Industry Development Summit" the chairman of the China Dairy Industry Association cited increased exports of milk powder as a factor inducing hundreds of idle milk processors to resume production.

Industry data indicate that raw milk prices more than doubled from 1.2-1.4 yuan/kg in 2006 to 2.4-2.6 yuan/kg in 2007. Li et al. reported that prices received by Heilongjiang milk producers in March 2008 were up 42% from a year earlier. The average retail milk price climbed 45% from July 2007 to July 2008.

The worldwide increase in commodity prices also pushed up feed prices and producer costs. A weighted average of corn, soymeal, and wheat bran prices for Inner Mongolia indicates a long-term rising trend in feed costs from about 1.2 yuan/kg. in early 2000 to 2.5 yuan in 2008 (fig.6), but the sharpest and most sustained increase occurred from late 2006 through 2008. China's government became so concerned about rising retail milk prices and widespread losses of dairy farmers that it expanded subsidies for breeding cattle and insurance for dairy farmers in October 2007. In 2008, a temporary price control measure was instituted that required large dairy companies to request permission from the National Development and Reform Commission before raising milk product prices.

Figure 5 shows that the farm milk price rose more than the feed cost in 2007, increasing the profit margin by about 0.1 yuan/kg. Price data from Inner Mongolia indicate that farmers began to experience a price-cost squeeze during 2008, coinciding with the period when the melamine contamination apparently became more widespread. Figure 7 shows the weekly average farm milk price, weighted average of Inner Mongolia feed prices from the Animal Husbandry and Veterinary net, and the average national retail milk price for January-September 2008.⁶ The retail price of milk continued rising through the first four months of 2008 until it plateaued at under 6.8 yuan/kg. The farm price in Inner Mongolia rose to about 3 yuan/kg and stayed at that level from March to May. Then the farm price fell in June and July and continued to fall gradually until early September. However, feed prices continued to drift upward throughout 2008, clearly indicating rising producer costs and declining revenues. Raw milk prices started falling in May-June 2008, as milk production reached its seasonal peak, consumption reached a seasonal

⁶ The Animal Husbandry and Veterinary net began publishing weekly milk prices in 2008 as part of its livestock and feed price reports (milk prices were not reported in previous years). The National Development and Reform Commission China Price Center reported an average national retail milk price for each 10-day period for 2008.

lull, and economic growth slowed. There were also reports of an increase in seemingly arbitrary rejections of farmers' milk by processors during this period as they scaled back procurement.

Melamine Adulteration Issues

Melamine and other "protein powders" were added to watered-down milk to increase its apparent protein content. One journalist described what a rural milk merchant routinely added to a 10-ton truckload of milk: 5-7.5 kg of "protein powder" which included melamine or other protein-enhancing substances, 6-7 bottles of hydrogen peroxide, 20-30 packages of gentamicin (an antibiotic), 4-5 ml. of vitamin C, 10-15 kg of whey powder, 2-2.5 kg of fat, and sometimes sulfuric acid which he stirred in with a rake (Xu). The truck driver kept a bottle of hydrogen peroxide under the driver's seat to add surreptitiously before the milk was tested. In 2007, *The New York Times*' investigation of wheat gluten adulteration had revealed the long-established practice of adding melamine and cyanuric acid to animal feed to increase the apparent nitrogen level but it was not widely known in China until after the milk adulteration incident (Barboza, 2007; Barboza and Barrioneuvo).

The low protein content of milk produced by poorly-nourished cattle raised on small farms may be one factor that encouraged adulteration. Zhu Juan (2008) notes that animals with poor diets and weak disease resistance produce milk with low protein and fat content. Zhang et al. (April 2008) report that protein levels are low in milk produced by small-scale farmers. Microbial contamination may also be higher; Zhang et al. also report that only 20% of small-scale "backyard" farmers use disinfectant prior to milking, compared with over 90% of large-scale farms.

There is no way to track the incidence of melamine adulteration over time, but the increased frequency of infant illnesses during 2008 that brought the scandal to light probably reflects an intensification of the practice. The deaths and hospitalizations of infants due to melamine were first publicized in September 2008, but news reports indicated that hospitals had been seeing cases of kidney stones in infants throughout the year. A clustering of cases big enough to link the

kidney ailments to Sanlu infant formula occurred in June/July 2008.⁷ These diagnoses may have followed many months of consuming tainted milk powder that would have been produced in late 2007-early 2008. The milk samples that tested positive for melamine in September 2008 were produced between January and September of that year (AQSIQ).

The scramble for raw milk supplies during 2007-08 and soaring prices of milk and feed seem to have created strong incentive to water down milk or accept substandard milk at a time when adulteration was apparently increasing. According to Gong, the severe cost-price squeeze in 2008 pushed the industry into chaos. Dairy companies competing to buy scarce milk paid less attention to quality. One farmer in Hebei reported that representatives from dairy companies regularly called or went door to door offering to buy milk at a premium price during this period (Hebei Youth Daily). Farmers in Shandong complained that companies' quality standards fluctuated with market demand—they were willing to accept any milk he delivered when demand was strong, but rejected similar milk (in mid-2008) when the companies had abundant inventories of milk (Zhu Zhi, June 2008). Accelerated feed price increases in 2007/08 squeezed profit margins for farmers (despite rising milk prices) and may have induced farmers to substitute poor-quality (less expensive) fodder that further eroded cow productivity, possibly reducing protein and fat content. With high demand, prices soaring, and limited supplies, milk dealers had strong incentives to water down milk. Farmers squeezed by rising feed costs and less robust growth in raw milk prices also had strong incentives to water down milk, although reports in the news media suggest that farmers were not responsible for the adulteration (Barboza, 2008).

Discussion

Economic conditions and market structure can influence food safety. The intense competition for raw milk and fluctuation in prices may have increased incentives to adulterate milk. The reliance on small farm suppliers and independent milk station operators probably reduces costs and increases flexibility in the supply chain, but it may sacrifice control and assurance of quality, safety, and traceability. Fruit, vegetable, and other industries in China have been able to increase

⁷ Cases cited by Wong include a 6-month-old who died May 2008 and a one-year-old who died in September—both would have begun consuming infant formula in late 2007.

supply rapidly by recruiting small-scale farmers who market their products through small traders and brokers (Lohmar et al.; Huang et al.; Hu). Establishing large-scale farms and vertically-integrated supply infrastructure incurs fixed costs to acquire and consolidate collectively-owned land and build facilities.

One reaction of policymakers to address price fluctuations and “disorderly” competition in the dairy sector is to control prices and regulate market participants. According to industry news, the NDRC has considered adopting a mechanism for setting raw milk prices. Heilongjiang Province already has a reference price for raw milk set by local commissions based on production costs and local market conditions. Some measures implemented to deal with the melamine crisis exclude small farmers and operators from supply chains by requiring that companies control milking stations and procure milk from their own farms or from cattle milked in animal husbandry zones.

Prices need to perform their function as market signals; inflexible prices can lead to other problems. When the procurement price is fixed, companies may arbitrarily refuse milk for failing to meet quality standards. When market demand is strong, rigid prices can lead to shortages and deny farmers a share of high profits. Accounts by journalists blame the NDRC’s price controls in 2008 as a factor inducing milk adulteration (Gong; Barboza, 2008). Other countries that have fixed milk prices by regulation have experienced milk surpluses.

It is unrealistic to exclude small farmers from supply chains since most farmland in China is controlled by small farmers. Many farmers rely on milk sales for most of their income and steady cash flow. It will be important to aid small farmers in increasing the scale of their operations, provide technical training, and increase farmers’ market power in the supply chain.

Allowing farmers to form independent cooperatives may increase their market power. A new 2007 law gave farmer cooperatives legal standing and the government is providing subsidies and other support (NDRC 2008). According to one news article, the raw milk price fluctuated less in Guangdong Province because most milk is supplied by relatively few large farms that jointly negotiate the price with companies periodically. In Shandong Province, groups of farmers

formed cooperatives or unions (lian he hui) that jointly market milk at a negotiated price. However, most farmer cooperatives are small and limited to a narrow geographic area. Cooperatives that can enroll members over a wide geographic region, achieve size economies, and raise capital may give farmers leverage in negotiating with companies and allow them to forward-integrate into processing operations.

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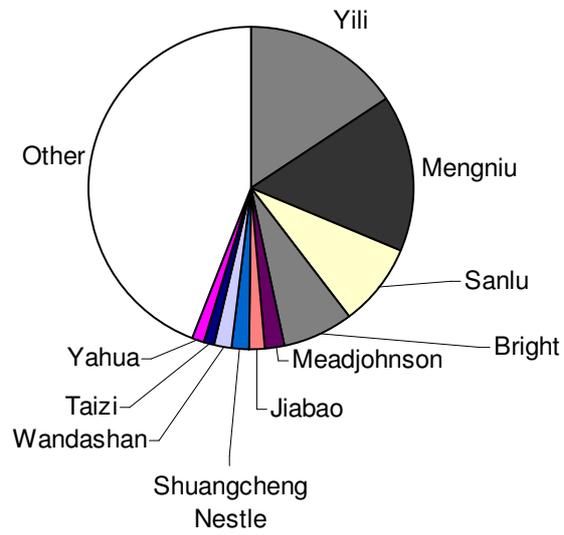
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Figure 1

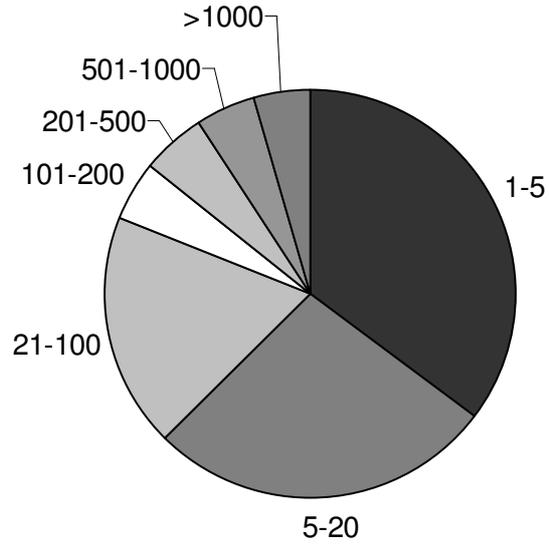
**Market share of Chinese dairy companies,
2006**



Source: China Dairy Industry Association.

Figure 2

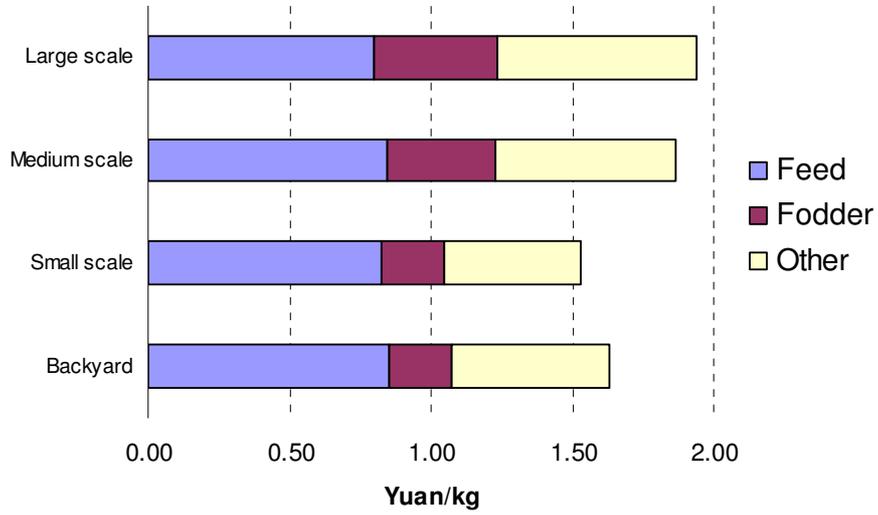
**Share of milk production by farm size, 2006
(number of cows)**



Source: Dairy Industry Yearbook

Figure 3

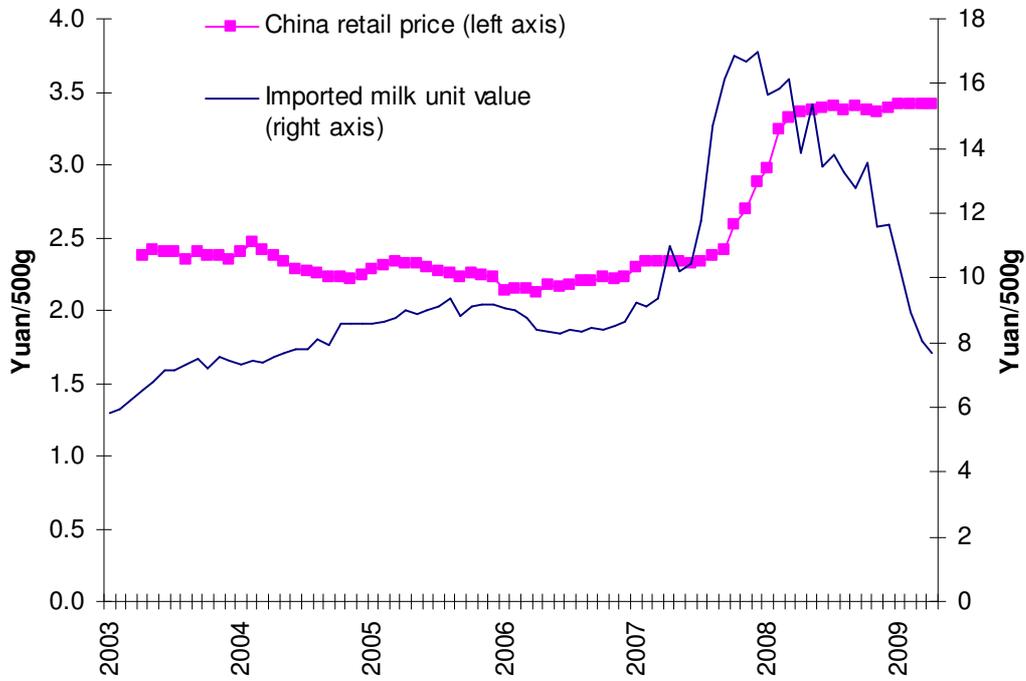
Average milk production costs by scale of farm, 2006



Source: National Development and Reform Commission.

Figure 4

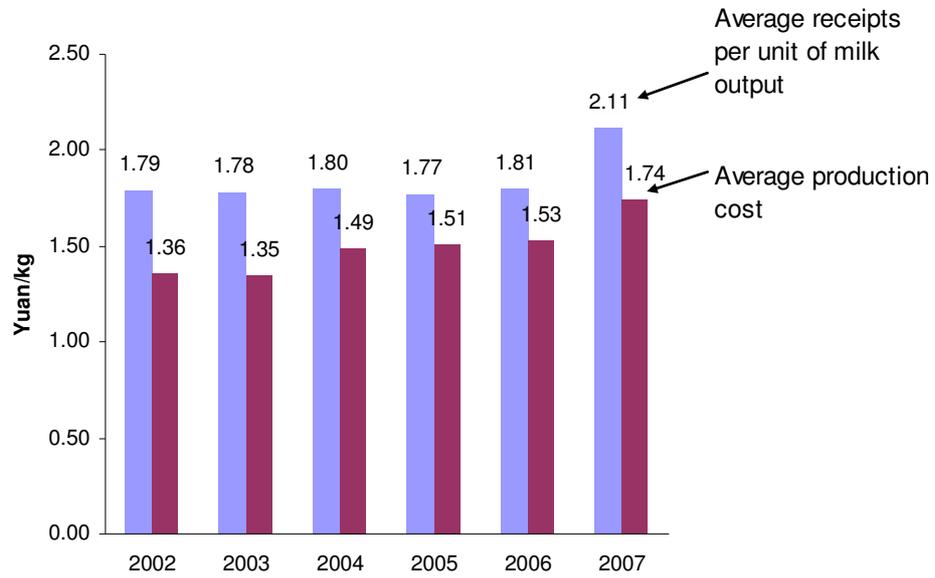
Milk prices: China retail and imports, 2003-09



Note: Imported milk is average unit value of imports of milk and cream, concentrated or sweetened (HS code 0402). Dollar value was converted to Chinese yuan at the official exchange rate.
Source: Calculated from China customs statistics and China Price Information Center.

Figure 5

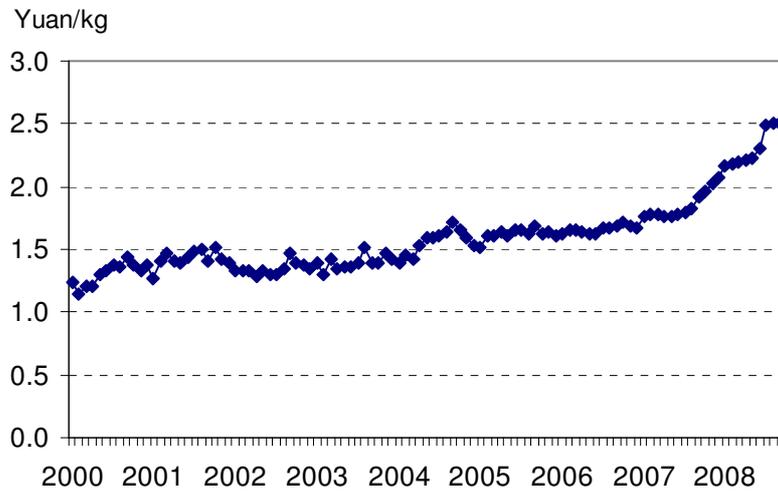
Small-scale dairy farmers average price and cost



Note: Data are for “specialized households” for 2002-04 and “small-scale” farms 2005-07.
Source: National Development and Reform Commission

Figure 6

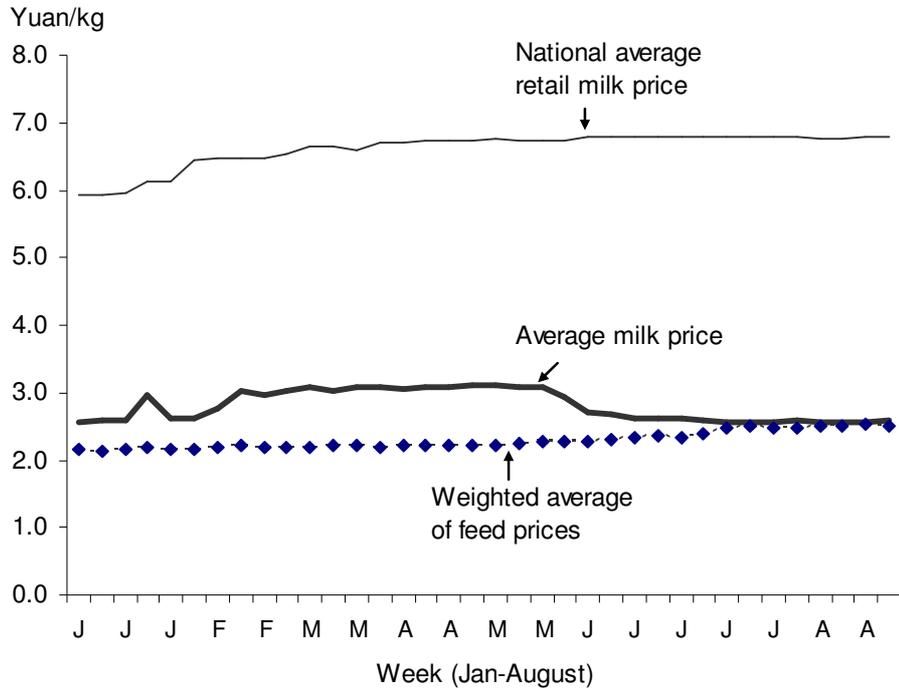
**Weighted average of dairy feed prices,
Inner Mongolia, monthly 2000-07**



Source: Weighted average prices of monthly corn, soymeal, and wheat bran for Inner Mongolia reported by China's Animal Husbandry and Veterinary net. Prices were weighted by daily feed requirements reported by Zhu of each commodity for Inner Mongolia dairy farms with 1-5 cows.

Figure 7

Weekly feed and milk prices, Inner Mongolia, 2008



Source: Retail price from China Price Information Center; other prices from Animal Husbandry and Veterinary net.