Enhancing Productivity on Suburban Dairy Farms in China

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Abstract

Dairy farms in China's suburban areas have been playing an important role in providing urban markets with fresh milk. With the rising demand for fluid milk and dairy products in the cities, there is a perception that small and scattered dairy farms in China's provinces are gradually disappearing and more concentrated dairy cattle farming is being formed near suburban areas. This paper uses farm-level survey data and stochastic input distance functions to make estimates of total factor productivity (TFP) on suburban dairy farms, as well as for the entire dairy sector. The results show that over the past decade TFP growth has been positive on suburban dairy farms, and this rise in productivity has been driven mostly by technological change. However, at the same time we find that, on average, the same farms have been falling behind the advancing technical frontier. We also find one of the drivers of the suburban dairy sector is the relatively robust rate of technological change of these farms, which has been more rapid than on farms in the dairy sector as a whole. The results suggest efforts to achieve greater adoption of new technologies and better advice on how to use the technologies and manage production and marketing within the suburban dairy sector will further advance productivity growth in the sector.

Keywords: Distance Function, Productivity Growth, Technical Inefficiency, China, Suburban Dairy Farms.
JEL Classification: D240, Q100, Q160.

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Milk production in China is struggling to keep up with demand**.** While output has increased from 5.8 million metric tons in 1995 to 17.5 million metric tons in 2003 (NSBC, 1996 and 2004), demand, especially in urban areas, has increased even more dramatically. As a result, China's net imports of dairy products have exploded from US$28 million in 1995 to US$295 million in 2003.

Farm productivity is a key variable needed to answer questions about China's future dairy self-sufficiency and net trade situation. The rapid growth in China's output has thus far been driven primarily by increased animal numbers rather than by higher yields (Yang, MacAulay and Shen 2004; Fuller et al., 2005). So what have been the trends in dairy farm productivity in China? Although yields have not risen by much, has total factor productivity increased? If it has, has productivity growth been due to technological change or to more efficient use of existing milk production technologies? In this paper we seek answers to these questions.

However, unlike our previous work Rae et al. (2006), in this paper we centre our attention on dairy production in China's suburban production districts. While there is no national data on which a definitive set of statistics can be based, it is commonly believed that the location of milk production in China is moving to suburban areas, closer to the major markets and the urban-based milk processing centres (Zhou, Tian and Zhou, 2002). Under a set of plausible assumptions we estimate that between 40 to 50 percent of China's dairy production is occurring in the city districts and/or the surrounding suburban counties of China's major cities.[1] As a consequence, it is important to understand the nature of production in these suburban districts. Since suburban dairy farms tend to be somewhat larger, more intensive and more market-oriented than the national average, could it be possible that productivity growth is more rapid on such farms? This is important to know as China's policymakers on both the agricultural production and environment quality sides of government develop plans to meet their goals.

In the next section we describe China's dairy farm systems including the suburban milk production sector, followed by a discussion of the data and some descriptive statistics about suburban dairy farms. We then use a stochastic distance function methodology to estimate productivity growth in the suburban milk production sector, followed by a discussion of our results. We also compare the results from the suburban sector to the dairy sector as a whole. The paper concludes with some policy implications of our findings and speculates what the future of China's dairy production structure and geographical location will be in the coming years. Unfortunately, because of the absence of information on the adverse environmental impacts of dairy production, we are unable to quantitatively examine this issue in our paper.

Dairy Farm Systems in China

Dairy systems in China can be classified into three general types. Pastoral dairy farm systems are found mainly in the relatively remote rural areas of Inner Mongolia, Tibet, Xinjiang, Qinghai and Gansu and cows depend primarily on pasture grazing (Gao, 2004). Although traditionally these systems produce a large share of

[1] From provincial statistical yearbooks we were able to calculate the share of total milk production from a subset of our sample cit ies. Extrapolating these calculations to the national level produced the above estimate.

China's milk, much of it is consumed on the farm. Cropping area production systems are located mainly in the rural areas of Heilongjiang, Liaoning, Hebei, Jiangsu, Shandong, Henan, Sichuan, Yunnan, Shaanxi and Ningxia provinces and cows are kept mostly in backyard sheds and are fed more grains and crop residues than those raised in pastoral system (Zhou, Tian and Zhou, 2002). More commercial than pastoral systems, in the 1980s and early 1990s, cropping area production systems contributed a larger share of China's milk. Suburban dairy farm systems, which are mainly found in the rural areas around Beijing, Tianjin and Shanghai as well as the suburban areas of all provincial capital cities and other large-sized cities around China (currently there are three such cities—Qingdao, Xiamen and Ningbo), differ from the other systems by their location in suburban areas, their relatively large scale and higher reliance on market-purchased feed. In this study, we focus primarily on suburban dairy farms.

While the term *suburban* is difficult to define and differs from country to country, we use the word here in a context that is China-specific. In our study—because the data are so organized—the term suburb refers to the rural areas in city districts and counties that surround China's large cities and are under the administrative jurisdiction of the city government. Our data come from the suburban areas of 35 cities, including Beijing and Tianjin, and 31 of the 35 sample cities are provincial capitals. Each city on average had 12 city districts and counties under its jurisdiction, contained over 4 million people (not including temporary migrants) and covered more than 10,000 square kilometres.

Unfortunately, since there are no statistical data that report total cow numbers or dairy output systematically for the entire country, we have to rely on indirect methods (using information from various studies and reports) to gauge the size of the suburban sector. According to MOA (2003), suburban dairy farms produced 54.4% of total milk output that supplied the demand of Beijing, Tianjin and Shanghai in 2000. Likewise, suburban dairy farms in a large Sichuan provincial city, Zigong, produced more than 50% of the total milk consumed in Zigong city in 2003 (ZAB, 2003). Even in Heilongjiang province (which produced 17.2% of all of China's dairy output in 2003), dairy farms are concentrated in the suburban areas of the large cities and nearly 80% of the province's dairy cattle are raised in the suburban districts of Harbin, Daqing and Qiqihar.

Factors that Encourage the Cows to Come to Town

Several factors have encouraged the development of suburban dairy farms in China. First, demand for dairy products is primarily concentrated in suburban areas where consumers have a strong preference for fresh milk over other substitutes such as soybean milk. This demand has encouraged the development of milk production in suburban areas of large cities and their geographical proximity has in several cases helped overcome the lack of specialised cooling transportation facilities (Zhou, Tian and Zhou, 2002). Second, the government has implemented a wide range of measures to promote the development of suburban dairy farms, including the provision of concessional loans for investment, feed subsidies, the supply of improved breeds and the provision of technical assistance to producers (Wu, Huang and Rozelle, 2006). Local governments have provided assistance in establishing large livestock farms to secure supply to nearby urban consumers. These may include investment subsidies (direct grants or subsidised credit) to farmers to move their livestock to special designated sites with the objective of reducing environmental problems in the villages. From a survey of 50 randomly selected villages in Greater Beijing, Wu, Huang and

Rozelle (2006) found that 26% of new dairy farms had received various supports from government, including subsidised credit, provision of additional land and subsidies on cow purchases. Other assistance includes that delivered through the Food Basket Project and the School Milk Program to encourage healthy diets and food diversity. The injection of foreign capital and the introduction of advanced technologies is the third factor to have helped promote suburban milk production (RTDDI, 1997; Tuo, 1999). Since the mid-1980s, international organisations and foreign governments have provided technical assistance in developing China's suburban dairy farms. For example the UNDP sponsored a project to develop dairy production in six major cities during 1984-90.[2] The EU implemented an even larger project in 20 cities during 1990-94.[3] With a total funding of US$156 million, these projects have made a significant contribution to the increase in suburban milk production. Large suburban dairy demonstration farms have been successfully constructed in several large northern cities (MSTC, 2004).

Data collected by the Center for Chinese Agricultural Policy from the agricultural bureaus in Beijing and Hebei show that in recent years there has been a rapid expansion of processing facilities in one of China's many suburban areas (in this case, that of Beijing). Before 1990, when dairy demand still had not started growing, national dairy processing firms established their processing plants in only three of the counties in and around Beijing (Figure 1, Panel A). During the 1990s, the pace of plant expansion accelerated (Panel B). During this period, plants opened up in six or more counties. The density of plant construction also rose. Most of the plants were next to or adjacent to the centre of Beijing. When comparing panels A and B, it is easy to see how the pace of plant openings not only rose between the 1980s and

[2] The six cities are Nanjing, Xian, Shanghai, Beiing, Wuhan and Tianjin.
[3] The twenty cities are Shenyang, Dalian, Qingdao, Hefei, Hangzhou, Changsha, Guangzhou, Cheng du, Chongqing, Fujian, Nanchang, Wuxi, Suzhou and Guilin in addition to the previous six cities.

1990s; plants are perceptibly being located in the immediate suburban districts and counties of the main population centres of Beijing.

Rising Production and Shifting Technologies

Since the 1990s, the growth in the number of dairy cows in suburban areas appears to have matched or exceeded the rate of growth in the national statistics. For example, in Beijing, our data show the total value of output of dairies almost doubled between 2000 and 2004. About one-third of the new volume came from new dairy farmers; two-thirds of the increase came from farmers expanding their dairy herd size. Clearly suburban dairies are growing rapidly in total numbers though the addition of new dairies and from the expansion of herd size of the existing farmers.

The rapid growth of dairy output is matched by changes in the ways that dairies are producing and marketing their product. Driven by demand-side pressures, intense competition has emerged among processing companies for raw milk (Liao, 2003). One realization of this competition is that it has encouraged the recent phenomenon of dairy cattle ‘concentration centres’ in suburban areas (Miao and Jiang, 2003; MOA, 2003; Yi, 2005). Small and scattered dairy farmers in the countryside are driving their cows into the concentration centres where they can rent space for their cows, and/or buy cows to start their business, and enjoy relatively modern production and marketing services such as access to concentrate feed, new owner training programs, animal disease control, milking facilities, milk collection and transportation (Zhang, 2005).

Concentration centres are but one type of several new institutional arrangements that have appeared in the suburban dairy sector. According to Wu, Huang and Rozelle (2006), when assessing the main ways that dairy cows are milked and the output is marketed in 30 sample communities in the suburbs of Beijing, there are more than 10 distinct ways that farmers produce and sell their milk. Moreover, the shift among milking and marketing institutions is occurring rapidly; at least 30 percent of farmers shifted their approach to milking or marketing between 2000 and 2004. Clearly, while this situation shows that dairy production is extremely dynamic in China today, such wholesale shifts in institutions (aside from the rise in the number of dairies) may mean that there is considerable inefficiency as dairies seek to learn how to produce and market in their new environment.

At the same time that *institutions* have been changing, so has the technology available to dairy farmers.[4] For example, dairy farmers—at times aided by processing firms or by the government—have sought other means to change their milking technology. Wu, Huang and Rozelle (2006) found that the share of farmers in suburban dairies that use traditional genetics has fallen by half. Imports of improved genetics and the emergence of private and public efforts to improve the dairy stock have risen dramatically (Fuller et al., 2005). Data from suburban areas of Beijing also show that milking by machine has risen sharply from 11 percent of total output in 2000 to 17 percent (of a much larger volume) in 2004 (Wu, Huang and Rozelle, 2006). Efforts by the government to promote animal health show up in the rising share of dairy cows that are vaccinated against endemic diseases and pests. Clearly, there is a rapid change going on in the institutions that are facilitating the production and marketing of dairy products as well as a large inflow of new technology. To the extent that such services are more accessible to dairies in suburban areas, it might be

[4] Unfortunately, we do not have the data that would allow us to distinguish between the effect of technological change and the effect of institutional change on productivity. Certainly both have the potential of affecting productivity. For this reason, in this section we describe the changes as a way to let the reader know that both of these phenomenon are affecting the dairy industry.

conjectured that this is part of the impetus for the rapid growth of suburban dairy production.

Such substantial investments in the development of new suburban dairy farms since the early 1990s, along with planned future investments, has contributed and can be expected to continue to contribute to the dramatic expansion of China's milk production capacity (although as is discussed below there may be other pressures to shift production back outside of suburban areas in the future). Where is this growth coming from? Is it only from the total number of cows or is it from increasing productivity? If productivity has changed, is the rise (or fall) in productivity due to increases (decreases) in technical efficiency or technological change? In short, to understand the future of suburban farming, and whether or not this growth in the sector will add to increased production primarily through increases in cow numbers or by enhancing productivity, remains to be evaluated.

Cost of Production and China's Suburban Dairy Farms

The main source of information for examining the productivity of suburban dairy farmers is the National Agricultural Commodity Production Cost and Return Data (ACPCRD). Published by the State Development Planning Commission (SDPC), the ACPCRD provides detailed output and cost information for many farming enterprises in China, including milk production. It also provides cost data for *suburban* (according to our definition) livestock farms, from which the cost data come for this study of suburban dairy farms. While the SDPC's data for crops have been widely used (e.g., Huang and Rozelle, 1996; Tian and Wan, 2000; Jin et al., 2002), this does not appear to be the case for the national livestock data (we are only aware of Rae *et al* (2006) and Ma and Rae (2004). To the best of our knowledge the cost data for suburban livestock production have never been analysed.

The SDPC survey of suburban fresh milk production covers 35 large and medium provincial, municipal and autonomous regional capital cities (except for Tibet) over 12 years (1992-2003). The survey also collects farm data for the dairy industry as a whole (suburban and rural farms) but separate results for non-suburban farms are not published. Prior to publication the cost data are summarized in terms of cohorts, by averaging similar farms in like areas for each observation. We excluded any city or region that had fewer than three observations over the 1992-2003 period. This resulted in unbalanced data panels of 137 observations for specialized household suburban dairy farms and 230 observations for state and collective suburban dairy farms, and 120 and 194 observations respectively for specialised households and state-collective farms for the entire dairy sector.[5]

The cost of production database includes sufficient information to allow us to have detailed estimates of dairy inputs and outputs on a per cow basis. The data include milk yield per cow (kg), by-product value[6] per cow (yuan), farm size (cow numbers), labour inputs per cow (days), concentrate feed and fodder[7] consumption

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[5] The data used for our analysis, then, is based on farm-level data, but is aggregated by city and province. Specifically, each year statistical teams in each city and province randomly select a sample of household-level farms (or state-owned farms) and conduct a survey. After collecting the data, the city/provincial statistical teams enter the data and produce a set of cost and return data for each type of farm (household; state-owned; etc.). This process is repeated each year. Therefore, the data that are used in the analysis are essentially city/province level data that are produced from specialized household-level surveys. This means that if a city/province had data for every year of our study period (1992-2003), the city/province would contribute 12 observations to the data set. This is essentially that same type of data that are available from the USDA's state-level panel, which is based on US National Agricultural Statistical System's data collection effort.

[6] According to way that the statistical team in the SDPC defined their terms in the ACPCRD, "by-products" of dairy farms include the value of calves (male and female), the value of animals that were retired and sold for slaughter, and manure.

[7] Further explanation is required on the construction of the fodder input data. The published data include the value of the fodder input since 1992 but quantity data only for 1998 and later. Since we do not have access to a fodder price series with which to deflate the value data prior to 1998, we used the 1998-2003 data to regress fodder unit values on a range of variables that might reasonably be related to fodder prices (these were the labour wage rate on dairy farms, prices of concentrate feed, maize, wheat

per cow (kg) and capital inputs per cow. We multiplied outputs and inputs per cow by animal numbers to construct total outputs (milk output, and by-product value deflated by the consumer price index) and total inputs. The survey also provides a breakdown of concentrate feed data into its grain and 'other fine feed' (brans and meals) components. For the capital input we used the sum of depreciation, machinery maintenance and small tool purchases, deflated by the agricultural machinery price index.[8]

Table 1 presents the average farm size, yields and major input levels per cow for two types of suburban dairy farms (state-collective and specialized household farms), and also for the whole dairy farm sample (i.e., suburban plus all other dairy farms). On average, the suburban state-collective farms have much larger herd sizes than the suburban specialized household farms. In 2001-2003, these were 548 and 27 cows, respectively. While the latter farm type increased average herd size by around 40% since 1992-94, average herd sizes for the suburban state-collective farms increased by 90% over the same period. For both state-collective and specialised household farms, those located in suburban areas had somewhat larger average herd sizes than for the whole dairy sector. Averaged over 2001–2003, milk yields per cow were somewhat higher on suburban dairy farms than they were for the entire sample of dairy farms, and therefore would have been even higher on suburban farms relative to non-suburban farms. This is true for both specialised household and state-collective farms. The same was true in 1992-94 for suburban state-collective farms. The annual

bran, rice bran and soybean and a feed price index). From that equation we back-casted fodder prices to 1992.

[8] We do not incorporate a land variable into our analysis. First, land is not reported in our data. Second, although dairy farm sizes in pastoral areas are directly related to the size of the grassland that is available, most dairy cows in suburban dairy farms are raised in penned environments. Therefore, dairy farming in China is more like a plant or factory and might have relatively little to do with land. Perhaps more importantly, the size of land per cow most likely does not change over time, so this is almost certainly not driving changes over time in productivity.

growth rate in yields between these two periods was faster for the suburban specialised household farms than for the entire sample of such dairy farms (1.84% versus 1.49%), but was slower in the case of state-collective dairy farms (1.63% versus 2.95%). Comparing both types of suburban dairy farms, average yields per cow on the state-collective farms were 17% higher than on specialised household farms in 2001-2003, and 19% higher in 1992-94.

Average labour inputs per cow were lower on the suburban dairy farms than for the entire dairy farm sample in 1992-94, irrespective of the type of farm. For both farm types, average labour input levels were similar in the suburban and entire farm samples, however, in 2001-2003. Between these time periods, labour usage per cow declined substantially. The average labour input per cow was also similar for both suburban specialised household and state-collective farms in both time periods. Capital inputs per cow were lower for both kinds of suburban dairy farm, in comparison with average capital inputs for the entire sample of farms, in 1992-94. By 2001-2003, however, capital usage on the suburban dairy farms exceeded that for the whole industry. By this time, the suburban state-collective farms were more capital intensive than were the suburban specialised household farms, by a factor of about three, indicative of a much faster rate of capital accumulation per cow on the suburban state-collective farms.

Average feed inputs per cow on the suburban state-collective farms were higher than for the whole industry in 1992-94, but were rather similar (but still higher for grains and fodder) by 2001-2003. In contrast, feed usage per cow on the suburban specialised household farms averaged less than for the whole industry in 1992-94, but was similar to average input levels across the entire sector by 2001-2003. Within the suburban dairy farm sample, average feed use per cow was higher on the state-collective than on the special household farms in both 1992-94 and 2001-2003. Over this time period, for both types of suburban dairy farms, average input levels per cow of each of the three feed types increased, with the largest increase being an almost threefold increase in the use of fodder on both farm types. If we use the sum of grain and other fine feed relative to milk yield per cow as a measure of feed efficiency, there is some evidence that efficiency has been higher on suburban than on non-suburban farms. Over 2001-2003, for example, this ratio was 0.52 and 0.57 for suburban state-collective and special household farms respectively, compared with values of 0.53 and 0.59 for the whole dairy farm sample.

Farm size, production practices, yields and input levels on suburban farms also vary substantially across locations within China (table 2). This may mean that geographical location (which can determine climate and local cropping patterns, for example) could affect the productivity of suburban dairy farms in China. In 2003 herd sizes on the suburban state-collective farms averaged from 147 in Shijiazhuang to 3,500 in Wuhan. The range for suburban specialised household farms is much narrower, from just 3 cows in Qingdao to 152 in Tianjin. There appears no clear correlation among yields per cow and input levels. On the suburban state-collective farms in 2003, for example, Beijing (North) and Wulumuqi (Far West) have the highest average yields (8421 kg and 7939 kg, respectively), while Zhengzhou (Central) and Guangzhou (South) have the lowest (3878 kg and 4000 kg, respectively). Both of these high-yield locations have a higher use of other fine feed inputs per cow than do the lowest-yielding areas, but this is not always the case for the grains, fodder, labour and capital inputs. The concentrate feed-to-yield ratio, as measured above, however, is lower for both high-yield locations than for the two low-yield areas. A similar story can be told for the suburban specialised household farms. The highest yields are found in the North (Tianjin and Beijing) and the lowest in the Southwest (Kunming) and South (Nanning). Both the high-yield locations have higher grain inputs per cow than either of the two low-yield areas, but this is not always the case for the other inputs. The concentrate feed-to-output ratio is lower for Kunming but higher in the case of Nanning, compared with those in the high-yield areas. Clearly, little can be concluded about suburban dairy farm productivity across cities in China in the absence of further analysis.

Methodology and Estimation

Over the last twenty years, the literature on productivity measurement has been extended from the standard index-number calculation of total factor productivity (TFP) toward more refined decomposition methods. In the simple TFP framework, the growth rate of this index is usually interpreted as a measure of technical change, but this interpretation incorporates several restrictive assumptions, such as constant returns to scale and allocative and technical efficiency. More recently, distance functions have been used in attempts to overcome some of these shortcomings and to identify the components of productivity change (Coelli and Perelman, 2000). This approach does not require any behavioural assumptions, such as cost minimization or profit maximization, to provide a valid representation of the underlying production technology (Brummer, Glauben and Thijssen, 2002). In this analysis of productivity in China's dairy industry, we employ the input distance function methodology.

We also assume that this input distance function can be approximated by the translog functional form. The homogeneity restrictions are imposed by choosing the quantity of one of inputs as *numeraire* (here it is number of cows per farm). We define technical inefficiency as a function of both time and locational dummy variables. Details of this type of model and its estimation can be found in Coelli and Perelman (2000), Karagiannis, Midmore and Tzouvelekas (2004) and Khumubakar and Lovell (2000).

There are serious econometric problems with two-stage formulation estimation (Khumbakar and Lovell, 2000, pp264), therefore, we use the FRONTIER 4.1 computer program developed by Coelli (1996) to estimate the stochastic frontier function and technical inefficiency models simultaneously as in Coelli and Perelman (2000) and Paul, Johnson and Frengley (2000). We then decompose productivity growth into technical change and efficiency components, as in Karagiannis, Midmore and Tzouvelekas (2004).

The input distance function is estimated using the suburban farm panel data, and again with the panel of data for the dairy sector as a whole. This will permit us to say something about whether or not productivity growth has been more rapid on suburban dairy farms than on those in rural locations. Should productivity growth be shown to be faster on suburban farms than for the whole industry, for example, then it must also have been faster than on the non-suburban dairy farms.

A concern with the estimation of distance functions is that the normalized inputs appearing as regressors may not be exogenous. In fact, the ratio model we adopt is less susceptible of input endogeneity bias than the normal model (Brummer, Glauben and Thijssen, 2002). Schmidt (1988) and Mundlak (1996) have also examined variables in ratio form and found that the ratio of two input variables does not suffer from endogeneity assuming expected profit maximization. Another concern is that our model does not include any environmental variables. While the majority of dairy cows in China, especially in the case of suburban dairy farm system, are farmed in housed facilities, so that productivity and performance may not be influenced by weather conditions to the extent that might occur in grazing systems, such influences may still be present. Thus our estimates of technical efficiency may be subject to downward bias, especially for the entire dairy industry because it also includes grazing systems.

Results and Discussion

Model specification tests were undertaken to indicate whether the suburban state-collective farm data and that for the suburban specialised households could be pooled, and to compare the translog functional form with a Cobb-Douglas specification of the production frontier. Results are shown in Appendix 1 for the suburban sample. These provided statistically significant support for estimating separate models for suburban state-collective and specialised household farms, and for the use of the translog functional form.

The estimated coefficients of the translog input distance functions for the suburban farms are presented in Table 3. The pooled model assumes that all parameters except the intercept are identical for both farm types (columns 2 and 3). This was rejected by the test referred to above—note also the significance of the suburban specialised household intercept dummy variable. The separately-estimated input distance functions for both suburban farm types are found to be well-behaved in that, at the point of approximation, they are non-increasing in outputs and non-decreasing in inputs (columns 4 to 7). The estimated variances of the one-sided error terms are 0.008 and 0.010 for suburban state-collective and specialised household farms, respectively, and the presence of technical inefficiency is related to the statistical significance of σ_u^2. Thus, a significant part of output variability among suburban dairy farms can be explained by the existing differences in the degree of technical efficiency (Karagiannis, Midmore and Tzouvelekas, 2004).

The estimates of TFP growth and its decomposition into technical efficiency and technological change components for China's suburban dairies show a remarkably consistent story of a sector that is undergoing dynamic, yet disruptive, changes. Perhaps most typically we see that TFP growth in the dairy sector has increased over time, rising at 2.04 percent per year in the suburban specialised household sector (Table 4, row 1). This rate of TFP growth, internationally, is considered healthy (and above the rate of growth of the population, albeit in the case of dairy below the rate of growth of demand). This rate of growth of dairy TFP, in fact, is similar to the rates of growth of China's cropping TFP (Jin et al., 2002) and livestock (Rae et al., 2006).

The decomposition analysis clearly shows that technological change, not improvements to efficiency, has been the driver of the rise in productivity (Table 4, row 1, columns 5 and 6). In fact, in the suburban specialised household dairy sector technological change increased output by 4.96 percent per year. In other words, the adoption of new genetics, feeding regimes and milking approaches have had a large impact on the suburban dairy sector. In contrast, disruption of fast growth or the lack of training and understanding of the dairy production and marketing processes, that might contribute to inefficiencies, has caused technical efficiency to have actually fallen over time, by 2.92 percent per year.

The suburban state-collective sector experienced almost identical contours in TFP, technological change and technical efficient, albeit the rates of changes were all somewhat attenuated (Table 5, row 1). TFP growth was slower in the suburban state-collective dairy sector, rising only 0.91 percent annually. Like the suburban specialised household sector, this growth rate was driven by increasing technological change (2.57 percent per year) although this was less than the rate of technological change in the suburban specialised household sector. Similarly, TFP would have been higher had whatever affects the efficiency of the production environment not contributed to a 1.66 slowdown in productivity.

One of the most interesting observations from our city analysis (Table 4, rows 2 to 16; Table 5, 2 to 25) is that although there were differences among the sample cities (as one might expect in a nation as big and diverse as China), most of the trends for TFP and its two component elements—technological change and efficiency—move in the same direction across the cities. For example, in the case of the suburban specialised household dairy sector 12 out of 15 cities experience positive growth rates in TFP (Table 4, column 1). Of the 15 cities, 14 of them experienced positive growth from technological change (column 3) and negative growth from technical efficiency (column 2). The same robustness across cities holds for the suburban state-collective dairy sector (Table 5); 18 out of 24 sample cities experienced rising TFP; all 24 of them rose due to technological change; all but 3 (21 of 24) would have had higher productivity growth had there not been falling efficiency.

The average level of efficiency of the suburban specialised household farms falls from 0.82 in 1992 to 0.68 in 2003; those for suburban state-collective household farms fall about the same from 0.88 to 0.64 (Appendix 2). Such evidence makes us think that the falling efficiency, at least in part, is due to the rapid expansion of China's dairy herd size and that at least part of the inefficiency drop may expect to correct itself when the explosive growth abates somewhat. At the same time, it can not be discounted that the fall in efficiency is occurring at a time when China's extension system is almost at its worst (Hu, Huang and Qiu, 2004).

After running the same productivity analysis and decomposition on the full set of dairies in the SDPC's cost of production data set (that is, including suburban and non-suburban dairy farms—see Appendix 3 for the estimates), it is clear that the dairy sector in China's suburban regions at the very least appears to be more dynamic and in the midst of some disequilibrium (Table 6). The dynamism of the suburban dairy sector can be seen by its relatively higher rate of growth from technological change. The fall in technical efficiencies, however, are also greater for the suburban dairies. Therefore, although in the past 10 years the two sectors—the suburban and non-suburban—have had somewhat similar rates of total productivity growth, in looking toward the future (assuming the rates of technological change will continue at their recent growth rates), the main challenge facing the suburban sector is to try to overcome the efficiency deterioration from which it has been increasingly suffering over the past few years.

Table 6 also demonstrates the relatively higher level of total factor productivity growth that is enjoyed by specialized household dairy farms (row 1 for suburban dairy farms and row 2 for all dairy farms) when compared to state-collective dairy farms (row 3 for suburban dairy farms and row 4 for all dairy farms). The higher rate of TFP growth for specialized household dairy farms is generated in both cases by higher rates of technical change. Although we do not know for sure if historically (or even recently) the state-collective dairy sector has received more than its share of concessional loans and other support, but if it has, clearly one policy implication of this finding is that relatively more support should be directed at the specialized household sector if officials want to increase the rate of the sector's productivity rise.

Conclusions and Implications

The rapid growth in consumption of milk and other dairy products in China is very much an urban phenomenon. Given the current state of development of the milk-handling infrastructure in China, it is not surprising that milk production is increasingly concentrated near urban demand areas. New dairy farm developments, including the large-scale ‘concentration centres’ have involved considerable national and international investments in modern facilities, technologies and high-performing livestock. One of our conclusions is that technical change in the suburban milk sector has been more rapid than for the milk sector as a whole, and especially in the case of suburban specialist household farms. Another conclusion is that suburban milk producers, on average, have not been able to keep up with the rapidly advancing production frontier, and have fallen further behind. While suburban dairy farms produced on average at 82% - 88% of potential in 1992, this had fallen to less than 70% by 2003. Evidently, the successful adoption of new technologies has not been evenly spread throughout the suburban industry, with the slow- and non-adopters falling behind. The low technical efficiency on suburban dairy farms is probably also influenced by the fact that milk production has been expanding rapidly around suburban areas during the last decade. In such an environment of new dairy farm developments and rapidly increasing input use, a lot of experimentation and perhaps mistakes by new farmers in the search for new technologies should not be too surprising. Positive and often rapid technical change coupled with negative efficiency growth was also a common finding across cities. Such an outcome is also likely where government priorities and policies favour certain localities and farm types over others for new investments.

There appears to be considerable scope for improving suburban dairy farm performance by increasing the efficiency of producers. Attention to the use of best practice techniques for given technologies and diffusion of modern successful technologies across more suburban areas would appear to be priorities if average total factor productivity growth is to more closely approach the rate of growth in technical change. While part of the inefficiency (as we argue) may be just a function of the dynamism of the sector (which we do not want to see disappear), more attention to extension and the development of more appropriate technologies might help mitigate some of the inefficiencies (even during times of rapid growth) which could turn into higher levels of productivity growth.

There are many factors contributing to variations in TFP growth and its components across cities, that we were not able to explicitly incorporate in our analyses. These include information on the breed composition of dairy herds, the influence of local and central government policies on credit and investment, local climatic conditions and the nature of available roughage resources. Had data been available to construct suitable variables, some of these could have been included in the efficiency model – in their absence, we had to use city dummy variables. We should also repeat our earlier warning that the omission of climatic variables could have caused a downward bias in our technical efficiency estimates.

While the dynamism of the suburban sector is apparent from our analysis, when we track the very recent trends in processing plant expansion, we can detect what appears to be a shifting pattern. Instead of moving in towards the middle of the concentrated urban areas and immediate suburbs, the map of new dairy processing centres after 2000 show that they have dispersed both to the far suburbs and to neighbouring, more remote prefectures and counties (Figure 1, Panel C). Clearly the rise of large processing plants is occurring despite the dynamism of the suburban dairy sector.

After seeing these trends in our data, we visited a number of suburban farmers, processors and government officials and discovered that indeed while they recognize the economies of concentrating dairy production closer to large cities there are other forces that are starting to work against suburban dairies. First, as China develops, its land, labour and other factor prices near the city are rising relatively faster than factor prices in more remote areas. Second, as China has developed its infrastructure and communications, there is less friction in distance. This is especially true when noting that so much of China's new dairy consumption is occurring in the form of yogurt and UHT milk, products that place lower demands on processors to get their product to city consumption centres as fast, since the products are less perishable. Finally, there has begun to be a realization that large concentrated livestock-based industries can be highly pollutive, especially when placed in close proximity to large concentration of urban residential and industrial districts. As a consequence, for the first time in recent years, large cities are beginning to question the attractiveness of having a dairy industry so close to the city and have begun to pass regulations to try to curb the location of new production and processing in the immediate location of the large cities. While we do not know the extent to which this is influencing the shift of plant location, it most likely plays a significant role. Hence, while there are many economic forces over the past two decades that have emerged to begin to take the cows to town, at the very time that they are becoming established here, equally powerful forces appear to be getting ready to escort them back out. Only time will tell which forces will win … and when.

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Table 1. Comparisons of Farm Size, Yields and Major Input Levels Per Cow: Suburban and all dairy farms

Periods/Types	Farm Size (head)	Yield (kg)	Labour (day)	Grains (kg)	Other Fine Feed (kg)	Fodder (kg)	Capital (Yuan)
			State-Collective Dairy Farms				
1992-1994:							
Suburban (1)	288	5408	99	2213	891	4697	323
All farms (2)	208	4652	107	1981	726	3422	351
(1)/(2)-1	0.38	0.16	-0.07	0.12	0.23	0.37	-0.08
2001-2003:							
Suburban (3)	548	6255	64	2222	1040	13790	1103
All farms (4)	512	6041	64	2143	1041	12778	1071
(3)/(4)-1	0.07	0.04	-0.00	0.04	0.00	0.08	0.03
1992-2003:							
Suburban (5)	396	5798	77	2262	945	11465	709
All farms (6)	340	5373	80	2117	809	10189	729
(5)/(6)-1	0.16	0.08	-0.03	0.07	0.17	0.13	-0.03
			Specialized Household Dairy Farms				
1992-1994:							
Suburban (7)	19	4553	95	1619	733	2834	143
All farms (8)	15	4576	113	1880	829	3001	160
(7)/(8)-1	0.26	-0.01	-0.16	-0.14	-0.12	-0.06	-0.11
2001-2003:							
Suburban (9)	27	5366	66	2171	863	7392	374
All farms (10)	24	5229	67	2134	946	7436	326
(9)/(10)-1	0.13	0.03	-0.02	0.02	-0.09	-0.01	0.15
1992-2003:							
Suburban (11)	23	4898	83	1961	732	5279	236
All farms (12)	22	4854	86	1958	833	6227	259
(11)/(12)-1	0.03	0.01	-0.04	0.00	-0.12	-0.15	-0.09
			Suburban Dairy Farms				
1992-1994:							
Stat/Coll.(13)	288	5408	99	2213	891	4697	323
SHHD (14)	19	4553	95	1619	733	2834	143
(13)/(14)-1	14.2	0.19	0.05	0.37	0.22	0.66	1.27
2001-2003:							
Stat/Coll.(15)	548	6255	64	2222	1040	13790	1103
SHHD (16)	27	5366	66	2171	863	7392	374
(15)/(16)-1	19.3	0.17	-0.04	0.02	0.20	0.87	1.95
1992-2003:							
Stat/Coll.(17)	396	5798	77	2262	945	11465	709
SHHD (18)	23	4898	83	1961	732	5279	236
(17)/(18)-1	16.1	0.18	-0.07	0.15	0.29	1.17	2.00

Data source: Agricultural Commodity Production Cost and Return Survey Handbooks, 1993 -2004.
Note: Concentrate feed is split into grains and other feed. Capital includes depreciation, fixed asset repair and maintenance and small tool purchase and is measured simply in present price.

Table 2. Variations in Farm Size, Yields and Major Inputs Per Cow Across Cities in China (2003)

Suburban Areas	Location [a]	Farm Size (head)	Yield (kg)	Labour (day)	Grains (kg)	Other fine Feed (kg)	Fodder (kg)	Capital (Yuan)
Suburban State-collective Dairy Farms								
Zhengzhou	Centre	220	3878	49	1320	1180	13000	399
Guangzhou	South	330	4000	36	2530	1280	10800	1210
Guiyang	South West	3400	5500	90	3096	4	16500	1865
Lanzhou	West	330	5949	24	2156	817	12423	963
Xining	West	594	6125	58	1948	1947	16229	573
Hangzhou	South East	882	6414	75	2966	817	17642	518
Changchun	North East	380	6540	132	3078	720	12521	324
Hefei	South East	902	6667	73	1324	567	15888	909
Jinan	East	1184	6750	15	3429	605	12962	2203
Wuhan	Centre	3500	6940	65	2430	1050	12900	1184
Shijiazhuang	North	147	7044	74	1450	1450	17683	1687
Shanghai	East	216	7494	55	2722	1173	17400	875
Wulumuqi	Far West	1138	7939	50	2259	1506	11805	3201
Beijing	North	512	8421	24	2154	2342	5423	952
Suburban Specialized Household Dairy Farms								
Kunming	South West	11	3770	43	1000	557	3696	175
Nanning	South	9	4424	42	1553	1650	9256	258
Xian	West	2	4861	118	2080	367	1399	182
Changsha	South	15	4900	59	2800	700	2480	1450
Qingdao	East	3	5000	68	1784	957	5127	238
Yinchuan	West	43	5116	17	3598	1136	4779	167
Zhengzhou	Centre	8	5169	66	1625	765	10000	356
Chengdu	South West	17	5290	61	2151	944	19599	291
Harbin	North East	6	5334	91	2803	91	3467	736
Taiyuan	Centre	9	5362	70	1630	1630	12000	270
Shenyang	North East	30	5705	39	1422	356	10160	66
Huhehaote	North	12	6003	56	2274	1048	6955	96
Jinan	East	8	6169	77	2469	675	9280	339
Beijing	North	171	6409	38	2368	971	6630	422
Tianjin	North	152	6454	42	2252	1051	9664	220

Data source: Agricultural Commodity Production Cost and Return Survey Handbooks 2004.

Table 3. The Estimates of Input Distance Function for Suburban Dairy Farms in China

Variables in log format	Pooled Data		State and Collective		Specialized Household	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Y_1	-0.137	-0.70	-0.622	-4.29	1.049	2.47
Y_2	-0.165	-1.23	-0.142	-0.92	-0.326	-1.07
X_2	0.525	1.65	-0.988	-2.23	2.552	4.54
X_3	-0.055	-0.15	-0.913	-5.77	1.994	2.24
X_4	0.220	1.11	0.379	0.97	1.009	4.43
X_5	-0.566	-2.33	-0.108	-0.36	-1.866	-3.66
$Y_1Y_1/2$	0.028	1.93	0.034	2.19	-0.009	-0.24
Y_1Y_2	-0.001	-0.12	-0.002	-0.17	-0.003	-0.13
$Y_2Y_2/2$	-0.003	-0.38	-0.008	-1.21	0.003	0.13
$X_2X_2/2$	-0.028	-1.42	0.016	0.79	-0.138	-2.21
X_2X_3	0.056	1.57	0.120	3.06	-0.130	-1.97
X_2X_4	-0.055	-3.00	-0.018	-1.01	-0.037	-1.14
X_2X_5	0.048	2.56	0.032	6.77	0.206	5.07
$X_3X_3/2$	0.034	0.80	-0.012	-0.37	0.074	0.84
X_3X_4	0.023	1.14	0.050	1.77	-0.091	-2.52
X_3X_5	0.034	1.31	0.035	1.69	0.066	1.39
$X_4X_4/2$	0.016	0.83	-0.050	-1.52	-0.008	-0.36
X_4X_5	-0.001	-0.07	0.003	0.20	0.041	3.27
$X_5X_5/2$	0.082	4.54	0.019	0.90	-0.058	-2.01
Y_1X_2	-0.032	-1.97	0.008	0.39	-0.121	-3.14
Y_1X_3	-0.070	-3.50	-0.041	-2.21	-0.127	-2.45
Y_1X_4	-0.017	-1.40	-0.024	-1.48	-0.051	-2.32
Y_1X_5	-0.050	-4.16	-0.039	-3.15	0.020	1.21
Y_2X_2	-0.018	-1.79	-0.019	-2.09	-0.008	-0.34
Y_2X_3	0.009	0.66	0.029	2.26	-0.023	-0.63
Y_2X_4	0.001	0.09	0.002	0.24	0.055	3.88
Y_2X_5	0.026	2.73	0.009	0.82	0.010	0.84
T	-0.001	-0.02	-0.350	-3.55	0.128	1.07
tt/2	0.004	2.59	0.000	0.31	0.016	6.50
tY_1	0.000	0.18	-0.001	-0.27	0.004	0.58
tY_2	0.001	0.78	0.002	0.90	-0.007	-1.84
tX_2	-0.002	-0.51	0.004	0.91	-0.029	-2.74
tX_3	0.007	1.26	0.020	2.53	0.013	1.26
tX_4	-0.012	-3.30	0.015	2.17	-0.034	-7.65
tX_5	0.005	1.63	0.008	2.64	0.024	4.90
SHHD	0.097	2.29	-	-	-	-
Log LF	351.3	-	253.76	-	156.25	-
Observations	367	-	230	-	137	-
Parameters	37	-	36	-	36	-
Inefficiency Model:						
Sigma-squared	0.011	181.8	0.008	5.71	0.010	6.36
Gamma	0.803	26.45	0.876	3.07	0.959	258.6
t	0.009	1.87	0.018	2.07	0.056	5.83

Note: Constant term and city dummies in the efficiency model were not displayed. X_1 is used as numeraire. Variables are milk output (Y_1), by-products (Y_2), labor (X_2), concentrate feed (X_3), fodder (X_4) and capital (X_5) All are expressed on a per cow (X_1) basis. T is a time trend.

Table 4. Decomposition of Total Factor Productivity (TFP) into Technical Efficiency (TE) and Technological Change (TC) on Suburban Specialized Household Dairy Farms in China

City	Period	Obs	TFP Decomposition (%)		
			TFP	TE	TC
Mean [a]	1992-03	12	2.04	-2.92	4.96
Tianjin	1992-03	10	-0.62	-4.12	3.49
Taiyuan	1999-03	5	1.86	-9.11	10.98
Huhehaote	1998-03	6	7.01	-2.19	9.20
Shenyang	1992-03	9	5.99	-0.10	6.09
Harbin	1992-03	12	1.46	-5.59	7.05
Fuzhou	1995-03	9	1.99	-5.25	7.24
Jinan	1995-03	9	3.24	-3.33	6.57
Changsa	1998-03	5	7.71	-7.23	14.94
Chongqing	1993-03	8	-2.33	-2.14	-0.19
Chengdu	1996-03	6	8.03	-3.86	11.89
Kunming	1994-03	9	1.30	-3.77	5.07
Xian	1993-03	9	1.04	-7.80	8.84
Yinchuan	1992-03	11	2.11	-4.36	6.47
Qingdao	1993-03	7	3.70	-6.15	9.85
Ningbo	1992-97	5	-0.96	-0.26	-0.70

Note: 1) In order to evaluate the reliability of the results, we present the period and observations for each suburban city. It should be noted that the periods only give the starting and ending years of observations. 2) The table retains only those cities having five or more observations. 3) It can be observed that TC growth is generally much faster during the second half of study period than during the first half. So, comparisons of TC growth across cities should be done with due caution.

[a] Estimated at data means.

Table 5. Decomposition of Total Factor Productivity (TFP) into Technical Efficiency (TE) and Technological Change (TC) on Suburban State -Collective Dairy Farms in China

City	Period	Obs	TFP Decomposition (%)		
			TFP	TE	TC
Mean [a]	1992-03	12	0.91	-1.66	2.57
Beijing	1992-03	11	3.16	0.16	3.00
Tianjin	1992-03	9	1.06	-1.63	2.69
Shijiazhuang	1992-03	12	1.38	-1.29	2.67
Changchun	1992-03	8	-1.58	-3.76	2.17
Harbin	1992-96	5	-2.12	-2.56	0.45
Shanghai	1992-03	12	1.26	-1.87	3.13
Nanjing	1992-03	10	3.22	-0.07	3.29
Hangzhou	1996-03	8	1.01	-3.10	4.11
Hefei	1992-03	9	3.08	0.54	2.53
Jinan	1994-03	10	0.09	-3.42	3.52
Zhengzhou	1992-03	11	-1.98	-3.36	1.39
Wuhan	1994-03	10	3.67	0.44	3.23
Guangzhou	1992-03	9	-1.74	-4.61	2.88
Nanning	1992-01	8	-3.01	-5.88	2.87
Chongqing	1992-03	7	1.53	-1.20	2.73
Chengdu	1996-01	5	3.42	-0.26	3.68
Guiyang	1992-03	7	-0.15	-3.83	3.68
Kunming	1992-99	7	0.88	-2.67	3.55
Xian	1992-03	12	3.85	0.88	2.97
Lanzhou	1992-03	8	2.47	-0.33	2.81
Xining	1993-03	11	0.00	-2.17	2.18
Wulumuqi	1996-03	7	0.81	-3.05	3.86
Dalian	1994-03	10	0.65	-2.01	2.66
Ningbo	1992-03	11	0.04	-2.44	2.48

Note: See Table 4.

[a] Estimated at mean values of all variables.

Table 6. Comparisons of Growth in Productivity and its Components, and Technical Efficiency, Across Suburban and All Dairy Farms

Farm Type	Annual TFP Decomposition growth (%)			TE Level	
	TFP	TE	TC	1992	2003
			Specialised Households		
Suburban	2.04	-2.92	4.96	0.88	0.64
All farms	2.33	0.78	1.55	0.82	0.90
			State-Collective		
Suburban	0.91	-1.66	2.57	0.82	0.68
All farms	0.25	-0.79	1.04	0.87	0.80

Note: The same methodology was used for both suburban and all dairy farms.

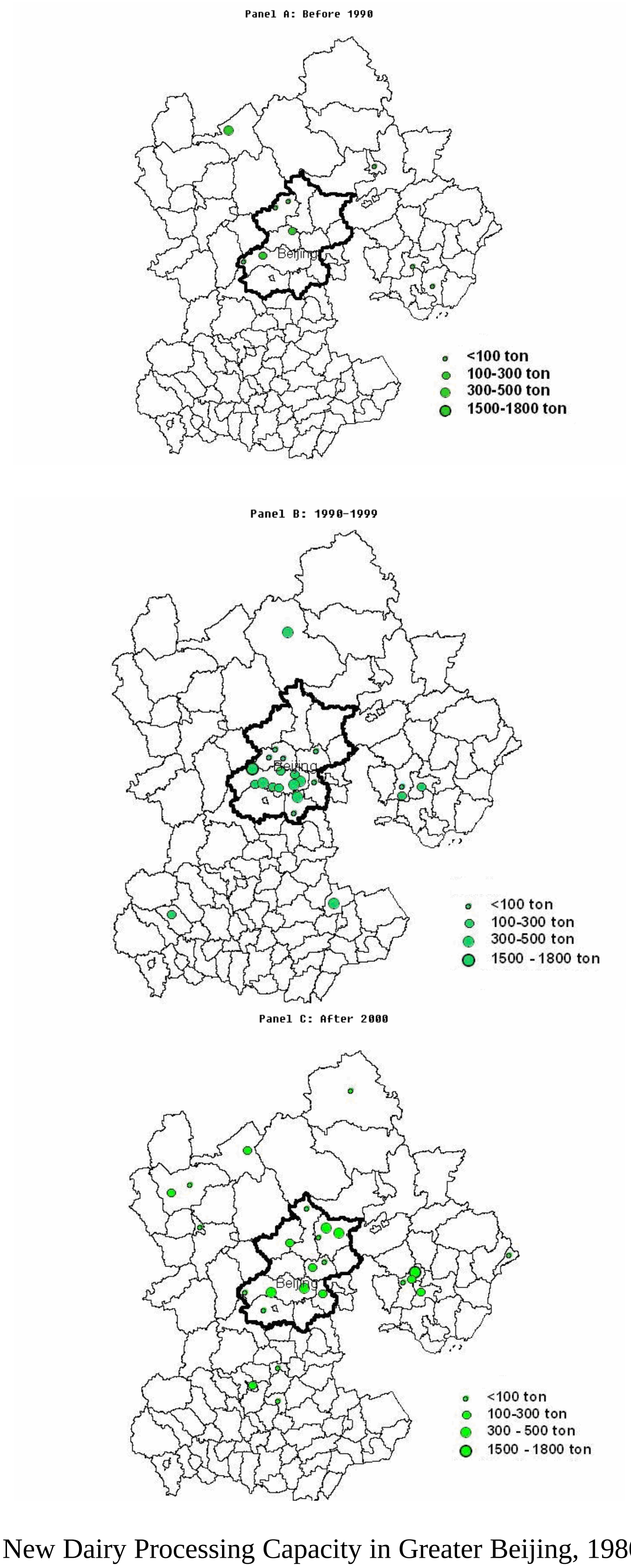

Figure 1. New Dairy Processing Capacity in Greater Beijing, 1980s to 2000

Appendix 1. Maximum Likelihood Ratio Tests for Splitting Suburban Specialized Household Dairy Farms and Suburban State -Collective Dairy Farms (LR Test 1) as well as C-D function vs Translog Function (LR Test 2)

Restricted Function	Likelihood Function		# of Restrictions	χ^2 Statistics
	Unrestricted	Restricted		
LR Test 1:	392.78	351.30	35	82.9***
LR Test 2:				
Specialized Household	156.25	75.18	28	162.1***
State and Collective	253.76	228.75	28	50.0***

Note: *** stands for 1% significant level.

Appendix 2. The Change of Technical Efficiency (TE) on Suburban Dairy Farms in China

State-Collective				Specialized Households			
City	1992-03	1992	2003	City	1992-03	1992	2003
Mean [a]	0.76	0.82	0.68	Mean [a]	0.80	0.88	0.64
Beijing	0.95	0.98	0.97	Tianjin	0.81	0.94	0.57
Tianjin	0.86	0.98	0.82	Taiyuan	0.75	-	0.67
Shijiazhuang	0.86	0.89	0.77	Huhehaote	0.91	-	0.87
Changchun	0.80	0.78	0.71	Shenyang	0.87	0.96	0.71
Harbin	0.79	0.85	-	Harbin	0.66	0.91	0.49
Shanghai	0.88	0.98	0.80	Fuzhou	0.71	-	0.60
Nanjing	0.66	0.89	0.65	Jinan	0.84	-	0.75
Hangzhou	0.79	-	0.67	Changsa	0.55	-	0.43
Hefei	0.71	0.72	0.74	Chongqing	0.84	*0.98*	0.70
Jinan	0.76	-	0.67	Chengdu	0.76	-	0.57
Zhengzhou	0.52	0.72	0.51	Kunming	0.67	*0.75*	0.56
Wuhan	0.67	-	0.61	Xian	0.76	*0.98*	0.53
Guangzhou	0.56	0.72	0.48	Yinchuan	0.76	0.80	0.54
Nanning	0.63	0.75	*0.53*	Qingdao	0.79	*0.98*	0.68
Chongqing	0.69	0.73	0.63	Ningbo	0.99	0.99	-
Chengdu	0.78	-	*0.73*				
Guiyang	0.58	0.71	0.53				
Kunming	0.77	0.75	*0.67*				
Xian	0.93	0.79	0.88				
Lanzhou	0.70	0.83	0.68				
Xining	0.74	*0.84*	0.67				
Wulumuqi	0.89	-	0.78				
Dalian	0.73	*0.74*	0.62				
Ningbo	0.75	0.82	0.66				

Source: model results.
Note: The numbers in italics are not in the year shown but either after the earlier or subsequent years to demonstrate the trend of technical efficiency change over time. The table only keeps those that have five-year or over observations.

[a] Simple unweighted means of all available regions.

Appendix 3. The Estimates of Input Distance Functions for A ll Dairy Farms in China

Variables in log format	State-Collective		Specialized Households	
	Coefficient	t-ratio	Coefficient	t-ratio
Y_1	-0.598	-1.57	2.499	5.15
Y_2	-0.491	-2.17	-2.087	-5.53
X_2	-0.180	-0.38	3.087	6.16
X_3	-1.118	-1.72	1.880	4.88
X_4	0.644	1.24	-0.619	-2.46
X_5	-0.091	-0.23	-1.009	-2.35
$Y_1Y_1/2$	0.110	4.87	0.069	4.73
Y_1Y_2	-0.021	-2.02	-0.066	-4.53
$Y_2Y_2/2$	0.005	0.74	0.067	4.95
$X_2X_2/2$	-0.074	-2.97	-0.562	-8.81
X_2X_3	0.052	0.88	-0.013	-0.19
X_2X_4	0.079	1.94	0.067	3.45
X_2X_5	-0.027	-1.03	0.246	4.86
$X_3X_3/2$	0.057	0.74	0.015	0.20
X_3X_4	0.094	1.64	-0.015	-1.19
X_3X_5	0.063	1.63	0.030	0.71
$X_4X_4/2$	-0.088	-2.07	-0.007	-0.73
X_4X_5	-0.040	-1.51	-0.007	-0.68
$X_5X_5/2$	0.046	1.81	-0.098	-4.18
Y_1X_2	-0.030	-0.86	-0.198	-8.23
Y_1X_3	-0.087	-2.30	-0.431	-7.59
Y_1X_4	-0.074	-3.61	0.074	14.07
Y_1X_5	-0.014	-0.97	0.014	0.78
Y_2X_2	0.008	0.50	0.021	0.91
Y_2X_3	0.042	1.86	0.309	8.22
Y_2X_4	0.036	2.81	-0.039	-3.02
Y_2X_5	-0.001	-0.15	0.016	1.33
T	-0.036	-0.46	0.046	0.59
tt/2	-0.005	-2.91	-0.005	-3.48
tY_1	-0.010	-2.52	-0.017	-4.26
tY_2	0.003	1.12	-0.005	-1.21
tX_2	-0.019	-3.16	-0.062	-12.83
tX_3	0.008	0.74	0.054	4.68
tX_4	0.019	3.13	0.005	1.18
tX_5	0.005	0.93	0.008	1.53
Log LF	176.44	-	143.08	-
Observations	194	-	120	-
Parameters	36	-	36	-
Inefficiency Model:				
Sigma-squared	0.011	10.06	0.021	9.74
Gamma	0.405	7.67	0.991	105.86
t	0.000	4.96	0.001	0.22

Note: Constant term and provin ce dummies in the efficiency model were not displayed. X_1 is used as numeraire.

Appendix 4. Decomposition of Total Factor Productivity (TFP) into Technical Efficiency (TE) and Technological Change (TC) on All Specialized Household Dairy Farms in China

Province	Period	Obs	TFP Decomposition (%)		
			TFP	TE	TC
Mean [a]	1992-03	12	2.33	0.78	1.55
Tianjin	1992-2003	12	1.39	0.84	0.55
Hebei	1992-2003	12	4.57	1.45	3.12
Shanxi	1993-2003	4	5.51	-0.26	5.77
Neimeng	1992-2003	10	-2.11	-0.38	-1.73
Liaoning	1994-2003	6	3.06	0.43	2.63
Jilin	1992-1999	4	-6.34	-7.28	0.94
Heilongjiang	1994-2003	10	0.06	0.04	0.03
Anhui	1992-2003	4	3.26	-2.10	5.36
Fujian	1996-2003	7	-3.65	-3.13	-0.52
Shandong	1997-2003	7	2.70	-0.92	3.62
Henan	1993-2003	11	1.10	0.14	0.96
Hunan	2000-2003	5	1.80	0.54	1.26
Chongqing	2000-2003	4	0.80	-1.76	2.56
Sichuan	2000-2003	3	-3.00	-4.37	1.37
Yunnan	2000-2003	4	-1.59	-0.28	-1.31
Shaanxi	1993-2003	9	-1.33	-2.04	0.71
Ningxia	2000-2003	4	8.23	-2.32	10.54
Xinjiang	1997-2003	4	8.34	5.15	3.20

Note: In order to evaluate the reliability of the results, we present the period and observations for each province. It should be noted that the periods only give the starting year and ending year of observations. When estimating the model, we dropped Beijing, Shanghai, Zhejiang, Jiangxi and Guanxi because they have less than three observations.

[a] Estimated at data means.

Appendix 5. Decomposition of Total Factor Productivity (TFP) into Technical Efficiency (TE) and Technological Change (TC) on All State -Collective Dairy Farms in China

Province	Period	Obs	TFP Decomposition (%)		
			TFP	TE	TC
Mean [a]	1992-03	12	0.25	-0.79	1.04
Beijing	1992-2003	12	1.41	0.00	1.41
Tianjin	1992-2003	8	1.49	-0.70	2.19
Hebei	1992-2003	12	0.36	-0.19	0.55
Neimeng	1992-1997	3	2.13	0.00	2.12
Liaoning	1995-2003	7	-1.00	-0.43	-0.56
Jilin	1992-2003	8	-0.03	0.06	-0.09
Shanghai	1992-2003	12	1.42	-0.05	1.47
Jiangsu	1992-2003	10	0.69	0.28	0.41
Zhejiang	1998-2003	6	0.17	0.55	-0.38
Anhui	1993-2003	11	-0.37	-0.10	-0.28
Fujian	1996-2003	4	-0.22	0.12	-0.34
Shandong	1992-2003	12	0.79	-1.46	2.25
Henan	1992-2003	12	-0.81	-1.58	0.77
Hubei	1992-2003	11	-0.10	-0.81	0.71
Hunan	1992-1997	4	-2.17	-1.39	-0.78
Guangdong	1993-2003	8	0.09	-1.90	1.99
Guangxi	1995-2003	8	-1.72	-1.26	-0.45
Hainan	2000-2003	4	0.35	-0.65	1.01
Chongqing	1997-2003	6	-0.75	-1.15	0.41
Guizhou	1992-2003	5	-1.10	0.05	-1.15
Shaanxi	1992-2003	8	5.13	2.67	2.46
Gansu	1992-2003	11	0.60	-1.29	1.89
Qinghai	2000-2003	4	-0.54	-0.50	-0.04
Xinjiang	1993-2003	8	0.46	-0.03	0.49

Note: See Appendix Table 4. When estimating model, we dropped Jiangxi, Sichuan, Yunnan and Ningxia because they have less than 3 observations.

[a] Estimated at data means