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Keywords
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DAIRY FOOD CONSUMPTION, PRODUCTION, AND POLICY IN JAPAN

1. Introduction

We explore and investigate Japanese dairy markets and policies. Japanese dairy is particularly interesting in the context of Asia because it is the most mature market among Asian economies. Consumers' income is the highest among Asian countries; consumer exposure to Westernized dairy products has been the longest among the same pool of countries as well. The analysis of Japanese dairy markets, therefore, provides lessons for other Asian countries with emerging dairy consumption in terms of their potential per capita consumption patterns and composition of dairy products consumed. The production side of dairy markets in Japan is also interesting because technology adoption and yield improvements have been rapid but in a context of isolation from world markets. The sector is also facing challenges common to many OECD (Organization for Economic Cooperation and Development) farming sectors, with aging and withering farming population, environmental pressures, and some reconsideration of agricultural subsidies.

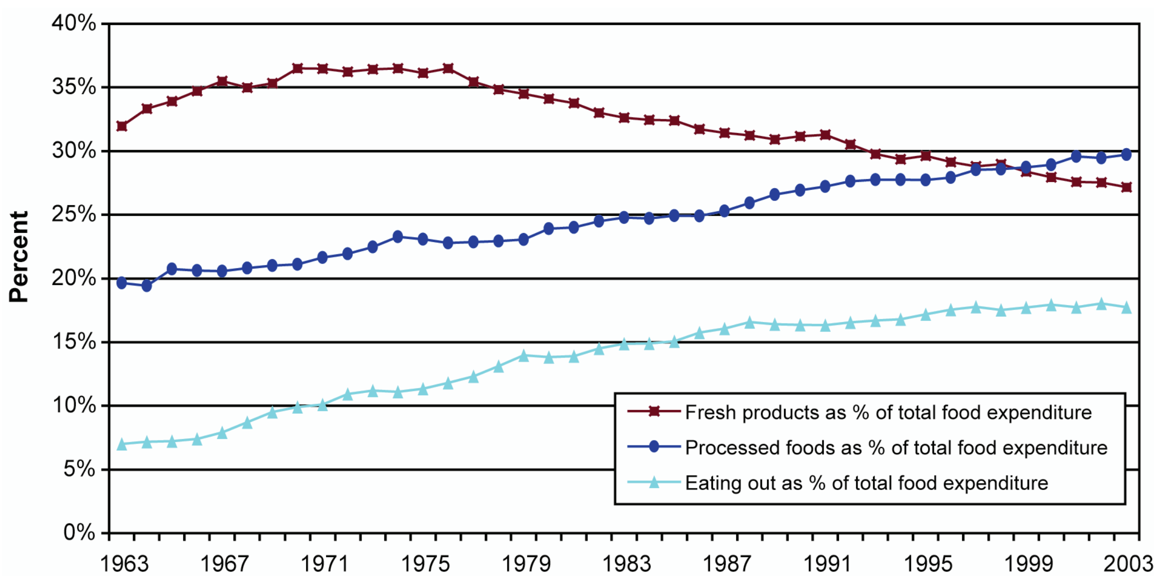
We first provide an overview of dairy consumption and how it evolved following World War II. Using new econometric estimates of Japanese dairy demand, we then identify cultural and demographic shifters and economic forces that have been shaping consumption patterns. We answer the question of whether further growth in dairy consumption is likely. We then summarize the characteristics of milk production and dairy processing in Japan. We follow with a description of the import regime and trade in dairy products. We further analyze the regulatory system of the dairy sector and show how its incentive structure affects competition, prices, and the long-term prospects of the industry. These last two parts shed some light on the likely evolution of the supply side of these markets and the relative composition of imports versus domestic supply. Finally, we provide policy recommendations to reform Japanese dairy.

2. The Evolution of Dairy Consumption Patterns

2.1. Changes in Japanese Dietary Habits

In the 60 years since the end of World War II, the Japanese diet has changed from one centered on rice, vegetables, and fish to one that incorporates many traditional Western food staples. Prior to World War II, rice accounted for about 60% of the caloric needs of Japanese people (Ohkawa, 1945). The five-year period from 1945 to 1950 was a time of crisis, characterized by chronic labor shortages, decreased economic power, and devastation of the urban landscape and the Japanese agricultural industry. During this period, rice, potatoes and sweet potatoes, vegetables, and minor cereals were the mainstays of the Japanese diet. Rice still accounted for 48% of caloric needs (Akitani and Yoshida, 1988). Chronic food shortages and the lack of availability of dairy products and meat meant that much of the Japanese population suffered from an insufficient intake of calories and protein. A first period of change in dietary habits occurred from 1950 to 1955. The government stabilized and improved food distribution through policies for increased food production and strengthened crop collection as well as acceptance of foreign food aid. With this, the variety of food started to increase, nutrition improved, and minimum caloric requirements were fulfilled. Provisions for a national school lunch program were also initiated during this period. A typical school lunch consisted of milk, a roll, margarine, and one or two side dishes (Japan Dairy Council, 2001). This was the first step toward incorporating Western food products into the Japanese diet. The fifteen years from 1955 to 1970 was a period of diversification and Westernization of eating styles. Household incomes rose rapidly, urban areas expanded, and nuclear families were increasing in number. Home electric appliances such as television sets, washing machines, refrigerators, and toasters were now affordable. The consumption of traditional Western foodstuffs such as milk, butter, cheese, meat, and eggs grew rapidly. Rice consumption, on the other hand, fell and accounted for only about 34% of caloric needs by 1970 (FAO, 2001). The appearance of instant Japanese foods such as “instant ramen” (instant noodles) (Higuchi, 1991) aimed to provide simplicity and convenience. The era between 1970 and 1990 was a period of further diversification of the variety of foods and dining habits (FAPRC, 1997). More flexible eating patterns evolved that were boosted by an increasing number of fast food stores and a flourishing food service sector. Microwave ovens became popular in the 1980s and automated the cooking process. The appreciation of the yen as well as improvement in the liberalization of imports beginning in the mid-1980s led to a rapid increase of food imports. The fourth period, beginning in the 1990s (FAPRC 1997), is characterized by the burst of the "bubble economy" and subsequent economic stagnation, which has tapered off expenditures on food in real terms and the food supply in calories as well as the stabilization of the variety of food. Another example of the diversification of Japanese dietary habits is eating out. How rapidly this has taken place is well illustrated by the fact that the proportion of eating out in the household food budget increased from 7% in 1963 to 17% in 2003 (see Figure 1). Similarly, the food budget allocated to processed foods, including pizza and cheese-containing products, has risen from 20% in 1963 to 30% in 2003. In contrast, the share of the food budget spent on fresh products (i.e., fresh meat, vegetables, and fruits) declined from an all-time high of 37% in 1970 to 27% in 2003.

The underlying forces of the structural change in food consumption were higher incomes and changes in relative prices, as well as a variety of other factors, including



Source: Derived from the Family Income and Expenditure Survey.

FIGURE 1. Eating out, fresh, and processed foods as percentage of total food expenditure

urbanization, population increase, education, occupation, access to information, changes in the employment structure —particularly the number of women in the labor force, an increasingly aging society, and the structure of household units. Japanese have increased consumption of luxury foods, such as imported delicacies and premium meat cuts, and foods with greater convenience of preparation. The presence of food service establishments serving international foods and increasing international travel by Japanese citizens have also affected Japanese tastes (Johnson et al., 1998).

Egaitsu and Tokoyama (1990) attempt to make a broad classification in terms of quality, convenience, and diversification. Regarding the question of "convenience," the increased opportunity cost of household labor is no doubt of great significance, and the argument that it would be incorrect to consider only the increased proportion of working women or housewives is convincing. Higuchi (1991) sees a trend toward higher "quality" in food consumption. For example, there is a large variety in beef quality that leads to enormous price differences. The same phenomenon is occurring with regard to rice. Higuchi (1991) also observes a diversification of dietary habits that has brought about the development of substitute food items (i.e., various types of processed food).

2.2. Dairy Product Consumption

The consumption of milk and other dairy products grew rapidly as the Japanese diet became more Westernized. Table 1 shows that the highest average annual growth rates of per capita consumption for milk and dairy products were recorded between 1965 and 1970. Per capita consumption for cheese grew faster than for any other product. The rate of growth began to decline around 1975 and stayed low most of the time for powdered milk and butter. Figure 2 further illustrates these dairy consumption patterns.

For milk and cheese, growth rates were positive for most periods but lower than in the 1960s, as Westernization became more complete, birth rates declined, and competition from other beverages such as soft drinks and sports drinks increased.

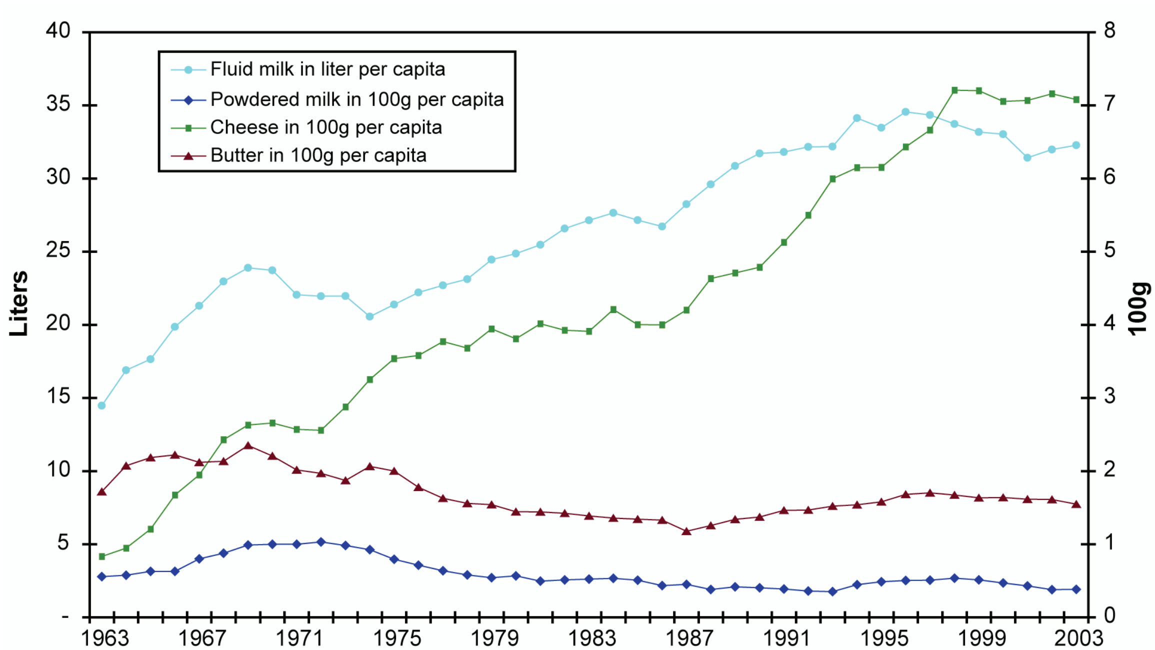
The Family Income and Expenditure Survey (FIES) data show that cheese consumption has been on the rise, and to a lesser degree fluid milk consumption as well. Butter and powdered milk consumption declined in earlier periods but remained more or less stable during the past two decades. As food tastes matured, the percentage increase declined until the mid-1980s. Then a wine and cheese boom toward the end of the 1980s

TABLE 1. Annual percentage changes of dairy product per capita consumption in Japan

Between	63-65	66-70	71-75	76-80	81-85	86-90	91-95	96-2000	01-03
Fluid Milk	6.8%	6.1%	-2.1%	3.1%	1.8%	3.2%	1.1%	-0.3%	-0.8%
Powdered Milk	4.1%	9.7%	-4.5%	-6.5%	-2.1%	-4.5%	3.8%	-0.7%	-6.7%
Butter	8.3%	0.2%	-1.9%	-6.3%	-1.5%	0.4%	2.9%	0.7%	-1.9%
Cheese	13.2%	17.1%	5.9%	1.5%	1.0%	3.7%	5.1%	2.8%	0.1%

Source: Derived from the Family Income and Expenditure Survey. Data are slightly different according to the MAFF Dairy Division, which gives the following. Fluid milk: 63-65, 8.0%; 71-75, 0.0%; 76-80, 2.4%. For powdered milk: 63-65, 1.9 %. For butter: 63-65, 8.9%; 66-70, 0.3%; 71-75, –2.0%; 81-85, -1.4%; 86-90, 0.5%; 91-95, 2.8%. For cheese: 63-65, 20.6%; 66-70, 17.0%.

Note: Average rates between n years computed as $(x_{t+n}/x_t)^{(1/n)} - 1$.



Source: Derived from the Family Income and Expenditure Survey.

FIGURE 2. Dairy product consumption per capita

and at the height of the bubble economy was observed, such that the annual percentage increase in cheese consumption picked up again and stayed strong until the mid-1990s. In the late 1990s, the Japanese economy went through several crises, and consumers in general cut back on their food consumption.

Starting in the early 1970s, European- and American-style fast food establishments, including family restaurants and hamburger stands, began to spring up throughout the country. This was accompanied by an increase in health-related problems such as obesity and high blood pressure. Partly because of these health concerns, beginning around 1975, meat consumption stagnated, and egg consumption started to decline. Despite this, consumption of milk and cheese increased steadily. Milk powder consumption declined between 1971 and 1990; it then increased for five years and then began again to decrease.

Table 2 compares consumption levels in the Western world based on the Production, Supply and Distribution (PS&D) disappearance data of the U.S. Department of Agriculture's (USDA) Foreign Agricultural Service. Data from the Food and Agriculture Organization (FAO) and data from consumer expenditure surveys by other agencies, such as Japan's FIES, vary but tell the same story, with patterns in all data sets being similar. Compared with other industrialized countries, per capita consumption of fluid milk, butter, and cheese in Japan is much lower, whereas per capita milk-powder consumption is on a par or slightly higher. The per capita consumption of fluid milk in Japan is roughly 43% of that of its OECD partners. Butter is about 24% of that of the OECD partners and cheese consumption is 15% of that of Japan's industrialized partners. It is worth noting that in Japan, unlike in Europe, the United States, and other Western countries, milk and other dairy products are not widely used in cooking. The Japan Dairy Council notes that there is a potential for increased consumption if the Japanese will incorporate more dairy products into their cooking in the future. As Japan's income compares favorably with most of its industrialized partners, income differences will not

TABLE 2. International comparison of dairy food consumption 2004 (kg per capita, per year)

Country	Fluid Milk	Butter	Cheese	Skim Milk Powder
Switzerland	93.8	6.0	17.1	2.1
EU-25	79.2	4.7	14.1	2.4
Australia	102.2	2.9	11.9	1.7
New Zealand	90.1	6.5	7.0	1.3
Canada	87.7	2.9	10.7	1.5
United States	92.1	2.0	14.1	1.3
Japan	39.0	0.7	2.0	1.7

Sources: USDA-FAS PS&D database, and FAPRI 2005.

be able to explain such between-country differences in consumption patterns, although the evolution of dairy consumption within Japan is strongly linked to its income growth.

After World War II, when school lunches were introduced in elementary schools and children began drinking milk, milk consumption at home also increased. At this time, most distribution was by home delivery. However, as the number of supermarkets in urban areas started to grow beginning in 1965, the volume of milk sales from such outlets sharply increased. Then, beginning around 1975, convenience stores began handling milk and the volume of milk sold through home delivery services accordingly decreased. By 1983, supermarkets and convenience stores handled 52% of total milk sales, while milk wholesalers handled 33%, of which home delivery accounted for 13%. By 1999, supermarkets and convenience stores accounted for 70.2% of total milk sales; schools accounted for 9%; small stores for 2.0%, vending machines for 0.5%, consumer cooperatives for 13.1%, and home delivery service for 5.2% (estimates by the Agriculture and Livestock Industry Corporation [ALIC], Japan). Home delivery is showing signs of resurgence in popularity. This reflects the increasing number of elderly and dual wage-earner households that do not have the time or ability to shop at supermarkets, and the convenience of home delivery. It is also clear that some people want to obtain fresh milk every day without having to go to a market (Japan Dairy Council, 2001).

The average price of a liter of milk is about ¥200 (retail). Additionally, the price has not changed over the last 10 years (Japan Dairy Council, 2001). However, Japanese consumers have been paying a lot more for dairy products than consumers in other countries. The consumer nominal protection coefficient (NPC), which measures the ratio of the price paid by consumers and the border price, has hovered around 400% in recent years (426% average for 2000-02, 406% in 2003) (OECD 2003, 2004). The NPC was even higher in earlier years; as indicated by the OECD, it was around 600% during the period 1986-88. Complementary evidence by Scrimgeour (1998) shows similar patterns at the retail level. Hence, even if dairy demand is price inelastic, such high prices must have stifled consumption. These distortion levels faced by Japanese consumers are the highest among the OECD member countries, as the average consumer NPC is 191% for the whole OECD membership. Therefore, a priori, high dairy consumer prices may partly explain the relatively lower dairy consumption levels in Japan, a conjecture we explore in the econometric estimation.

2.4. Demographics, Health, and Dairy Consumption

Milk is a regular food staple in about 87% of all Japanese households and is consumed by persons of all ages and both genders (NMPAJ, 1995). Consumption, however, varies greatly by age and gender. As children advance from nursery school to kindergarten and to elementary school, where milk is a part of all school lunches, per capita consumption continues to increase. However, after elementary school, school lunches are no longer provided and consumption rapidly decreases. For young adults, the average daily per capita consumption is only 1.4 deciliter (dl), less than half the daily average of elementary school students. Although young working Japanese have substantial disposable incomes, they tend to follow prevailing trends to consume more "sophisticated" beverages, and milk consumption drops (NMPAJ, 1995).

This trend is particularly evident among diet-conscious young women, who on average consume 0.6-1 dl less than do men. However, when Japanese women enter their thirties, typically after marriage and childbirth, they begin to pay closer attention to family health (NMPAJ, 1995). At this point, per capita milk consumption increases to about 1.6 dl a day on average. Drinking milk is one of the most effective ways of obtaining dietary calcium, a nutrient lacking in many Japanese diets. Approximately 80% of Japanese surveyed acknowledge the importance of milk in maintaining good health. In fact, milk receives a health rating three to four times higher than that of sports drinks and Chinese oolong tea, two beverages enjoying recent popularity (NMPAJ, 1995).

The annual report of the FIES provides data on the consumption of dairy products according to the age group of the household head. Milk consumption has been declining steadily for the 29-and-under age group but has been increasing for all other age groups across time. Yet, from 2000 to 2003 the milk consumption declined for the 30-to-50 and 70-and-over age groups, increased for the 60-to-69 age group, and stabilized for the 29-and-under and 50-to-59 age groups. It is especially remarkable that milk consumption for people older than 70 is the highest among all groups. This might have to do with the steadily increasing number of retired people who seem to be very health conscious. Cheese has experienced an increase in popularity over the years among all age groups, but especially among the 30-to-50 year olds and the people 60 years and older. Powdered milk is consumed mostly among younger age groups and shows a decreasing trend over the years. It could be that powdered milk is mainly used for infants and has no wider application. Butter consumption was at an all-time high in 1990 for all age groups. Since then it has declined sharply across all age groups.

Several conjectures emerge from these stylized patterns of consumption. First, the shifts in demand for butter might have to do with the health consciousness of Japanese people. Butter is not widely used in cooking; it is mostly consumed as a spread on bread. As such other spreads such as margarine can be easily substituted. Second, the inward shifts (decrease) of powdered-milk demand could be explained as follows. After World War II, food aid brought powdered milk to the country (a popular item to send as food aid to developing countries), but with rising incomes, the Japanese could afford milk as a substitute for powdered milk. Powdered milk remains an item for children, and with the aging of the population its consumption will decrease, other things being equal. Third, fluid-milk demand may have experienced a major initial outward shift caused by the introduction of the school lunch program in the 1960s, then some inward tapering as the Japanese population aged. Another potential shift of fluid milk demand may have occurred over time with promotions by the Japan Dairy Council, and an increased awareness of the healthy nature of milk. We also investigate these non-price shifters in the econometric analysis.

3. Evidence on Dairy Consumption Decisions

Previous estimations of Japanese dairy demand include the derived demand for imported cheese products into Japan by Christou et al. (2005); Watanabe, Suzuki, and Kaiser (1999) who used qualitative final consumer survey data; and Watanabe, Suzuki, and Kaiser (1997) who looked at the role of health concerns in decisions to consume milk. We next report on our own estimation effort, which extends the comprehensive unpublished econometric analysis of Schluep Campo (2002) with the latest available (2003) data.

3.1. Procedure and Estimation

The methodology used in the study is the almost ideal (AI) demand system by Deaton and Muellbauer (1980) and its variant, the semiflexible almost ideal (SAI) demand system developed by Moschini (1998), which allows an easy imposition of concavity locally by reducing the rank of the substitution matrix of price responses of Hicksian demands. The approach is described in detail in Appendix A. We estimate three specifications: first a full system comprising four dairy products (fluid milk, powder milk, cheese, and butter), and an all-other-goods aggregate; second a subsystem for food made of five goods (the four dairy goods and an all-other-food aggregate; and finally, a subsystem of the four dairy products. The minimum distance estimator is used to estimate the demand system. It is an approximation to maximum likelihood developed by Malinvaud (1980). The software package TSP 4.5 Through the Looking Glass is used to carry out the econometric analysis.

3.2. Data

Both the expenditure and the price data are taken from the "Annual Report on the Family Income and Expenditure Survey" (FIES) published by the Statistics Bureau, Management and Coordination Agency, Japan (SBMCA, 1983, 1987, 1988, 1990, 2000), and from the *Japan Statistical Yearbook* (SBMCA, various). There are 41 years of observation from 1963 to 2003 available. The survey covers all the consumer household types in Japan except one-person households, households that manage restaurants, hotels, boarding houses or dormitories, households whose heads are absent for a long time, and foreigner households (SBMCA, various). About 8,000 households are randomly selected for the survey out of about 31 million qualified households. The sample households are selected based on a three-stage stratified sampling method. The sampling units at three stages are the municipality (i.e., city, town and village), the survey unit area, and the household. Japan is stratified into 168 strata (SBMCA, 2000). Essential for this study is Table 17 (SBMCA, 2000, 2003) that contains "Yearly Amount of Expenditures, Quantities and Average Prices per Household (All Households - Workers' Households)."

The study involves four dairy food groups and two aggregates of other goods. Expenditures are per annum in yen. Dairy goods and the all-other-food aggregate expenditures are deflated by the food price index while expenditures on all other goods are deflated by the consumer price index (CPI). Dairy good prices per year (in yen) are deflated by the food price index. The CPI is a proxy for the price of the all-other-goods aggregate and the food price index one for the all-other-food aggregate.

3.3. Results

In this section we present key results on the full-expenditure SAI specification and comments on results from other specifications. Results are shown in Tables 3 and 4. The results of the three expenditure specifications and the two approaches (AI, SAI) are contained in Appendix B.

Income/expenditure elasticities are always positive for fluid milk, powdered milk, and cheese. The expenditure elasticity of butter demand is negative for four out of the six estimations (the two full-expenditure systems with AI and SAI, the food-expenditure system with AI, and the dairy expenditure system with SAI). The significance of the expenditure coefficients increases from the full expenditure system to the food expenditure system but then decreases slightly in the dairy sub-expenditure system. These results are not inconsistent but show that the link between aggregate expenditure and food expenditure could be approximate by a proportional move, but then the link between

TABLE 3. Marshallian elasticities at the mean point, rank 4 SAI model

		With respect to					
Elasticity of		p_{ofnf}	p_{fm}	p_c	p_{pm}	p_b	**Expenditure**
(1)	Other food & non-food	**-1.00**	0.00	0.00	0.00	0.00	1.00
(2)	Fluid milk	0.39	**-1.10**	-0.05	0.01	-0.04	0.80
(3)	Cheese	1.15	-0.53	**-1.29**	-0.11	-0.06	0.83
(4)	Powdered milk	-0.22	0.07	-0.13	**-1.28**	0.32	1.24
(5)	Butter	0.91	-0.78	-0.10	0.50	**-0.16**	-0.37
	Mean share	0.990	0.008	0.001	0.001	0.000	

TABLE 4. Hicksian elasticities at the mean point, full rank SAI model

		With respect to				
Elasticity of		p_{ofnf}	p_{fm}	p_c	p_{pm}	p_b
(1)	Other food & non-food	-0.01	0.01	0.00	0.00	0.00
(2)	Fluid milk	1.18	-1.10	-0.05	0.01	-0.04
(3)	Cheese	1.97	-0.52	-1.29	-0.11	-0.06
(4)	Powdered milk	1.01	0.08	-0.13	-1.28	0.32
(5)	Butter	0.54	-0.78	-0.10	0.50	-0.16
	Mean share	0.990	0.008	0.001	0.001	0.000

food expenditure and dairy-only expenditure is not proportional at all as the expenditure response of butter changes signs.

Own-price responses are large in absolute values (price-elastic) and cross-price effects are more modest as one would expect and suggest that dairy products are substitutes except for cheese, which appears as a complement. Fluid milk and milk powder are substitutes, as suggested by Tables 3 and 4. This substitution holds in four of the six estimated systems but is reversed in the food-expenditure estimation. The fluid to powder milk substitution is consistent with stylized facts of consumption patterns away from milk powder toward fluid milk. The substitution effect appears particularly strong in the dairy sub-expenditure system.

The trend variable influences all dairy products positively in most of the estimated systems. This persistent result indicates that some fundamental influence has been at work, which is not explained by prices, expenditure, and demographic dynamics (aging, population density, female participation in the labor force) included in the specification. The positive trend result is consistent with the positive influence of promotion and health awareness campaigns discussed in section 2. Trends are always challenging to pin down as several effects could have been captured in a single variable. In any case, the trend does not account for population influences already accounted for in the estimation (population density, aging and other demographic aspects). Cheese is positively influenced by aging (rising dependency ratio). All the other per capita consumptions of other products are negatively influenced by aging. The aging result is consistent with the tapering of the initial boom created by school programs in the early 1960s as population ages. Population density, a linear transformation of population, has been growing faster than consumption per capita as suggested by the negative influence of this variable on per capita consumption.

As shown in Appendix B, some eigenvalues of the substitution matrix are positive but most of these positive eigenvalues are near zero, except for the AI and SAI food expenditure systems for which the eigenvalue associated with other food is a bit larger. Given that these violations of curvature are minor, their correction induces limited changes in qualitative results as shown when comparing AI and restricted SAI specifications of any given expenditure system.

4. Dairy Supply and Imports

4.1. Structure of the Dairy Sector

Commercial dairy farming began in Japan in the late Meiji era, about 100 years ago. However, it was not until the early 1950s that it developed on a full scale, about the same time that the school lunch system was introduced in elementary schools. The total annual raw milk production in Japan was about 8.36 million tons in 2004 (FAPRI 1997). Currently there are approximately 30,000 dairy farms (see Figure 3), but data on the number of dairy cattle vary. USDA PS&D data indicate a total of 936,000 dairy cows. FAO data indicate a higher number (1.21 million head) of dairy cows and lower yields but similar milk production for 2004. Japanese data from the Ministry of Agriculture, Forestry and Fisheries (MAFF, various) indicate a much higher number of head (1.72 million head) but milking cattle numbers are close to those of the USDA (1999). Dairy farm operations are small on average but this average hides a rather wide distribution of farm size. Larger farms are more prevalent in the north of Japan (Hokkaido).

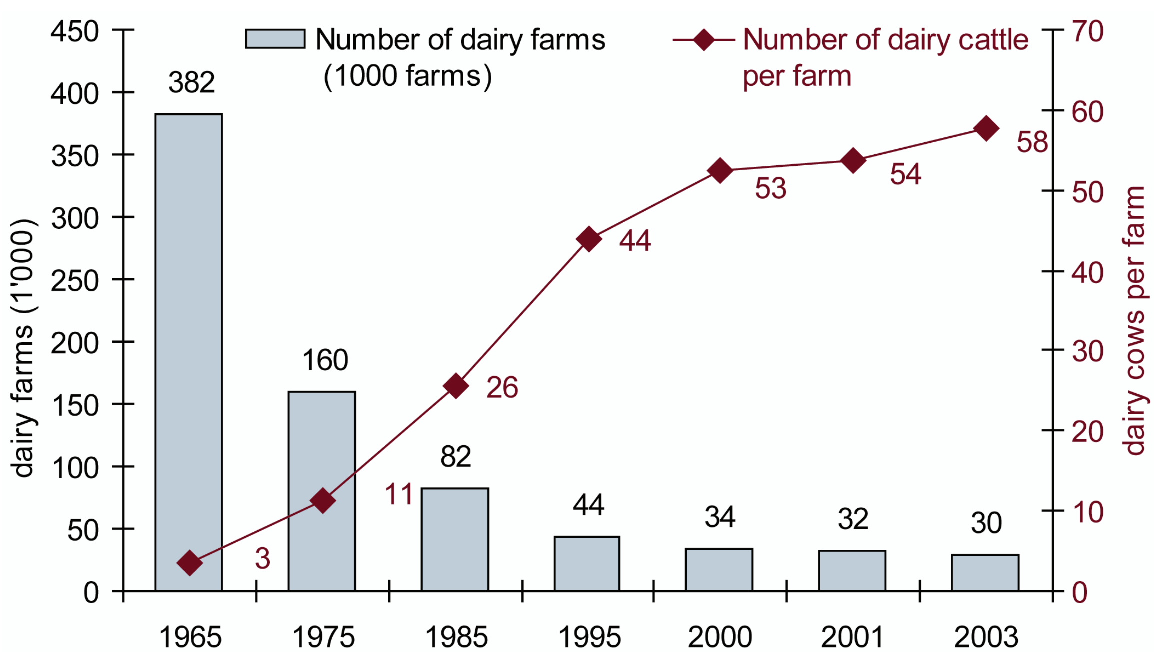


FIGURE 3. Evolution of dairy farms

Relative to rice farming, dairy farms tend to be much more profitable. About 60% of the milk production is used for fluid milk and the remaining 40% is processed into other dairy products such as cheese, butter, and powdered milk (MAFF, various).

Although Japanese agriculture is centered on rice, which accounts for one-third of gross agricultural income and is cultivated on roughly 40% of farmland, dairy, livestock, fruits, and vegetables are also important sectors of Japanese agriculture in terms of value added. Dairy represents about 8% of agricultural value added but only about 1.3% of the number of farms. In places where dairy farmers have to compete with rice farmers it is still more attractive to grow rice for human consumption given the higher protection given to rice producers, which explains why dairy farmers usually operate on small acreage and buy most of the feed. Only in regions that are not suitable for rice, such as in Hokkaido, are dairy farms larger. The Hokkaido region's larger dairy farms specialize in processed dairy products. About 75% of Hokkaido's milk goes to processing. For the rest of Japan, the opposite is true. More than 80% of the milk is consumed as fluid milk and less than 20% is processed. About two-thirds of the processing factories are small, producing less than 15,000 mt of fluid milk per year. However, large factories have emerged in the last decade that are more efficient (Pritchard and Curtis, 2004). Dairy processors suffer from tariff de-escalation, meaning that fluid milk faces much higher tariffs than does cheese, which implies that the domestic industry is not encouraged to produce value-added products such as cheese. The effective protection of dairy processors is limited if not negative since fluid milk going to processing is expensive and the protection on some dairy products is limited.

Cheese imports have expanded a lot, although domestic cheese production has expanded at the same rate. Self-sufficiency in cheese has changed little in the last 15 years, although overall dairy self-sufficiency has decreased as cheese imports have grown substantially both in value and volume terms and have become the largest component of dairy imports.

4.2. Recent and Present Dairy Farm Policy

Before 2001, Japanese dairy policy was composed of three basic programs: price supports for milk used for manufactured dairy products, classified pricing and revenue pooling through prefectural milk marketing boards, and import quotas (Suzuki and Kaiser, 1994). The Japanese dairy industry conformed to production guidelines set by the government and based on supply/demand data provided by the ALIC. In order to assure the stable supply of raw milk, a subsidy system for dairy producers was established in 1965. Since then, the government has set production ceilings in order to prevent market surpluses and price instability. Furthermore, dairy producers voluntarily organized a planned production system in 1979. Annual production allowances based on demand estimates were determined by the Japan Dairy Council and were allotted to each prefecture (nine in total). In turn, the authorities on the prefecture level set production quotas for individual agricultural cooperatives and dairy farmers within the prefecture. Allocation formulas varied among the different prefecture councils. Until 1995, production quotas were under the control of the national and prefectural councils. In 1996, however, a system allowing individual dairy farmers to adjust production quotas among themselves was instituted.

Deficiency payments based on the difference between the average cost of producing one kilogram of milk (the guaranteed price) and the price dairy producers receive for the same quantity (the standard transaction price) were determined annually. Also, farmers received a subsidy for their annually determined production quotas. That is to say, the price the dairy producers received was the guaranteed price (standard transaction price paid by the milk processors plus the deficiency payments paid by the government). In addition, before 2001, fluid milk prices were determined by negotiations between each marketing board and the processors that it supplied. Given the manufacturing milk price, prefectural marketing boards usually obtained fluid milk premiums through their market power (Suzuki and Kaiser, 1994). The recent trend has seen steady price declines for fluid milk that progressed independently of production costs to dairy farmers (Japan Dairy Council, 2001).

The current dairy policy has been in place since 2001 (Suzuki and Kaiser, 2005). The production quota is still in effect and is determined as before. All government-regulated prices were abolished, including the guaranteed manufacturing milk price for farmers, and the standard transactions price for manufactures. The difference between the guaranteed price and the standard transactions price used to be paid to farmers as deficiency payments. In the new system, only the amount of the former deficiency payment, almost

¥10/kg, is maintained as a fixed payment. The fixed payment level is reviewed every year, considering the demand/supply situation and farmers' production costs. Now, the private market determines the manufacturing milk prices. Regardless of the market price level, farmers receive the market price plus the fixed payment.

However, the new policy has a built-in security measure in case of a sudden price decline and operates along the lines of a revenue insurance program. A fund has been established that is charged by deductions of ¥0.4/kg of milk that is delivered and by an additional ¥1.2/kg of milk quota for which farmers are getting subsidies. These funds are then matched by government money. If the price for manufactured milk is below the past three-year average, farmers can receive 80% of the difference between the current price and the past three-year average from the fund. Overall, it seems that the policy changes have been cosmetic rather than fundamental in nature. The essence of the policy is that it is paid by consumers through market prices that are much higher than their international equivalents. According to the OECD, the market price support (MPS) component indicates the producer support obtained through market price distortions. In Japanese dairy production the MPS has been about 90% of the producer support estimate (PSE) between 1986 and 2003, with very little change during this period. Still, according to the OECD, the consumer NPC explains 96% of the producer NPC during the same period and with virtually no change. Hence, the nature of policy has remained the same in the last two decades. The level of support, as measured by the PSE per unit of production in nominal terms, has been falling from ¥91,000/mt in 1986 to a little less than ¥66,000/mt, quite a substantial decrease, especially in real terms, although the intervention level remains extremely high.

4.3. Dairy Trade Patterns and Policies

As part of the Uruguay Round Agreement on Agriculture (URAA), Japan accepted tariffication for all of its agricultural commodities except rice, which received a waiver.[1] Agricultural products with prior import bans (or very low access) faced minimum market access commitments as a part of tariff rate quota (TRQ) programs and others held the current market access provisions (IATRC, 2001). Japan has enforced TRQs strictly during the first four years of the URAA implementation period. Under the URAA, Japan converted 28 commodities from non-tariff protection to tariffs (IATRC, 1997). TRQs were created for 19 items (IATRC, 2001). Of these, 10 are dairy products, including skim milk powder, whey, and butter (see Table 5). In Japan, imports of dairy products such as milk powder, condensed milk, buttermilk powder, whey, and butter are managed by the ALIC, a state trading enterprise (STE). The major exception is natural cheese, for which neither the STE nor an import quota applies (Suzuki and Kaiser, 1994). The import penetration rate for cheese is above 80% for Japan, reflecting the relatively low barriers on cheese and the limited domestic cheese supply, which suffers from negative effective protection.

Table 5 shows the TRQ structure with the in-quota tariff level. No average tariff is calculated if several tariff lines of a product are involved. As for the quota, the initial levels are for 1995 and the final levels are for 2000. If the initial and the final quotas are the same, it is because Japan didn't have to make commitments for the respective products since at the time of the URAA Japan already had imported more than 5% of domestic consumption. Private traders can import dairy products subject to out-of-quota tariffs (at the much higher tariff). The markups on designated imported dairy products are

TABLE 5: Tariff Rate Quotas for Dairy Products, Japan, 1995-2000 and 2003 Fill Rates

	Quota (tons)		Tariff (¥/kg or in %)			Quota Fill Rate (2003) (%)
Product	Initial	Final	In-quota	Out of Quota Initial	Out of Quota Final	
Skim milk powder (school lunch)	7,264	7,264	0	¥466	¥396	40%
Skim milk powder (others)	85,878	85,878	Various	¥466 + 25%	¥396 + 21.3%	41%
Evaporated milk	1,585	1,585	Various	Various	various	92%
Whey (feed)	45,000	45,000	0	Various	various	51%
Whey (infant)	25,000	25,000	10%	Various	various	42%
Butter & butter oil	1,873	1,873	35%	Various	various	12%
Concentrated whey	14,000	14,000	Various	Various	various	27%
Prepared edible fat	18,977	18,977	25%	Various	various	100%
Other dairy products	124,640	133,940	Various	Various	various	99%
Designated dairy products	137,202	137,202	Various	Various	various	92%

Source: Notification by Japan to the WTO (2004); IATRC 2001; quota fill rates are from WTO 2004.

bound by the Country Schedule of Japan. The bound markups were reduced by 15% between 1995 and 2000 but starting from a very high level. For example, for out-of-quota skim milk powder (others), there was a 21.3% ad valorem tariff plus ¥396/kg in 2000. Domestic sale prices for dairy products are based on import prices, management costs, and domestic prices for dairy products (IATRC, 2001).

The TRQ fill rates for dairy products in Japan have been increasing over time. They were rather low in the late 1990s but are now quite high, as shown in Table 5, and with much variability remaining. The lowest fill rates occur for butter, whey, and milk powder. These low rates could be an indication of non-tariff trade barriers, such as a cumbersome TRQ administration and allocation system. Dairy product import policy in Japan seems to be designed to minimize the impacts of imports on domestic markets in which Japanese farmers compete. As a result, consumer benefits are reduced, and allocation across import suppliers has been affected (IATRC, 2001).

Import quotas regulated the importation of ice cream to Japan until the 1980s, which was then liberalized in 1990. Because of this regime change the volume and the value of imports increased rapidly in the following years. Between 1990 and 1995, the volume of imports multiplied ten-fold and the value six-fold. The strong yen and consumers "seeking real value and high quality" were the driving forces (JETRO, 2002b). However, since 1995, ice cream imports have leveled off because of declining imports of "private brand" ice creams from Australia and New Zealand—a cheaper type of ice cream that didn't suit the public's taste in Japan. Between 2000 and 2002 even import of the preferred super premium ice cream slacked because of the weaker yen. No precise figure is available for imported products' share in the Japanese market. The industry estimates imports' share to be about 5%. This figure may seem small, but licensed Japanese manufactures produce most of the foreign branded ice cream in Japan. The majority of the imports originate from the United States (mostly super premium and premium ice creams), followed by imports from Australia and New Zealand. The tariff rates on ice cream vary between 21% and 29.8% according to the content of milk fat and added sugar. In addition, a consumption tax of 5% is raised on the import value plus the tariff. Ice cream is shipped in refrigerated containers, which are smaller than normal containers, leading to lower efficiency and higher transportation costs. It is then delivered to distributors at the port and carried by refrigerated trucks to wholesalers or the warehouses of retailers. Most products are distributed through wholesalers. Recently it has become more common to see leading mass merchandisers and convenience stores jointly planning new products with overseas manufacturers and importing their original products. Also because of cost-cutting measures, a growing number of corporations choose joint planning and direct delivery (JETRO, 2002b).

Japan distinguishes broadly between natural and processed cheeses. Natural cheese includes soft cheeses (e.g., Camembert or mozzarella), semi-hard (e.g., Gouda), hard (e.g., Emmental and Gruyère) and extra hard cheeses (e.g., Parmesan). Processed cheese is made out of one or more varieties of natural cheese. Examples are carton packaged, sliced, spread cheese, and cream cheese. Processed cheese became popular in the 1960s. Natural cheese was first not much appreciated in Japan because of the strong aroma. But with the widespread adoption of home refrigeration, increasing Westernization, the emergence of processed foods (pizza, cheesecake), and the increased international travel of the Japanese, gradually natural cheese assumed a larger role in Japanese cuisine (JETRO, 1999). Today, most imported cheese consists of natural cheese. On natural cheese imports intended for direct consumption Japan levies import tariffs ranging between 22.4% to 40%. The imported natural cheese for direct consumption has a 90.1% share (2002) in the Japanese market. Australia is the leading exporter of natural cheese to Japan. On a volume basis it accounts for 39.7% (2001). Together with second-place New Zealand (26.5%) exports from these two nations in Oceania account for nearly 66.2% of all imports.

Natural cheese destined as an ingredient for processed cheese is imported through the "pooled quota" and enters Japan duty free up to 2.5 times the amount of Japanese domestic natural cheese production used for processed cheese. An over-quota tariff of 35% is applied to imports exceeding that volume. Importers must apply to the MAFF for the in-quota duty rate. Further, qualified applicants must own or operate processed cheese production facilities and must prove that they are also utilizing natural cheese made in Japan as raw material (a domestic purchasing requirement). Along with the application they must file a domestic natural cheese utilization plan for the time period stipulated in the TRQ notice. After the positive examination, a TRQ certificate is issued stating the quota amount. When this certificate is presented at customs, the quota amount listed is duty free. In 2001, New Zealand's share of natural cheese imports under the TRQ was 43.9% Australia's was 39.1% and Canada's was 5.7%. For New Zealand, the Japanese cheese market is a so-called designated market, for which the export licensing regime applies. Fonterra, New Zealand's largest dairy cooperative, has exclusive rights to export cheese to Japan.[2] Most processed cheeses are domestic products made from a blend of imported and domestically produced raw ingredients. Imported processed cheese accounts for just 6.4% (2002) of the processed cheese market. Japan levies a 40% ad valorem tariff on processed cheese imports.

Butter imports generally compensate for shortages of domestically produced Japanese butter relative to demand. Hence, butter imports are just a very narrow residual market. To stabilize Japanese butter prices, all butter imports pass through a single importer channel, the ALIC (JETRO, 2002a). Since 1996, butter imports have shrunk to the 300-350 ton range. The butter imports' share is only around 1%.[3] The state trading importing regime of the ALIC basically ensures that a much higher domestic fluid milk price can be maintained. Japan imports butter mainly from New Zealand, which had a share of 45.5% on a volume basis in 2001. Australia ranks second with a share of 22.1%. Though it is possible to import butter through the "pooled quota" at the in-quota rate of 35%, this is limited to butter for specific uses (e.g., for display at international trade fairs and for airplanes on international flights) (JETRO, 2002a). In order to apply for the primary duty rate, importers must apply to MAFF and obtain a TRQ certificate. Ad valorem equivalents for over-quota rates for the butter TRQs range between 465.5% (Nuzum, 1999) and 592% (OECD). Clearly these rates are prohibitive in addition to the import monopoly by the ALIC. JETRO (2002a) notes that imported butter differs considerably in terms of texture and aroma from Japanese butter and that most imported butter is used by dairy companies in processed dairy foods, ice cream, and spreads. Further, very little imported butter is consumed directly by end users. The ALIC sells through open competitive bidding imported butter to domestic purchasers (JETRO, 2002a). Only confectioners and dairy product processors are allowed to submit bids, and the standard lot size is about 2.5 tons (JETRO, 2002a).

Under customs tariff classification, milk and cream are divided roughly into non-prepared milk; concentrated milk, and cream (powdered or condensed); and curdled, fermented or acidified milk and cream. Milk and cream are further classified by fat content, added sugar, and usage. Powdered skim milk is imported through the TRQ system. TRQ quantities depend on the end use, such as for school lunch, and child welfare institutions, for feed, or for other uses. To apply for the primary duty rate, importers submit a TRQ application form to the MAFF to obtain a TRQ license. The import of powdered skim milk for uses other than for feed, school lunch, or other special uses is mainly managed by the ALIC (JETRO, 2003) and product is sold to major dairy industry manufacturers or those affiliated with agricultural cooperative associations.

5. Conclusions

We looked at market and policy developments in Japanese dairy over the last four decades. Consumption patterns have evolved with increasing individual consumption of cheese and fluid milk. The individual consumption of butter and milk powder has been stagnating, as butter is not widely used in cooking or as a spread and as fluid milk has been substituted for milk powder. Overall, dairy consumption per capita has increased substantially. This increase in per capita consumption is linked to a decline in real dairy prices, rising individual incomes, and changes in taste/information. The income and own-price responses of individual dairy consumption are large; real prices, although still very high by international standards, have been falling dramatically in the last 40 years. Income growth between 1960 and 2003 has also been important, even though income stagnated in the last decade. As these prices will eventually fall with further trade liberalization, further increases in consumption can be expected.

Higher cheese consumption is further linked to the increasing consumption of convenience and processed foods by Japanese consumers. Fluid milk is linked to various factors such as health concerns and promotion campaigns. As Japan's population has been increasing in the last 40 years, aggregate market consumption has been rising, although not at as high a pace. Japan consumes much less dairy than do other OECD countries with comparable purchasing power. High consumer prices are a major part of the explanation but a less developed taste for dairy products in Japan is also a reason and is likely to be a recurrent theme in Asian markets.

The Japanese dairy supply is still isolated from world markets because of prohibitive tariffs, the high transportation cost, and the perishability of fluid milk. Processors have been disadvantaged by their low level of effective protection and by a lack of scale economies. The fluid milk supply has expanded through substantial yield increases, although the cost of production is very high and the typical dairy farm size is small and inefficient. The greater availability of dairy products has been achieved through trade, especially for cheese products from Australia and New Zealand. Hence, much like the situation in Korea, domestic milk producers in Japan will remain significantly isolated from world markets, at least for the fresh milk segment of their demand. The derived demand for milk from processors is unlikely to expand in this context of trade integration unless the price of milk is drastically reduced.

The protection of fluid milk production could be greatly decreased by a production quota expansion and a reduction in farm subsidies for several reasons. Fluid milk enjoys significant natural protection thanks to high trade and transportation costs and perishability. Fluid milk prices in Japan are a heresy when compared with New Zealand equivalents. They could be decreased by half and would still remain prohibitive for fluid milk trade but this would significantly improve the incentive structure of processors and would allow them to compete with international exporters in their home markets. Lower milk prices would also induce an acceleration of the rationalization of dairy farms, as the dairy farmer population is aging and retiring. Incentives to voluntarily exit the industry, linked to retirement security, could be put in place.

The political economy of agricultural protection in Japan favors rice over dairy as rice remains extremely protected and imports are marginal, unlike the case of dairy, which exhibits significant import penetration and low self-sufficiency ratios, but this phenomena is occurring in processed dairy markets, not in the fluid milk market. Fluid milk is protected by perishability, high transportation cost, and prohibitive trade barriers and domestic farm subsidies. In the World Trade Organization negotiations, dairy may well be “given up” as a bargaining chip to protect rice, especially in the bargaining with the Cairns group members such as Australia and New Zealand. The latter are the two largest dairy exporters to Japan and would stand to gain the most from further dairy trade opening (Pritchard and Curtis 2004). This is relative, of course, as the proposed average cuts in bound tariffs may not lead to further actual trade opening of any particular or sensitive product. Further imports may not expand in this round of negotiations, as actual TRQs are already above import commitments (minimum import levels as 5% [URAA] or 8% [Harbinson proposal] of consumption) (Martin and Anderson, 2005).

Endnotes

1. In 1999 Japan changed its rice import policy to tariffication with minimum market access (682,000 tons in 2000) (IATRC, 2001).

2. The success of a unique New Zealand cheese, Egmont, in the largest market, Japan, has prompted the development of another cheese especially for use in processing (and that is imported through the Pooled Quota). Japan buys more than 50,000 tons of New Zealand cheese a year worth over NZ$235 million, with most being used in food preparations such as pizza toppings.

3. According to the JETRO (2002a) marketing guidebook for major imported products, the reason for this low import share is that "butter requires freshness." However, butter can be stored frozen (-18 to -24 degrees Celsius eight to twelve months; at -10 degrees for up to three months; and at -1 to +4 degrees up to two months).

Appendix A

Demand System and Estimation

The Almost Ideal (AI) Demand System

This system is both flexible and easy to estimate. The AI model gives an arbitrary second-order approximation to any demand system. Deaton and Muellbauer (1980) show that it satisfies the axioms of choice, aggregates over consumers without a need to assume parallel Engel curves, and has a functional form consistent with known household budget data. In addition, it is simple to estimate and it can be used to test whether or not demand functions have the desirable properties of homogeneity and symmetry.

The beginning point for the AI model is the expenditure function, c(u,p), the least amount of money needed to reach utility level *u* when prices are *p*. The AI expenditure function is (Deaton and Muellbauer, 1980)

$$\log c(u,p) = \alpha_o + \sum_i \alpha_i \log(p_i) + \tfrac{1}{2}\sum_i \sum_j \gamma_{ij} \log(p_i)\log(p_j) + u\beta_o \prod_i p_i^{\beta_i}, \tag{A.1}$$

where α_i, β_i and γ_{ij} are parameters and $i,j = 1,....,n$ index the goods.

Deaton and Muellbauer (1980) chose the particular cost function because it is flexible, it represents preferences that permit exact nonlinear aggregation over consumers, and it results in demand functions with desirable properties (Blanciforti, Green, and King, 1986). Applying Shepard's Lemma yields demand functions expressed in expenditure shares:

$$\frac{\partial \log c_t(u,p)}{\partial \log(p_i)} = \frac{\partial c\ (u,p)}{\partial p_i}\frac{p_i}{c(u,p)} = \frac{p_i q_i}{c(u,p)} = w_i, \tag{A.2}$$

where, w_i is the share of good i in total expenditure *c*. After appropriate substitutions we obtain the AI model in expenditure share form:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log(p_j) + \beta_i \log\left(\frac{x}{PP}\right). \tag{A.3}$$

Here, *PP* is a translog price index defined by

$$\log PP = \alpha_o + \sum_i \alpha_i \log(p_i) + \tfrac{1}{2}\sum_i \sum_j \gamma_{ij} \log(p_t)\log(p_j). \qquad (A.4)$$

As a linear approximation to this demand system, Deaton and Muellbauer (1980) adopt Stone's (1954) index:

$$\log PP^* = \sum_i w_i \log(p_i)\,. \qquad (A.5)$$

PP is assumed to be approximately proportional to *PP**. This typically provides a good approximation of the original system and is relatively easily estimated. Since the Stone share-weighted price index is not invariant to changes in units of measurement of prices (Moschini, 1995), the commonly used procedure of normalizing the price series on their average value is applied. Equation (A.3) is redefined as

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log(p_j) + \beta_i \log\left(\frac{x}{PP^*}\right). \qquad (A.6)$$

This is referred to as the linear AI demand system. The *i*th budget share is expressed in terms of prices and real income or expenditures, (*x/PP**). Parameter α_i is the intercept and represents the budget share when all logarithmic prices and real expenditures are zero. Parameter γ_{ij} is equivalent to the change in the *i*th budget share with respect to a percentage change in the *j*th price with real expenditures or income held constant; that is, $\gamma_{ij} = \partial w_{it} / \partial \log(x / PP)$. The β_i represents the change in the *i*th budget share with respect to a percentage change in real income or expenditures with prices held constant; that is, $\beta_i = \partial w_{it} / \partial \log(x / PP)$.

The following three restrictions are imposed on demand parameters:

$$\text{Adding up: } \sum_{\text{i}} \alpha_{\text{i}} = 1, \quad \sum_{\text{i}} \gamma_{\text{ij}} = 0, \quad \sum_{\text{i}} \beta_{\text{i}} = 0; \qquad (A.7)$$

$$\text{Homogeneity of degree zero in prices and income: } \sum_{\text{j}} \gamma_{ij} = 0; \qquad (A.8)$$

$$\text{Slutsky Symmetry: } \gamma_{ij} = \gamma_{ji}\,. \qquad (A.9)$$

Demand functions must add up (eq. (A.7)). That is, total expenditure on goods and services must equal total income less taxes less savings. The adding-up conditions imply a singular variance-covariance matrix for the disturbances and this is handled by deleting the *n*th equation. Equation (A.8) is known as the homogeneity restriction. An equal percentage increase in income and prices should have no effect on what is purchased. This is also known as the "absence of money illusion." Deaton and Muellbauer (1980) note that to get this result, we need to assume that prices and expenditures play no role in choice other than in determining the budget constraint, so that the units in which prices and expenditures are measured have no effect on the consumer's perception of opportunities. Finally, theory asserts that the substitution matrix is symmetric (eq. (A.9)).

The Locally Concave Almost Ideal Demand Model

Moschini (1998) applies the concept of a semiflexible functional form to the AI demand system of Deaton and Muellbauer (1980). The semiflexible almost ideal demand model (SAI model) deals well with two problems that arise in the AI model: the curvature property and the degrees of freedom. In the AI model, concavity of the expenditure function, which implies that the Slutsky matrix is negative semidefinite, cannot be ensured by any restrictions on the parameters alone. It can be checked by calculating the eigenvalues of the Slutsky substitution terms $S_{ij} = \partial h_i(p,u)/\partial p_j$, where $h_i(p,u)$ denote Hicksian demands.

The Slutsky substitution terms for the AI model can be written as

$$S_{ij} = \frac{x}{P_i P_j}\left[\gamma_{ij} + w_i w_j - \delta_{ij} w_i + \beta_i \beta_j \log\left(\frac{x}{PP}\right)\right], \tag{A.10}$$

where δ_{ij} is the Kronecker delta (δ_{ij} = 1 for $i = j$ and δ_{ij} = 0 for $i \neq j$).
Without loss of generality, one can choose the sample mean (point with highest sample information) as the point at which concavity is maintained such that $p_i = x = 1$. Then at this point, $w_i = \alpha_i$. The substitution term at the mean point (i.e., $\theta_{ij} = S_{ij}$ when $p = x = 1$) then reduces to

$$\theta_{ij} = \gamma_{ij} + \alpha_i \alpha_j - \delta_{ij}\alpha_i . \tag{A.11}$$

For concavity to hold at the mean point, the matrix $[\theta_{ij}]$ must be negative semidefinite. Equation (A.11) is used to facilitate the imposition of concavity at the mean point. First, the γ_{ij} can be rewritten in terms of $\{\theta_{ij}, \alpha_i\}$. It is also recognized that the homogeneity property of demand implies $\sum_j \gamma_{ij} = \sum_j \theta_{ij} = 0$. Concavity of the (n-1)x(n-1) matrix $\Theta \equiv [\theta_{ij}]$ can be maintained by using the version of the Cholesky decomposition implemented by Diewert and Wales (1987), such that $\Theta = -T'T$ where $T \equiv [\tau_{ij}]$ is an (n-1)x(n-1) upper triangular matrix. Hence, the θ_{ij} parameters are rewritten in terms of the τ_{ij} parameters and so $\Theta = -T'T$. As an example, if n = 5, then the 4 x 4 matrix T can be represented as follows:

$$T = \begin{bmatrix} \tau_{11} & \tau_{12} & \tau_{13} & \tau_{14} \\ 0 & \tau_{22} & \tau_{23} & \tau_{24} \\ 0 & 0 & \tau_{33} & \tau_{34} \\ 0 & 0 & 0 & \tau_{44} \end{bmatrix}.$$

The matrix Θ is then

$$\Theta = -\begin{bmatrix} \tau_{11}^2 & \tau_{11}\tau_{12} & \tau_{11}\tau_{13} & \tau_{11}\tau_{14} \\ & \tau_{12}^2 - \tau_{22}^2 & \tau_{12}\tau_{13} + \tau_{22}\tau_{23} & \tau_{12}\tau_{14} + \tau_{22}\tau_{24} \\ & & \tau_{13}^2 + \tau_{23}^2 + \tau_{33}^2 & \tau_{13}\tau_{14} + \tau_{23}\tau_{24} + \tau_{33}\tau_{34} \\ & \textit{symmetric} & & \tau_{14}^2 + \tau_{24}^2 + \tau_{34}^2 + \tau_{44}^2 \end{bmatrix}.$$

Taking all these reparametrizations into account, the locally concave AI model can be written as

$$w_i = \alpha_i + \alpha_i \log\left(\frac{p_i}{P^\alpha}\right) - \sum_{s=1}^{i} \tau_{si} \log(P_s^\tau) + \beta_i \log\left(\frac{x}{PP}\right),\ i = 1,2,...,n-1. \qquad \text{(A.12)}$$

where n is the number of goods, P^α is a price function homogeneous of degree plus one, and defined by

$$\log P^\alpha = \sum_i \alpha_i \log p_i. \qquad \text{(A.13)}$$

The aggregator functions are homogenous of degree zero in prices and satisfy

$$\log P_s^\tau \equiv \sum_{j=s}^{n-1} \tau_{sj} \log\left(\frac{p_j}{p_n}\right),\ s = 1,2,....,n-1. \qquad \text{(A.14)}$$

To simplify the estimation procedure, the Stone price (*PP**; see eq. (A.5)) index is used to approximate the translog price index that is of the form

$$\log PP = \log P^\alpha - \tfrac{1}{2}(\log P^\alpha) + \tfrac{1}{2}\sum_{i=1}^{n} \alpha_{\mathrm{i}} (\log p_i)^2 - \tfrac{1}{2}\sum_{s=1}^{n-1} (\log P_s^\tau). \qquad \text{(A.15)}$$

Imposing Concavity

The degrees-of-freedom problem is alleviated by restricting the rank of the substitution matrix (i.e., the substitution possibilities across goods) of the locally concave AI system as of equation (A.12). This yields the SAI demand system. Also, the SAI model can handle violations of local concavity. When the unrestricted model in equation (A.6) yields positive eigenvalues of the Slutsky matrix and hence violates concavity, then the estimation of the locally concave model in equation (A.12) may be difficult. A possible solution to this problem may be a model with a substitution matrix of rank $K < (n - 1)$ such that convergence of the parameters of the locally concave model can be achieved. Rank $K < (n - 1)$ can be accomplished by setting $\tau_{ij} = 0$ for all $i > K$. Following up on the previous example with $n = 5$, we choose $K = 2$. This requires us to set the last two rows of the T matrix to zero; in other words, we do not allow any substitution between goods three and four. Hence, the Θ is as follows:

$$\Theta = -\begin{bmatrix} \tau_{11}^2 & \tau_{11}\tau_{12} & \tau_{11}\tau_{13} & \tau_{11}\tau_{14} \\ & \tau_{12}^2 - \tau_{22}^2 & \tau_{12}\tau_{13} + \tau_{22}\tau_{23} & \tau_{12}\tau_{14} + \tau_{22}\tau_{24} \\ & & \tau_{13}^2 + \tau_{23}^2 & \tau_{13}\tau_{14} + \tau_{23}\tau_{24} \\ & \mathit{symmetric} & & \tau_{14}^2 + \tau_{24}^2 \end{bmatrix}.$$

The SAI system of rank K is then

$$w_i = \alpha_i + \alpha_i \log\left(\frac{p_i}{P^\alpha}\right) - \sum_{\substack{s=1 \\ s \le K}}^{i} \tau_{si} \log(P_s^\tau) + \beta_i \log\left(\frac{x}{PP}\right), \tag{A.16}$$

where P^α and P_s^τ are defined in equations (A.13) and (A.14), respectively. The restrictions $\tau_{si} = 0$ for all $s > K$ imply $\log(P_s^\tau) \equiv 0$ for all $s > K$.

Appendix B

Detailed Econometric Results

1. Full system of four dairy products (fluid milk, cheese, powdered milk, and butter) and an all-other goods aggregate consisting of non-food and other food

1.a. Unrestricted Linear Almost Ideal Demand System: Non-food and other food, fluid milk, cheese, powdered milk, and butter

The linear AI consists of five equations; however, because of singularity of the matrix, one equation is omitted. The expenditure share (w_i) depends on the own price and the prices of the other goods, a time trend (*tr*), the percentage of females participating in the labor force (*r*), the population density (*km*), the dependency ratio—measure for the aging population (*ku*), and on total expenditures that are divided by the Stone price index (*x* / *PP*):

$$w_1 = \alpha_1 + d_1 tr + e_1 r + f_1 km + l_1 ku + c_{11} \log p_1 + c_{12} \log p_2 + c_{13} p_3 + c_{14} p_4 + \beta_1 \log \frac{x}{PP};$$

$$w_2 = \alpha_2 + d_2 tr + e_2 r + f_2 km + l_2 ku + c_{12} \log p_1 + c_{22} \log p_2 + c_{23} p_3 + c_{24} p_4 + \beta_2 \log \frac{x}{PP};$$

$$w_3 = \alpha_3 + d_3 tr + e_3 r + f_3 km + l_3 ku + c_{13} \log p_1 + c_{23} \log p_2 + c_{33} p_3 + c_{34} p_4 + \beta_3 \log \frac{x}{PP};$$

$$w_4 = \alpha_4 + d_4 tr + e_4 r + f_4 km + l_4 ku + c_{14} \log p_1 + c_{24} \log p_2 + c_{34} p_3 + c_{44} p_4 + \beta_4 \log \frac{x}{PP};$$

where:
w_i = expenditure share of category *i*,
w_1 = non food & other food,
w_2 = fluid milk,
w_3 = cheese,
w_4 = powdered milk,
w_5 = butter,
Because of singularity of the matrix, equation (5) is omitted
x = total expenditure
PP = linear Stone price index,
tr = time trend,
r = percentage of females participating in the labor force,
km = population density,
ku = dependency ratio,
p_i = price ratios (p_1/p_5, p_2/p_5, p_3/p_5 and p_4/p_5),
α, β, *d*, *e*, *f*, *l*, and the c_{ij} are parameter vectors that have to be estimated.

Table B-1. Parameter estimates of the linear AI model with four dairy products and an all-other goods aggregate

Number of observations=41
Log likelihood=1341.48
Schwarz B.I.C.=-1254.78

Parameter	Estimate	std Error	t-statistic	P-value
A1	.989775	.193585E-03	5112.87	[.000]
A2	.836265E-02	.157027E-03	53.2562	[.000]
A3	.755681E-03	.275826E-04	27.3970	[.000]
A4	.648774E-03	.250616E-04	25.8872	[.000]
B1	.251982E-02	.189582E-02	1.32915	[.184]
B2	-.173085E-02	.155180E-02	-1.11538	[.265]
B3	-.354704E-03	.254492E-03	-1.39377	[.163]
B4	.286640E-04	.221233E-03	.129565	[.897]
C11	-.122851E-02	.292885E-02	-.419452	[.675]
C12	.128598E-02	.238436E-02	.539337	[.590]
C13	.202118E-03	.397550E-03	.508410	[.611]
C14	-.241113E-03	.346124E-03	-.696611	[.486]
D1	-2.79296	.580916	-4.80784	[.000]
E1	.040043	.014517	2.75830	[.006]
F1	.559777E-03	.127381E-03	4.39452	[.000]
L1	.132764E-02	.271501E-03	4.88999	[.000]
C22	-.889586E-03	.197944E-02	-.449413	[.653]
C23	-.415024E-03	.321727E-03	-1.28999	[.197]
C24	.167519E-03	.291232E-03	.575209	[.565]
D2	2.06000	.473806	4.34777	[.000]
E2	-.030067	.012046	-2.49597	[.013]
F2	-.419120E-03	.103672E-03	-4.04277	[.000]
L2	-.101917E-02	.221715E-03	-4.59674	[.000]
C33	-.246320E-03	.154400E-03	-1.59534	[.111]
C34	-.331262E-04	.156113E-03	-.212194	[.832]
D3	.335189	.078645	4.26204	[.000]
E3	-.617802E-02	.211246E-02	-2.92456	[.003]
F3	-.609798E-04	.172906E-04	-3.52677	[.000]
L3	-.147300E-03	.366209E-04	-4.02229	[.000]
C44	-.353430E-03	.230962E-03	-1.53026	[.126]
D4	.284396	.068212	4.16927	[.000]
E4	-.138173E-02	.202416E-02	-.682620	[.495]
F4	-.504018E-04	.149923E-04	-3.36185	[.001]
L4	-.124862E-03	.316860E-04	-3.94059	[.000]

Equation: EQ1: **Non food and other food**
Dependent variable: W1
Mean of dep. var. = .990112
Std. dev. of dep. var. = .331734E-02
Sum of squared residuals = .108866E-04
Variance of residuals = .265528E-06
Std. error of regression = .515294E-03
R-squared = .975268
LM het. test = 7.99960 [.005]
Durbin-Watson = 1.02413

Equation: EQ2: **Fluid milk**
Dependent variable: W2

Mean of dep. var. = .808921E-02
Std. dev. of dep. var. = .259280E-02
Sum of squared residuals = .725008E-05
Variance of residuals = .176831E-06
Std. error of regression = .420513E-03
R-squared = .973039
LM het. test = 7.85941 [.005]
Durbin-Watson = 1.11656

Equation: EQ3: **Cheese**
Dependent variable: W3
Mean of dep. var. = .722054E-03
Std. dev. of dep. var. = .936270E-04
Sum of squared residuals = .198057E-06
Variance of residuals = .483065E-08
Std. error of regression = .695029E-04
R-squared = .435164
LM het. test = 3.63777 [.056]
Durbin-Watson = .723220

Equation: EQ4: **Powdered milk**
Dependent variable: W4
Mean of dep. var. = .671113E-03
Std. dev. of dep. var. = .429662E-03
Sum of squared residuals = .147592E-06
Variance of residuals = .359982E-08
Std. error of regression = .599985E-04
R-squared = .980017
LM het. test = 7.32927 [.007]
Durbin-Watson = 1.20127

Table B-2. Marshallian elasticities at the mean point, AI model

Elasticity of		With respect to					
		p_{nfof}	p_{fm}	p_c	p_{pm}	p_b	Income
(1)	Non food & other food	**-1.00**	0.00	0.00	0.00	0.00	1.00
(2)	Fluid milk	0.36	**-1.10**	-0.05	0.02	-0.02	0.79
(3)	Cheese	0.76	-0.55	**-1.33**	-0.04	0.65	0.53
(4)	Powdered milk	-0.42	0.26	-0.05	**-1.54**	0.71	1.04
(5)	Butter	0.96	-0.32	1.08	1.01	**-2.72**	-0.01
	Mean share	0.990	0.008	0.001	0.001	0.000	

Table B-3. Hicksian elasticities at the mean point, AI model

Elasticity of		With respect to				
		p_{nfof}	p_{fm}	p_c	p_{pm}	p_b
(1)	Non food & other food	**-0.01**	0.01	0.00	0.00	0.00
(2)	Fluid milk	1.14	**-1.10**	-0.05	0.02	-0.02
(3)	Cheese	1.26	-0.54	**-1.33**	-0.04	0.65
(4)	Powdered milk	0.62	0.27	-0.05	**-1.54**	0.71
(5)	Butter	0.95	-0.32	1.08	1.01	**-2.72**
	Mean share	0.990	0.008	0.001	0.001	0.000

1.b. Semiflexible Almost Ideal Demand System (curvature imposed): Non-food and other food, fluid milk, cheese, powdered milk and butter -Rank 4 model

The SAI model has the same structure, variables etc. as the AI model.

Table B-4. Parameter estimates of the SAI model (rank 4) with four dairy products and an all-other goods aggregate

Number of observations = 41

Trace of Matrix = 70.6104

Parameter	Estimate	Std. Error	t-statistic	P-value
A1	.989712	.268440E-03	3686.90	[.000]
A2	.838118E-02	.209902E-03	39.9291	[.000]
A3	.804481E-03	.414775E-04	19.3956	[.000]
A4	.669425E-03	.498870E-04	13.4188	[.000]
B1	.221768E-02	.259571E-02	.854365	[.393]
B2	-.164924E-02	.207268E-02	-.795703	[.426]
B3	-.138504E-03	.381938E-03	-.362636	[.717]
B4	.163188E-03	.415307E-03	.392934	[.694]
T11	-.111329	.019102	-5.82820	[.000]
T14	.606434E-02	.560420E-02	1.08211	[.279]
T13	.014227	.396384E-02	3.58917	[.000]
T12	.088926	.015722	5.65611	[.000]
D1	-2.87920	.797199	-3.61164	[.000]
E1	.038896	.019828	1.96171	[.050]
F1	.597470E-03	.175596E-03	3.40252	[.001]
L1	.135645E-02	.371826E-03	3.64807	[.000]
T22	.035896	.674179E-02	5.32440	[.000]
T24	-.016482	.857869E-02	-1.92131	[.055]
T23	-.023609	.332168E-02	-7.10763	[.000]
D2	2.05937	.632562	3.25561	[.001]
E2	-.028361	.016495	-1.71939	[.086]
F2	-.428428E-03	.138552E-03	-3.09218	[.002]
L2	-.101642E-02	.295776E-03	-3.43643	[.001]
T33	.016599	.609445E-02	2.72367	[.006]
T34	-.023435	.012534	-1.86972	[.062]
D3	.377298	.120098	3.14160	[.002]
E3	-.561899E-02	.317470E-02	-1.76993	[.077]

F3	-.773316E-04	.260896E-04	-2.96407	[.003]
L3	-.163128E-03	.555086E-04	-2.93879	[.003]
D4	.316880	.135311	2.34187	[.019]
E4	-.284635E-02	.395368E-02	-.719924	[.472]
F4	-.575858E-04	.281435E-04	-2.04615	[.041]
L4	-.141002E-03	.596853E-04	-2.36242	[.018]

Equation: EQ1: **Non food and other food**
Dependent variable: W1
Mean of dep. var. = .990112
Std. dev. of dep. var. = .331734E-02
Sum of squared residuals = .104002E-04
Variance of residuals = .253664E-06
Std. error of regression = .503651E-03
R-squared = .976373
LM het. test = 7.93117 [.005]
Durbin-Watson = 1.13166

Equation: EQ2: **Fluid milk**
Dependent variable: W2
Mean of dep. var. = .808921E-02
Std. dev. of dep. var. = .259280E-02
Sum of squared residuals = .702869E-05
Variance of residuals = .171431E-06
Std. error of regression = .414043E-03
R-squared = .973862
LM het. test = 8.10610 [.004]
Durbin-Watson = 1.17188

Equation: EQ3: **Cheese**
Dependent variable: W3: cheese
Mean of dep. var. = .722054E-03
Std. dev. of dep. var. = .936270E-04
Sum of squared residuals = .182030E-06
Variance of residuals = .443976E-08
Std. error of regression = .666315E-04
R-squared = .480875
LM het. test = 4.00548 [.045]
Durbin-Watson = .879594

Equation: EQ4: **Powdered milk**
Dependent variable: W4: powdered milk
Mean of dep. var. = .671113E-03
Std. dev. of dep. var. = .429662E-03
Sum of squared residuals = .191137E-06
Variance of residuals = .466188E-08
Std. error of regression = .682780E-04
R-squared = .974116

LM het. test = 4.51476 [.034]
Durbin-Watson = 1.02278

Table B-5. Eigenvalues of the Slutsky matrix at the mean point, rank 4 SAI model

		SAI models of rank				Unrestricted AI model
		1	2	3	4	
(1)	Non food & other food				0	-1.48641D-08
(2)	Fluid milk				0	-0.00091330
(3)	Cheese				-0.00087082	-0.0010593
(4)	Powdered milk				-0.0017289	-0.0018534
(5)	Butter				-0.020952	-0.019950

Table B-6. Marshallian elasticities at the mean point, rank 4 SAI model

Elasticity of		With respect to					
		p_{nfof}	p_{fm}	p_c	p_{pm}	p_b	expenditure
(1)	Non food & other food	**-1.00**	0.00	0.00	0.00	0.00	1.00
(2)	Fluid milk	0.39	**-1.10**	-0.05	0.01	-0.04	0.80
(3)	Cheese	1.15	-0.53	**-1.29**	-0.11	-0.06	0.83
(4)	Powdered milk	-0.22	0.07	-0.13	**-1.28**	0.32	1.24
(5)	Butter	0.91	-0.78	-0.10	0.50	**-0.16**	-0.37
	Mean share	0.990	0.008	0.001	0.001	0.000	

Table B-7. Hicksian elasticities at the mean point, rank 4 SAI model

Elasticity of		With respect to				
		p_{nfof}	p_{fm}	p_c	p_{pm}	p_b
(1)	Non food & other food	**-0.01**	0.01	0.00	0.00	0.00
(2)	Fluid milk	1.18	**-1.10**	-0.05	0.01	-0.04
(3)	Cheese	1.97	-0.52	**-1.29**	-0.11	-0.06
(4)	Powdered milk	1.01	0.08	-0.13	**-1.28**	0.32
(5)	Butter	0.54	-0.78	-0.10	0.50	**-0.16**
	Mean share	0.990	0.008	0.001	0.001	0.000

2. A subsystem of five goods (the four dairy goods and an all-other food aggregate)

2.a. Unrestricted Linear Almost Ideal Demand System: Other food, fluid milk, cheese, powdered milk, and butter

The linear AI consists of five equations; however, because of singularity of the matrix, one equation is omitted. The expenditure share (w_i) depends on the own price and the prices of the other goods, a time trend (*tr*), the percentage of females participating in the labor force (*r*), the population density (*km*), the dependency ratio – measure for the aging population (*ku*), and on total expenditures that are divided by the Stone price index (*x / PP*):

$$w_1 = \alpha_1 + d_1 tr + e_1 r + f_1 km + l_1 ku + c_{11} \log p_1 + c_{12} \log p_2 + c_{13} p_3 + c_{14} p_4 + \beta_1 \log \frac{x}{PP};$$

$$w_2 = \alpha_2 + d_2 tr + e_2 r + f_2 km + l_2 ku + c_{12} \log p_1 + c_{22} \log p_2 + c_{23} p_3 + c_{24} p_4 + \beta_2 \log \frac{x}{PP};$$

$$w_3 = \alpha_3 + d_3 tr + e_3 r + f_3 km + l_3 ku + c_{13} \log p_1 + c_{23} \log p_2 + c_{33} p_3 + c_{34} p_4 + \beta_3 \log \frac{x}{PP};$$

$$w_4 = \alpha_4 + d_4 tr + e_4 r + f_4 km + l_4 ku + c_{14} \log p_1 + c_{24} \log p_2 + c_{34} p_3 + c_{44} p_4 + \beta_4 \log \frac{x}{PP};$$

where:
w_i = expenditure share of category *i,*
w_1 = other food
w_2 = fluid milk,
w_3 = cheese,
w_4 = powdered milk,
w_5 = butter,
Because of singularity of the matrix, equation 5 is omitted
x = total expenditure
PP = linear Stone price index,
tr = time trend,
r = percentage of females participating in the labor force,
km = population density,
ku = dependency ratio,
p_i = price ratios (p_1/p_5, p_2/p_5, p_3/p_5 and p_4/p_5),
α, β, *d*, *e*, *f*, *l*, and the c_{ij} are parameter vectors that have to be estimated.

Table B-8. Parameter estimates of the linear AI model with four dairy products and an all-other food aggregate

Number of observations=41
log likelihood=1178.34
Schwarz B.I.C.=-1091.64

Parameter	Estimate	std Error	t-statistic	P-value
A1	.967850	.511667E-03	1891.56	[.000]
A2	.026371	.417515E-03	63.1611	[.000]
A3	.251611E-02	.734994E-04	34.2331	[.000]
A4	.193465E-02	.704341E-04	27.4676	[.000]

B1	-.015622	.868726E-02	-1.79827	[.072]
B2	.011607	.715901E-02	1.62132	[.105]
B3	.225598E-02	.118460E-02	1.90442	[.057]
B4	.500164E-02	.111916E-02	4.46909	[.000]
C11	-.022135	.953765E-02	-2.32079	[.020]
C12	.016658	.782095E-02	2.12989	[.033]
C13	.389866E-02	.129585E-02	3.00857	[.003]
C14	.406082E-02	.120920E-02	3.35827	[.001]
D1	-6.53640	1.48023	-4.41580	[.000]
E1	.144435	.034637	4.17002	[.000]
F1	.151282E-02	.297438E-03	5.08615	[.000]
L1	.285895E-02	.718720E-03	3.97783	[.000]
C22	-.010532	.664579E-02	-1.58474	[.113]
C23	-.393220E-02	.105674E-02	-3.72107	[.000]
C24	-.224832E-02	.105652E-02	-2.12804	[.033]
D2	4.72193	1.20703	3.91203	[.000]
E2	-.103458	.029824	-3.46900	[.001]
F2	-.107915E-02	.242440E-03	-4.45121	[.000]
L2	-.218404E-02	.585709E-03	-3.72888	[.000]
C33	-.822466E-03	.432910E-03	-1.89985	[.057]
C34	-.232379E-03	.454111E-03	-.511723	[.609]
D3	.750443	.206988	3.62554	[.000]
E3	-.022630	.539967E-02	-4.19108	[.000]
F3	-.192711E-03	.411939E-04	-4.67815	[.000]
L3	-.255934E-03	.100521E-03	-2.54608	[.011]
D4	.655634	.190609	3.43969	[.001]
E4	-.013258	.586107E-02	-2.26199	[.024]
F4	-.168006E-03	.377072E-04	-4.45554	[.000]
L4	-.243080E-03	.921852E-04	-2.63687	[.008]
C44	-.164731E-02	.674651E-03	-2.44172	[.015]

Equation: EQ1: **Other food**
Dependent variable: W1
Mean of dep. var. = .968141
Std. dev. of dep. var. = .521026E-02
Sum of squared residuals = .695759E-04
Variance of residuals = .169697E-05
Std. error of regression = .130268E-02
R-squared = .935936
LM het. test = 6.93873 [.008]
Durbin-Watson = 1.25607

Equation: EQ2: **Fluid milk**
Dependent variable: W2
Mean of dep. var. = .026103
Std. dev. of dep. var. = .394313E-02
Sum of squared residuals = .462500E-04
Variance of residuals = .112805E-05
Std. error of regression = .106210E-02
R-squared = .925685
LM het. test = 5.86164 [.015]
Durbin-Watson = 1.24098

Equation: EQ3: **Cheese**
Dependent variable: W3
Mean of dep. var. = .245686E-02
Std. dev. of dep. var. = .535220E-03
Sum of squared residuals = .135160E-05
Variance of residuals = .329659E-07
Std. error of regression = .181565E-03
R-squared = .882227
LM het. test = .466857 [.494]
Durbin-Watson = .903843

Equation: EQ4: **Powdered milk**
Dependent variable: W4
Mean of dep. var. = .206878E-02
Std. dev. of dep. var. = .981020E-03
Sum of squared residuals = .113669E-05
Variance of residuals = .277242E-07
Std. error of regression = .166506E-03
R-squared = .970473
LM het. test = 4.55488 [.033]
Durbin-Watson = 1.83328

Table B-9. Marshallian elasticities at the mean point, AI model

Elasticity of		With respect to					
		p_{of}	p_{fm}	p_c	p_{pm}	p_b	expenditure
(1)	Other food	**-1.01**	0.02	0.00	0.00	0.00	0.98
(2)	Fluid milk	0.21	**-1.41**	-0.15	-0.09	0.00	1.44
(3)	Cheese	0.68	-1.59	**-1.33**	-0.09	0.43	1.90
(4)	Powdered milk	-0.40	-1.23	-0.13	**-1.86**	0.03	3.59
(5)	Butter	0.49	0.11	0.83	0.06	**-0.04**	-1.44
	Mean share	0.968	0.026	0.003	0.002	0.001	

Table B-10. Hicksian elasticities at the mean point, AI model

Elasticity of		With respect to				
		p_{of}	p_{fm}	p_c	p_{pm}	p_b
(1)	Other food	**-0.06**	0.04	0.01	0.01	0.00
(2)	Fluid milk	1.60	**-1.37**	-0.15	-0.08	0.00
(3)	Cheese	2.52	-1.54	**-1.32**	-0.09	0.43
(4)	Powdered milk	3.07	-1.14	-0.12	**-1.85**	0.04
(5)	Butter	-0.90	0.07	0.82	0.05	**-0.04**
	Mean share	0.968	0.026	0.003	0.002	0.001

2.b. Semiflexible Almost Ideal Demand System (curvature imposed): Other food, fluid milk, cheese, powdered milk and butter -Rank 4 model

The SAI model has the same structure, variables etc. as the AI model.

Table B-11. Parameter estimates of the rank 4 SAI model with four dairy products and an all-other food aggregate

Number of observations = 41

Trace of Matrix = 54.3867

Parameter	Estimate	Std Error	t-statistic	P-value
A1	.948094	.734294E-02	129.116	[.000]
A2	.038245	.617279E-02	6.19579	[.000]
A3	.685415E-02	.145713E-02	4.70387	[.000]
A4	.572414E-02	.212137E-02	2.69832	[.007]
B1	-.019800	.729429E-02	-2.71442	[.007]
B2	.011988	.613065E-02	1.95539	[.051]
B3	.435224E-02	.144804E-02	3.00562	[.003]
B4	.361434E-02	.210605E-02	1.71617	[.086]
T11	-.269062	.026918	-9.99562	[.000]
T12	.186246	.027182	6.85181	[.000]
T13	.045859	.972329E-02	4.71641	[.000]
T14	.030545	.014431	2.11666	[.034]
D1	-5.31215	1.83774	-2.89059	[.004]
E1	.114318	.056669	2.01729	[.044]
F1	.130450E-02	.363115E-03	3.59253	[.000]
L1	.219779E-02	.919890E-03	2.38919	[.017]
T22	.091089	.010422	8.73991	[.000]
T23	-.041991	.010393	-4.04023	[.000]
T24	-.059017	.016405	-3.59750	[.000]
D2	3.48384	1.38125	2.52224	[.012]
E2	-.065526	.045798	-1.43076	[.152]
F2	-.835366E-03	.268502E-03	-3.11121	[.002]
L2	-.157583E-02	.693569E-03	-2.27206	[.023]
T33	.064344	.010338	6.22411	[.000]
T34	-.065185	.020260	-3.21743	[.001]
D3	.639101	.452869	1.41123	[.158]
E3	-.029007	.014276	-2.03187	[.042]
F3	-.193614E-03	.872298E-04	-2.21958	[.026]
L3	-.184037E-03	.224023E-03	-.821509	[.411]
D4	.765673	.513373	1.49146	[.136]
E4	-.328030E-02	.016482	-.199023	[.842]
F4	-.165833E-03	.935675E-04	-1.77234	[.076]
L4	-.267080E-03	.243247E-03	-1.09798	[.272]

Equation: EQ2: **Other food**
Dependent variable: W1
Mean of dep. var. = .968141
Std. dev. of dep. var. = .521026E-02
Sum of squared residuals = .619935E-04
Variance of residuals = .151204E-05
Std. error of regression = .122965E-02
R-squared = .942911
LM het. test = 10.3511 [.001]
Durbin-Watson = 1.36142

Equation: EQ2: **Fluid milk**
Dependent variable: W2
Mean of dep. var. = .026103
Std. dev. of dep. var. = .394313E-02
Sum of squared residuals = .399986E-04
Variance of residuals = .975575E-06
Std. error of regression = .987712E-03
R-squared = .935746
LM het. test = 8.95141 [.003]
Durbin-Watson = 1.25345

Equation: EQ3: **Cheese**
Dependent variable: W3
Mean of dep. var. = .245686E-02
Std. dev. of dep. var. = .535220E-03
Sum of squared residuals = .185026E-05
Variance of residuals = .451283E-07
Std. error of regression = .212434E-03
R-squared = .842687
LM het. test = .128634 [.720]
Durbin-Watson = .939871

Equation: EQ4
Dependent variable: W4: **powdered milk**
Equation: EQ4
Dependent variable: W4
Mean of dep. var. = .206878E-02
Std. dev. of dep. var. = .981020E-03
Sum of squared residuals = .103360E-05
Variance of residuals = .252098E-07
Std. error of regression = .158776E-03
R-squared = .973151
LM het. test = 4.41366 [.036]
Durbin-Watson = 1.79447

Table B-12. Eigenvalues of the Slutsky matrix at the mean point, rank 4 SAI model

	SAI models of rank				Unrestricted AI model
	1	2	3	4	
(1) Other food				1.12904D-08	0.00045577
(2) Fluid milk				-4.34400D-12	1.86423D-08
(3) Cheese				-0.0081033	-0.0032906
(4) Powdered milk				-0.012117	-0.0047578
(5) Butter				-0.11197	-0.088830

Table B-13. Marshallian elasticities at the mean point, rank 4 SAI model

Elasticity of		With respect to					
		p_{of}	p_{fm}	p_c	p_{pm}	p_b	expenditure
(1)	Other food	**-1.00**	0.02	0.01	0.00	0.00	0.98
(2)	Fluid milk	0.06	**-1.17**	-0.13	-0.02	-0.06	1.31
(3)	Cheese	0.25	-0.75	**-1.18**	0.04	0.01	1.63
(4)	Powdered milk	-0.11	-0.12	0.04	**-1.52**	0.08	1.63
(5)	Butter	0.78	-1.97	0.06	0.41	**-0.13**	0.86
	Mean share	0.948	0.038	0.007	0.006	0.001	

Table B-14. Hicksian elasticities at the mean point, rank 4 SAI model

Elasticity of		With respect to				
		p_{of}	p_{fm}	p_c	p_{pm}	p_b
(1)	Other food	**-0.08**	0.05	0.01	0.01	0.00
(2)	Fluid milk	1.31	**-1.12**	-0.13	-0.01	-0.05
(3)	Cheese	1.80	-0.69	**-1.18**	0.05	0.01
(4)	Powdered milk	1.44	-0.05	0.04	**-1.51**	0.08
(5)	Butter	1.59	-1.94	0.06	0.41	**-0.13**
	Mean share	0.948	0.038	0.007	0.006	0.001

3. The subsystem of the four dairy products

3.a Unrestricted Linear Almost Ideal Demand System: Fluid milk, cheese, powdered milk, and butter

The linear AI consists of four equations; however, because of singularity of the matrix, one equation is omitted. The expenditure share (w_i) depends on the own price and the prices of the other goods, a time trend (*tr*), the percentage of females participating in the labor force (*r*), the population density (*km*), the dependency ratio – measure for the aging population (*ku*), and on total expenditures that are divided by the Stone price index (x / PP):

$$w_1 = \alpha_1 + d_1 tr + e_1 r + f_1 km + l_1 ku + c_{11} \log p_1 + c_{12} \log p_2 + c_{13} p_3 + \beta_1 \log \frac{x}{PP};$$

$$w_2 = \alpha_2 + d_2 tr + e_2 r + f_2 km + l_2 ku + c_{12} \log p_1 + c_{22} \log p_2 + c_{23} p_3 + \beta_2 \log \frac{x}{PP};$$

$$w_3 = \alpha_3 + d_3 tr + e_3 r + f_3 km + l_3 ku + c_{13} \log p_1 + c_{23} \log p_2 + c_{33} p_3 + \beta_3 \log \frac{x}{PP};$$

where:
w_i = expenditure share of category *i,*
w_1 = fluid milk,
w_2 = cheese,
w_3 = powdered milk,
w_4 = butter,
Because of singularity of the matrix, equation 4 is omitted
x = total expenditure
PP = linear Stone price index,
tr = time trend,
r = percentage of females participating in the labor force,
km = population density,
ku = dependency ratio,
p_i = price ratios (p_1/p_4, p_2/p_4, and p_3/p_4),
α, β, d, e, f, l, and the c_{ij} are parameter vectors that have to be estimated.

Table B-15. Parameter estimates of the linear AI model with four dairy products
Number of observations = 41
Log likelihood = 529.402
Schwarz B.I.C. = -471.656

Parameter	Estimate	Std Error	t-statistic	P-value
A1	.820172	.137638E-02	595.892	[.000]
A2	.077789	.915929E-03	84.9293	[.000]
A3	.064429	.123896E-02	52.0021	[.000]
B1	-.701966E-02	.021620	-.324688	[.745]
B2	.041294	.014036	2.94203	[.003]
B3	-.614638E-02	.017883	-.343709	[.731]
C11	.013893	.023552	.589899	[.555]
C12	-.038334	.014653	-2.61621	[.009]
C13	.042260	.018681	2.26225	[.024]
D1	-16.5803	7.12337	-2.32759	[.020]
E1	.187788	.217985	.861472	[.389]
F1	.344323E-02	.833510E-03	4.13100	[.000]
L1	.266467E-02	.345967E-02	.770210	[.441]
C22	-.363939E-02	.015676	-.232157	[.816]
C23	.027191	.016746	1.62370	[.104]
D2	-3.32710	4.64435	-.716376	[.474]
E2	-.233964	.136265	-1.71697	[.086]
F2	.271924E-03	.550476E-03	.493980	[.621]
L2	.394404E-02	.226295E-02	1.74288	[.081]
C33	-.093961	.027395	-3.42982	[.001]
D3	18.4919	5.89377	3.13754	[.002]
E3	.067901	.178788	.379784	[.704]
F3	-.312286E-02	.689868E-03	-4.52675	[.000]
L3	-.657594E-02	.283279E-02	-2.32136	[.020]

Equation: EQ1: **Fluid milk**
Dependent variable: W1
Std. dev. of dep. var. = .019820
Sum of squared residuals = .154004E-02
Variance of residuals = .375620E-04
Std. error of regression = .612878E-02
R-squared = .902161
LM het. test = 1.95588 [.162]
Durbin-Watson = .944512

Equation: EQ2: **Cheese**
Dependent variable: W2
Mean of dep. var. = .080258
Std. dev. of dep. var. = .025445
Sum of squared residuals = .657917E-03
Variance of residuals = .160468E-04
Std. error of regression = .400584E-02
R-squared = .974604
LM het. test = 4.14491 [.042]
Durbin-Watson = 1.06274

Equation: EQ3: **Powdered milk**
Dependent variable: W3
Mean of dep. var. = .245686E-02
Mean of dep. var. = .062177
Std. dev. of dep. var. = .019160
Sum of squared residuals = .102258E-02
Variance of residuals = .249410E-04
Std. error of regression = .499410E-02
R-squared = .930403
LM het. test = 3.62811 [.057]
Durbin-Watson = 1.16265

Table B-16. Marshallian elasticities at the mean point, AI model

Elasticity of		With respect to				
		p_{fm}	p_c	p_{pm}	p_b	expenditure
(1)	Fluid milk	**-0.98**	-0.05	0.05	-0.02	0.99
(2)	Cheese	-0.93	**-1.09**	0.32	0.17	1.53
(3)	Powdered milk	0.73	0.43	**-2.45**	0.38	0.9
(4)	Butter	0.14	0.45	0.70	**-1.54**	0.25
	Mean share	0.820	0.078	0.064	0.038	

Table B-17. Hicksian elasticities at the mean point, AI model

Elasticity of		With respect to the price			
		p_{fm}	p_c	p_{pm}	p_b
(1)	Fluid milk	**-0.16**	0.03	0.12	0.02
(2)	Cheese	0.33	**-0.97**	0.41	0.23
(3)	Powdered milk	1.48	0.50	**-2.39**	0.42
(4)	Butter	0.35	0.47	0.72	**-1.53**

3.b Semiflexible Almost Ideal Demand System (curvature imposed): Fluid milk, cheese, powdered milk and butter – Full rank model

The SAI model has the same structure, variables etc. as the AI model.

Table B-18. Parameter estimates of the full rank SAI model with four dairy products

Number of observations = 41

Trace of Matrix = 44.0347

Parameter	Estimate	Standard Error	t-statistic	P-value
A1	.819261	.346102E-02	236.711	[.000]
A2	.077894	.187995E-02	41.4342	[.000]
A3	.065112	.211482E-02	30.7883	[.000]
B1	-.115598E-02	.056653	-.020404	[.984]
B2	.042245	.030082	1.40434	[.160]
B3	.210994E-02	.028956	.072868	[.942]
T11	.399559	.077070	5.18440	[.000]
T13	-.254703	.048416	-5.26071	[.000]
T12	-.093005	.068763	-1.35255	[.176]
D1	-18.0291	18.6488	-.966770	[.334]
E1	.035897	.568873	.063103	[.950]
F1	.345317E-02	.217814E-02	1.58538	[.113]
L1	.296289E-02	.914428E-02	.324015	[.746]
T22	-.243492	.058215	-4.18263	[.000]
T23	.288621	.061790	4.67100	[.000]
D2	-4.94017	10.0142	-.493318	[.622]
E2	-.190442	.296439	-.642433	[.521]
F2	.576547E-03	.117896E-02	.489030	[.625]
L2	.448970E-02	.487911E-02	.920189	[.357]
T33	.102549	.125526	.816958	[.414]
D3	17.6124	9.80671	1.79595	[.073]
E3	.051308	.297164	.172660	[.863]
F3	-.283097E-02	.112981E-02	-2.50571	[.012]
L3	-.605095E-02	.470225E-02	-1.28682	[.198]

Dependent variable: W1: **Fluid milk**

Mean of dep. var. = .820877

Std. dev. of dep. var. = .019820

Sum of squared residuals = .170190E-02

Variance of residuals = .415098E-04

Std. error of regression = .644281E-02

R-squared = .891767
LM het. test = .718934 [.396]
Durbin-Watson = .929273

Equation: EQ2: **Cheese**
Dependent variable: W2
Mean of dep. var. = .080258
Std. dev. of dep. var. = .025445
Sum of squared residuals = .562072E-03
Variance of residuals = .137091E-04
Std. error of regression = .370258E-02
R-squared = .978297
LM het. test = 3.08313 [.079]
Durbin-Watson = 1.19735

Equation: EQ3: **Powdered milk**
Dependent variable: W3
Mean of dep. var. = .062177
Std. dev. of dep. var. = .019160
Sum of squared residuals = .102883E-02
Variance of residuals = .250934E-04
Std. error of regression = .500933E-02
R-squared = .929980
LM het. test = 4.46912 [.035]
Durbin-Watson = 1.13766

Table B-19. Eigenvalues of the Slutsky matrix at the mean point, full rank SAI model

		SAI models of rank				Unrestricted AI model
		1	2	3	Full rank	
(1)	Fluid milk				-7.60742D-09	-3.65456D-09
(2)	Cheese				-0.011875	-0.076027
(3)	Powdered milk				-0.12828	-0.10431
(4)	Butter				-0.26136	-0.24055

Table B-20. Marshallian elasticities at the mean point, full rank SAI model

Elasticity of		With respect to				
		p_{fm}	p_c	p_{pm}	p_b	expenditure
(1)	Fluid milk	**-1.01**	-0.03	0.06	-0.01	1.00
(2)	Cheese	-0.79	**-0.99**	0.50	-0.26	1.54
(3)	Powdered milk	0.72	0.64	**-2.50**	0.12	1.03
(4)	Butter	0.67	-0.41	0.28	**-0.40**	-0.14
	Mean share	0.819	0.078	0.065	0.038	

Table B-21. Hicksian elasticities at the mean point, full rank SAI Model

Elasticity of		With respect to the price			
		p_{fm}	p_c	p_{pm}	p_b
(1)	Fluid milk	**-0.19**	0.05	0.12	0.03
(2)	Cheese	0.48	**-0.87**	0.60	-0.20
(3)	Powdered milk	1.56	0.72	**-2.44**	0.16
(4)	Butter	0.55	-0.42	0.27	**-0.40**

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