Farm Policies and Added Sugars in US Diets

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Abstract

Major changes in the use of US sweeteners have occurred since 1970, in both the amount and composition. Increased consumption of caloric sweeteners, especially in beverages, has been linked to excess energy intake and lower-quality diets. We examine how US farm policies (specifically agricultural research and development [R&D] expenditures and commodity programs) have affected the consumption and composition of sweeteners in the US diet. R&D expenditures have lowered the unit cost of most commodities and increased their use in food production, ceteris paribus, although corn has benefited more than sugar crops in the technical progress. Commodity programs have raised the price of sugar and decreased the price of corn; high fructose corn syrup (HFCS) became an inexpensive substitute for sugar in food beginning in 1970. However, the effect of this change in the price of ingredients has become less important over time. Today the farm value share in sweetened food is very small (below 5%), and HFCS has become a specialized input in many food items. Countries with different or no commodity programs experience similar increases in consumption of added sugar. We conclude that the current link between the US consumption of caloric sweeteners and farm policy is tenuous, although historically the link was stronger.

Keywords: added sugar, agricultural policy, caloric, corn, diet, farm policies, HFCS, subsidy, sugar, sweetener.

JEL codes: Q18, D12, I18

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Major changes in the use of US sweeteners have occurred since 1970, in both the amount and composition. The changes are reflected in many parts of the world as well, as most of the world has experienced growth in per-capita food consumption and diets that include greater consumption of sugar, livestock products, and vegetable oils as sources of energy. Increased consumption of caloric sweeteners, especially in beverages and snacks, has been linked to excess energy intake and lower-quality diets, although the mechanism and factors associated with their role in excess calorie intake is not fully understood (Bray, Nielsen, and Popkin 2004; Jacobson et al. 2004; Miljkovic, Nganje, and de Chastenet 2008; and Popkin and Nielsen 2003). Added sugar intake has also been associated with compromising intakes of micronutrients, but again, there is no conclusive evidence on its adverse effects (Rennie and Livingstone 2007).

The increase in consumption of sweeteners has been marked by a change in the sweetener source. Until the 1970s, most sugar was obtained from sugar beet or sugarcane in the form of sucrose. However, from the 1970s onward, high fructose corn syrup (HFCS) gained popularity with food processors as a sweetener (Coulston and Johnson 2002), a change induced by the relatively higher price of sugar and the emergence of cheaper sweeteners based on corn. In the United States, as well as in many other countries, agricultural policies play an important role in the sugar and corn markets, and their importance has led to concerns about the role of agricultural policies in effecting changes in diets and the composition of sweeteners. These policies include both those that affect commodity programs (income support) as well as those related to research and development (R&D) expenditures in agriculture.

The main issue addressed in this paper is whether US farm policies (specifically agricultural R&D expenditures and commodity programs) have affected the consumption and composition of sweeteners in the US diet. We provide background on consumption of sweeteners and changes over time and then examine the policies that have affected sweetener use and consumption. Although US farm policies have favored the substitution of corn-based sweeteners for sugar, two facts suggest a relatively weak link between the farm policies and resulting consumption today: first, the falling and relatively small farm value share of sweeteners in foods today, and second, experience with increased consumption of sweetened foods and beverages in other countries with different or no commodity programs. We use evidence on differences in relative prices of sweeteners as well as comparative country evidence to conclude that the current link between US consumption of added sugars and farm policy is tenuous, although historically the link was stronger. These findings are broadly consistent with those of Alston, Sumner, and Vosti (2006), with an important qualification on the asymmetric effects of public policies on the two types of sweeteners.

1. Background: Dietary consumption of sugar and sweeteners

US sweetener consumption

Although the body does not distinguish between added and naturally occurring sweeteners (as in fresh fruits), dietary guidance focuses on added sugars. These constitute calories with little additional nutritive value. Added sugars include refined cane and beet sugar, corn sweeteners, edible syrups, and honey not naturally occurring in food but used as ingredients in processing or prepared foods or added to foods at the table (USDA/DHHS 2000). According to US food supply data, per-capita consumption of caloric sweeteners (adjusted for losses) was nearly 30 teaspoons per day in 2005, compared to 25 teaspoons per day in 1970 (USDA/ERS 2008a).

This amount of added sugars is attributed to increased consumption of foods with added sucrose or HFCS. For most sex/age groups, nonalcoholic beverages (e.g., soft drinks and fruit-flavored drinks) and grain products (e.g., sweet bakery products) are the major sources of fructose, and nonalcoholic beverages are the major sources of added fructose (Gibney et al. 1995). Soft drinks and fruit drinks/fruitades contribute almost 43% of total intake of added sweeteners, and intake of added sweeteners is highest in adolescence (Guthrie and Morton 2000). The contribution of added sugars to the diet has increased dramatically, especially for children (Briefel and Johnson 2004; Rennie and Livingstone 2007). The problem of increased consumption is exacerbated by the fact that caloric sweeteners are often “hidden” in prepared foods, making it difficult for consumers to determine the exact amount of added sugar (Putnam, Allshouse, and Kantor 2002).

Changes in the food sources (food location and types of foods consumed) are associated with the increase in caloric sweetener intake. US per-capita consumption of caloric sweeteners for all people two years of age and older increased by 83 kcal between the years 1977 and 1996. Forty percent of the increase, or 34 kcal per day, can be attributed to restaurants and fast food sources, and 50% to snacks. Of the total increase of 83 kcal per day, 54 kcal came from soft drinks and 13 came from sugared fruit drinks. Combined, these two drink sources represent about 81% of the increase in caloric sweetener intake between 1977 and 1996 for the average US resident two years of age and older (Popkin and Nielsen 2003). However, recently diet soft drinks and other low-calorie options, including bottled water, have replaced some of the sweetened beverages and slowed the increase of caloric sweeteners from drinks (Wells and Buzby 2008).

Changes in the composition of sweetener use

US deliveries data show that per-capita average use of all sweeteners has increased significantly, from 123 pounds in 1966 to 151 pounds in 1999 when it peaked. In recent years, consumption of all caloric sweeteners has fallen to a level of 142 pounds per capita (USDA/ERS 2008a).[i] The 40-pound increase in annual per-capita consumption in the last 40 years is remarkable and came mostly through an expansion of corn-based sweeteners, which now dominate sugar in the deliveries. Within corn-based sweeteners, the increase in the consumption of HFCS is the major component of the growth, as shown in Table 1. Honey and other sweeteners are marginal contributors to sweetener intake.

Concurrently, the composition of industrial use of sugar has changed dramatically, as shown in Figure 1. Deliveries of sugar to the beverage sector withered starting in 1975 and dropped from over 2,500 thousand short tons (tst) in 1978 to 212 tst in 1987 (USDA/ERS 2008b). There has been little industrial use of sugar in beverages since 1985. In contrast, the use of sugar in bakery and cereal products has expanded along with expansion of this food sector and is the largest user today (2,231 tst in 2006). The confectionery use of sugar has expanded somewhat; the use in canned, bottled, and frozen foods has fallen and the use of sugar in ice cream has been flat for the last 30 years. The non-industrial use of sugar (total level) has been nearly flat despite population growth. Hence, non-industrial use of sugar per capita has been falling.

Table 2 shows the evolution of US consumption of HFCS.[ii] Despite some data issues, it is clear that the beverages sector has become and remains the largest user of HFCS. The canned, bottled, and frozen foods sector was the second-largest user. Some shifting in use is occurring within the industry.

Changes in the relative prices of sweeteners

Relatively low prices of sweeteners have contributed to their increased use in foods. The HFCS price fell rapidly in the 1970s and remained relatively low for the next 30 years, with the resulting impact of lowering the unit price of the composite sweetener (weighted average of corn sweeteners and sugar prices computed by the authors), as shown in Figure 2 (USDA/ERS 2008b). The composite sweetener price experienced a 35% decrease in nominal terms from its peak in 1980 (from about 33¢/lb to 21¢/lb). The price was below 20¢/lb for most of the 1990s. HFCS prices fell by about 25% in nominal terms between the early 1980s and 2005, although between 2005 and 2007 the wholesale price of HFCS (HFCS-42) increased 56% (from 13.6¢/lb to 21.2¢/lb, dry weight). The US wholesale price of sugar has been quite variable but with no clear trend in nominal terms. The falling HFCS price and its increasing share explain the overall fall of the price index for the composite sweetener index in the last 20 years.

During the late 1990s, the price of HFCS fell, as corn prices fell to extremely low levels. Increases in the price of HFCS since 2005 are related to the recent rise in corn prices with increased demand from ethanol markets. However, the link between HFCS and the corn price, although significant, is more tenuous than presumed because corn value represents only about 44% of the cost of production of HFCS (estimated average 1990-2004 value of corn at the farm gate normalized the value of HFCS and corn by-products). Energy costs and a return to capital prices play a big role as well in the cost of HFCS.

The evolution of sweetener substitution in food processing

In the early 1970s, HFCS started as a substitute for sugar in food processing, but the substitution between the two ingredients has changed over time. Although the beverage industry was the major industrial user of sugar before the early 1980s, sugar use in beverages and soft drinks is very small today. Instead, the US soft drink industry has become the largest user of HFCS. With this shift, sweetener use has become more specialized, and the substitution possibilities have fallen as food processing technology has become more specialized as well. Evans and Davis (2002) and Moss and Schmitz (2002) estimated that the two sweetener markets have become virtually independent since the late 1990s with little substitution possibilities left given the current technology in US food processing.

These profound long-term changes imply that some significant adjustments in technology and logistics would have to take place before the soft drink industry could substitute back to sugar following a reversal of the sugar/HFCS relative price ratio. HFCS is also used as a specialized input in other products such as bakery and cereal goods, as it tends to increase shelf life of products. However, its major use is in beverages.

Evidence from other countries suggests that the substitution possibilities between sugar and HFCS have specifically evolved with technology and logistics in place in the United States. The use of HFCS in the United States is in sharp contrast to that in Mexico. Mexican HFCS use has a shorter track record and is confined to soft drinks. The older capital vintage of some Mexican bottlers may also be at work. During a trade dispute with the United States in 2002, Mexico raised a 20% tax on soft drinks containing HFCS or any other non-cane sweetener. The United States is a major source of HFCS for Mexico, and although sizeable, Mexican HFCS domestic production is not as competitive as that of the United States. Following the imposition of the 20% tax, HFCS vanished in Mexican soft drink production within a year; it reappeared in 2005 after court waivers obtained by Mexican bottlers exempted them from the tax. Its use expanded further in 2006 after the US-Mexico trade dispute was resolved with the removal of the offending tax. This natural experiment demonstrates the high substitution possibilities in sweetener use in Mexico via an implicit tax on the use of HFCS implemented through the output market.

In summary, the evidence on the US consumption and use of sugar and other sweeteners shows significant increase in per-capita consumption of sweeteners, marked by a significant change in source—from sugar to corn-based HFCS. The shift in the share and composition of sweetener use has been driven by the nearly wholesale shift from sugar to HFCS use in beverages in the mid-1980s. The relatively lower price of HFCS and its relative decline compared to the sugar price in the 1990s contributed to the shift in use. Although substitution technologies do exist between the two, evidence in the United States suggests that the two markets are nearly independent in the manufacturing/industrial use today. The next section addresses the role that public policies have played in the changes in availability and prices of the two major sweetener commodities: corn and sugar crops.

2. Public policies affect sweetener availability and use

Public policies have affected sweetener availability and use in two major ways. Public investment in agricultural R&D has lowered the unit cost of farm commodities. Between corn and sugar crops, the effects have been asymmetric and have favored increased yields and lower corn prices, as discussed next. Concurrently, price policy distortions have effects on relative prices in the domestic market. We turn first to the role of agricultural R&D, and then to the role of price policies and other factors that have influenced the use of sweeteners in foods.

Public investment in R&D

Evidence from farm price changes

Public (and private) agricultural R&D has decreased the unit cost of farm commodities by increasing total factor productivity. Although it is impossible to have a solid grasp of the partial impact of public R&D on a specific crop because of numerous confounding factors, including price policy distortions, strong evidence exists on falling real commodity prices and on farm supply shifts for sweetener crops. Measurement of the impact of public R&D farm expenditures is replete with difficulties, including identifying spillover in R&D across sectors and between private and public sources (Griliches 1992). Disentangling the respective role of infrastructure improvements, other sources of reductions of transaction costs, and price policy distortions on individual crops is virtually impossible. However, there is a consensus view that public research, in aggregate, has had longer and stronger effects than private research on agricultural cost reduction (Alston et al. 2000; Chavas and Cox 1992; and Huffman and Evenson 2006) but not for all crops (Huffman and Evenson 1989).[iii]

Abstracting from spillovers and market power, marginal/unit cost determines price, whereas demand explains where equilibrium quantities locate. Hence, one can look at the evolution of farm prices as a "revealed" indicator of the evolution of the unit cost of producing individual crops keeping in mind the mentioned pitfalls. The real price of corn (deflated by a farm producer price) has fallen dramatically over time whereas the real price of sugar crops has fallen much more slowly. As shown in Figure 3 and based on 1963-2005 data from Iowa, Florida and North Dakota, the evidence shows that real corn prices have fallen more than twice as fast as real prices of sugar crops. Assuming a constant rate of change over time, the 1963-2005 data suggest that the price of corn fell by 3.2% whereas the price of beet fell by 1.3% and the price of cane fell by 1.6%.[iv] The data series suggests a strong asymmetry between the rates of change of corn prices versus the prices of beet and cane.

The asymmetry in rates of change in prices does not explain the role of farm policy. These changes provide bounds on the effect of farm policy on commodity prices assuming all the price changes have been caused by public R&D and farm policy. Later on in the paper we link this change in the price of corn relative to beet and cane to the emergence of HFCS as a cheap substitute for cane and beet sugar. It is important to note that cheaper corn has led directly to cheaper meat, poultry products, and dairy products via lower feed cost, a pecuniary externality. Thus, public R&D has also led to productivity gains and lower prices for many agricultural and food items beyond corn, including nutritious ones.

Changes in Yields

Regarding yields, public and private agricultural research has had major impacts on productivity in agriculture and has translated into increases in agricultural yields. Yields are clearly not an exhaustive measure of total factor productivity (TFP) changes. However, early attempts to measure returns to research (Griliches 1958) measured the gains in Marshallian surplus arising from supply shifts approximated by yield increases. More recent papers also link yield changes to research spending (Craig, Pardey, and Roseboom 1997; and Evenson and Gollin 2003).[v]

National and state data on yields suggest a story similar to that of prices. National sugar yields from cane and beet crops have grown very slowly overtime whereas corn yields have been increasing steadily over time, as shown in Figure 4. The national data suggest that the national average corn yield has grown about 6.5 times faster than the national cane yield and 2.7 times faster than the average beet yield (authors’ estimates). Low growth in cane yield has been somewhat compensated by an increasing sugar recovery rate, but this may have more to do with improvements in processing technology. Using state data (Florida, Iowa, and North Dakota), sugarcane yields (and sugar recovery rates) have increased but at a much lower rate than those of corn in the Midwest, as shown in Figure 5. Iowa corn yields have grown about 9 times faster than Florida sugarcane yields. Sugar beet yields have increased faster than sugarcane yields but Iowa corn yields have still grown 1.7 times faster than North Dakota beet yields.

Research Expenditures

Finally, a third piece of evidence from indirect data on research expenditures supports this view of an asymmetric situation between sugar crops and corn. The number of researchers working on crop breeding, genetics, and cytology in grains (feed and food) dwarfs the number of US researchers working on sugar crops (892 against 44 science-person-years in plant breeding R&D in 1994, and 977 against 24 in 2001). This pattern holds for researchers in public universities, USDA's Agricultural Research Service, and private industry (Baenziger et al. 2006). Clearly, more knowledge has been generated on grains than on sugar crops.[vi]

The agricultural tax/subsidy on food intake

The second type of public policies that affect sweetener availability and relative shares are those that distort prices. Farm price policies have systematically subsidized sweetener crop producers in various ways. Sugar crops have been receiving a much higher price than the price that would prevail in unfettered markets. These higher prices are possible thanks to prohibitive trade restrictions on sugar trade and sugar production allotments, effectively production quotas, which limit the US sugar supply in order to raise the price of sugar domestically and keep government payments to a minimum (Abler et al. 2008; Beghin 2007; and Haley and Ali 2007). Policies are set at the sugar level (raw cane and refined beet sugar) but translate directly into benefits to cane and beet growers, who are often integrated into the processing sector (raw cane sugar production and beet sugar production). The US sugar support is borne by sugar users who implicitly pay the subsidy, as they could buy equivalent raw or refined sugar on the world market at a much cheaper price (Beghin et al. 2003). The sugar support, as calculated by the Organization for Economic Co-operation and Development (OECD) (see Table 3), has induced US domestic prices equivalent to 2 to 3 times the world price. The nominal assistance coefficient (NAC) measures the value of farm production, inclusive of subsidies and payments, normalized by the value of production at border prices.

By contrast, the subsidies received by US corn producers are borne by taxpayers and lead to a moderate subsidy to corn users who purchase corn domestically for less than its opportunity cost (border price), especially in periods of low market prices. Low prices trigger subsidies through payments (loan deficiency payments) received on a fixed land base. The subsidies use reference yields that are pro-cyclical and lower the price of corn to users.[vii] Since 1996, however, US corn policies have been more decoupled than in the past. Removal of supply restrictions and a payments policy that is more decoupled have decreased the distortions induced by US price policies on world corn markets, especially in years of high prices for which few or no coupled payments take place.

In summary, farm price policies have distorted the relative prices of corn and sugar (and sugar crops) in favor of corn users and against sugar users. This price policy effect reinforces the asymmetric effect of technical change in these sweetener crop sectors. The high price of sugar has offset some of the cost decreases from R&D expenditures. In contrast, corn price distortions have reinforced the use of corn, including its use in HFCS production, and hence have also led to a switch away from sugar to HFCS in food processing. In relative terms, US farm programs

(R&D and price policy) have created a large, positive pecuniary externality on corn users, and hence on HFCS users, and have created a negative one on US sugar users by raising the price of sugar above its opportunity cost.

3. Falling farm value shares and tenuous link between farm and retail prices

Over time the farm value share of retail food has fallen relative to other inputs. From the early 1950s to 1975, the price received by farmers, the farm-retail price spread, and hence the food retail price evolved in sync. But for the last three decades, the retail-farm spread has increased dramatically, and this trend reflects the increase in labor costs and changes in food characteristics, including distribution, convenience, and packaging, among other factors. The cost share of farm inputs in food retail has fallen from over 40% in the early 1950s to around 20% in the early 2000s (USDA/ERS 2008c). Following Marshall's rules, the demand for these farm inputs has become much less price-elastic over time.

The cost of non-agricultural inputs and the change in characteristics of retail food goods have gained importance in determining the retail price of food and have dwarfed the cost of agricultural inputs. For sweetener-intensive sectors, such as bakery and cereal products, the share of sweeteners in the unit price of retail food has fallen dramatically from what it was in 1975 or earlier. Despite shortcomings of retail spread, farm values, and marketing margins estimates (Reed, Elitzak, and Wohlgenant 2002), the falling trend over time is unmistakable.

Consistent with the trend of falling farm value share, the contribution of the unit cost of sweeteners to the cost of food processing has decreased over time. The share of sweeteners and other agricultural inputs in the total cost of food processing has fallen to low levels (e.g., from around 25% to around 5% for bakery and cereals products), and concurrently the share of other non-agricultural inputs has increased dramatically as the cost shares add up to one (USDA/ERS 2008c). To illustrate the importance of wholesale-retail margins for something as simple as corn syrup, the share of farm value has been around 3% in recent years for bottled corn syrup sold retail, although corn value represents about 44% of the cost of HFCS and associated by-products.

The fall in value share has occurred even for HFCS. Its share of total cost in food processing first increased in the early 1980s as its use expanded, but then, starting in 1990, its cost share started falling as well. Labor, capital, and marketing inputs in food processing have grown tremendously. Based on 2002 census data (Census Bureau 2004), HFCS represents 6.4% of the total material cost in soft drink manufacturing (industry 312111), and 3.5% of total cost as approximated by value of shipments; the corn content of HFCS represents 1.6% of the value of shipment of soft drink manufacturers; sugar represents 0.1% of soft drink manufacturing's total cost.

Table 4 shows partial correlation coefficients ρ between the prices of soft drinks, HFCS, and corn. The coefficients suggest that the price of HFCS was correlated with the price of soft drinks during its initial phase from 1978 to 1992 (ρ= 0.51), but after that the correlation collapsed to near zero (ρ= 0.07). Corn prices have never been correlated with soft drink prices. HFCS and corn prices have been positively correlated, and still are, but the link is lower than presumed.

Refined sugar also follows this logic. For retail sugar, the retail-wholesale markup has increased and the link between retail, wholesale, and raw sugar prices has progressively broken down over time. Table 5 shows the correlation between the retail price of sugar, the wholesale price of refined sugar, and the price of raw sugar faced by food processors. The strong link between wholesale and retail prices of refined sugar has remained significant although somewhat diminished and less compelling than it was 25 years ago. The link between the prices of raw sugar and retail sugar was very strong in 1960-1981 but eventually became nonexistent in recent years. The link between the prices of raw sugar and wholesale refined sugar has remained strong, as raw sugar is an important input in refined cane sugar production. The latter correlation has decreased from 0.99 to 0.65, or by about one-third, in the last 25 years.

Hence, the evidence indicates that sugar and corn sweeteners account for a small share of final food product value, and this share has decreased over time. Furthermore, evidence on the correlation of prices shows that, although higher in the past, today there is very little correlation between HFCS and carbonated drink prices. A positive but weakened correlation between wholesale refined sugar and raw sugar prices remains.

4. Some estimates of the impact of farm price policies on food prices

We formalize the essence of the argument of the previous section with a simple equilibrium condition (price = unit cost) in a food market and quantify the likely impact of price policies on food cost using some reference-level price distortions and cost share estimates. We characterize the unit cost of food production as $c(w,Q)$, with c denoting the unit cost function of sugar-intensive food production, w the vector of input prices in food processing, and Q a vector of consumer attributes such as convenience, nutrition, and taste that can change over time. The input prices can be decomposed into the prices of sweeteners (HFCS, sugar), and an aggregate marketing input, or $w=(w_{hfcs}, w_s, w_m)$. The attributes can be decomposed into marketing attributes such as packaging, convenience, and shelf life; and "food" attributes such as nutrition, or $Q = (Q_m, Q_f)$. Long-term equilibrium implies that the cost structure determines the market price, p_r, or that

$$P_r(Q) = c((w_{hfcs},\ w_s),\ w_m,\ Q) \tag{1}$$

To gauge the impact of changes in attributes and input prices, especially those of sweeteners and marketing inputs, on the price of the food item, we totally differentiate the equilibrium condition with respect to input prices, w_i (subscript $i = hfcs, m, s$), and the bundle of attributes Q:

$$\begin{aligned} d\ln p_r &= d\ln c(w, Q_m, Q_f) = \sum_{\text{all } i} \alpha_i\, d\ln w_i + \varepsilon_m\, d\ln Q_m + \varepsilon_f\, d\ln Q_f \\ &= \alpha_{hfcs}\, d\ln w_{hfcs} + \alpha_s\, d\ln w_s + \alpha_m\, d\ln w_m + \varepsilon_m\, d\ln Q_m + \varepsilon_f\, d\ln Q_f. \end{aligned} \tag{2}$$

The latter equation says that at equilibrium the proportional change in a food item price reflects the relative changes in input prices weighted by their respective cost shares α_i, and the proportional changes in attributes weighted by their respective scale elasticity in the unit cost of the food item.

To measure the impact of farm policy distortions on the prices of sweetener-intensive food items, we need one more link, that between farm price policy and sweetener prices. For sugar the link is direct, as the US sugar program establishes the policy for the sweetener rather than for the crops. The cane raw sugar price and the beet sugar wholesale price reflect the US sugar policy directly. The trade restrictions and management of US sugar production through allotment directly raise the unit cost of raw and refined sugar (Beghin 2007). There is also a tendency toward arbitrage between raw and refined sugar both in world and US markets. Their price differences reflect the sugar refining margin.

For HFCS, the link is indirect, as the farm program affects the price of corn, a key input in the production of HFCS. The impact of the farm policy can be traced back through the price of the corn input in the unit price of HFCS. In proportional changes it is expressed by $d\ln w_{hfcs} = \alpha_{corn} d\ln p_c$, where p_c indicates the market price of corn inclusive of the policy effect and α_{corn}

represents the cost share of corn in the HFCS cost of production. Hence, we see that the impact of corn policy as measured by a change in corn prices is scaled down by the cost shares of corn in the cost of production of HFCS.

Including these changes in policies in equation (2) leads to

$$d \ln p_r = d \ln c = \alpha_{hfcs}\ \alpha_{corn}\ d \ln p_{corn} + \alpha_s\ d \ln w_s + \alpha_m\ d \ln w_m + \varepsilon_m\ d\ln Q_m + \varepsilon_f\ d \ln Q_f\ . \qquad (3)$$

Equation (3) shows changes in two components, "farm value" ($\alpha_{hfcs}\alpha_{corn}\ d \ln p_{corn} + \alpha_s\ d \ln w_s$) and the "retail-farm spread" component ($\alpha_m\ d \ln w_m + \varepsilon_m\ d\ln Q_m + \varepsilon_f\ d \ln Q_f$), reflecting the change in the unit cost of marketing inputs and the change coming from added or decreased characteristics.[viii] We see that the influence of the price of corn on the retail price of food is twice weighted down by the cost share of corn in HFCS and the cost share of HFCS in the food items. We consider a 20% subsidy for corn users and a 100% tax on sugar users. These NAC values are in the ballpark of the OECD producer support estimate (PSE) data shown in Table 3.

In 1975, a 20% corn subsidy for corn users (a consumer NAC=0.8) weighted by a 44% share of corn in HFCS and a 20% share of sweetener in retail food (an upper bound estimate on the share of HFCS) would have provided a decrease in food prices of 1.8%. In recent years the same subsidy with a reduced share of HFCS in retail food cost at 3.5% as in soft drink manufacturing would translate into a 0.3% decrease in retail food prices and a 0.15% increase in the quantity consumed of that food item, assuming an own-price demand elasticity of -0.5.

For sugar policy, the link is a bit more direct because the policy is directly affecting the price of sugar. A 100% increase in sugar prices (domestic prices twice as high as world prices or an NAC=200) weighted by a 20% cost share of sweetener in retail cost in 1975 would have caused a 20% increase in food prices, whereas a current 5% share, such as in bakery and cereal product manufacturing, would induce a 5% increase in the retail unit cost of food and a reduction in the quantity consumed of that food item by 2.5%, assuming a similar value of own-price elasticity of food demand of -0.5.

Hence, the current influence of farm price policies concerning sweeteners and sweetener crops on retail food prices is negligible for corn, small for sugar, and ambiguous in sign in aggregate depending on the mix of sweeteners used. Historically, large distortions in the sugar market induced a search for a cheaper sweetener, which was found in HFCS. Cheaper corn made HFCS slightly cheaper, as a 20% user subsidy for corn is equivalent to an 8% subsidy on the unit cost of HFCS. In the United States, sugar price policies, rather than corn price policies, have distorted the sweetener price ratio. Technical progress in corn production has been much stronger than in sugar-crop production. It has resulted in much lower corn prices relative to sugar prices. It is hard to determine the precise contribution of public R&D to this structural change.

5. International comparisons and context

Obesity is increasing globally, especially among OECD countries (Bleich et al. 2007; Cutler, Glaeser, and Shapiro 2003; Huffman et al. 2007; and Loureiro and Nayga 2005), as shown in Figure 6. Sugar and sweetener intake per capita has been increasing worldwide, both much more rapidly in developing countries than in the developed world, at least in aggregate, as shown in Table 6. Sugar consumption has actually decreased in many developed countries, where the change in consumption reflects a decrease in sugar consumption per capita but an increase in the consumption of other sweeteners, often via food processing. Among OECD countries, the United States and Mexico show increases in per-capita consumption of sweeteners in the last 30 years (1970-2001), especially via an increase in sweeteners other than sugar. Sparse data for more recent years indicate leveling of consumption per capita. In the developing world, all sweetener consumptions are on the rise, but sugar remains the most important sweetener, and the share of other sweeteners has remained small, at around 3%.

Is there a direct link between farm policies affecting the consumer price of refined sugar and sugar consumption when one looks at international patterns of protection in sugar markets across OECD countries? Japan has had extremely high sugar prices, declining sugar consumption per capita, and obesity there is the lowest among OECD countries while rising moderately. This example would suggest that high sugar prices yield more desirable health outcomes. But a closer inspection of the patterns in other countries suggests a more complex structure.

This question eventually should be addressed econometrically, but a casual look at agricultural protection patterns, sweetener consumption, and rising obesity suggests that different sugar farm policies are observed along with a general decline of total sweetener consumption and, at the same time, increasing obesity, although with a large variation across countries. The incidence of farm policy on the user price of sugar shows no clear decline in the distortion of consumer prices as measured by the OECD consumer NAC (see Figure 7). The NACs oscillate with variations of the world prices but show no clear trend for most countries. The real price of sugar (consumer price normalized by the CPI) has decreased over time in most countries, yet sweetener consumption among developed countries has decreased on average, with some exceptions such as the United States. Yet, despite the level of declining sweetener consumption, obesity has been rising in most developed countries.

Australia and the United States have a high and rising prevalence of obesity. They have opposite sugar policies: virtually no distortions affect Australia's use of sugar, whereas sugar policy in the United States taxes sugar use. Sugar consumption per capita in Australia has been flat from 1980 to 2001, after which it increased by 10%-15%. Sugar is the major sweetener consumed in Australia. The United Kingdom and France have the same sugar policy and similar sugar consumer prices, but the two countries have very different sugar consumption patterns (falling in France; increasing in the UK), and different health outcomes (a much higher incidence of obesity in the UK). In the EU countries, sugar consumption per capita varies widely, with Dutch, Belgian and British consumers having the highest sugar consumption, and the Basques and Germans having the lowest sugar consumption per capita (Gibney et al. 1995). All of these EU countries have the same agricultural policy. Hence, other country-specific effects, both economic and cultural, are obviously at work. Delineating the economics of global sweetener consumption (direct and indirect through processed food) and its link to farm policy should include such specific effects. Such a task is beyond the scope of our paper and suggests that caution should be taken in assessing the impact of sugar farm policy on health.

Endnotes

[i] There are some limitations with these data. Sugar consumption through imports of sugar-intensive foods has expanded by 4 to 5 pounds in recent years (Haley and Ali 2007), and actual intake is usually lower than suggested by deliveries data as food is wasted.

[ii] Data availability is problematic for HFCS. USDA provided a breakdown of HFCS use from 1970 to 1992. Beyond that, BLS data have to be used to disaggregate HFCS use using materials consumed by kind in the census industry series. BLS also changed its nomenclature, making comparison difficult over time. The latter data were used to compute Table 2.

[iii] The emergence of private R&D in the last 15 years is likely to complicate the proper measurement of the contribution of public agricultural R&D to lower prices.

[iv] Using longer series from 1924 for Iowa and North Dakota, the evidence is similar, with the corn price falling even faster relative to the price of sugar beet. The longer series from 1924 suggests that corn prices fell by 1.86% and the price of beets fell by 0.6%.

[v] Most of the vast literature on TFP and public agricultural research does not attempt to link the impact of research on individual crops or on yields as Griliches (1958) did.

[vi] Public R&D and other nonrival public support to total agriculture such as infrastructure has been about $15.7 billion on average for 1986-88, $20.6 billion for 1997-99, and $33 billion for 2003-05 (OECD, various) based on general services support (GSS) data. Some expenditures in GSS relate to promotion and marketing and are not purely nonrival. Among OECD countries, the US has the largest GSS expenditures, which are about 3 times the EU’s GSS and more than 30 times the Australian GSS.

[vii] The numbers in Table 3 do not take into account the large country effect. The expansion of US corn supply beyond its optimum depresses the world price of corn, as the United States is a large exporter. Both the consumer and producer NACs would be lower when using the proper higher shadow price and reflect a larger subsidy to consumers and lower subsidy to producers.

[viii] The latter equation (3) holds for small changes, with constant cost shares. Over time, large changes in input prices and quantities occur and their corresponding cost shares do change as well. The approximation provided by equation (3) deteriorates and must be re-evaluated at the new shares.

References

Abler, D., J. Beghin, D Blandford, and A. Elobeid. 2008. “Changing the U.S. Sugar Program into a Standard Crop Program: Consequences under NAFTA and Doha.” *Review of Agricultural Economics* 30, in press.

Alston, J.M., M.C. Marra, P.G. Pardey, and T J Wyatt. 2000. “Research Returns Redux: A Meta-Analysis of Agricultural R&D Evaluations.” *Austral. J. Ag. and Resour. Econ.* 44 (2, June): 185-216.

Alston, J.M., D.A. Sumner, and S.A. Vosti. 2006. “Are Agricultural Policies Making Us Fat? Likely Links between Agricultural Policies and Human Nutrition and Obesity, and Their Policy Implications.” *Rev. Ag. Econ.* 28 (3): 313-322.

Baenziger, P.S., W.K. Russell, G.L. Graef, and B.T. Campbell. 2006. “Improving Lives: 50 Years of Crop Breeding, Genetics, and Cytology (C-1).” *Crop Sci.* 46: 2230-2244. Available online at http://crop.scijournals.org/contents-by-date.0.shtml.

Beghin, J. 2007. “U.S. Sugar Policy: Analysis and Options.” In B.L. Gardner and D.A. Sumner, eds., *Agricultural Policy for the 2007 Farm Bill and Beyond*, AEI Press, American Enterprise Institute: 47-51.

Beghin, J., B. El Osta, J. Cherlow, and S. Mohanty. 2003. “The Cost of the US Sugar Program Revisited.” *Contemporary Economic Policy* 21 (1): 106-16.

Bleich, S., D. Cutler, C. Murray, and A. Adams. 2007. “Why Is the Developed World Obese?” National Bureau of Economic Research, NBER Working paper 12957. Available online at http://www.nber.org/papers/w12954.

Bray, G.A., S.J. Nielsen, and B.M. Popkin. 2004. “Consumption of High-Fructose Corn Syrup in Beverages May Play a Role in the Epidemic of Obesity.” *Amer. J. Clin. Nutr.* 79: 537-543.

Briefel, R.R., and C.L. Johnson. 2004. “Secular Trends in Dietary Intake in the United States.” *Annu. Rev. Nutr.* 24: 401-431.

Census Bureau. 2004. Economic Census, Manufacturing Reports, Industry Series, 1992, 1997 and 2002. US Department of Commerce, Census Bureau. http://www.census.gov/prod/www/abs/manu-min.html#mm (accessed February 4, 2008).

Chavas, J-P., and T.L. Cox. 1992. “A Nonparametric Analysis of the Influence of Research on Agricultural Productivity.” *Amer. J. Ag. Econ.* 74 (3): 583-591. Available online at http://www.jstor.org.

Coulston, A.M., and R.K. Johnson. 2002. “Sugar and Sugars: Myths and Realities.” *Commentary J. Amer. Dietetic Assoc.* 102 (3, March): 351-353.

Craig, B.J., P.G. Pardey, and J. Roseboom. 1997. “International Productivity Patterns: Accounting for Input Quality, Infrastructure, and Research.” *Amer. J. Ag. Econ.* 79 (4):1064-1076. Available online at http://www.jstor.org.

Cutler, D.M., E.L. Glaeser, and J.M. Shapiro. 2003. “Why Have Americans Become More Obese?” *J. Econ. Perspectives* 17(3):93-118.

Evans, E.A., and C.G. Davis. 2002. “Dynamics of the United States High Fructose Corn Sweetener Market.” In Schmitz, A., T.H. Spreen, W.A. Messina, and C.B. Moss, eds. *Sugar and Related Sweetener Markets: International Perspectives.* Wallingford, UK: CABI Publishing, Chapter 19 (pp. 281-297).

Evenson, R.E., and D. Gollin. 2003. “Assessing the Impact of the Green Revolution, 1960-2000.” *Science* 300: 758-762. Available online at http://www. sciencemag.org.

FAOSTAT. 2003. FAO Statistical Database. http://apps.fao.org/lim500/wrap.pl?FoodBalanceSheet&Domain=FoodBalanceSheet&Language=english (accessed 1/6/04).

Gibney, M., M. Sigman-Grant, J.L. Stanton, Jr. and D.R. Keast. 1995. “Consumption of Sugars.” *American Journal of Clinical Nutrition* 62(suppl): 178S–94S. [Published erratum appears as Sigman-Grant, M. and D.R. Keast. 1997. “Addendum to AJCN 1995; 62 (suppl):1785-945.” *Amer. J. Clin. Nutr.* 65 (5): 1572–74.]

Griliches, Z. 1958. “Research Costs and Social Returns: Hybrid Corn and Related Innovations.” *J. Pol. Econ.* 66(5): 419-431. Available only at: http://ww.jstor.org.

Griliches, Z. 1992. “The Search for R&D Spillovers.” *Scandinavian J. Econ.* 94: 29-47. Available online at http://www.jstor.org.

Guthrie, J.F., and J.F. Morton. 2000. “Food Sources of Added Sweeteners in the Diets of Americans.” *J. Amer. Dietetic Assoc.* 100: 43-8.

Haley, S., and M. Ali. 2007. “Sugar Backgrounder.” US Department of Agriculture. Economic Research Service, Outlook Report SSS-249-01, July. http://www.ers.usda.gov/publications/sss/Jul07/SSS249/sss249.pdf .

Huffman, W.E., and R.E. Evenson. 1989. “Supply and Demand Functions for Multiproduct US Cash Grain Farms: Biases Caused by Research and Other Policies.” *Amer. J. Ag. Econ.* 71 (3): 761-773. Available online at http://www.jstor.org.

Huffman, W.E., and R.E. Evenson. 2006. “Do Formula or Competitive Grant Funds have Greater Impacts on State Agricultural Productivity?” *Amer. J. Agr. Econ.*88: 783-798.

Huffman, W.E., S. Huffman, K. Rickertsen, and A. Tegene. 2007. “Over-Nutrition and Changing

Health Status in High Income Countries." Iowa State University. Unpublished manuscript. September.

Jacobson, M.F., G.A. Bray, S.J. Nielsen, and B.M. Popkin. 2004. "High-Fructose Corn Syrup and the Obesity Epidemic." Letters to the Editor, *Amer. J. Clin. Nutr.* 80: 1081-82.

Loureiro, M.L., and R.M. Nayga, Jr. 2005. "International Dimensions of Obesity and Overweight Related Problems: An Economics Perspective." *Amer. J. Ag. Econ.* 87 (5): 1147-1153.

Miljkovic, D., W. Nganje, and H. de Chastenet. 2008. "Economic Factors Affecting the Increase in Obesity in the United States: Differential Response to Prices." *Food Policy* 33: 48-60.

Moss, C.B. and A. Schmitz. 2002. "Trade in HFCS: Cointegration with Substitute Goods." In Schmitz, A., T.H. Spreen, W.A. Messina, and C.B. Moss, eds. 2002. *Sugar and Related Sweetener Markets: International Perspectives.* Wallingford, UK: CABI Publishing, Chapter 20 (pp. 299-314).

OECD. 2006. *Agricultural Policies in OECD Countries. At a Glance.* Organisation of Economic Co-operation and Development, Paris.

OECD. 2005. *Agricultural Policies in OECD Countries. Monitoring and Evaluation.* Organisation of Economic Co-operation and Development, Paris.

OECD. 2000. *Agricultural Policies in OECD Countries. Monitoring and Evaluation. 2000.* Organisation of Economic Co-operation and Development, Paris.

Popkin, B.M., and S.J. Nielsen. 2003. "The Sweetening of the World's Diet." *Obesity Res.* 11: 1325-32.

Putnam, J., J. Allshouse, and L. S. Kantor. 2002. "US Per Capita Food Supply Trends: More Calories, Refined Carbohydrates, and Fats." *Food Rev.* 25 (3): 1-15.

Reed, A.J., H. Elitzak, and M.K. Wohlgenant. 2002. "Retail-Farm Price Margins and Consumer Product Diversity." United States Department of Agriculture, Electronic Report from the Economic Research Service, Technical Bulletin No. 1899.

Rennie, K.L., and M.B.E. Livingstone. 2007. "Associations between Dietary Added Sugar Intake and Micronutrient Intake: A Systematic Review." *British J. Nutr.* 97: 832-841.

US Department of Agriculture, Economic Research Service (USDA/ERS). 2008a. "Food Availability (Per Capita) Data System" http://www.ers.usda.gov/data/foodconsumption/ (accessed January 15, 2008).

———. 2008b. “Briefing Room. Sugar and Sweetener: Data Tables.” http://www.ers.usda.gov/Briefing/Sugar/Data.htm . (accessed February 1, 2008, last update February 15, 2007).

———. 2008c. “Data Sets: Price Spreads from Farm to Consumer”. http://www.ers.usda.gov/Data/FarmToConsumer/marketingbill.htm

US Department of Agriculture and Department of Health and Human Services (USDA/DHHS). 2000. *Nutrition and Your Health: Dietary Guidelines for Americans*. 5th edition. Available from http://www.health.gov/dietaryguidelines

Wells, H.G., and J.C. Buzby. 2008. “High-Fructose Corn Syrup Usage May be Leveling Off.” *Amber Waves*, February. http://www.ers.usda.gov/Amberwaves/

Table 1. US sweetener consumption from 1960-69 to 2006 (annual averages, per capita)

	1960-69	1970-79	1980-89	1990-99	2000	2006	% Δ 1960/69 to 2006
			Pounds per capita, dry weight				
Total caloric sweeteners	114.4	120.1	123.7	141.9	148.9	139.3	21.7%
Cane and beet sugar	98.0	96.0	68.4	64.7	65.5	62.5	-36.2%
Corn sweeteners	14.9	22.7	54.0	75.9	81.8	75.2	404.6%
HFCS	0.0	5.5	37.3	56.4	62.7	58.3	969.6%[2]
Glucose	10.9	13.0	13.3	15.8	15.8	13.8	26.2%
Dextrose	4.1	4.3	3.5	3.7	3.4	3.1	-24.3%
Other caloric sweeteners[1]	1.5	1.4	1.3	1.4	1.5	1.5	0.0%

SOURCE: USDA/ERS 2008b. NOTE: Totals may not add up because of rounding.
[1] Edible syrups (sugarcane, sorgo, maple, and refiners), edible molasses, and honey.
[2] Percentage change between 1970-79 and 2006.

Table 2. US HFCS consumption by type of user (thousand short tons)[1]

Industry	1987	1992	1997	2002	% change 1987-2002
Confectionery and related products	27.4	114.0	106.4	83.0	202.4%
Bakery, cereals and allied products	411.2	441.9	401.8	513.1	24.8%
Ice cream and dairy products	402.3	567.6	772.0	258.5	-35.8%[2]
Canned, bottled, and frozen foods	592.8	647.0	502.4	685.7	15.7%
Beverages (mostly soft drinks)	3888.2	3877.6	5845.0	5270.2	35.5%
Miscellaneous food manufacturing		100.7			
Total (calendar)	5698	6727.3	8517	9294	63.1%
Contribution of beverages to total HFCS consumption	68%	58%	69%	57%	

SOURCE: Calculated from U.S. Census Bureau. 2002 is the latest census available as of February 2008.
[1] For some categories and some years, the Census Bureau withholds data in order to avoid disclosing information about individual companies or if estimates did not meet publication standards.
[2] The reduction in HFCS consumption by the ice cream and dairy products industry may reflect a change in classification of the industry; also, some data were withheld, as estimates did not meet publication standards.

Table 3. US corn and sugar farm policy support

	1986-88	1977-99	2002-04
US Corn			
Producer NAC	1.64	1.32	1.26
Consumer NAC	0.88	0.86	0.82
US sugar			
Producer NAC	2.46	2.39	2.19
Consumer NAC	2.96	2.75	2.59

SOURCE: OECD (various years).

Table 4. Correlation of corn, HFCS, and carbonated drinks prices

	Corn, carbonated drinks	HFCS, carbonated drinks	Corn, HFCS
1978-2006	-0.21	-0.30	0.42
1978-1992	-0.06	0.51	0.47
1993-2006	-0.28	0.07	0.33

Table 5. Correlation of US sugar prices

Time period	Retail, wholesale refined	Wholesale refined, raw	Retail, raw
1960-1981	0.97	0.99	0.94
1982-2006	0.44	0.58	0.14
1995-2006	0.60	0.65	0.01

Table 6. Changes in sweetener consumption by major regions for 1970-75 and 1999-2001

	Average 1970-75			**Average 1999-2001**			**Percentage change 1970-75 to 1999-2001**		
	(kilocalories per capita per day)								
	Total sugar[1]	Other sweeteners	Total sweeteners[2]	Total sugar	Other sweeteners	Total sweeteners	Total sugar	Other sweeteners	Total sweeteners
World	210.65	9.24	221.55	217.32	23.32	242.32	3.17	152.38	9.37
Developed	396.79	24.63	425.39	322.18	89.77	416.26	-18.80	264.47	-2.15
Developing	136.29	3.08	140.13	188.12	4.81	193.88	38.03	56.17	38.36
USA	464.34	100.74	569.10	328.77	328.60	662.30	-29.20	226.19	16.38
Mexico	383.91	1.82	388.02	439.82	28.80	471.40	14.56	1482.42	21.49

SOURCE: FAOSTAT.

[1] The sum of non-centrifugal sugar and sugar in raw equivalent

[2] The total sweeteners category includes honey.

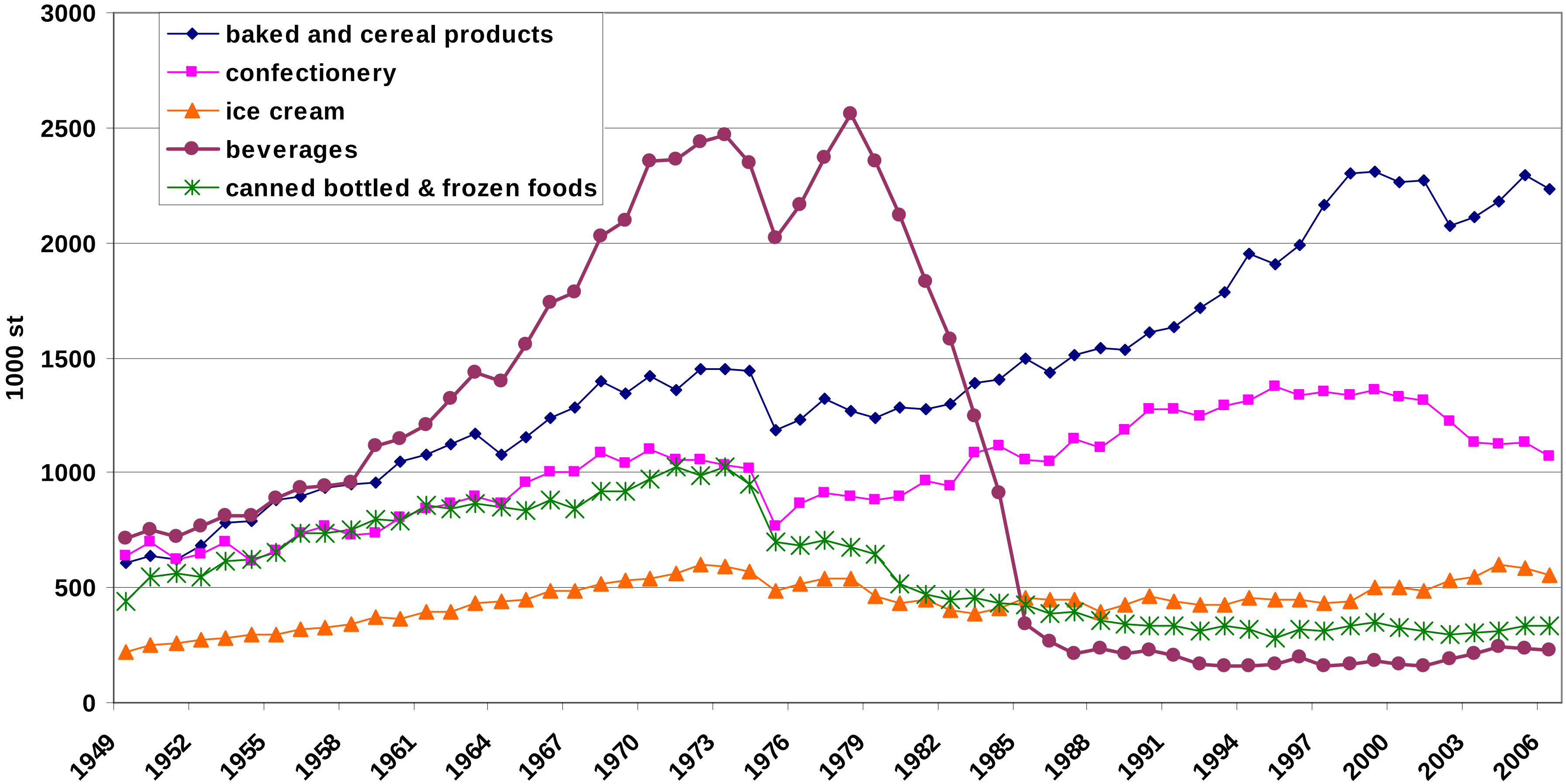

Figure 1. US Industrial use of sugar by product group

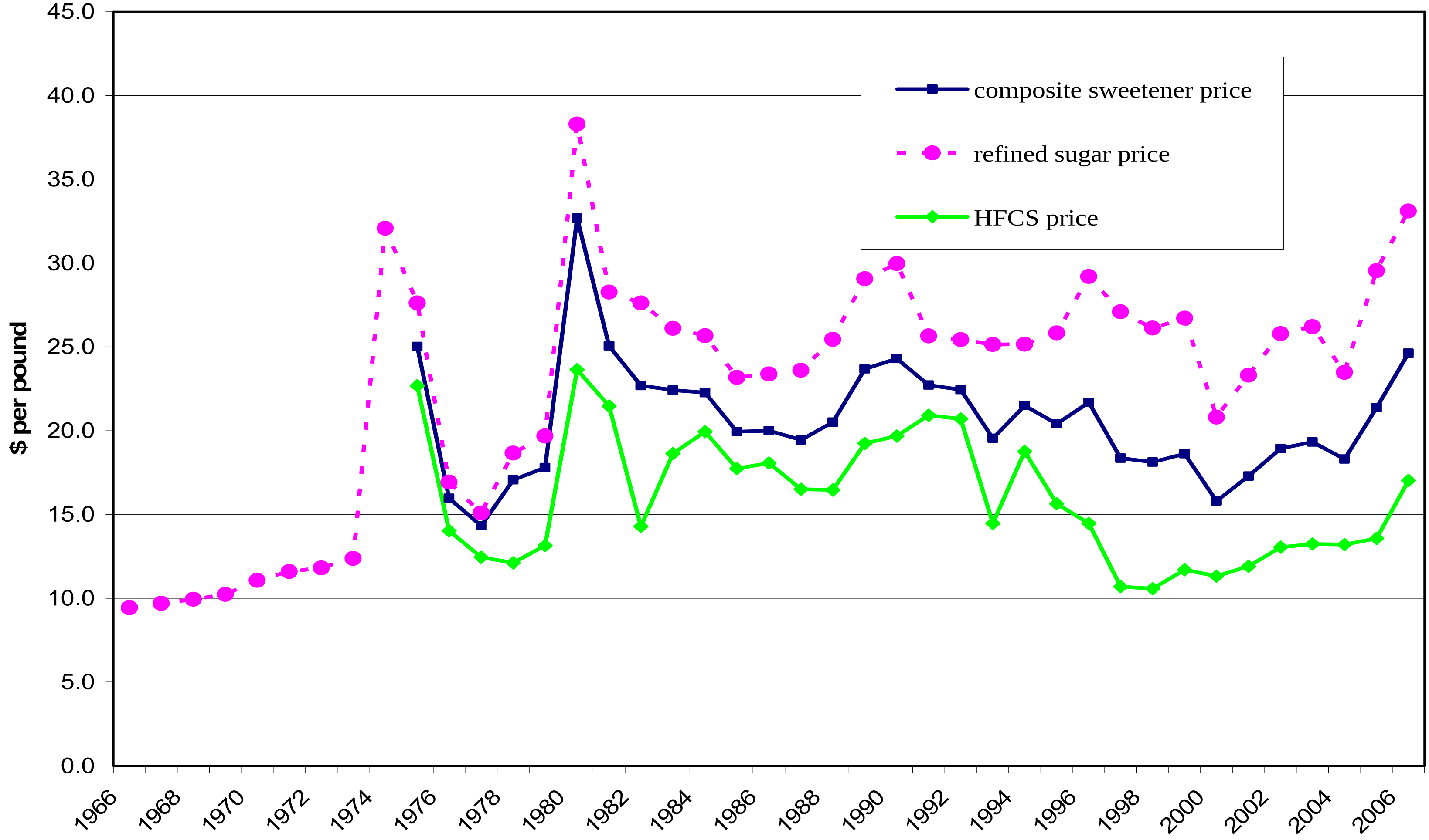

Figure 2. Nominal sweetener price faced by US food processors

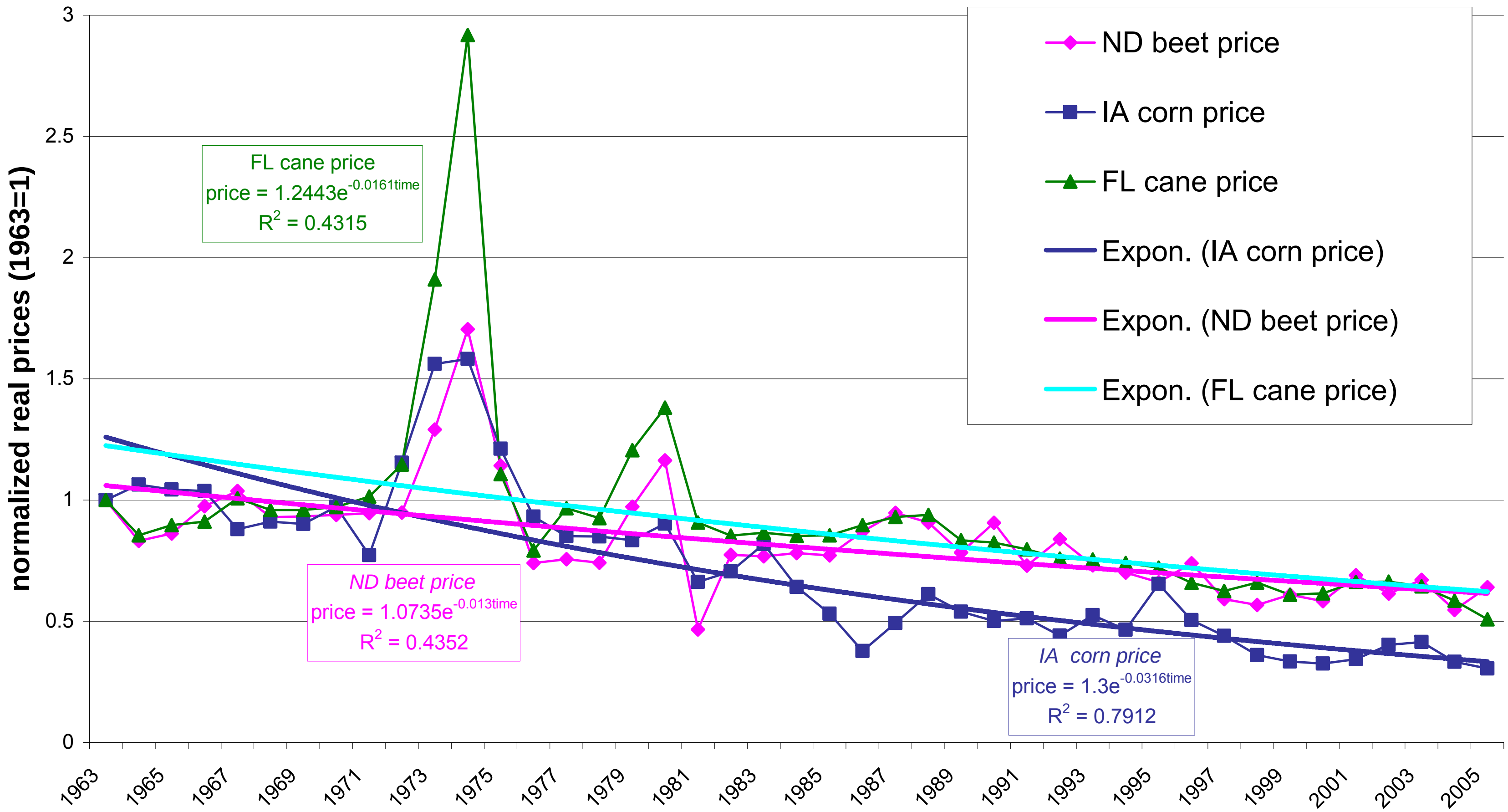

Figure 3. Real farm prices for sweetener crops in selected US states

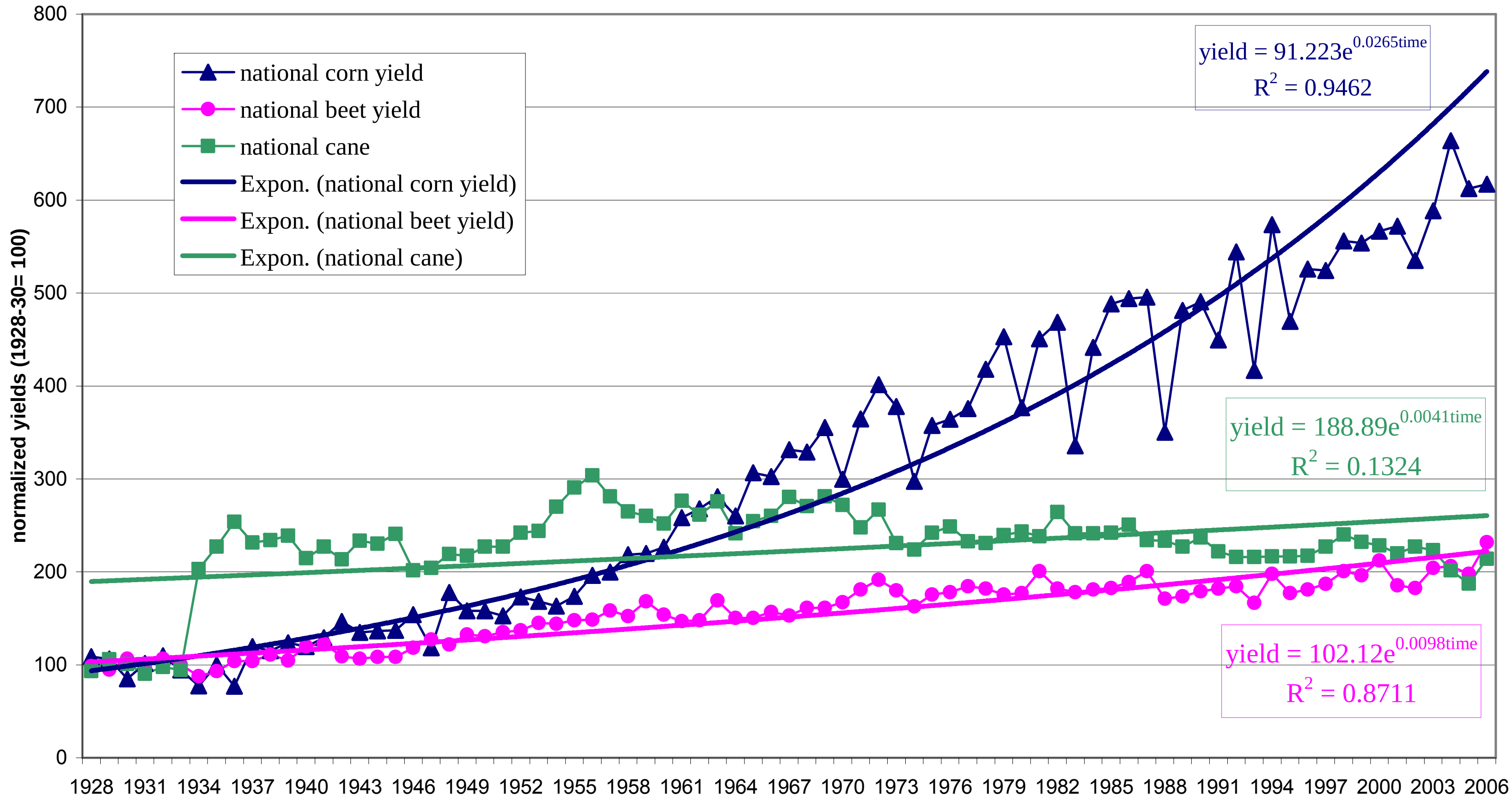

Figure 4. Asymmetric growth of beet, cane, and corn national yields in the United States

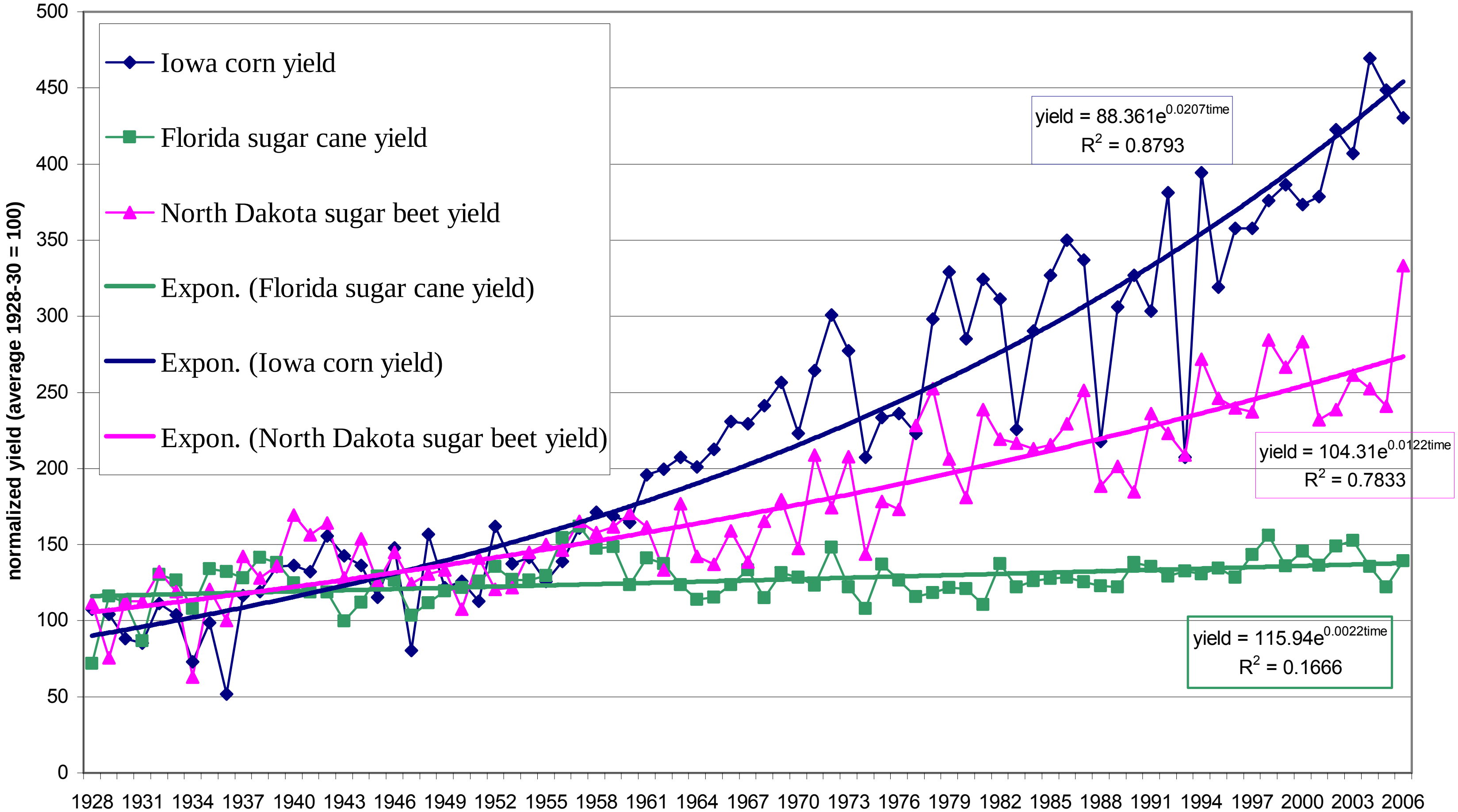

Figure 5. Asymmetric growth of beet, corn, and sugar cane yields in selected US states

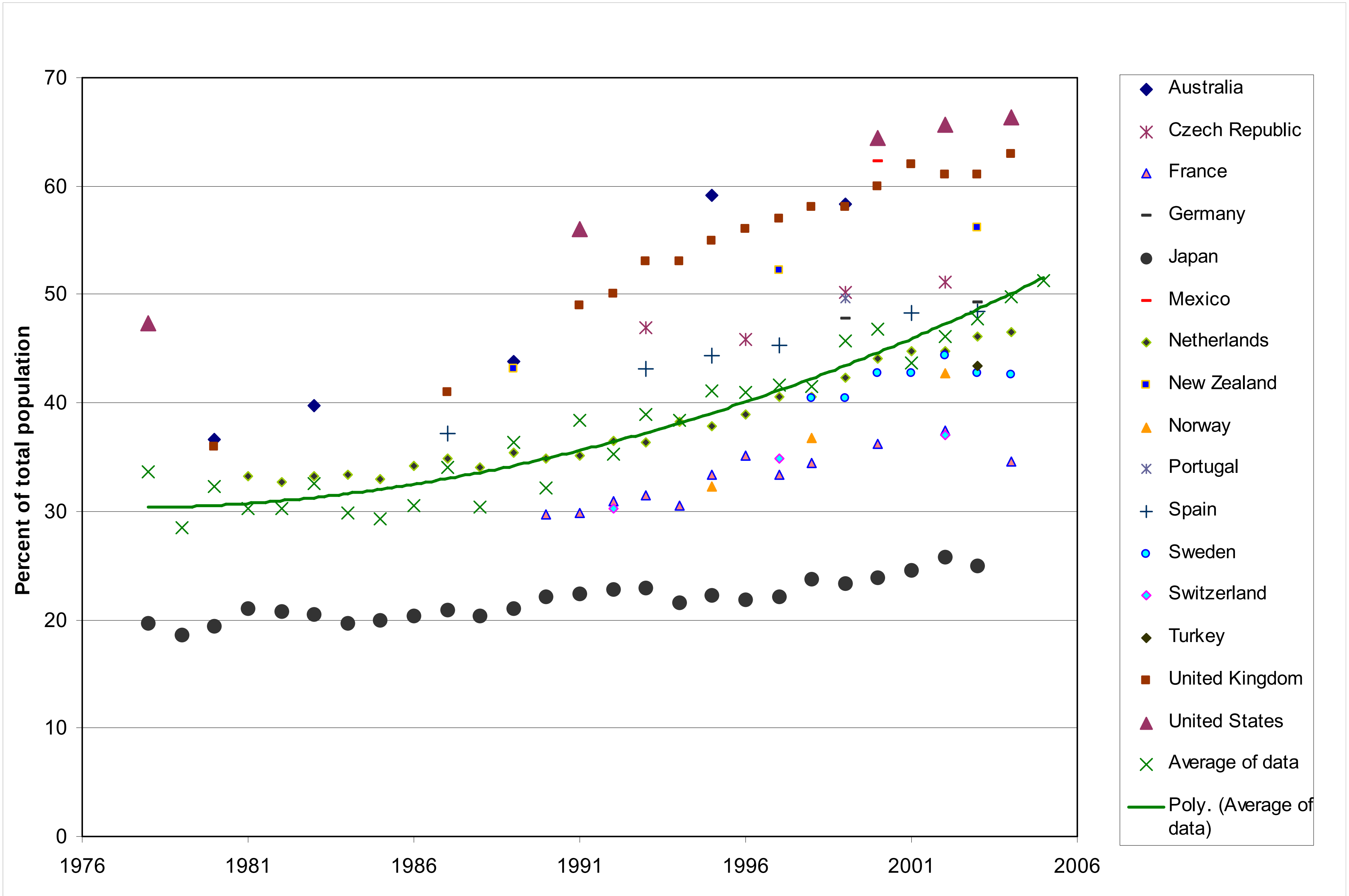

Figure 6. Overweight and obese populations in some OECD countries

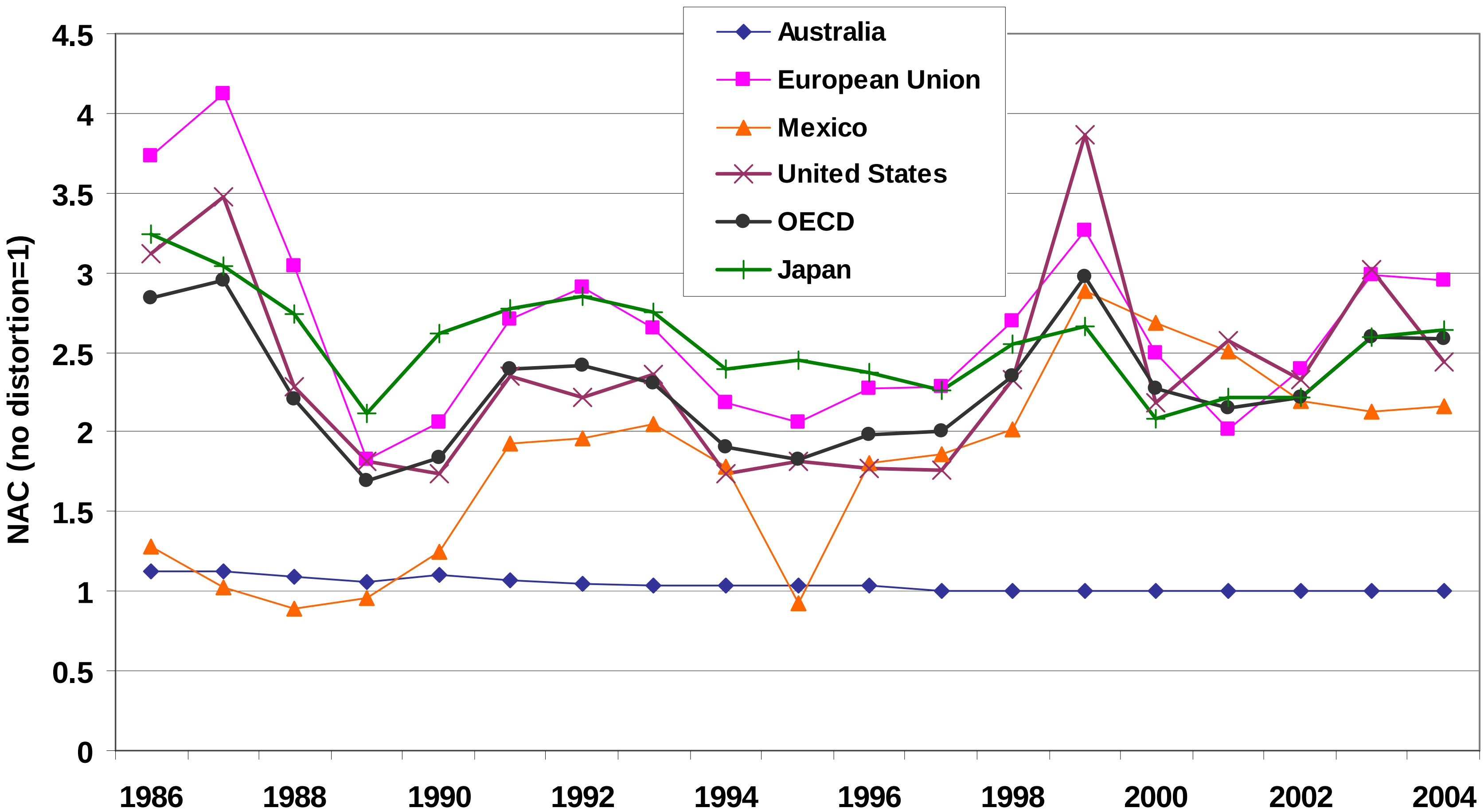

Figure 7. Refined sugar user price distortions in OECD countries from agricultural policies (NAC) measured at the farm gate