An empirical investigation of the demand for bananas in Germany

ALISON BURRELL and ARNE HENNINGSEN

Abstract

We use econometric methods to investigate consumer demand for bananas and for other fruit in Germany. Monthly household survey data for the period 1986-1998 are analysed. Demand for bananas is significantly responsive to own price, suggesting that policy-induced price increases generate the usual dead-weight losses. Demand is also responsive to income changes, indicating that there is scope for further market expansion as incomes grow. There is evidence that other categories of fruit are both gross and net substitutes for bananas.

Keywords: bananas; fruit; dynamic demand system; Germany

Eine empirische Untersuchung der Bananennachfrage in Deutschland

Wir verwenden ökonometrische Methoden, um die Nachfrage der Konsumenten nach Bananen und anderen Obstarten in Deutschland zu untersuchen. Dabei werden Daten von monatlichen Haushaltsstichproben aus den Jahren 1986-1998 verwendet. Die Bananennachfrage wird sowohl durch den Preis als auch durch die Einkommenshöhe signifikant beeinflusst. Dies lässt die üblichen Wohlfahrtsverluste durch politikbedingte Preisanstiege erwarten und zeigt, dass durch steigendes Einkommen weiteres Potential zur Marktexpansion besteht. Weiter wurde nachgewiesen, dass andere Kategorien von Obst sowohl Brutto- als auch Nettosubstitute für Bananen sind.

Schlüsselwörter: Bananen; Obst; Nachfrage; dynamisches Nachfragesystem; Deutschland

1 Introduction

This paper investigates consumer demand for bananas in Germany. We present estimates of the main parameters of interest to market analysts and policy makers. As part of the analysis, demand for other types of fruit is also covered. The analysis uses monthly household survey data for the period 1986-1998. To our knowledge, the agricultural economics literature does not offer any study of demand for bananas in Germany based on recent data, nor any analysis of German consumers' demand for fruit at household level.

Section 2 of the paper presents the motivation for our research, describes the policy context and summarizes previous research. Section 3 describes the data used, and the two modelling approaches adopted. Section 4 presents the results, and conclusions are drawn in Section 5. Additional technical material is available in the **Appendix**.

2 Background

In 1997, Germany accounted for 10 per cent of the world's banana imports, representing about 1.1 million tons of the 3.15 million tons of bananas imported into the EU (FAO, 1999). Since the mid-1980s, Germany's per capita banana consumption has been consistently among the highest in Europe. In the last few years, per capita consumption of bananas in Germany was about 13 kilograms per year. This represents a small decline compared with 1991-92, when lower prices and the aftermath of reunification boosted per capita national consumption to record levels of over 15 kg per head.

Most previous studies of the German banana market have focussed on the supply side of the market. Vertical integration in the chain between importation and the retail market is well developed, and there is strong market concentration at the level of importers and ripeners, where three firms share about three quarters of the market. These structural characteristics have motivated research into the functioning of the market. DEODHAR and SHELDON (1995) showed that the German banana market is not perfectly competitive, with firms exhibiting Cournot-Nash behaviour. HERRMANN and SEXTON (1999), however, have argued that weekly import price formation is guided by the Chiquita price. By contrast, WEISS (1995) found strong price transmission from world market price to consumer price, suggesting that there is strong competition despite market concentration.

The German market has also been of interest because, prior to the common banana regime that came into force on 1 July 1993 (Official Journal, 1993), Germany was the only EU country to enjoy virtually free trade in bananas[1]). Completion of the EU's single internal market in 1993 required the adoption of a common market regulation for bananas[2]). As a consequence, German banana imports from traditional suppliers faced an import quota and a new tariff of 100 ECUs per ton. KERSTEN (2000) estimated that this policy increased the German wholesale price by around 400 US-$/t. We note that German consumers still enjoy the lowest banana prices within the EU (for example, in 1998, retail banana prices in Germany were 11, 10, 16 and 32 per cent lower than in France, the United Kingdom, Italy and Denmark respectively) (FAO, 1999). It is unlikely that the new EU banana regime starting on 1 April 2001 will bring downward pressure on prices[3]).

1) Under a special protocol to the Treaty of Rome, Germany benefited from a duty-free quota for banana imports that was nearly sufficient for domestic requirements. This quota was largely filled by imports from Latin America, under the control of a small number of US trading companies. Other EU member countries applied the common external tariff, or imported more expensively produced bananas from ACP countries and overseas territories of Spain, France and Portugal.

2) The main features of this regulation were a duty-free quota for ACP bananas of 857 700 tons, a tariff rate quota (TRQ) (within-quota tariff=100 ECU/t) of 2 million tons and deficiency payments for EU producers (including overseas territories) up to 854 000 tons. The normal tariff rate on non-quota imports is 750 (850) ECU/t for ACP (non-ACP) countries. For more details, see KERSTEN (1994), TANGERMANN (1997), HALLAM and PESTON (1997). Almost immediately, this regulation was challenged by four Latin American countries under the GATT. As a result, the TRQ was increased progressively by 0.2 million t and the in-quota tariff was reduced to 75 ECU/t. With the accession of three new member countries in 1995, the TRQ was extended by a further 0.353 million t. Following further protests, the EU revised its rules for allocating quotas to importing countries.

3) In December 2000, the Council of Ministers agreed on a new regime comprising three tariff-rate quotas (quota A=2.2 million t, quota B=0.353 million t (adjustable) and quota C=0.850 million t with tariff rates of € 75,

The implications of the 1993 policy change in terms of consumer welfare losses and the adjustment strategies of the market have been studied by KERSTEN (1995), HERRMANN (1999) and HERRMANN and SEXTON (1999). Despite this recent research, the economic characteristics of the German consumer's demand for bananas have been insufficiently explored. The literature offers conflicting evidence on the responsiveness of consumer demand to changes in banana price, and on the possible existence of close substitutes. Table 1 reports empirical estimates taken from recent literature.

Table 1: **Estimated elasticities of demand for bananas from previous studies**

Source	Period	Level	Elasticity with respect to price of			Static (S) or (D) dynamic
			bananas	apples	oranges	
WEGNER [1]	'70-'85	Import	–0.29	–	1.06**	D
DEODHAR et al.[2]	'70-'92	Consum.	–0.32**	–	–	S
WEISS	'70-'92	Consum.	–0.42	0.35*	–	S
WEISS	'70-'92	Import	–0.34	0.33*	–	S
HERRMANN [3]	'60-'92	Import	–0.36/ 0.41**	0.19	–	S
HERRMANN et al.[4]	'77-'92	Import	–0.55**	n.s.	–	S

*: significant at the 5 % significance level. – **: significant at the 1 % significance level. – n.s.: not significant. – [1] Derived from WEGNER's semi-logarithmic model (1989, p. 268) using reported average real price (p. 309). – [2] DEODHAR and SHELDON (1995) estimate a linear model (p. 344). The figure shown is the response coefficient $\partial q / \partial p$. Sample averages are not given, thus derivation of an elasticity is not possible. – [3] HERRMANN (1996) finds elasticities in the range –0.36 to -0.41, depending on the model specification. – [4] HERRMANN and SEXTON (1999, p.13, equation (3)) estimate a linear model, from which they calculate the own-price elasticity (at sample means) shown above. The coefficient on apple price ($-0.4164 \cdot 10^{-05}$) is insignificant, and the corresponding cross-price elasticity for apples is not calculated.

All models summarized in table 1 are estimated using annual data. Only WEGNER's model is dynamic (short-run elasticities are reported in table 1). Only two of these studies analyse demand at consumer level. Of these, DEODHAR and SHELDON find that consumers have a significant negative own-price response, whereas in WEISS's model the elasticity is significantly different from zero at 10 % only. WEISS finds that bananas and apples are gross substitutes at consumer level, whereas HERRMANN and SEXTON argue against any substitution relationship with apples on the basis of their finding that banana imports are not significantly affected by changes in the *import* price of apples.

The models and estimates of consumer demand behaviour presented in this paper not only complement the studies reported in table 1, but also go beyond them in several respects. First, we extend the time period used for estimation to the end of 1998. Previous studies use data up to 1992 only, on the grounds that subsequent national import or consumption data are less accurate due to the removal of border controls after the advent of the single market. In addition, as far as studies of import demand are concerned, the possibility of structural changes due to the common market regulation introduced in 1993 may have discouraged extending these models beyond 1992. However, for modelling demand at household level, consistently accurate data are available from household surveys right up to the present period. Moreover, it is unlikely that the policy changes introduced during the 1990s had any effect on consumer demand other than via price changes. Therefore, we expect the structure of household demand relationships to have remained unaffected by policy changes.

€ 75 and € 300/t respectively), which will operate for five years from 1 April 2001. These quotas will be open to imports from all third countries. ACP countries will benefit from a tariff preference of € 300/t (Official Journal, 2001).

Second, we estimate demand on a monthly basis, thereby allowing a more accurate representation of the links between changes in economic variables and demand. The market for fresh fruit in Germany is highly seasonal. Banana prices are lowest from August to January, apples are cheapest from October to February, and oranges are less expensive from December to March. Clearly, much information is lost in models that seek to capture consumers' reactions to prices using annual data. Contrary to expectations, however, seasonal fluctuations in demand for individual fruits are not simply the inverse of own-price movements. Seasonal fluctuations in banana demand are relatively small (compared to other fresh fruit), with demand highest from March to May and lowest in December, and demand shows a positive correlation with the seasonal variation in banana price. Apple demand has a strong seasonal peak in October, increases again from March to May and slumps between June and September. Demand for oranges is high from December to March, and particularly low from June to September. Modelling demand on a monthly basis, therefore, requires some action to control for seasonal changes in demand that are unrelated to price and income changes. Moreover, since consumers' reactions to a price change may not be completed within a month due to habit persistence (see, for example, ALESSIE and KAPTEYN, 1991), dynamic adjustment effects should be included in a monthly demand model.

Third, our data set allows us to complement the aggregate analyses reported above by studying the demand behaviour of several different types of household that vary in terms of composition and income level.

Two sets of model results are presented. First, we report single-equation models that are more directly comparable with the results shown in table 1. Second, we present the results of estimating a demand system for fresh fruit in which bananas and other fruit categories are included. This allows us to account in a systematic way for the possibility of substitutes or complements among different categories of fruit, including bananas.

Both approaches are used to model per capita household demand for each of three clearly defined household types. A description of the data used is given in the following section.

3 Data and specification of models

3.1 Data

We use data obtained from the German Federal Statistical Office (Statistisches Bundesamt). The data are derived from sample surveys of households in the former Federal Republic of Germany. Households from the former German Democratic Republic are not included in this study because relevant data are only available for a much shorter period, and because we assume that initial differences between consumption patterns in these two segments will rapidly disappear. Whilst in a strict statistical sense the sample households represent just 5 per cent of all households in the old Länder, their behaviour is most likely typical of large segments of the population from which they are drawn.

The households surveyed are divided into three groups according to structural and income criteria. The income boundaries are adjusted annually in line with the average change in German wages. Households remain in the survey as long as they meet the survey requirements, and are replaced when this is no longer the case. The characteristics and sample averages for the three household types are shown in the **Appendix** (table A1). Household type 1 consists largely of older couples whose income is composed mainly of pensions or social security payments. Household type 2 corresponds more or less to the "average" German household, with an average gross income similar to that of a male industrial worker. Household type 3 has the same structure as household type 2, but receives a much higher income. Household type 1 has the highest per capita consumption of all types of fruit, reflecting the fact that these households consist only of adults but suggesting also the possibility that older people consume more fruit for health reasons.

The banana prices paid by the sample households are consistently lower than the price calculated by the Statistisches Bundesamt on the basis of its consumer price survey[4]), although there are strong correlations between all these prices. Statistical tests confirm that the "richer" households (type 3) pay significantly higher prices for bananas than the other two household types, with an average price difference of over 5 per cent.

During the sample period, real expenditure on food and on all fresh fruit, and their shares in total expenditure, declined for all three household types. Taking all households together, the food expenditure share fell from 17.5 % to 13.5 %. However, real expenditure on bananas remained more or less unchanged, ignoring short-run fluctuations, so that its share in fresh fruit expenditure and in food expenditure increased.

3.2 Model specifications

Households are assumed to follow a two-stage budgeting process. At the upper level (first stage), expenditure is allocated to the category fresh fruit, as a function of the fresh fruit price index relative to the prices of other goods, and permanent disposable income[5]). Total expenditure is used as a proxy for permanent disposable income, since actual disposable income as measured in the survey is subject to large seasonal fluctuations due to Christmas and holiday bonuses. The first stage relationship between fresh fruit consumption (fresh fruit expenditure divided by the corresponding price index for fresh fruit), and the fresh fruit price index and total expenditure, both deflated by the consumer price index, is modelled using a simple loglinear function with monthly dummy variables and partial adjustment.

At the second stage, the fresh fruit budget is allocated between *n* categories of fruit. Two different approaches are used to model demand for bananas at the second stage: a single demand equation for bananas, and a demand system from which mutually consistent demand equations for all *n* categories of fruit are derived. Price elasticities of demand calculated at the lower stage show responses to price, assuming the budget allocated to fresh fruit remains unchanged (=*conditional* elasticities). *Unconditional* price elasticities assume that when the price of a fruit category changes, the budget allocated to fresh fruit also adjusts but total expenditure (permanent disposable income) is held constant. Conditional expenditure elasticities show the reaction of demand for a fruit category to a change in the budget allocated to fruit, whereas unconditional expenditure elasticities show the demand response to an increase in total expenditure. Unconditional elasticities are calculated from the results of the two stages of estimation using the formulae given in FAN, WAILES and CRAMER (1995, p. 62), with standard errors calculated using the formula given in KLEIN (1953, p. 258).

For the lower level, our first approach involves a log-linear specification with partial adjustment, as shown in (1):

$$(1)\quad \log q_{it}^{B} = \beta_{i0} + \sum_{j=1}^{n} \beta_{ij} \log p_{jt}^{r} + \gamma_i \log FX_{it}^{r} + \lambda_i \log q_{it-1}^{B} + \sum_{k=1}^{12} \phi_{ik} M_{kt} + u_{it},$$

for: i= 1, 2, 3 and for t = 1,……,155,

where i denotes household type i, t indexes the months from February 1986 to December 1998, j denotes one of n categories of fruit (where j=1 for bananas), M_{kt} =1 if t falls in the k-th month and zero otherwise, and $\phi_{i,12} = 0 - \sum_{k=1}^{11} \phi_{ik}$ to avoid perfect multicollinearity between the monthly dummy variables. q_{it}^{B} is monthly per capita demand for bananas (in grams/head) by household type i, p_{jt}^{r} is the real price index for fruit of category j (1995=100), and FX_{it}^{r} is real expenditure on fresh fruit (in constant 1995 DM) by household type i, all at time t. The consumer price index is used to deflated the price indices and fruit expenditure. In this model, short-run elasticities with respect to prices and fruit expenditure are $\beta_{i1},\ldots,\beta_{in}, \gamma_i$. Long-run elasticities are $\beta_{i1}/(1-\lambda_i),\ldots,\beta_{in}/(1-\lambda_i), \gamma_i/(1-\lambda_i)$.

For the lower level, our second approach uses a general dynamic version of the linearized Almost Ideal Demand model (DEATON and MUELLBAUER, 1980b), for which the long-run equilibrium model for the k-th category of fruit is (dropping the subscript i for household types)

$$(2)\quad w_{kt} = \alpha_k + \sum_{j=1}^{n} \alpha_{kj} \log p_{jt} + \beta_k \log(FX/P)_t$$

for k = 1,..., n,

where w_{kt} is the share of category k in fruit expenditure, p_{jt} is the consumer price index for fruit category j, FX_t is fruit expenditure (in current DM), P_t is a price index for all fruit and the other variables are as before. To obtain a model that is linear in parameters, the price index P is rep-

4) Based on random samples of several retailers in 118 communities, collected on the fifteenth day of each month.

5) his assumption depends in turn on the assumption that fresh fruit as a group is *weakly separable* in consumers' utility functions, that is, that consumers' preference orderings between different fruits within the category, conditional upon expenditure on the category as a whole, are independent of the level of consumption of goods outside that category (see DEATON and MUELLBAUER, 1980a, p. 127).

resented by Stone's index, defined (in log form) as $\log P_t = \sum_{j=1}^{n} w_{jt} \log p_{jt}$.

Demand theory places the following restrictions on the system given by (2): *adding up*:

$$\sum_{k=1}^{n}\alpha_k = 1, \quad \sum_{k=1}^{n} \alpha_{kj} = 0, \quad \sum_{k=1}^{n} \beta_k = 0,$$

(these restrictions ensure that the shares sum to one); *homogeneity*: $\sum_{j=1}^{n} \alpha_{kj} = 0,$ (these restrictions ensure that demands are homogeneous of degree zero in prices and income); and *symmetry*: $\alpha_{kj} = \alpha_{jk}$ for all *j* and *k* (these restrictions ensure the symmetry of the Slutsky matrix).

The system given by (2) is written in matrix form as

(3) $\underline{w}_t = \Pi(\alpha,\beta)\underline{x}_t$,

where $\underline{w}_t$ is a $n \times 1$ vector,

$\Pi(\alpha,\beta)$ is a $n \times N$ matrix of the parameters of the long-run system (2) and

$\underline{x}_t$ is a $N \times 1$ vector of prices and expenditure.

The general dynamic version of the AID model is described in ANDERSON and BLUNDELL (1982) and has been applied by various other authors (see, for example, ANDERSON and BLUNDELL (1983, 1984), KESAVAN et al (1993) and MCGUIRK et al (1995)). Short-run dynamic adjustment takes the form of both autoregressive and moving average (partial adjustment) processes. Assuming first-order processes of both kinds, (3) becomes

(4) $(I - \Gamma L)\underline{w}_t = (\Theta_1 + \Theta_2 L)\underline{x}_t$,

where

I is the $n \times n$ identity matrix,

Γ is a $n \times n$ matrix of adjustment coefficients γ_{ij},

L is the (scalar) lag operator,

Θ_1 and Θ_2 are $n \times N$ matrices such that

$\Pi(\alpha,\beta) = (I - \Gamma)^{-1}(\Theta_1 + \Theta_2)$. Θ_1 contains the short-run response parameters of the dynamic system.

The system given by (4) can also be expressed as an error-correction model by writing

(5) $\Delta\underline{w}_t = \Theta_1\Delta\underline{x}_t - (I - \Gamma)(\underline{w}_{t-1} - \Pi(\alpha,\beta)\underline{x}_{t-1})$.

To each equation of (5) monthly dummies and a time trend are added (see KESAVAN et al, 1993); for the *k*-th equation, this involves adding the terms $\sum_{j=1}^{12} \phi_{kj} M_{jt}$ and $\mu_k t$, for which "adding up" requires the parameter restrictions $\sum_{k=1}^{n} \phi_{kj} = 0$ and $\sum_{k=1}^{n} \mu_k = 0$. As in the single-equation model, in order to avoid perfect multicollinearity between the monthly dummies, we impose the restrictions $\sum_{j=1}^{12}\phi_{kj} = 0$ for each *k*; this means that the monthly dummies measure deviations of each month from the annual average (rather than from a "base" month).

As ANDERSON and BLUNDELL (1982) explain, the adjustment coefficients in the matrix Γ remain unidentified unless additional identifying restrictions are imposed. In this paper, we are not interested in the adjustment process but rather in the parameters of the long-run model, since they are directly comparable with the previously estimated annual elasticities reported in table 1. Therefore, following the procedure described by ANDERSON and BLUNDELL (1982), we estimate the system in the form (5) without restricting the adjustment process.

There are two advantages of estimating the dynamic model in the form given by (5). First, it is possible to impose the theoretical restrictions of symmetry and homogeneity on the long-run parameters. We note, however, that this does not guarantee these properties for the short run. Second, we obtain standard errors of the long-run parameters as part of the estimation output. This simplifies the calculation of standard errors for the long-run elasticities.

Long-run price and expenditure elasticities (see CHALFANT, 1987; GREEN and ALSTON, 1990) are calculated using the formulae

(6) $\varepsilon_{kj} = \frac{1}{w_k}\left(\alpha_{kj} - \beta_k w_j\right) - \delta_{kj}$,

where δ_{kj} is the KRONECKER δ and

(7) $\varepsilon_k = 1 + \frac{\beta_k}{w_k}$.

The relative merits of our two approaches for the lower level need some discussion. The long-run AID model conforms fully to the static theory of consumer choice, with dynamic adjustment characteristics superimposed. Since the demands for the different fruit categories are estimated together, all uncompensated (expenditure-constant) and compensated (utility-constant) cross-price elasticities for pairs of categories are mutually consistent. By contrast, the loglinear model is simpler to understand and corresponds to the model specifications underlying the estimates in table 1. It is easily shown, however, that the loglinear model is incompatible with consumer theory except in the special case of linear Engel curves ($\varepsilon_k = 1, \forall k$), unit own-price elasticity and zero cross-price elasticities. Of course, the upper-stage model used here with both approaches suffers from this defect. We use it to obtain elasticities that are comparable with those cited above from the literature.

4 Results

4.1 Single-equation approach

Initially, the price of oranges was included in these equations. However, in that specification, oranges appeared to be net complements for bananas for two household types, which is counter-intuitive. When banana demand was regressed on all prices, including orange price, and *total* expenditure (rather than fruit expenditure), both Marshallian and Hicksian elasticities of demand for bananas with respect to the price of oranges were insignificant. It was therefore decided to drop the orange price. Oranges were also dropped from the system model on theoretical grounds (see section 4.2). The corresponding total fruit expenditure and fruit price index at the upper stage were modified accordingly.

Table 2 presents the results of the single-equation approach. Panel A of this table contains the estimated parameters of the conditional uncompensated elasticities. Summary statistics for these regressions are given in note 1 to the table.

Table 2: **Elasticities of demand for bananas (single equation)**[1]

	Household type 1		Household type 2		Household type 3	
	Short run	Long run	Short run	Long run	Short run	Long run
A. Conditional uncompensated elasticities with respect to						
Banana price	–0.63**	–0.91**	–0.38**	–0.64**	–0.26**	–0.54**
Apple price	–0.06	–0.08	–0.13	–0.21	–0.11	–0.22
Other fruit price	0.11	0.16	–0.09	–0.15	–0.11	–0.22
Fruit Expenditure[2]	0.52**	0.75**	0.45**	0.75**	0.45**	0.92**
B. Unconditional[3] uncompensated elasticities with respect to						
Banana price	–0.53**	–0.79**	–0.26**	–0.45**	–0.16**	–0.33**
Apple price	0.10	0.12	0.04	0.07	0.06	0.12
Other fruit price	0.32+	0.43	0.07	0.11	0.07	0.15
Total expenditure	0.15**	0.45**	0.09+	0.41+	0.16*	0.68*
C. Conditional compensated[4] elasticities with respect to						
Banana price	–0.52**	–0.75**	–0.26**	–0.44**	–0.16*	–0.33**
Apple price	0.12	0.18	0.04	0.07	0.06	0.12
Other fruit price	0.35+	0.50+	0.07	0.12	0.07	0.15

+ [*] (**) denotes significantly different from zero in a 2-tailed test at the 10 [5] (1) % significance level. – [1] $\bar{R}^2$ = 0.764, 0.777, 0.815, and Durbin's *h* (see JOHNSTON and DINARDO,1997, pp. 182-184) = –0.84, –1.29, –4.14 respectively for the three household types. The coefficients on the lagged endogenous variables are 0.31 (4.72), 0.41 (6.40), 0.51 (7.04) respectively (t-ratios in parentheses). – [2] Fruit expenditure does not contain the expenditure on oranges. – [3] The unconditional elasticities are calculated using the results of the upper stage, shown in table A2. – [4] The compensated elasticities (ε^*_{kj}) are calculated as $\varepsilon^*_{kj} = \varepsilon_{kj} + w_j \varepsilon_k$.

The demand for bananas for all three household types responds significantly to own price changes. Long-run responses are much greater than short-run responses, with household type 1 reallocating its expenditure among different types of fruit after a price change most quickly. For household type 1, 96 per cent of the adjustment is complete 2 months after the month of the price change, whereas household type 2 takes 3 months and household type 3 takes 4 months to make 96 per cent of its adjustment.

The compensated elasticities shown in panel C of table 2 suggest that bananas and the category "other fruit" (comprising mainly grapes, peaches, berries, plums, cherries, lemons, grapefruit and tropical fruit (ZMP, 1998, pp. 33, 35, 36) are weak net substitutes for household type 1. Other relationships of substitutability or complementarity between the different types of fruit were not found. Behaviour is significantly different between the three household types[6]).

Elasticities of banana demand with respect to total expenditure (our proxy for permanent disposable income) indicate that there is still some scope for demand to grow with income for all household types, with the greatest potential exhibited by household type 3. This suggests that, despite high consumption levels in Germany, the market is not yet saturated.

4.2 Demand system

The demand system was originally estimated with four categories of fruit: bananas, apples and pears ("apples") [7]), oranges and mandarins ("oranges") and the category other fruit ("other") defined as in section 4.1. With long-run homogeneity and symmetry imposed, the own-price elasticity for oranges for all three household types violated the necessary condition for concavity, and oranges exhibited significant complementarity with apples, which is counter-intuitive. Imposing concavity at minimum cost to the goodness-of-fit of the system effectively resulted in forcing to zero all elements in the Slutsky matrix corresponding to oranges. Using the test described by SELLEN and GODDARD (1997), we tested for weak separability between oranges and the other three fruit categories. For household types 2 and 3, the null hypothesis of weak separability was accepted with *p*-values of over 0.12 [8]). For household type 1, the test was inconclusive since the test model failed to converge. Based on this partial evidence in favour of weak separability, we dropped the oranges category from the system for all three household types.

In the three-fruit system, the share equations for bananas and apples were estimated with long-run homogeneity and symmetry imposed, and the adding-up restrictions on the long-run parameters were used to derive the parameters of the third equation (other fruit) [9]). Concavity was satisfied at the sample means for all three household types. A time trend was included to capture any long-run shifts in preferences between the fruit categories; in the banana equations it was significant only for household type 1, and indicated a ceteris paribus cumulative decline in the banana expenditure share of 1.3 percentage points over the whole sample period for this household type.

The estimated demand system of household type 1 was significantly different from that of household types 2 and 3 at the 1 per cent significance level. By contrast, the estimated systems of household types 2 and 3 were not significantly different from each other at the 10 percent level[10]). However, we have kept household types 2 and 3 separate because they differ in their upper-level behaviour.

The elasticities obtained from the demand system are summarized in table 3. Panels A and B show long-run conditional and unconditional elasticities respectively. First, we note that demand for bananas responds significantly to changes in own price for all three household types, although banana demand is more inelastic for household

6) An F-test rejected a model where parameters were restricted to be the same for all household types in favour of a model where each household type may have different parameters ($F_{36,411}$ = 7.95).

7) An index of the (weighted) prices of these two fruits was used.

8) This implies that consumers view oranges and the composite group composed of bananas, apples and other fruit as competing categories at the same budgeting level. Changes in the price of oranges affect demand for bananas only via a change in the amount allocated to be spent on this composite group, ruling out any direct substitution or complementarity.

9) When homogeneity and symmetry were tested together using a likelihood ratio test, they were rejected with χ^2 (3) values of 28.8, 36.7 and 46.1 respectively (critical value = 7.8). Given our aim to obtain a theoretically consistent set of demand parameters, we give priority to theory. However, we note that these properties have been imposed on the data at some statistical cost.

10) According to pairwise likelihood ratio tests of pooled models. Chi-square (df=43) values were 77.7, 70.0 and 11.7 respectively.

types 2 and 3. Demand for the other two fruit categories is also significantly responsive to changes in own price. Demand for other fruit is the most responsive to changes in its own price for household types 2 and 3, whereas demand for bananas is the most price responsive for household type 1.

Table 3: **Elasticities of demand for three fruit categories**

Demand for	Bananas	Apples	Other fruit
Household type 1[1]			
A. Long-run conditional uncompensated elasticities with respect to			
Banana price	–0.71**	0.03	–0.15**
Apple price	0.03	–0.64**	–0.29**
Price of other fruit	–0.04	–0.06	–0.94**
Fruit expenditure	0.72**	0.68**	1.37**
B. Long-run unconditional uncompensated elasticities with respect to			
Banana price	–0.60**	0.13**	0.07
Apple price	0.22**	–0.46**	0.08
Price of other fruit	0.22*	0.18+	–0.45**
Total expenditure	0.43**	0.41*	0.83**
C. Long-run conditional compensated elasticities (holding utility constant) with respect to			
Banana price	–0.56**	0.16**	0.13**
Apple price	0.28**	–0.41**	0.19*
Price of other fruit	0.29**	0.25*	–0.32**
Household type 2[2]			
A. Long-run conditional uncompensated elasticities with respect to			
Banana price	–0.59**	–0.23**	–0.06
Apple price	–0.15	–0.76**	–0.14
Price of other fruit	0.10	–0.10	–0.96**
Fruit expenditure	0.65**	1.09**	1.16**
B. Long-run unconditional uncompensated elasticities with respect to			
Banana price	–0.42**	0.05	0.23*
Apple price	0.08	–0.36*	0.29+
Price of other fruit	0.32**	0.27+	–0.56**
Total expenditure	0.35+	0.60+	0.64+
C. Long-run conditional compensated elasticities (holding utility constant) with respect to			
Banana price	–0.42**	0.06	0.24**
Apple price	0.09	–0.35*	0.30*
Price of other fruit	0.33**	0.28*	–0.55**
Household type 3[3]			
A. Long-run conditional uncompensated elasticities with respect to			
Banana price	–0.63**	–0.16*	–0.06
Apple price	–0.26+	–0.69**	–0.14
Price of other fruit	0.06	0.01	–1.04**
Fruit expenditure	0.83**	0.84**	1.24**
B. Long-run unconditional uncompensated elasticities with respect to			
Banana price	–0.44**	0.03	0.23**
Apple price	0.05	–0.37**	0.33**
Price of other fruit	0.40**	0.35**	–0.54**
Total expenditure	0.62*	0.63*	0.92*
C. Long-run conditional compensated elasticities (holding utility constant) with respect to			
Banana price	–0.44**	0.03	0.22**
Apple price	0.04	–0.37**	0.32**
Price of other fruit	0.40**	0.35**	–0.54**

+ [*] (**) denotes significantly different from zero in a 2-tailed test at the 10 [5] (1) % significance level. – [1] $\overline{R}^2$ = 0.830, 0.787, and Durbin Watson = 2.11, 2.18 respectively for the first two equations of panel A. – [2] $\overline{R}^2$ = 0.885, 0.727, and Durbin Watson = 2.28, 2.08 respectively for the first two equations of panel A. – [3] $\overline{R}^2$ = 0.906, 0.806, and Durbin Watson = 2.10, 2.10 respectively for the first two equations of panel A.

Second, long-run conditional elasticities of demand for bananas with respect to expenditure are significantly positive for all household types. Long-run unconditional income elasticities for bananas are also significant for all household types, although only weakly significant for household type 2. The overall results suggest that there is potential for growth in demand for all three categories of fruit as per capita income increases. For household types 1 and 3, the potential for income-driven growth in banana consumption is similar to that for apples, but lower than that for other fruit. For household type 2, growth potential is lower for bananas than for the other two categories.

Third, the greater input of data and economic theory in the demand system, relative to the single-equation approach, enables a more detailed investigation of substitution and complementarity relationships between the three categories of fruit. For household type 1, bananas and apples are long-run gross substitutes in both the banana and the apple demand functions for household type 1, whereas other fruit are gross substitutes for bananas and apples only in the banana and apple equations. For the other two household types, there are two-way relationships of gross substitution between other fruit and bananas, and other fruit and apples, but no gross substitution between bananas and apples. The C panels in table 3 indicate that all three fruit categories are net (Hicksian) substitutes for each other for household type 1, whereas all pairs except bananas and apples are net substitutes for household types 2 and 3.

5 Conclusions

This paper presents two different sets of parameter estimates for German households' demand for bananas. Demand patterns have remained quite stable during the sample period, despite underlying policy changes. Bananas are a normal good for German households (i.e. with an income elasticity between zero and one). Clearly, this market is not saturated and has potential for further expansion as incomes rise. According to the single-equation results, households are found to adjust their demands to price changes within 2-4 months after the month of the price change. Demand for bananas is significantly responsive to own price for all household groups, indicating that the 1993 policy change generated the usual dead-weight losses.

The range of own-price demand elasticities for bananas is greater in the single equation model (unconditional long-run own-price elasticities between –0.79 for low-income households and –0.33 for high-income households) than in the demand system (unconditional long-run own-price elasticities between –0.60 and –0.42 for low- and medium-income households respectively). Long-run elasticities of demand with respect to total expenditure, which is used here as a proxy for "permanent" disposable income, are also considerably larger in the single-equation model than in the demand system. Price responsiveness is generally lower for the higher-income households in both models.

The higher banana consumption and greater price sensitivity of lower-income households suggests that if the new EU banana regulation that becomes operational on 1 April 2001 were to result in a price reduction for bananas in Germany, the welfare of low-income households, when measured in money terms, would increase relatively more than that of higher-income households. Given that the marginal utility of money is higher for these households, the relative welfare effect in utility terms would of course be even greater.

The system estimates show that bananas are net substitutes for apples and pears and for other fruit for low-income households, and for other fruit only for the other two household types. This pattern is largely maintained when the income effects of price changes are allowed for: in the system-estimated banana demand function, bananas and the category of other fruit are gross substitutes for all household types and in addition, bananas and apples are gross substitutes for the lowest-income households. This result contradicts the statements from the literature referred to above that suggest bananas have no close substitutes for the German consumer. We note, however, that bananas do not appear to have gross substitutes in the single-equation model.

Although our results are based on data for a small, clearly defined proportion of German households, we consider that the behaviour described here is probably typical of a large segment of the German market. It remains a disadvantage, of course, that our estimates do not directly describe the aggregate behaviour of the German market. The advantages of using household survey information, however, are important. They include the high quality and consistency of the data, the fact that demand behaviour can be analysed as close as possible to the decision-making unit (as opposed to market data, which do not always coincide exactly with what households have purchased), the ability to obtain up-to-date estimates, and the possibility of identifying different responses at different levels in the income distribution.

Appendix

A-1 Data description

Table A1: **Description of households and household data**

	Household type 1	Household type 2	Household type 3
Household characteristics			
Approx. sample size	165	378	388
Composition	2 adults	2 adults, 2 children	2 adults, 2 children
Age of children	-	at least one < 15	at least one <15
Employment status	mainly not working	only 1 adult working	at least 1 adult working
Average values (1986-1998) in DM (1995)/month			
Total disposable income	2 555	5 313	8 626
Total consumption expenditure	2 129	4 082	5 991
Total food expenditure	394	610	738
Per capita expenditure on fresh fruit	14.93	8.41	11.32
bananas	2.39	1.78	2.07
apples	4.03	2.68	3.53
other fruit	6.13	2.75	4.18
oranges	2.38	1.20	1.54
Average expenditure shares (1986-1998) in per cent			
Share food in total consumption	18.5	14.9	12.3
Share of fresh fruit (including oranges) in total food	7.6	5.5	6.1
Share in expenditure on freshfruit (excluding oranges)			
bananas	19.0	24.7	21.2
apples	32.1	37.2	36.1
other fruit	48.8	38.1	42.7

Source: Own computations with data from the German Federal Statistical Office (Statistisches Bundesamt)

A-2 Results of upper-stage estimation

Table A2: **First stage: uncompensated elasticities of fruit demand**[1]

	Household type 1		Household type 2		Household type 3	
	Elasticity	t-ratio	Elasticity	t-ratio	Elasticity	t-ratio
Short-run elasticities with respect to						
Price of fruit	–0.10	–1.37	–0.01	–0.15	0.01	0.11
Total expenditure	0.28	2.96	0.20	1.86	0.36	2.67
Long-run elasticities with respect to						
Price of fruit	–0.22	–1.34	–0.03	–0.15	0.02	0.11
Total expenditure	0.60	3.28	0.55	1.86	0.74	2.46

1. Fruit demand and the fruit price index do not contain the expenditure on oranges or the orange price respectively. $\overline{R}^2$ = 0.923, 0.933, 0.929. Durbin's *h* (see JOHNSTON and DINARDO, 1997, pp. 182-184) = –0.810, 0.544, 1.858 respectively for the three household types. The coefficients on the lagged endogenous variables are 0.54 (7.68), 0.64 (8.76), 0.51 (6.69) respectively (t-ratios in parentheses).

A-3 Calculation of unconditional elasticities (FAN, WAILES and CRAMER, 1995)

A-3.1 Unconditional price elasticities

$$E_{ij}^{\overline{X}} = E_{ij}^{\overline{E}} + E_{iE} w_j (E_{FP}^{\overline{X}} + 1)$$

where:

$E_{ij}^{\overline{X}}$ = Elasticity of demand for fruit i with respect to the price of fruit j holding total expenditure (X) constant

$E_{ij}^{\overline{E}}$ = Elasticity of demand for fruit i with respect to the price of fruit j holding expenditure on fruit (E) constant

E_{iE} = Elasticity of demand for fruit i with respect to expenditure on fruit

w_j = Expenditure share of fruit j of expenditure on all fruit

$E_{FP}^{\overline{X}}$ = Elasticity of demand for total fruit with respect to fruit price (P) holding total expenditure constant

A-3.2 Unconditional expenditure elasticities

$$E_{iX} = E_{iE} E_{FX}$$

where

E_{iX} = Elasticity of demand for fruit i with respect to total expenditure

E_{iE} = Elasticity of demand for fruit i with respect to expenditure on fruit

E_{FX} = Elasticity of total fruit demand with respect to total expenditure

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Authors (senior authorship is shared):

Dr. ALISON BURRELL, Associate Professor of Agricultural Economics, Department of Social Sciences, Wageningen, University, Hollandseweg 1, NL-6701 KN Wageningen (The Netherlands) (E-Mail: Alison.Burrell @alg.aae.wau.nl) and

ARNE HENNINGSEN, student of Christian-Albrechts-Universität Kiel, priv. Norgaard/Gintoft 34, D-24972 Steinbergkirche (Germany) (E-Mail: AHenningsen@web.de)