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DEMAND FOR HIGH-VALUE SECONDARY CROPS IN DEVELOPING COUNTRIES: THE CASE OF POTATOES IN BANGLADESH AND PAKISTAN

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ABSTRACT

Secondary crops are of increasing interest to policymakers and planners in developing countries because of a desire to diversify economic activities and because of their proven potential to raise farm incomes and rural employment. To assess this potential, basic information on the demand characteristics for these crops is required. But, given the large number of possible crops to be studied, policy analysts require an estimation procedure that is less data-intensive and time-intensive than standard econometric estimation procedures. In this paper, a relatively new, low-cost procedure, based on demand for food characteristics, is applied, illustrating its usefulness for analysis of demand for potatoes in Bangladesh and Pakistan.

In Asia, the potato should not be regarded as a starchy staple whose consumption declines as income increases, but rather as a food with a positive income elasticity. Due to the high calorie cost of potatoes relative to wheat and rice, potatoes are often valued primarily for the variety they contribute to the diet and their taste, rather than for the calories they provide. This means that demand for potatoes should increase with income in the future. However, expansion of demand for potatoes as an alternative food staple is conditional upon the cost per calorie for potatoes approaching that for wheat and rice. Results from Bangladesh for more recent years show that with the rise in potato production, relative prices for potatoes versus wheat fell and per capita consumption of potatoes increased considerably. These findings are consistent with demand parameters generated utilizing the new estimation procedure.

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DEMAND FOR HIGH-VALUE SECONDARY CROPS IN DEVELOPING COUNTRIES: THE CASE OF POTATOES IN BANGLADESH AND PAKISTAN

1. INTRODUCTION

Successful development and dissemination of high-yielding cereal technologies over the past three decades, particularly in Asia, has contributed greatly to rapid growth of output of basic staples such as wheat and rice in developing countries. With higher yields and expansion in area planted to these crops, supply has outpaced demand. Real cereal prices have fallen dramatically. Lower cereal prices give farmers cause to consider production of more profitable alternatives, including nonstaple food crops. At the same time, governments, less concerned with the politically destabilizing effects of unexpected increases in prices for staple foods, have undertaken policies to curtail their involvement in food markets, to promote the diversification of crop production, and to reduce farmers' heavy dependence on incomes from cereal crops.

Over the past three decades, the bulk of public investments in agricultural research have concentrated on the three most widely consumed food staples: rice, wheat, and maize. However, now that concerns for meeting demand for staple foods have waned for the immediate future, future gains in agricultural productivity will depend increasingly on yield increases for nonstaple crops. While achieving such gains will depend on public investments in agricultural research, the optimal investment choices for nonstaple crops is much less obvious. A major reason for this dilemma is a lack of information on demand for these crops.

Per capita consumption of any individual nonstaple food is low as compared with cereals. Unlike for food staples, however, there is considerable potential for per capita production of individual nonstaple foods to increase by several multiples over a relatively short period of time, resulting in sharp declines in producer prices, such as those observed on a seasonal basis for vegetables. Therefore, understanding the

factors driving demand for nonstaple foods is crucial to planning for investments in agricultural diversification.

This paper examines a specific case: demand for potatoes in Bangladesh and Pakistan. Supply of and demand for potatoes provides an interesting case study in that potatoes are widely regarded as an inferior staple. The paper will demonstrate that due to the high calorie cost of potatoes relative to wheat and rice in these countries, potatoes can be valued primarily for the variety they provide in the diet and their taste, rather than for the calories they contribute to the diet. Demand for potatoes should therefore increase with income in the future. This increase can be reinforced as the cost per calorie for potatoes approaches that for wheat or rice. Results from Bangladesh are consistent with these demand parameters and therefore tend to validate the new estimation procedure.

2. SECONDARY CROPS IN DEVELOPING COUNTRIES: THE CASE OF POTATO

Since the early 1960s, a number of secondary crops have experienced very rapid increases in production in developing countries (Table 1). Typically, these crops are high-value, short-duration, labor-intensive crops grown primarily for sale rather than for on-farm consumption. Potatoes, tomatoes, cabbages, and lentils are perhaps the most promising examples worldwide. As a result, several countries—particularly in Asia—have looked increasingly to secondary crops as a source of increased output, foreign exchange, or for import substitution (see Scott 1985, 1988; Rachim et al. 1992; Jansen 1994).

Potato is a particularly interesting case, in part because the growth in production has been so noteworthy. The percentage increase in production for

Table 1 Food crop production in developing countries, 1961-93

1991-1993				Growth Rate[a]		
Production	Area	Yield	Production	Area	Yield	
	('000 tons)	('000 hectares)	(ton/hectare)		(percent)	
Rice, paddy	500,141	143,531	3.5	2.9	0.2	2.2
Wheat	246,374	101,949	2.4	4.5	0.5	3.4
Maize	219,812	83,771	2.6	3.9	0.5	2.7
Cassava	153,249	15,928	9.6	2.4	0.8	0.8
Sweet potato	121,904	8,999	13.5	0.9	-1.0	2.0
Potatoes	84,354	6,677	12.6	3.6	1.2	1.5
Soybeans	50,558	30,304	1.7	6.2	2.4	3.0
Sorghum	41,437	37,834	1.1	1.1	-0.3	1.4
Tomatoes	38,471	1,774	21.7	5.4	1.5	2.2
Barley	26,607	18,762	1.4	0.9	0.3	1.2
Yams	25,951	2,762	9.4	3.7	1.8	0.9
Millets	24,375	32,806	0.7	0.3	-0.7	0.9
Groundnuts	22,238	19,591	1.1	1.6	0.1	1.0
Cabbages	19,793	883	22.4	5.2	1.5	2.6
Beans, dry	14,231	23,453	0.6	1.5	0.4	0.6
Chickpeas	6,886	9,884	0.7	-0.1	0.1	0.4
Broad beans	3,535	2,672	1.3	-0.9	-0.9	0.9
Lentils	2,151	2,848	0.8	3.3	1.5	1.1
Rye	931	715	1.3	-3.3	-3.6	1.2

Source: FAO, Agrostat-PC, unpublished statistics, 1993.

[a] Average annual rate 1961-63/1991-93.

potatoes in developing countries during 1961-1993 was greater than for any other major food crop except wheat (FAO/CIP 1995). For example, potato production in India increased by 550 percent during the last three decades to nearly 16 million tons (Table 2). In Pakistan, potato production increased from 28,400 tons in 1947-48 to over one million tons by 1986-87 (Kobab and Smith 1989). Turkey, Iran, North Korea, and Bangladesh also witnessed substantial increases in potato production (Table 2).

Table 2 Potato production, area, and yield in selected developing countries, 1961-93

1991-1993			Growth Rate[a]		
Production	Area	Yield	Production	Area	Yield
	('000 tons)	('000 hectares)	(ton/hectare)	(percent)	
China	34,435	2,960	12.0	3.2	2.4	0.9
India	15,771	1,014	16.0	5.9	3.3	2.5
Turkey	4,617	195	24.0	3.8	1.1	2.7
Iran	2,847	149	19.0	7.6	5.4	2.0
Colombia	2,456	161	15.0	4.5	3.1	1.3
Brazil	2,353	165	14.0	2.5	-0.6	3.1
Argentina	2,015	111	18.0	0.8	-1.4	2.3
Korea, DPR	1,842	150	12.0	2.1	1.6	0.4
Egypt	1,702	82	21.0	5.0	4.2	0.9
Bangladesh	1,333	127	10.0	4.6	2.7	1.8
Peru	1,314	165	8.0	0.2	-1.1	1.4
Mexico	1,211	73	17.0	4.1	1.5	2.6
Algeria	1,135	114	10.0	5.4	5.4	-0.0
Morocco	957	60	16.0	5.4	3.6	1.8
Chile	931	62	15.0	0.4	-1.3	1.8
All developing countries	84,957	6,677	13	3.6	2.1	1.5

Source: FAO/CIP (1995).

[a] Data are for the 15 countries with the largest production.

[b] Average annual rate 1961-63/1991-93.

Because of the potato's short vegetative cycle, this crop can be easily grown between two cereal crops. Improved wheat and rice varieties have served as an incentive for improving irrigation systems. This, in turn, enables farmers to grow potatoes during the off-season when water is scarce (Chowdhury and Sen 1981; Scott 1988). The introduction of improved varieties from India and Western Europe

combined with the application of chemical fertilizers have also generated impressive increases in average yields (Table 2).

Growth in potato output in Asia has been accompanied by a remarkable shift in the location of production. In India and Pakistan, and to a lesser extent in Bangladesh, potato production has moved down from higher altitudes through the introduction of seed schemes into lowland plains, thus moving the source of supply closer to the consumer (Srivastava 1980; Kobab and Smith 1989; Dahiya and Sharma 1994). This development has helped reduce transportation time and costs, thereby reducing postproduction losses, and has made available a fresher, more affordable product to both urban and rural consumers (Horton 1987; Scott 1988). As a result, for example, per capita potato consumption in rural Bangladesh rose from 6 kilograms per year in 1976-78 to 16 kilograms per year in 1981-82 (Ahmad and Hassan 1983, 19) as potato prices fell relative to rice prices.

These trends have raised a series of questions about the future potential for expanded potato consumption and production. Has the observed increase in consumption been due to changes in relative prices or changes in income? To what extent would even lower prices, through increased production, stimulate even higher demand?

We attempt to answer these questions in the paper by generating demand elasticity estimates for potatoes for Bangladesh and Pakistan and comparing these historical estimates with observed trends in utilization. A relatively new methodology is used to generate these consumption parameters, but a methodology whose data requirements are sparse. In our concluding remarks, we mention briefly the prospects for increased output of potatoes in Bangladesh based on existing or soon-to-be available technology before reviewing the evolution of potato production and utilization in more recent years. We then note that the fall in relative prices for potatoes versus wheat and the associated increase in potato consumption are

consistent with the estimated demand parameters and therefore tend to validate the accuracy of the new estimation procedure.

3. FOOD CONSUMPTION PATTERNS IN BANGLADESH AND PAKISTAN

For Bangladesh, data are taken from the Household Expenditure Survey for 1973-74, conducted by the Bureau of Statistics. The data for Pakistan are taken from the Household Income and Expenditure Survey 1984-85, conducted by the Federal Bureau of Statistics. Overall food consumption patterns, using an eight-food-group disaggregation of these data, are shown in Tables 3 and 4 for Bangladesh and Pakistan, respectively. Price data per kilogram and per calorie in Tables 3 and 4 are expressed as a ratio of the price paid for the least expensive grain by the low-income urban quartile, in this case, for wheat. For example, the lowest income consumer in Bangladesh pays 1.63 times the price of wheat for one kilo of potatoes—a kilo that contains roughly one-fifth the quantity of calories 0.75/3.40. Hence, on a price per calorie basis, potatoes are 7.39 times more expensive that wheat, due partly to their high price per kilo, but more importantly, the lower quantity of calories per kilo. Per capita potato consumption for Bangladesh (1973-74) and Pakistan (1984-85) by urban and rural populations and by income group is summarized in Table 5.

The two main staple foods consumed in Bangladesh are rice and wheat. As a source of calories, rice is more than twice as expensive in calorie equivalents as wheat for urban areas at the time of this survey. Both urban and rural populations apparently buy better quality wheat and rice as incomes rise, although the tendency is more marked for rice than for wheat. Wheat is more expensive to purchase in rural areas than in urban areas. The price of rice was apparently about equal between urban and rural areas when these food expenditure surveys were undertaken. Note that per capita consumption of the cheaper staple, wheat,

Table 3 Per capita consumption, price, and calorie conversion rates for seven aggregate food groups, by income group, by urban and rural populations for Bangladesh, 1973-74

Urban/Rural	Income Group	Food	Per Capita Consumption[a]	Market Price[b]	Calories/ Kilogram[c]	Calorie Price[d]	Calorie Share	Food Budget Share	Staple?
Urban	1	Rice	1.60	2.24	3.50	2.18	0.52	0.44	Yes
Urban	1	Wheat	1.32	1.00	3.40	1.00	0.42	0.16	Yes
Urban	1	Potatoes	0.07	1.63	0.75	7.39	0.00	0.01	Yes
Urban	1	Milk	0.05	1.84	0.60	10.43	0.00	0.01	Yes
Urban	1	Meat	0.14	5.53	1.50	12.54	0.02	0.09	No
Urban	1	Pulses	0.11	2.86	0.60	16.21	0.01	0.04	No
Urban	1	Others	0.33	6.00	0.80	25.51	0.02	0.24	No
Urban	2	Rice	1.90	2.46	3.50	2.39	0.56	0.45	Yes
Urban	2	Wheat	1.23	1.01	3.40	1.01	0.36	0.12	Yes
Urban	2	Potatoes	0.10	1.76	0.75	7.98	0.01	0.02	Yes
Urban	2	Milk	0.11	1.73	0.60	9.81	0.01	0.02	Yes
Urban	2	Meat	0.20	5.89	1.50	13.36	0.03	0.11	No
Urban	2	Pulses	0.12	3.32	1.30	8.69	0.01	0.04	No
Urban	2	Others	0.43	6.00	0.80	25.51	0.03	0.25	No
Urban	3	Rice	2.15	2.56	3.50	2.49	0.59	0.41	Yes
Urban	3	Wheat	1.12	1.04	3.40	1.04	0.30	0.09	Yes
Urban	3	Potatoes	0.14	1.77	0.75	8.03	0.01	0.02	Yes
Urban	3	Milk	0.23	1.80	0.60	10.20	0.01	0.03	Yes
Urban	3	Meat	0.28	6.06	1.50	13.74	0.03	0.13	No
Urban	3	Pulses	0.14	3.76	1.30	9.84	0.01	0.04	No
Urban	3	Others	0.62	6.00	0.80	25.51	0.04	0.28	No
Urban	4	Rice	2.41	2.75	3.50	2.67	0.61	0.37	Yes
Urban	4	Wheat	1.04	1.06	3.40	1.06	0.25	0.06	Yes
Urban	4	Potatoes	0.17	1.98	0.75	8.98	0.01	0.02	Yes
Urban	4	Milk	0.35	1.87	0.60	10.60	0.02	0.04	Yes
Urban	4	Meat	0.37	7.05	1.50	15.99	0.04	0.14	No
Urban	4	Pulses	0.16	3.83	1.30	10.02	0.01	0.03	No
Urban	4	Others	1.01	6.00	0.80	25.51	0.06	0.34	No
Rural	1	Rice	1.45	2.34	3.50	2.28	0.61	0.45	Yes
Rural	1	Wheat	0.79	1.43	3.40	1.43	0.32	0.15	Yes
Rural	1	Potatoes	0.02	1.46	0.75	6.62	0.00	0.00	Yes

(continued)

Table 3 (continued)

Urban/Rural	Income Group	Food	Per Capita Consumption[a]	Market Price[b]	Calories/ Kilogram[c]	Calorie Price[d]	Calorie Share	Food Budget Share	Staple?
Rural	1	Milk	0.03	1.57	0.60	8.90	0.00	0.01	Yes
Rural	1	Meat	0.12	4.85	1.50	11.00	0.02	0.08	No
Rural	1	Pulses	0.09	2.39	0.60	13.55	0.01	0.03	No
Rural	1	Others	0.35	6.00	0.80	25.51	0.03	0.28	No
Rural	2	Rice	1.98	2.43	3.50	2.36	0.66	0.49	Yes
Rural	2	Wheat	0.79	1.50	3.40	1.50	0.26	0.12	Yes
Rural	2	Potatoes	0.05	1.41	0.75	6.39	0.00	0.01	Yes
Rural	2	Milk	0.06	1.38	0.60	7.82	0.00	0.01	Yes
Rural	2	Meat	0.18	4.76	1.50	10.79	0.03	0.09	No
Rural	2	Pulses	0.11	2.95	1.30	7.72	0.01	0.03	No
Rural	2	Others	0.40	6.00	0.80	25.51	0.03	0.25	No
Rural	3	Rice	2.51	2.48	3.50	2.41	0.73	0.54	Yes
Rural	3	Wheat	0.67	1.46	3.40	1.46	0.19	0.08	Yes
Rural	3	Potatoes	0.06	1.64	0.75	7.44	0.00	0.01	Yes
Rural	3	Milk	0.14	1.50	0.60	8.50	0.01	0.02	Yes
Rural	3	Meat	0.21	4.93	1.50	11.18	0.03	0.09	No
Rural	3	Pulses	0.13	2.99	1.30	7.82	0.01	0.03	No
Rural	3	Others	0.45	6.00	0.80	25.51	0.03	0.23	No
Rural	4	Rice	3.13	2.74	3.50	2.66	0.78	0.53	Yes
Rural	4	Wheat	0.50	1.64	3.40	1.64	0.12	0.05	Yes
Rural	4	Potatoes	0.09	1.75	0.75	7.94	0.00	0.01	Yes
Rural	4	Milk	0.32	1.62	0.60	9.18	0.01	0.03	Yes
Rural	4	Meat	0.29	5.40	1.50	12.24	0.03	0.10	No
Rural	4	Pulses	0.18	3.57	1.30	9.34	0.02	0.04	No
Rural	4	Others	0.63	6.00	0.80	25.51	0.04	0.23	No

[a] Kilograms per capita per week.

[b] Relative to price of cheapest grain calorie source.

[c] 1,000 calories per kilogram.

[d] Relative to price of cheapest grain calorie source.

Table 4 Per capita consumption, price, and calorie conversion rates for seven aggregate food groups, by income group, by urban and rural populations for Pakistan, 1984-1985

Urban/Rural	Income Group	Food	Per Capita Consumption[a]	Market Price[b]	Calories/ Kilogram[c]	Calorie Price[d]	Calorie Share	Food Budget Share	Staple?
Urban	1	Wheat	2.11	1.00	3.40	1.00	0.74	0.21	Yes
Urban	1	Rice	0.15	2.13	3.50	2.07	0.05	0.03	Yes
Urban	1	Milk	0.97	1.86	0.60	10.54	0.06	0.18	No
Urban	1	Meat	0.13	6.85	1.50	15.53	0.02	0.09	No
Urban	1	Potatoes	0.16	1.25	0.75	5.67	0.01	0.02	No
Urban	1	Vegetables	0.51	1.52	0.30	17.23	0.02	0.08	No
Urban	1	Fruits	0.11	2.31	0.30	26.19	0.00	0.03	No
Urban	1	Others	0.54	6.97	1.80	13.17	0.10	0.37	No
Urban	2	Wheat	2.10	1.03	3.40	1.03	0.70	0.19	Yes
Urban	2	Rice	0.20	2.12	3.50	2.06	0.07	0.04	Yes
Urban	2	Milk	1.06	1.91	0.60	10.83	0.06	0.18	No
Urban	2	Meat	0.15	6.99	1.50	15.85	0.02	0.09	No
Urban	2	Potatoes	0.16	1.24	0.75	5.46	0.01	0.02	No
Urban	2	Vegetables	0.54	1.58	0.30	17.38	0.02	0.08	No
Urban	2	Fruits	0.14	2.31	0.30	26.19	0.00	0.03	No
Urban	2	Others	0.58	7.16	2.20	11.07	0.12	0.37	No
Urban	3	Wheat	1.99	1.06	3.40	1.06	0.65	0.17	Yes
Urban	3	Rice	0.24	2.25	3.50	2.19	0.08	0.04	Yes
Urban	3	Milk	1.16	2.06	0.60	11.68	0.07	0.19	No
Urban	3	Meat	0.21	7.38	1.50	16.73	0.03	0.12	No
Urban	3	Potatoes	0.17	1.26	0.75	5.38	0.01	0.02	No
Urban	3	Vegetables	0.59	1.58	0.30	16.88	0.02	0.07	No
Urban	3	Fruits	0.19	2.48	0.30	28.12	0.01	0.04	No
Urban	3	Others	0.60	7.57	2.60	9.90	0.15	0.36	No
Urban	4	Wheat	1.96	1.11	3.40	1.11	0.57	0.12	Yes
Urban	4	Rice	0.29	2.54	3.50	2.47	0.09	0.04	Yes
Urban	4	Milk	1.57	2.20	0.60	12.47	0.08	0.18	No
Urban	4	Meat	0.38	8.60	1.50	19.50	0.05	0.17	No
Urban	4	Potatoes	0.18	1.28	0.75	5.24	0.01	0.01	No
Urban	4	Vegetables	0.76	1.63	0.30	16.67	0.02	0.07	No
Urban	4	Fruits	0.32	3.07	0.30	34.81	0.01	0.05	No
Urban	4	Others	0.71	9.72	3.00	11.02	0.18	0.36	No
Rural	1	Wheat	2.48	1.01	3.40	1.01	0.72	0.25	Yes
Rural	1	Rice	0.22	2.13	3.50	2.07	0.07	0.05	Yes

(continued)

Table 4 (continued)

Urban/Rural	Income Group	Food	Per Capita Consumption[a]	Market Price[b]	Calories/ Kilogram[c]	Calorie Price[d]	Calorie Share	Food Budget Share	Staple?
Rural	1	Milk	1.16	1.48	0.60	8.39	0.06	0.17	No
Rural	1	Meat	0.10	7.12	1.50	16.15	0.01	0.07	No
Rural	1	Potatoes	0.17	1.27	0.75	5.70	0.01	0.02	No
Rural	1	Vegetables	0.46	1.51	0.30	16.95	0.01	0.07	No
Rural	1	Fruits	0.08	2.35	0.30	26.64	0.00	0.02	No
Rural	1	Others	0.59	5.72	2.40	8.11	0.12	0.34	No
Rural	2	Wheat	2.53	1.05	3.40	1.05	0.68	0.23	Yes
Rural	2	Rice	0.33	1.76	3.50	1.71	0.09	0.05	Yes
Rural	2	Milk	1.47	1.51	0.60	8.56	0.07	0.20	No
Rural	2	Meat	0.12	6.75	1.50	15.31	0.01	0.07	No
Rural	2	Potatoes	0.18	1.26	0.75	5.44	0.01	0.02	No
Rural	2	Vegetables	0.56	1.28	0.30	13.81	0.01	0.06	No
Rural	2	Fruits	0.10	2.40	0.30	27.21	0.00	0.02	No
Rural	2	Others	0.63	6.17	2.40	8.74	0.12	0.34	No
Rural	3	Wheat	2.84	1.04	3.40	1.04	0.70	0.22	Yes
Rural	3	Rice	0.30	1.96	3.50	1.90	0.08	0.05	Yes
Rural	3	Milk	1.72	1.54	0.60	8.73	0.07	0.20	No
Rural	3	Meat	0.15	7.40	1.50	16.78	0.02	0.09	No
Rural	3	Potatoes	0.18	1.28	0.75	5.58	0.01	0.02	No
Rural	3	Vegetables	0.48	1.55	0.30	16.89	0.01	0.06	No
Rural	3	Fruits	0.12	2.55	0.30	28.91	0.00	0.02	No
Rural	3	Others	0.69	6.59	2.40	9.34	0.12	0.35	No
Rural	4	Wheat	3.06	1.04	3.40	1.04	0.66	0.18	Yes
Rural	4	Rice	0.37	2.21	3.50	2.15	0.08	0.05	Yes
Rural	4	Milk	2.14	1.59	0.60	9.01	0.08	0.19	No
Rural	4	Meat	0.25	7.97	1.50	18.07	0.02	0.11	No
Rural	4	Potatoes	0.20	1.31	0.75	5.71	0.01	0.02	No
Rural	4	Vegetables	0.58	1.61	0.30	17.54	0.01	0.05	No
Rural	4	Fruits	0.20	2.86	0.30	32.43	0.00	0.03	No
Rural	4	Others	0.86	7.57	2.40	10.73	0.13	0.37	No

[a] Kilograms per capita per week.
[b] Relative to price of cheapest grain calorie source.
[c] 1,000 calories per kilogram.
[d] Relative to price of cheapest grain calorie source.

Table 5 Per capita annual consumption, calorie shares, and budget shares of potatoes in Bangladesh and Pakistan

Country	Income Group	Per Capita Consumption	Calorie Share	Food Budget Share
		(kilograms)		
Bangladesh (potatoes, 1973-74)				
Urban	1	3.6	0.00	0.01
	2	5.2	0.01	0.02
	3	7.3	0.01	0.02
	4	8.8	0.01	0.02
All		6.8	0.01	0.02
Rural	1	1.0	0.00	0.00
	2	2.6	0.00	0.01
	3	3.1	0.00	0.01
	4	4.7	0.00	0.01
All		3.5	0.00	0.01
Pakistan (potatoes, 1984-85)				
Urban	1	8.3	0.01	0.02
	2	8.3	0.01	0.02
	3	8.8	0.01	0.02
	4	9.4	0.01	0.01
All		8.8	0.01	0.02
Rural	1	8.8	0.01	0.02
	2	9.4	0.01	0.02
	3	9.4	0.01	0.02
	4	10.4	0.01	0.02
All		9.2	0.01	0.02

Source: See discussion in Section 5.

Note: Income groups refer to total expenditure quartiles with 1 designating the lowest expenditure quartile.

declines as income increases, and that the consumption of rice increases. Note also that, in general, the percentage increases in the remaining food groups (which are typically much more expensive sources of calories), across income groups, are much larger than for rice.

Similar consumption relationships between inexpensive staples, expensive staples, and nonstaples are evidenced for Pakistan. However, in contrast to Bangladesh, wheat is overwhelmingly the predominant staple; wheat consumption shows some tendency to decline with income in urban areas. Rice is a relatively minor food item, both in terms of budget share and calorie share. Also unique to Pakistan is the important contribution that milk makes to total calorie consumption and its high food budget share.

Per capita annual potato consumption in Bangladesh in 1973-74 was higher in urban areas at 6.8 kilograms than for rural areas at 3.5 kilograms. It should be noted that both Bangladesh and Pakistan are overwhelmingly rural countries. Over 85 percent of the population in Bangladesh and over 70 percent in Pakistan were residing in rural areas for the time periods in question. Still, in urban areas, potatoes were more than seven times as expensive a source of calories as wheat for low-income groups and nearly nine times as expensive for high-income groups; better quality potatoes were purchased by higher-income groups. In urban areas, potatoes were more than three times as expensive a source of calories as rice. In rural areas, the price differential between wheat and potatoes was much smaller, and somewhat smaller between rice and potatoes.

Historical information about food production imports and real wages help to put these figures in perspective. In 1973-74, Bangladesh had just recently achieved nationhood after a bloody war of independence. The devastation of the aftermath was further aggravated by the famine of 1974. Hence, in 1973-74, Bangladesh was

heavily dependent on foreign food supplies in the form of food aid and commercial cereal imports.

Total supply of wheat was in the neighborhood of 1.7 million tons. Nearly 95 percent at this supply was imported—with over 50 percent of these imports coming in the form of food aid—as domestic wheat production (1973-74) stood at slightly over 100,000 tons (FAO 1982). Domestic potato supply consisted of some 725,000 tons, virtually all of which was produced locally (Scott 1988). Local wheat prices were depressed by aid, imports, and food subsidies (particularly in urban areas). Hence, the large (7.39) differences in relative prices per calorie for potatoes versus wheat were at least partly due to the unusual circumstances that prevailed at the time the household survey was carried out.

Although some disagreement exists about recent trends, there is consensus that real wages in Bangladesh were also at a relatively low point in 1973-74 (Palmer-Jones 1994). Reasons cited for this include the political unrest leading up to independence, destruction caused by the war of liberation, and the famine of 1974. Effective demand was severely constrained as a result.

The 1973-74 survey data for Bangladesh reveal large percentage increases in per capita consumption of potatoes across income quartiles in both urban and rural areas, although levels of consumption are low even for high-income groups; the food budget share for potatoes averaged about 1.0 percent in rural areas and just above 1.5 percent in urban areas.

Per capita annual consumption of potatoes was higher in Pakistan in 1984-85, 8.8 kilograms in urban areas and 9.2 kilograms in rural areas, than in Bangladesh in 1973-74. Food budget shares were between 1 percent and 2 percent in both urban and rural areas for all income quartiles. Potatoes were more than five times as expensive a source of calories as wheat, and were about two-and-a-half times as expensive a source of calories as rice. Per capita consumption of potatoes across income quartiles

indicates modestly increasing consumption with increasing income. Utilizing these data and historical information, we now attempt to estimate the effects of income and price changes on potato consumption.

4. THE FOOD CHARACTERISTIC DEMAND SYSTEM (FCDS)

AN INTUITIVE UNDERSTANDING OF FCDS

A food demand system based on demand for characteristics, outlined in Bouis (1996), is used for estimating matrices of food demand parameters for Bangladesh and Pakistan. In this system, three characteristics—energy, variety, and tastes of individual foods—are assumed to be additive in the utility function. Energy and variety enter the utility function in such a way that utility from consumption of one food depends on the level of consumption of all other foods (formal specification of the model is provided in the Appendix).

As background for the discussion of income elasticities in the following section, Figure 1 facilitates an intuitive explanation of the factors that determine the relative magnitudes of income elasticities for various foods. The total height of each rectangle, measured against the vertical axis, represents the retail price for a specific food. The (say, per kilo) price paid for each food is the sum of the shadow prices paid for energy, variety, and tastes of individual foods.

A simplification used in constructing Figure 1 is an assumption that the calorie conversion rate per kilo is constant across the five foods depicted (say 2,000 calories per kilo).[1] The particular individual pictured is willing to pay $1.00 at the margin (given his/her level of calorie consumption) for 2,000 calories.

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[1] In actuality, vegetables tend to have about a tenth as many, and meats from one-half to two-thirds as many, calories per kilo as staples, although these fractions vary widely for individual foods. Thus, the shaded portions for "energy" for vegetables and meats in Figure 1 should be smaller than depicted.

Figure 1 The retail price for each food is the sum of the shadow prices for energy, variety, and tastes of individual foods

Each kilo of vegetables and meat provides an identical amount of variety in the diet (this is a simplifying assumption embedded in the model, and is not specific to Figure 1). Given the particular breakdown between staple and nonstaple consumption for our consumer, at the margin he/she is willing to pay $1.50 for each extra kilo of variety. Note that staple consumption (wheat and rice) reduces variety in the diet; the

model assumes that this shadow price is negative for staples, which is difficult to show graphically.[2]

Thus, the difference between the retail price and the sum of the shadow prices for energy and variety is the premium that the consumer is willing to pay, at the margin, for the specific intrinsic characteristics ("tastes") contained in an extra kilo of that food. That premium is relatively small for inferior staples such as wheat, and relatively large for expensive meats.

Using this framework, foods tend to fall into four categories: (1) inexpensive, nonpreferred staples with income elasticities close to zero or possibly negative (e.g., wheat in Figure 1; "energy-intensive" foods), (2) preferred staples with positive income elasticities (e.g., rice; income elasticities are typically well below 0.5 for staples that are major sources of calories, but possibly above 0.5 for lightly consumed staples, especially if the calorie cost is high; some combination of "energy-intensive" and "taste-intensive" foods), (3) inexpensive sources of variety with income elasticities below 0.5 and sometimes negative (e.g., vegetables, inexpensive meats; "variety-intensive" foods), and (4) expensive nonstaple foods for which the taste shadow price predominates (income elasticities above 0.5 and sometimes above 1.0).

The FCDS generates the highest income elasticities for foods for which the shadow price of taste is a high proportion of the total retail price. These might be called "taste-intensive" foods.

DATA REQUIREMENTS FOR IMPLEMENTATION

By specifying an explicit functional form for these characteristics in the utility function, it turns out that the entire matrix of price and income elasticities can be

[2] Shadow prices for energy may also be negative at sufficiently high levels of calorie consumption.

derived for a system of *n* foods and one nonfood good from prior knowledge of just four elasticities in the (*n*+1) by (*n*+2) matrix of price and income elasticities.[3]

In addition to a priori knowledge of any combination of four demand elasticities and/or utility function parameters, the remaining data requirements for implementation of the methodology outlined above are (1) per capita quantities consumed for each food group (data cited in Tables 3 and 4 for Bangladesh and Pakistan are expressed in kilograms per capita per week), (2) prices paid per kilogram, (3) total nonfood expenditures, (4) calorie conversion rates per kilogram, and (5) the ratio of adult equivalents over total persons, all for the particular population for which food demand parameters are to be estimated. Data for calorie conversion rates (item 4) and the age and sex structure of an average household (item 5) are often not available from published summaries of expenditure survey data.

Calorie conversion rates for particular food groups do not vary greatly across countries, nor does age and sex structure for countries with similar average household sizes (as is assumed for the three countries being studied here), so that, where unavailable, rough assumptions may be made for these data inputs.[4] The focus of attention in data collection, then, is quantities consumed, prices paid, and the percent of nonfood expenditures in total income (including savings), which, of course, can vary a great deal across various socioeconomic groups within the same country, but are typically provided by standard household expenditure surveys such as those used to construct Tables 3 and 4.

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[3] A brief mathematical exposition of the model is provided in the appendix of Bouis (1990).

[4] Bouis (1989) provides information on assumptions made (1) for items 4 and 5 for deriving the demand estimates for Bangladesh and Pakistan and (2) for values for the four utility function parameters and assumed to be known a priori.

THE "ROLE" OF POTATOES IN DIETARY PATTERNS

In applying the food characteristic framework to potatoes, two key decisions need to be made. First, are potatoes a staple or a nonstaple? The answer to this question varies in both developed and developing countries (Woolfe 1987). For the countries and time periods in question, it was already seen in a previous section that potatoes are quite expensive sources of calories relative to rice and wheat. In the case of Bangladesh, potatoes are treated as a "luxury" staple, which generate moderately high income elasticities (analogous to "rice" in Figure 1), as suggested by the increase in per capita consumption of potatoes shown in Table 5. In the case of Pakistan, potatoes are treated as an inexpensive source of variety, a nonstaple food (analogous to "vegetables" in Figure 1), as suggested by the rather modest increase in per capita potato consumption shown in Table 5.

The second decision relates to the "form" (boiled or dried). This is most easily explained with an example. The data on rice consumption presented in Tables 3 and 4 are in the form of milled rice at the retail outlet, which typically has a low moisture content (10 percent) and roughly 3,500 calories per kilo. This rice is boiled before eating. One kilo of "dry" rice is the equivalent of something over three kilos of boiled rice; studies indicate that a kilo of boiled rice is about two-thirds water and contains about 1,300 calories (e.g., FNRI 1980). Except for the extra expense of preparing boiled rice, one would expect the cost of a kilo of boiled rice to be about one-third that of a kilo of "dry" rice.[5]

Because in calculating variety it is necessary to add kilos of rice to kilos of potatoes and other foods, demand elasticity estimates may be critically affected, for example, by the decision to use kilos of boiled rice or kilos of dry rice purchased.

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[5] Intuitively, if rice were depicted in boiled form in Figure 1 instead of dry form, the height of the retail price "bar" for rice would be much lower; consequently, the shadow price for rice "taste" would be considerably lower, affecting the entire matrix of estimated elasticities.

Because the food demand matrices presented below have been previously calibrated and estimated using rice in its "dry" form, and because potato is a relatively minor food in overall food consumption, it will be easier (where necessary) to express the input data for potatoes in its dry form equivalent.[6]

5. DEMAND ELASTICITY ESTIMATES

The full matrices of demand elasticity estimates for Bangladesh are presented in Table 6 and for Pakistan in Table 7.

DEMAND ESTIMATES FOR BANGLADESH

The cross-price elasticities with rice and wheat are negative because of the high budget shares for wheat and rice. As the prices of these less-preferred staples increase, consumers are forced to spend more for wheat and rice (to maintain calorie consumption levels) and to cut back on the consumption of potatoes, which might be characterized as a "luxury" staple food. Comparing Tables 8 and 9, note that the high estimated income elasticities for potatoes (in Table 8) are quite consistent with the observed arc income elasticities (in Table 9). Income elasticities in both of these tables are higher for rural consumers, and decline with income.

Table 10 allows a comparison of demand estimates obtained by Pitt (1983) for rural Bangladesh, and those presented in Table 6. The Pitt results show a rapidly declining price response as income increases, but income (expenditure) elasticities are higher for high-income groups. The results in Table 6 show a

[6] Since the demand elasticities for potatoes can be dramatically affected by whether the input data for these foods are expressed in their raw or dry form equivalent, and in the absence of prior information that use of the raw or dry form equivalent input data is more appropriate, in practice this allows an extra degree of freedom. Both ways of expressing the input data for potatoes may be tried and the more "sensible" set of estimates chosen. The essence of the food characteristic approach is to use as much prior information as possible.

Table 6 Estimated food demand elasticities, by income group, by urban and rural populations for Bangladesh, 1973-74

Income	Rice	Wheat	Potatoes	Milk	Meat	Pulses	Other Foods	Nonfoods	Income
Urban first quartile (low income)									
Rice	-0.954	0.163	-0.002	-0.002	0.009	0.001	0.004	0.023	0.758
Wheat	0.800	-0.601	-0.002	-0.003	0.074	0.039	0.127	-0.013	-0.421
Potatoes	-0.195	-0.202	-1.019	-0.015	0.065	0.041	0.121	0.036	1.169
Milk	-0.219	-0.224	-0.019	-1.000	0.056	0.035	0.103	0.038	1.231
Meat	-0.063	-0.043	0.010	0.008	-1.069	0.007	0.013	0.034	1.103
Pulses	0.010	0.034	0.019	0.014	0.039	-1.005	0.104	0.024	0.761
Others	-0.106	-0.089	0.007	0.006	0.003	0.007	-0.997	0.035	1.134
Nonfoods	-0.251	-0.237	-0.004	-0.002	-0.029	-0.022	-0.069	-1.048	1.662
Urban second quartile									
Rice	-0.882	0.143	-0.003	-0.003	0.012	0.007	0.008	0.043	0.675
Wheat	0.913	-0.601	-0.002	-0.006	0.093	0.054	0.141	-0.036	0.556
Potatoes	-0.192	-0.151	-1.018	-0.029	0.070	0.043	0.119	0.070	1.088
Milk	-0.220	-0.172	-0.027	-1.017	0.074	0.046	0.126	0.072	1.118
Meat	-0.057	-0.030	0.011	0.013	-1.053	0.006	0.022	0.065	1.023
Pulses	0.063	0.064	0.023	0.027	0.039	-1.093	0.099	0.047	0.732
Others	-0.098	-0.061	0.009	0.010	0.009	0.007	-0.984	0.067	1.042
Nonfoods	-0.267	-0.191	-0.004	-0.004	-0.035	-0.021	-0.074	-1.092	1.689
Urban third quartile									
Rice	-0.799	0.136	-0.003	-0.006	0.018	0.008	0.015	0.057	0.572
Wheat	0.969	-0.623	-0.003	-0.011	0.109	0.052	0.164	-0.059	-0.598
Potatoes	-0.181	-0.110	-1.020	-0.057	0.077	0.038	0.131	0.101	1.021
Milk	-0.213	-0.128	-0.035	-1.040	0.077	0.038	0.131	0.105	1.064
Meat	-0.040	-0.015	0.012	0.022	-1.041	0.007	0.032	0.092	0.931
Pulses	0.048	0.037	0.022	0.038	0.040	-1.068	0.102	0.070	0.711
Others	-0.083	-0.040	0.010	0.017	0.013	0.008	-0.971	0.094	0.952
Nonfoods	-0.268	-0.146	-0.005	-0.007	-0.043	-0.021	-0.088	-1.131	1.708
Urban fourth quartile									
Rice	-0.689	0.126	-0.000	-0.003	0.024	0.009	0.029	0.081	0.424
Wheat	0.993	-0.583	0.001	-0.005	0.106	0.042	0.179	-0.117	0.616
Potatoes	-0.112	-0.053	-1.004	-0.062	0.056	0.024	0.112	0.166	0.872
Milk	-0.143	-0.066	-0.032	-1.043	0.062	0.026	0.125	0.171	0.900
Meat	-0.032	-0.010	0.008	0.017	-1.019	0.006	0.040	0.158	0.832
Pulses	0.057	0.029	0.016	0.034	0.045	-1.047	0.134	0.117	0.614
Others	-0.059	-0.022	0.007	0.015	0.018	0.009	-0.946	0.156	0.821
Nonfoods	-0.237	-0.099	-0.004	-0.007	-0.039	-0.016	-0.093	-1.181	1.677

(continued)

Table 6 (continued)

Income	Rice	Wheat	Potatoes	Milk	Meat	Pulses	Other Foods	Nonfoods	Income
Rural first quartile (low income)									
Rice	-0.966	0.110	-0.003	-0.004	0.022	0.006	0.025	-0.022	0.833
Wheat	0.542	-1.005	-0.005	-0.009	0.084	0.042	0.165	-0.005	0.192
Potatoes	-0.583	-0.373	-1.014	-0.023	0.102	0.057	0.208	-0.045	1.672
Milk	-0.604	-0.384	-0.015	-1.004	0.092	0.051	0.185	-0.047	1.725
Meat	0.113	0.088	0.007	0.011	-1.108	0.011	0.026	-0.024	0.875
Pulses	0.331	0.224	0.012	0.018	0.071	-1.010	0.221	-0.004	0.137
Others	-0.038	-0.007	0.005	0.007	-0.004	0.003	-1.005	-0.029	1.068
Nonfoods	-0.267	-0.152	-0.000	0.000	-0.044	-0.030	-0.122	-0.942	1.556
Rural second quartile									
Rice	-0.827	0.110	-0.003	-0.004	0.022	0.013	0.020	0.000	0.669
Wheat	0.715	-0.892	-0.005	-0.007	0.079	0.047	0.117	0.000	0.053
Potatoes	-0.495	-0.219	-1.022	-0.030	0.101	0.063	0.165	0.000	1.437
Milk	-0.559	-0.247	-0.026	-1.020	0.105	0.066	0.173	0.000	1.509
Meat	0.008	0.014	0.011	0.013	-1.081	0.011	0.039	0.000	0.986
Pulses	0.256	0.122	0.019	0.023	0.061	-1.123	0.145	0.000	0.497
Others	-0.152	-0.055	0.006	0.008	0.001	0.002	-0.998	0.000	1.188
Nonfoods	-0.408	-0.166	-0.002	-0.002	-0.052	-0.032	-0.107	-1.000	1.768
Rural third quartile									
Rice	-0.706	0.093	-0.002	-0.006	0.023	0.013	0.023	0.015	0.546
Wheat	0.907	-0.865	-0.003	-0.009	0.077	0.046	0.113	-0.007	-0.260
Potatoes	-0.427	-0.122	-1.005	-0.044	0.073	0.047	0.120	0.036	1.322
Milk	-0.492	-0.141	-0.021	-1.033	0.085	0.054	0.142	0.037	1.369
Meat	-0.035	-0.004	0.009	0.022	-1.063	0.011	0.040	0.027	0.993
Pulses	0.214	0.067	0.017	0.040	0.059	-1.095	0.136	0.015	0.547
Others	-0.188	-0.047	0.005	0.014	0.004	0.005	-0.990	0.031	1.166
Nonfoods	-0.490	-0.131	-0.002	-0.005	-0.050	-0.031	-0.097	-1.050	1.856
Rural fourth quartile									
Rice	-0.528	0.068	-0.000	-0.003	0.027	0.015	0.030	0.050	0.342
Wheat	0.954	-0.824	0.001	-0.003	0.068	0.039	0.093	-0.041	0.285
Potatoes	-0.267	-0.044	-0.988	-0.059	0.059	0.036	0.101	0.147	1.015
Milk	-0.327	-0.053	-0.018	-1.039	0.066	0.041	0.116	0.154	1.061
Meat	-0.057	-0.007	0.007	0.026	-1.029	0.012	0.044	0.127	0.877
Pulses	0.083	0.016	0.011	0.042	0.044	-1.041	0.105	0.094	0.646
Others	-0.180	-0.026	0.004	0.017	0.010	0.008	-0.973	0.144	0.995
Nonfoods	-0.595	-0.091	-0.004	-0.011	-0.053	-0.032	-0.099	-1.198	2.083

Table 7 Estimated food demand elasticities, by income group, by urban and rural populations for Pakistan, 1984-85

	Wheat	Rice	Milk	Meat	Potatoes	Vegetables	Nonfruits	Others	Foods	Income
Urban first quartile (low income)										
Wheat	-0.372	0.049	0.043	0.025	0.013	-0.004	-0.001	0.133	0.017	0.096
Rice	0.249	-0.974	-0.020	0.004	-0.001	-0.020	-0.005	0.027	0.110	0.630
Milk	-0.005	-0.001	-0.855	0.022	0.035	0.094	0.020	0.092	0.089	0.509
Meat	-0.053	-0.005	-0.003	-1.002	0.000	-0.000	-0.001	-0.018	0.161	0.921
Potatoes	0.132	0.008	0.363	0.045	-1.117	0.183	0.038	0.187	0.024	0.137
Vegetable	-0.053	-0.004	0.231	0.029	0.044	-0.875	0.024	0.121	0.072	0.412
Fruits	-0.081	-0.006	0.123	0.014	0.024	0.061	-0.950	0.059	0.113	0.644
Others	-0.037	-0.004	-0.004	-0.004	-0.000	-0.000	-0.001	-1.034	0.162	0.923
Nonfoods	-0.215	-0.016	-0.112	-0.020	-0.020	-0.056	-0.013	-0.084	-1.197	1.733
Urban second quartile										
Wheat	-0.345	0.066	0.045	0.028	0.012	-0.003	-0.001	0.178	0.005	0.016
Rice	0.284	-0.956	-0.007	0.007	0.001	-0.015	-0.004	0.058	0.144	0.488
Milk	0.001	-0.001	-0.845	0.025	0.033	0.093	0.023	0.099	0.130	0.443
Meat	-0.029	-0.004	0.011	-0.997	0.002	0.007	0.001	-0.007	0.231	0.785
Potatoes	0.124	0.011	0.373	0.050	-1.111	0.181	0.046	0.198	0.029	0.100
Vegetables	-0.049	-0.005	0.228	0.031	0.039	-0.877	0.028	0.125	0.109	0.370
Fruits	-0.066	-0.006	0.135	0.017	0.024	0.065	-0.948	0.071	0.161	0.547
Others	0.006	-0.001	0.012	-0.002	0.002	0.007	0.002	-1.043	0.231	0.785
Nonfoods	-0.185	-0.019	-0.097	-0.018	-0.015	-0.046	-0.012	-0.073	-1.208	1.673
Urban third quartile										
Wheat	-0.345	0.082	0.045	0.038	0.012	-0.006	-0.002	0.228	-0.016	0.036
Rice	0.284	-0.942	0.001	0.012	0.002	-0.012	-0.004	0.086	0.177	0.394
Milk	0.004	0.000	-0.854	0.032	0.031	0.090	0.028	0.099	0.177	0.393
Meat	-0.005	-0.001	0.024	-1.002	0.004	0.013	0.004	0.004	0.298	0.663
Potatoes	0.112	0.013	0.375	0.066	-1.115	0.183	0.057	0.203	0.033	0.073
Vegetables	-0.042	-0.005	0.238	0.043	0.040	-0.884	0.036	0.136	0.136	0.302
Fruits	-0.051	-0.006	0.134	0.023	0.023	0.065	-0.953	0.074	0.215	0.478
Others	0.049	0.005	0.027	0.002	0.005	0.015	0.004	-1.059	0.296	0.657
Nonfoods	-0.135	-0.017	-0.076	-0.018	-0.012	-0.036	-0.012	-0.056	-1.198	1.560
Urban fourth quartile										
Wheat	-0.331	0.097	0.052	0.063	0.011	-0.010	-0.004	0.287	-0.080	0.085
Rice	0.272	-0.922	0.015	0.025	0.004	-0.008	-0.003	0.122	0.241	0.255
Milk	0.017	0.003	-0.877	0.047	0.024	0.085	0.035	0.102	0.275	0.291
Meat	0.018	0.003	0.037	-1.022	0.005	0.017	0.007	0.017	0.446	0.472
Potatoes	0.099	0.015	0.374	0.095	-1.129	0.171	0.070	0.207	0.048	0.050
Vegetables	-0.030	-0.004	0.241	0.062	0.031	-0.924	0.045	0.137	0.215	0.228
Fruits	-0.029	-0.004	0.116	0.029	0.015	0.053	-0.986	0.065	0.359	0.380
Others	0.067	0.010	0.040	0.009	0.005	0.019	0.008	-1.059	0.438	0.464
Nonfoods	-0.068	-0.011	-0.045	-0.013	-0.006	-0.020	-0.008	- 0.031	-1.188	1.389

(continued)

Table 7 (continued)

	Wheat	Rice	Milk	Meat	Potatoes	Vegetables	Nonfruits	Others	Foods	Income
Rural first quartile (low income)										
Wheat	-0.306	0.062	0.046	0.015	0.011	-0.000	0.000	0.166	0.000	0.005
Rice	0.205	-0.941	-0.035	-0.001	-0.004	-0.021	-0.004	0.032	0.043	0.724
Milk	-0.030	-0.004	-0.805	0.016	0.036	0.085	0.014	0.101	0.033	0.553
Meat	-0.156	-0.016	-0.038	-0.974	-0.006	-0.014	-0.003	-0.043	0.071	1.179
Potatoes	0.063	0.004	0.309	0.023	-1.058	0.115	0.019	0.141	0.022	0.361
Vegetables	-0.110	-0.011	0.202	0.014	0.032	-0.888	0.012	0.091	0.037	0.620
Fruits	-0.156	-0.015	0.089	0.004	0.014	0.033	-0.935	0.029	0.053	0.885
Others	-0.076	-0.009	-0.019	-0.007	-0.003	-0.006	-0.002	-1.076	0.068	1.129
Nonfoods	-0.313	-0.030	-0.134	-0.018	-0.020	-0.050	-0.009	-0.099	-1.094	1.768
Rural second quartile										
Wheat	-0.286	0.092	0.053	0.016	0.010	0.000	0.000	0.158	-0.006	0.039
Rice	0.350	-0.909	-0.001	0.006	0.002	-0.011	-0.002	0.072	0.064	0.431
Milk	-0.018	-0.003	-0.810	0.017	0.031	0.086	0.015	0.093	0.076	0.515
Meat	-0.100	-0.014	-0.015	-0.996	-0.002	-0.004	-0.001	-0.023	0.149	1.006
Potatoes	0.067	0.008	0.323	0.024	-1.071	0.118	0.020	0.132	0.049	0.330
Vegetables	-0.072	-0.010	0.273	0.020	0.036	-0.896	0.017	0.112	0.067	0.452
Fruits	-0.122	-0.017	0.101	0.006	0.013	0.037	-0.958	0.033	0.117	0.790
Others	-0.041	-0.007	-0.004	-0.003	-0.000	0.000	-0.000	-1.062	0.144	0.974
Nonfoods	-0.263	-0.036	-0.124	-0.014	-0.016	-0.044	-0.008	-0.079	-1.144	1.730
Rural third quartile										
Wheat	-0.226	0.075	0.058	0.018	0.009	0.001	0.000	0.151	-0.019	0.070
Rice	0.321	-0.879	0.005	0.006	0.002	-0.006	-0.002	0.065	0.104	0.384
Milk	0.003	-0.000	-0.777	0.020	0.028	0.067	0.016	0.096	0.116	0.431
Meat	-0.064	-0.008	0.002	-0.986	0.000	0.001	0.000	-0.011	0.227	0.839
Potatoes	0.077	0.008	0.337	0.027	-1.046	0.090	0.022	0.131	0.075	0.279
Vegetables	-0.062	-0.007	0.235	0.018	0.026	-0.920	0.015	0.089	0.129	0.478
Fruits	-0.088	-0.010	0.115	0.008	0.013	0.031	-0.957	0.038	0.181	0.670
Others	-0.010	-0.002	0.014	-0.001	0.002	0.004	0.001	-1.031	0.218	0.806
Nonfoods	-0.215	-0.025	-0.104	-0.013	-0.011	-0.027	-0.007	-0.065	-1.160	1.628
Rural fourth quartile										
Wheat	-0.201	0.082	0.063	0.027	0.009	0.001	0.001	0.163	-0.053	0.092
Rice	0.290	-0.834	0.019	0.012	0.003	-0.003	-0.001	0.075	0.161	0.277
Milk	0.028	0.004	-0.778	0.028	0.024	0.064	0.022	0.101	0.187	0.322
Meat	-0.010	-0.002	0.025	-0.989	0.002	0.007	0.002	0.005	0.353	0.608
Potatoes	0.085	0.011	0.317	0.037	-1.026	0.082	0.028	0.134	0.122	0.210
Vegetables	-0.029	-0.004	0.228	0.026	0.022	-0.931	0.020	0.092	0.211	0.364
Fruits	-0.043	-0.006	0.113	0.012	0.011	0.030	-0.967	0.042	0.297	0.511
Others	0.029	0.003	0.031	0.002	0.003	0.008	0.003	-1.004	0.339	0.584
Nonfoods	-0.123	-0.017	-0.065	-0.011	-0.006	-0.016	-0.006	-0.043	-1.160	1.448

Table 8 Summary of selected income, own-price, and cross-price elasticity estimates for potatoes by income quartile and urban and rural populations for Bangladesh and Pakistan

Country/ Urban-Rural/ Income Quartile	Income Elasticity	Own-Price Elasticity	Cross-Price Elasticity In Demand for Potatoes	
			Food #1	Food #2
Bangladesh (potatoes, 1973-74)			Rice	Wheat
Urban				
1 (low income)	1.17	-1.02	-0.20	-0.20
2	1.09	-1.02	-0.19	-0.15
3	1.02	-1.02	-0.18	-0.11
4	0.872	-1.04	-0.11	-0.05
Rural				
1 (low income)	1.67	-1.01	-0.58	-0.37
2	1.44	-1.02	-0.50	-0.22
3	1.32	-1.01	-0.43	-0.12
4	1.02	-0.99	-0.27	-0.04
Pakistan (potatoes, 1984-85)			Vegetables	Wheat
Urban				
1 (low income)	0.14	-1.12	0.18	0.13
2	0.10	-1.11	0.18	0.12
3	0.07	-1.12	0.18	0.11
4	0.05	-1.13	0.17	0.10
Rural				
1 (low income)	0.36	-1.06	0.12	0.06
2	0.33	-1.07	0.12	0.07
3	0.28	-1.05	0.09	0.08
4	0.21	-1.03	0.08	0.09

constant price response as income increases, and a declining income elasticity. Since own-price, cross-price, and income elasticities for any one food should sum to zero, the Pitt results suggest that cross-price effects increase in influence at higher incomes, while the results presented in Table 7 suggest that these cross-price effects decline in influence at higher incomes.

Table 9 Income per capita per week divided by price per kilogram of cheapest grain calorie source, per capita consumption of potatoes by income quartile, and urban and rural populations, and implied potato and sweet potato arc income elasticities for Bangladesh and Pakistan

Country/ Urban-Rural/ Income Quartile	Income	Per Capita Consumption Per Year	Arc Income Elasticity Between Income Quartile 1	2	3
		(kilograms)			
Bangladesh (1973-74)					
Urban					
1 (low-income)	11.85	3.6	-	-	-
2	15.35	5.2	1.5	-	-
3	19.81	7.3	1.5	1.4	-
4	29.04	8.8	1.0	0.8	0.5
Rural					
1 (low-income)	10.37	1.0	-	-	-
2	12.98	2.6	6.4	-	-
3	15.94	3.1	3.9	0.9	-
4	22.62	4.7	3.1	1.1	1.2
Pakistan (1984-85)					
Urban					
1 (low-income)	15.56	8.3	-	-	-
2	19.26	8.3	0.0	-	-
3	25.50	8.8	0.1	0.2	-
4	51.31	9.4	0.1	0.1	0.1
Rural					
1 (low-income)	14.11	8.8	-	-	-
2	18.00	9.4	0.2	-	-
3	23.87	9.4	0.1	0.0	-
4	42.07	10.4	0.1	0.1	0.1

Table 10 Comparison of demand estimates for rural Bangladesh

Source	Own-Price Elasticity Low-Income	Own-Price Elasticity High-Income	Income Elasticity Low-Income	Income Elasticity High-Income
Pitt (1983)	-1.7	-1.0	1.6	1.9
Table 6	-1.0	-1.0	1.7	1.0

DEMAND ESTIMATES FOR PAKISTAN

Note that the cross-price elasticity with wheat is positive, in contrast with the results for Bangladesh. As the price of wheat increases and calories become more expensive, purchasing marginally more variety in the diet (more potato consumption) becomes relatively more attractive. Vegetables, another inexpensive source of variety, may substitute for potatoes in the diet, so that the cross-price elasticity with vegetables is also positive.

6. SIMULATIONS OF PRICE AND INCOME CHANGES

Based on the estimated demand characteristics for potatoes in Bangladesh and Pakistan, various simulations were run to examine the effect on the demand for potatoes of exogenous changes in the prices of particular foods and income. Initial consumption levels given in Tables 3 and 4 were applied to the food demand elasticities given in Tables 6 and 7, to give the results shown in Table 11.

The first set of simulations assumed a 25-percent increase in income for each income quartile. Not unexpectedly, increases in consumption are larger in Bangladesh, which had the lower initial levels of potato consumption and the higher income elasticities. The second set of simulations assumed a 25-percent increase in the prices of all foods. This is somewhat equivalent to a decrease in income (except that nonfood expenditures become relatively more attractive). Consumption decreases more precipitously in Bangladesh.

A third set of simulations assumed a 25-percent decrease in the price of the primary staple food (rice in Bangladesh and wheat in Pakistan). Because of the role of potatoes as a source of variety in Pakistani diets, consumption of these foods falls as the purchase of the preferred staple becomes more attractive, both for its calorie content and "taste." The positive income effect of the staple price decline mitigates the decline in potato consumption in Pakistan (where potatoes

Table 11 Simulated changes in demand for potatoes by income quartile and urban and rural populations for Bangladesh and Pakistan

Country/ Urban-Rural/ Income Quartile	Initial Per Capita Consumption Per Year	25% Increase in Per Capita Income	Change in Per Capita Consumption Per Year		
			25% Increase in Price of All Foods	25% Decrease in Price of Primary Staple Foods	25% Decrease in Price of Potatoes
	(kilograms by year)				
Bangladesh (1973-74)					
Urban					
1 (low-income)	3.6	1.06	-1.10	0.18	0.93
2	5.2	1.41	-1.51	0.25	1.32
3	7.3	1.86	-2.04	0.33	1.86
4	8.8	1.93	-2.30	0.25	2.22
Rural					
1 (low-income)	1.0	0.43	-0.42	0.15	0.26
2	2.6	0.93	-0.93	0.32	0.66
3	3.1	1.03	-1.06	0.33	0.78
4	4.7	1.19	-1.36	0.31	1.16
Pakistan (1984-85)					
Urban					
1 (low-income)	8.3	0.28	-0.33	-0.27	2.32
2	8.3	0.21	-0.27	-0.26	2.31
3	8.8	0.16	-0.23	-0.25	2.46
4	9.4	0.12	-0.23	-0.23	2.64
Rural					
1 (low-income)	8.8	0.80	-0.85	-0.14	2.34
2	9.4	0.77	-0.89	-0.16	2.51
3	9.4	0.65	-0.83	-0.18	2.45
4	10.4	0.55	-0.86	-0.22	2.67

have a positive income elasticity). In Bangladesh, the positive income effect of the rice price declines more than compensates for the substitution effect of rice becoming an even cheaper source of calories vis-à-vis potatoes, so that potato consumption increases.

A fourth and final set of simulation assumed a 25-percent decline in the price of potatoes. The increase in consumption of potatoes was larger in Pakistan, which has the larger own-price elasticity. Adding the effects of the third and fourth simulations, and subtracting this combined effect from the result of the absolute value of the second simulation, gives the combined cross-price effects of foods other than the main staple and potatoes. These cross-price effects are much stronger in Pakistan than in Bangladesh.

Scott (1988) argues that in the case of Bangladesh between 1973-74 and 1983, "the potato has evolved from a minor vegetable to become a complement to and an occasional substitute for rice," which concurs with demand parameter estimates reported in the previous section and an observed increase in the price of rice relative to potatoes (this price ratio rose 45 percent during 1973-83 in Dhaka, Table 12). This fall in the relative cost of potatoes greatly contributed to the increase in consumption from around 5 kilograms per capita in 1973-74 to around 16 kilograms per capita in 1981-82 (Table 13). Conversely, relative prices for potatoes versus wheat in Pakistan remained fairly stable in recent years.[7] This would account for the relatively stable levels of potato consumption.

[7] In the Pakistan case, we use wholesale price trends as a proxy for retail price movements. Experience in a number of countries suggest that this is reasonable in the case of potatoes (see, e.g., Scott 1985, 1988).

Table 12 Monthly price ratio for rice (medium quality) versus potatoes in Dhaka, 1973-83

Year/ Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual Average
1973	2.19	2.80	1.98	1.82	2.03	1.88	1.41	1.38	1.41	1.48	1.27	1.12	1.73
1974	1.37	1.74	2.21	2.15	2.16	2.06	1.64	1.76	2.07	2.56	2.60	2.36	2.06
1975	3.97	4.43	4.47	3.25	2.22	1.74	1.74	1.48	1.49	1.13	0.79	1.08	2.32
1976	1.64	2.55	2.47	2.31	2.39	1.98	1.64	1.47	1.43	1.56	1.52	1.05	1.83
1977	2.64	3.31	2.99	2.88	2.40	2.62	2.86	1.85	2.12	1.91	1.12	1.06	2.31
1978	1.84	3.04	3.31	2.83	2.87	2.45	1.83	1.39	1.54	1.40	1.13	1.41	2.09
1979	3.12	3.57	3.69	3.94	3.61	3.74	3.35	2.31	2.11	2.04	1.93	1.67	2.92
1980	3.04	4.05	3.37	2.73	2.29	2.21	1.78	1.59	1.56	1.71	1.17	1.14	2.22
1981	2.47	3.41	2.85	2.44	2.48	3.38	2.28	1.51	1.58	1.59	1.05	3.23	2.36
1982	3.07	4.38	4.51	5.48	5.85	5.25	4.61	2.44	2.79	2.83	2.96	2.18	3.86
1983	3.36	4.21	4.78	3.54	2.97	2.47	2.28	2.08	1.96	1.68	1.36	1.16	2.65
Monthly Average	2.61	3.41	3.33	3.03	2.84	2.71	2.31	1.75	1.82	1.81	1.54	1.59	

Source: Economic indicators of Bangladesh and calculations for this study, as cited in Scott (1988).

Note: Ratio = (Retail price of rice) / (Retail price of potato).

Table 13 Food intake of the rural population in Bangladesh, 1975 versus 1981-82

Food Group	1975 Intake	1981-82 Intake
	(grams per capita per day)	
Cereals	523	488
Roots and tubers	52	63
Potatoes	17	45
Pulses	28	8
Vegetables	126	120
Fruits	21	17
Meat	4	5
Fish	23	23
Milk and milk products	17	15
Fats and oils	3	3
Others	10	23
Total	807	765

Source: Scott (1988), Table 4.2.

7. POTENTIAL FOR INCREASED CONSUMPTION OF POTATOES

The estimation of demand elasticities for potatoes for Bangladesh and Pakistan provides an interesting comparison in that consumption rises positively and strongly with income in Bangladesh, and positively but weakly with income in Pakistan. Both patterns of consumption could be accounted for using a food demand framework based on demand for characteristics, in particular, demand for calories, variety in the diet, and tastes of individual foods.[8]

[8] Methodologically, in applying the food characteristic demand system, potato demand estimates are sensitive to assumptions made about the calorie/moisture content of purchased commodities. Further applications of this methodology to root crops, in particular, would benefit greatly from more detailed survey data that recorded moisture content information. It would also be helpful to know what combinations of specific foods were eaten at particular meals, so as to assist in identifying the "role" of specific foods in the diets of the populations for which demand estimates are being derived.

Potatoes in these two countries are expensive sources of calories, relative to the most commonly consumed staple foods. Consequently, consumption levels of potatoes are low and account for small shares of food budgets. The demand analysis suggests that relative prices for potatoes would have to be substantially lower in order for potatoes to compete with traditional staples as an important source of calories in the diet.

In Pakistan, it appears that potatoes are treated more as alternative "vegetables," which provide an inexpensive source of variety in the diet. In this country, cross-price effects are large, such that demand for potatoes is strongly affected by price changes outside of the potato market. In Bangladesh, there is some indication that potatoes are treated as an alternative (albeit expensive) staple food in the diet.

However, if potato prices were to fall significantly, the food characteristic demand framework suggests that demand for potatoes could increase rapidly, to some extent replacing rice and wheat as main staples.[9] Indeed, an advantage of taking a "characteristics" approach to demand is the ability to evaluate a realignment of demand structures if the price of a staple (in particular for a nontraditional food) were to fall dramatically. That is, estimates of income and price elasticities based on variation around present average relative prices may give a quite misleading picture of future demand if a fundamental shift in relative prices were to occur.

What are the prospects for significantly increasing potato production and lowering potato prices in the future? According to Scott (1988), the former could be achieved by (1) making good quality planting material available to smallholder farmers on a timely basis at lower prices; (2) improving extension services to make more efficient use of costly chemical inputs; (3) developing varieties suited to specific

[9] Conversely, without a substantial fall in prices to a point at which potatoes are as inexpensive a source of calories as the main staples, per capita consumption levels will change only marginally with changes in prices and income.

regional growing conditions; and (4) increasing the availability of storage facilities. Ways to reduce relative prices for potatoes would include lowering (1) cereal imports (e.g., by reducing the subsidies on imported cereals)[10] and (2) the subsidized production and sale of domestically produced foodgrains. These policy initiatives are by no means mutually exclusive.

In the case of Pakistan, Kobab and Smith (1989) mention the use of varieties suitable for longer storage, wider diffusion of the seed plot seed production technique, and improvements in the quality of available planting material; all could help reduce production costs, lower retail prices, and facilitate the presentation to consumers of a more attractive potato. All of these technical initiatives could be intensified, utilizing available technologies.

It is interesting to note what actually occurred in Bangladesh during the remainder of the 1970s and 1980s. First, potato production continued to rise at a remarkable rate—due to both increases in productivity and area planted. These growth rates averaged 2.7 percent and 1.8 percent on an annual basis, respectively, between 1961-61 and 1991-93 (Table 2). Production increases were also impressive for wheat, although in recent years, these have tended to level off. By 1991-93, potato production stood at 1.3 million tons as area planted expanded by nearly 20 percent since the early 1980s. Wheat production was 1.08 million tons in 1991-93, but only slightly higher than the 1.03 million tons reached in 1981-82. Area planted in wheat grew by about 7 percent in the 1980s, from 563,000 to 604,000 hectares.

Second, total available wheat supplies also changed. Not only did local production of wheat increase, but imports in 1988-89 were higher in absolute terms than in 1973-74. However, strong population growth in Bangladesh virtually eliminated any increases in per capita availability of wheat.

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[10] Such a policy has had a significant effect on relative prices for cereal products versus potatoes in Ecuador and led to resurgent growth in potato consumption (Byerlee and Sain 1991).

Third, total rice supplies increased by over 40 percent from 12.9 to 18.8 million tons (Table 14). The spread of hybrid varieties was a principal factor. Rice imports increased in only minor absolute quantities relative to increases in domestic production.

Fourth, real incomes increased sharply during the 1980s (Figure 2). Among the possible reasons cited are the spread of high-yielding rice varieties capable of good yields in the dry season (Palmer-Jones 1994).

Fifth, results from the Bangladesh household expenditure survey for 1988-89 show that per capita potato consumption rose sharply (Table 15). This result appears consistent with the shift in relative prices for potatoes versus wheat—particularly in urban areas where relative prices fell by 50 percent. In the case of relative prices for potatoes versus rice, these remained virtually unchanged in urban areas and actually rose in the countryside (Table 15). As rice consumption also increased, particularly among low-income consumers, this added sense of wealth engendered increased potato consumption as well. The shift upward in potato consumption is also consistent with the rise in real wages.

8. CONCLUSION

Secondary crops are of increasing interest to policymakers and planners in developing countries because of a desire to diversify economic activities and because of their proven potential to raise farm incomes and rural employment. To assess this potential, basic information on the demand characteristics for these crops is required. But given the large number of possible crops to be studied,

Table 14 Bangladesh: Wheat, rice, and potatoes, 1973-74 and 1988-89

	Wheat		Rice		Potatoes	
	1973-74	1988-89	1973-74	1988-89	1973-74	1988-89
Production ('000 tons)	101	1,035	13,569	19,540	745	1,183
Imports ('000 tons)	2,134	2,246	286	434	29	4
Stock Changes ('000 tons)	+143	+79	+933	+1,175	-	-
Total Supply ('000 tons)	2,093	3,202	12,922	18,798	774	1,186

Source: FAO, FAOSTAT-PC unpublished statistics, 1995.

Figure 2 Real wages of agricultural laborers, Bangladesh, 1949-91

Source: Palmer-Jones (1994).

Table 15 Consumption of rice, wheat, and potatoes, and computed relative prices per 1,000 calories, 1973-74 versus 1988-89

	1973-74 Quartiles		1988-89 Quartiles	
	High	Low	High	Low
Consumption (kg./cap/year)				
Urban				
Rice	125.3	83.2	149.8	135.3
Wheat	54.1	68.6	19.7	20.1
Potatoes	8.8	3.6	29.7	14.4
Rural				
Rice	162.8	75.4	196.3	132.3
Wheat	26.0	41.1	17.9	25.1
Potatoes	4.7	1.0	23.7	8.5
Relative prices (per 1,000 calories)				
Urban				
Potatoes versus wheat	8.47	7.39	4.18	3.93
Potatoes versus rice	3.36	3.39	3.16	3.19
Rural				
Potatoes versus wheat	4.84	4.63	4.14	3.84
Potatoes versus rice	2.98	2.90	3.28	3.18

Source: 1973-74, Tables 6, 7; 1988-89, Goletti (1993).

policy analysts require an estimation procedure that is less data-intensive and time-intensive than standard econometric estimation techniques. In this paper, we have applied a low-cost procedure, illustrating its usefulness for analysis of demand for potatoes in Bangladesh and Pakistan.

Unlike in North America and Europe, potatoes in Asia are not regarded as a starchy staple, but rather are valued for the variety they provide in the diet and their unique taste. Potatoes can be an expensive source of calories relative to wheat and rice, but this situation can change rapidly.

Estimation results in the specific case of Bangladesh and Pakistan indicate that the prospects are favorable for increased potato consumption, given that incomes could improve and potato prices may continue to decline relative to basic staples. These findings are substantiated by time series data from Bangladesh, which show that where incomes increased and relative prices improved with respect to potatoes, consumption increased markedly.

Government policy can greatly influence the future demand for potatoes. Various measures might be adapted to help further lower production costs and the retail price paid by consumers, including lowering the cost and improving the availability of planting material and storage facilities. In addition, relative prices for potatoes versus rice or wheat might be altered by lowering subsidies on imports or on the domestic production of these cereals. These measures can be adopted with the prior knowledge that given the estimated demand parameters, increases in supply of potatoes can be readily consumed in the local market.

APPENDIX
SPECIFICATION OF THE FOOD CHARACTERISTIC DEMAND SYSTEM

Utility is a function of energy, variety, and tastes (characteristics of quantities of food consumed) and of nonfood purchases. Total utility derived from these three characteristics and from nonfoods is the weighted sum of their individual utilities:

$$U = w_e U_e(E) + w_v U_v(V) + \sum_{I=1}^{n} w_{ti} U_{ti}(q_i) + w_{nf} U_{nf}(q_{nf}), \quad (1)$$

where U = total utility from all food and nonfood goods,

q = quantity of a good,

I = $1,\ldots,n$ are the n foods consumed,

E = a measure of energy in the diet,

V = a measure of variety in the diet,

U_e = utility derived from energy,

U_v = utility derived from variety,

$U_{ti}(q_i)$ = utility derived from the taste of q units of good i,

$U_{nf}(q_{nf})$ = utility derived from q units of the nonfood good,

w_e = weight placed on utility from energy,

w_v = weight placed on utility from variety,

w_{ti} = weight placed on taste from individual food i,

w_{nf} = weight placed on utility from the nonfood good.

UTILITY FROM ENERGY

$$E = \sum_{I=1}^{n} z_i q_i, \quad (2)$$

where z_i = a factor converting quantity of the *i*th food into calories. E is total calories consumed per adult equivalent.[11]

$$U_e(E) = e_2E + e_3E^2, \quad (3)$$

where $e_2 > 0$ and $e_3 < 0$.

At low levels of total energy, each additional unit of energy increases utility, but at a decreasing rate. The functional form chosen, however, allows for marginal decreases in utility from additional units of energy at sufficiently high intakes of energy.

$$E_i = w_e(e_2z_i + 2e_3Ez_i) > 0 \text{ for low-income groups}, \quad (4)$$

where $$E_i = \frac{MU}{MU_e(E)} \frac{MU_e(E)}{Mq_i}.$$

$$E_{ij} = 2w_e e_3 z_i z_j < 0, \quad (5)$$

where $$E_{ij} = \frac{ME_i}{Mq_j}.$$

Analogous notation is used below for V_i, V_{ij}, T_i, and T_{ij}.

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[11] The demand system being presented appeals to some notion of an *individual's* preference structure. An interesting and important but difficult extension of the model would be to incorporate intrahousehold distribution of food into the utility function. For now, what is being implicitly assumed is that foods are being distributed in an egalitarian fashion. Nevertheless, some account is taken of the age/gender structure of the household by expressing E in per adult equivalent terms, rather than per capita terms. What this means mathematically is that when derivatives are taken (the change in per capita q_i), the z_i terms in (4) and (5) need to be corrected for the ratio of the number of household members divided by the number of household adult equivalents.

UTILITY FROM TASTE

$$U_{ti}(q_i) = log(q_i), \tag{6}$$

$$T_i = w_{ti}(1/q_i) > 0, \tag{7}$$

$$T_{ii} = -w_{ti}(1/q_i)^2 < 0, \tag{8}$$

$$T_{ij} = 0. \tag{9}$$

Each additional unit of taste of good *i*, no matter what the quantity, adds additional utility, but at a decreasing rate. The first derivative is positive and the second derivative negative, the same signs as for utility from energy for low-income groups. However, for taste, the "across food" second derivative is zero.

UTILITY FROM VARIETY

$$U_v(V) = M/T, \tag{10}$$

where M = nonstaple kilograms of food consumed per adult equivalent, and T = total kilograms of food consumed per adult equivalent.

$$V_i = -w_v M/T^2 < 0 \qquad \text{for } i \# s, \tag{11}$$

$$V_i = w_v[(T - M)/T^2] > 0 \qquad \text{for } s < i \# n,$$

where $i = 1,..., s$ are staple foods.

Each additional unit of a staple good reduces utility from variety and each additional unit of a nonstaple good increases utility from variety.

$$V_{ij} = 2w_v M/T^3 > 0 \qquad \text{for } i,j \# s, \tag{12}$$

$$V_{ij} = (w_v/T^3)[2M - T] \qquad \text{for } i \# s \text{ and } s < j \# n$$

$$V_{ij} = (2w_v/T^3)[M - T] < 0 \qquad \text{for } s < i,j \# n.$$

For all three sets of i and j, $V_{ij} = V_{ji}$.

UTILITY FROM NONFOODS

Utility from consumption of any food and nonfood is assumed to be want independent. In contrast with foods, no explicit functional form is specified for utility from nonfoods. Following Frisch (1959), and in order to solve the model for the (n+1) by (n+2) matrix of food demand elasticities, it is necessary with respect to utility from nonfoods, only to specify the following relationship:

$$\partial\ (\partial U/\partial q_{nf})\ /\partial q_{nf} = \lambda\ \frac{p_{nf}}{q_{nf}}\left[\ \frac{\phi}{\eta_{nf}}\ \right], \qquad \textbf{(13)}$$

where N = money flexibility,

O_{nf} = the nonfood income elasticity,

p_i = price of quantity i,

8 = Lagrangian multiplier associated with the constrained maximization; the marginal utility of income.

SOLVING THE MODEL

For any food i, i = 1, ..., n, from the first-order conditions:[12]

$$p_i = \frac{\dfrac{\partial U}{\partial U_e}}{\lambda}\left[\ \frac{\partial U_e}{\partial E}\ \frac{\partial E}{\partial q_i}\ \right] + \frac{\dfrac{\partial U}{\partial U_v}}{\lambda}\left[\ \frac{\partial U_v}{\partial V}\ \frac{\partial V}{\partial q_i}\ \right] + \frac{\dfrac{\partial U}{\partial U_T}}{\lambda}\left[\ \frac{\partial U_T}{\partial T}\ \frac{\partial T}{\partial q_i}\ \right]. \qquad \textbf{(14)}$$

[12] Equation (14) is very similar to Gorman (1980), equation (7). His term r_i and the last term on the right-hand-side of (14), the shadow price for the intrinsic characteristics of a specific good, are similar concepts. As Boyle, Gorman, and Pudney (1977) point out, without this characteristic of "uniqueness," a good would not be consumed which was not the cheapest source of at least one characteristic (characteristics obtainable from two or more goods) in the utility function (see also Figure 1 in Gorman 1980).

There are *n* equations associated with equation (14), which for the first food, a staple, gives

$$p_1 = \frac{w_e}{\lambda}\left[\, e_2 z_1 + 2e_3 z_1 E \,\right] + \frac{w_v}{\lambda}\left[\, -M/T^2 \,\right] + \frac{w_{t1}}{\lambda}\left[\, \frac{1}{q_1} \,\right]. \qquad \textbf{(15)}$$

Shadow prices for energy and variety are given by the product of the coefficient outside the brackets times the first partial derivatives inside the brackets, for the first and second terms in equation (15), respectively. Generally, the marginal utilities for all three characteristics will decrease (at a different rate for each characteristic) with increased food consumption at higher income levels. However, the marginal utility of income (θ) declines with income, which raises each shadow price by a constant factor. Shadow prices sum to the retail price for each food at all income levels. Consequently, the proportion of the retail price for each food accounted for by the shadow price of each characteristic will vary by income group.

Given data on food prices and food quantities (say from household surveys) and values for $w_e e_2$, $w_e e_3$, and w_v, it is possible to solve the n equations represented by equation (14) for the n w_{ti}'s.[13] Given, in addition, a value for $N/0_{nf}$ and data on nonfood expenditures, it is possible to obtain values for the entire (*n*+1) by (*n*+1) matrix of second partial derivatives of the utility function with respect to n foods and the nonfood good. These values, in turn, may be used to calculate the full matrix of (*n*+1) by (*n*+2) demand elasticities (e.g., Henderson and Quandt 1980, pp. 25-35). Thus, four parameters (in addition to data on *average* prices and quantities) are required a priori to solve the model for the entire matrix of demand elasticities. Prior specification of any four elasticities in the (*n*+1) by (*n*+2) demand matrix may be used to identify these four parameters.

[13] This is not precisely correct since θ is unknown. However, the resulting expressions for the w_{ti}'s are to be used in calculating food demand elasticities which do not depend on θ.

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