Universidad de la República
Facultad de Ciencias Sociales
DEPARTAMENTO DE ECONOMIA

Documentos de trabajo

Income elasticity of environmental amenitie

D. Miles, A. Pereyra & M. Rossi

Documento No. 02/00
Diciembre, 2000

Income Elasticity of Environmental Amenities

Daniel Miles[¤] Andrés Pereyra[y] Máximo Rossi[z]

July 4, 2000

Abstract

In this paper we are concerned with the estimation of income elasticities of environmental amenities. The novelty is the application of econometric methods that take into account the problem of measurement errors when estimating these elasticities, which are common in microeconomic data and are not usually considered in the applied literature related with this issue. Our aim is to discuss whether the measurement error has signi…cant e¤ects on the elasticities. Data from the Expenditure Budget Survey of Uruguay (1996) are used.

[¤] Universidad de Vigo, España. Departamento Economía Aplicada, dmiles@uvigo.es
[y] Universidad de Uruguay. Departamento de Economía, andres@decon.edu.uy
[z] Universidad de Uruguay. Departamento de Economía, mito@decon.edu.uy.

INTRODUCTION

In the environmental literature there has been an increasing interest on analyzing the income elasticity of environmental amenities, and particularly, of the willingness to pay for an environmental improvement (see, among others, Kriström and Riera, 1996 and references therein). In this paper we are concerned only with estimating the income elasticity of environmental amenities, leaving aside the discussion about its use as an approximation to the elasticity of willingness to pay (Flores and Carson, 1995). Actually, in this paper we discuss if the estimated income elasticities are noticeably affected by the measurement error problem, which is present when estimating demand equations, or by the way household characteristics are introduced in the parametric specifications.

Basically, most studies estimating elasticities do not take into account the measurement error problem that appears when approximating consumption by observed expenditure or income. This problem is present whenever we use budget microecenomic data to estimate demand equations (see Miles, 1998). In the case in which the measurement error is taken into account, the traditional estimation procedure is the instrumental variables method (see, for example, Curiel 1997 or Kriström and Riera, 1996). The problem is that not taking into account the measurement error problem or correcting it by the traditional instrumental variables method leads to inconsistent estimates under the usual demand specifications (Hausman et al.,1995; Lewbel 1996). The novelty of this paper is that we apply methods that lead to consistent estimates of the paramenters of demand equations that are also coherent with economic theory. Our simple concern is on whether the elasticities are sensitive to the different methods used for correcting this problem.

The paper is organized in three sections. In the first section, we briefly review the literature related with the functional forms of Engel curves and the econometric methods applied. In the second section we apply this methods to the Uruguayan Budget Survey, 1996 data. Finally, in the third section we conclude.

FUNCTIONAL FORM OF THE ENGEL CURVE AND THE MEASUREMENT ERROR CORRECTIONS

The functional forms most commonly used in applied work are those derived from the PIGLOG specification, nesting the Working-Leser, the translog or the almost ideal specification (Deaton and Muellbauer 1980; Jorgenson, et al., 1983; Pollak and Wales, 1992). Basically, these functional forms are stated in terms of the budget share as a linear function of total expenditure.

Recently, Banks et al. (1997) proposed a generalization showing that the quadratic in logarithms Engel curve specification is preference consistent[1]. This quadratic in logs specification has been widely used in empirical estimation of demand systems (see, Fry and Pashardes, 1992). This specification is given by

$$w_k^* = C_k/C = \beta_{0k} + \beta_{1k} \ln(C) + \beta_{2k} \ln(C)^2 + \varepsilon_k \quad k = 1, \ldots, K; \qquad (1)$$

where w_k^* is the budget share defined as the ratio of consumption allocated in good k; C_k; to total consumption, C; ε_k is a disturbance term which satisfies $E(\varepsilon_k | C) = 0$ and K is the total number of goods.

The problem that appears when trying to estimate equation (1) is that consumption in good k; C_k; and total consumption, C; are not observable. Usually, in applied work these quantities are approximated by the expenditure in good k; G_k and total expenditure, G; introducing a measurement error problem, i.e. $G_k = C_k + U_k$, where U_k is

[1] Gorman, 1981 and Lewbel, 1987 had shown that quadratic in logs specification are preference consistent.

the measurement error of consumption of good k. Therefore, the estimation method should take care of the measurement error so as to produce consistent estimators.

Traditionally, measurement error has been corrected by means of the traditional instrumental variable method. However, in a context of a model linear in parameters and nonlinear in variables, this method produces inconsistent estimates. To see this, let the measurement error equation for total consumption be $G = CU$. Substituting in equation (1) and operating we get

$$w_k = \beta_{0k} + \beta_{1k} \ln(G) + \beta_{2k} \ln(G)^2 + \eta_k \tag{2}$$

with

$$\eta_k = \varepsilon_k + (w_k - w_k^*) - \beta_{1k} \ln(U) - 2\beta_{2k} \ln(G) \ln(U) + \beta_{2k} \ln(U)^2.$$

The instrumental variables, Z, should verify simultaneously $E(\eta_k Z) = 0$ and $E(Z \ln(G)) \neq 0$. But, given that η_k is a function of $\ln(G)$, it does not seem possible to find an instrumental variable that is simultaneously correlated with total expenditure and uncorrelated with a function of it (Miles, 1998). That is, the traditional instrumental variable method is not feasible when the model is linear in the parameters and nonlinear in the missmeasured variable.

An additional problem that complicates the application of instrumental variables to Engel curves is given by the fact that the measurement error affects the dependent variable.nonlinearly That is, given that $w_k^* = C_k/C$, the measurement error on the dependent variable can not be separated additively, as is done in the classical context of measurement error problems.

In this paper we apply three newly developed approaches for taking care of measurement errors in non-linear in variables models. In first place, we apply the instrumental variable method developed by Hausman et al (1991, 1995), which corrects the measurement error problem when it affects nonlinearly the independent variables, assuming that there is no measurement error affecting the dependent variable. In second place, we apply the method proposed by Lewbel (1996), which corrects for the measurement error affecting nonlinearly both the dependent and the independent variables. Basically, the concern of this paper is to observe whether applying these methods, together with ordinary least squares and the traditional instrumental variable method, can affect the conclusions with respect to the elasticity of income of environmental amenities, as well as to observe the sensitiveness of these estimations. That is, the interest is to observe if the economic conclusions are affected depending on the method used for estimating the elasticities.

In the next section we present the results of applying this methods.

ENVIRONMENTAL AMENITIES INCOME ELASTICITY

In this section we present the results of applying the different methods cited above to estimate the income elasticities for environmental amenities. The data used was obtained from the 1996 Uruguayan expenditure budget survey, which is undertaking by the Instituto Nacional de Estadística de Uruguay and consists of 3749 observations. The coverage of this survey reaches urban households in towns with more than 10000 inhabitants at the time of the 1995 Census.

The environmental amenities considered are:

Camping1: Rent of campings, day trips, hunt permits.

Camping2: Rent of campings, day trips, hunt permits and goods for camping and hunting.

Recreation: Recreation expenditures, travel expenses, sports clubs fees, minor travel expenses.

Env1: Camping2 plus recreation.

Electricity: electricity expenditures.

Gas: gas expenditures.

Car: fuel and car manteinance expenditures.

It is clear that household characteristics a¤ect consumer behavior with respect to these goods. There are basically two di¤erent ways in which an equation could be estimated to take care of household characteristics (Pollak and Wales, 1992). One is to consider the sample as a whole, where characteristics are introduced as dummy variables in the equation to be estimated. The other, is to divide the sample into homogenous subsamples, depending on household characteristics. In this last approach, a better understanding of the e¤ect of household characteristics on its consumption behaviour can be achieved. In this paper we follow this last approach, subdividing a sample of households of married couples in which the head of the household is employed, into subsamples depending on the age of the partner, the number of sons and whether they live in Montevideo, the capital or in the rest of the urban country (RUC). This subdivision spanned up to eight subsamples, the composition of which is presented in Table 1.

Table 1: Mean expenditure on environmental Commodities, measured in prices of 1990.

Subsample	Partner age	Children	City	# Obs.
1	Less 45	No Children	R.U.C.	87
2	Less 45	No Children	Montevideo	139
3	Less 45	With Children	R.U.C.	442
4	Less 45	With Children	Montevideo	459
5	Larger 45	No Children	R.U.C.	360
6	Larger 45	No Children	Montevideo	391
7	Larger 45	With Children	R.U.C.	221
8	Larger 45	With Children	Montevideo	202

R.U.C. is Rest of Urban Country.

For estimating the income elasiticities of environmental amenities we consider 8 commodities that could be thought as having some kind of relationship with the environment. In particular, we follow the classi…cation of Curiel (1997). In Table 2 we present the mean expenditure in each commodity.

Table 2: Mean expenditure on environmental Commodities, measured in prices of 1990							
Subsample	Camping1	Camping 2	Recreation	Env1	Electricity	Gas	Car
1	0.022	0.0022	0.0026	0.0048	0.0279	0.0095	0.0284
2	0.0016	0.0023	0.0058	0.0081	0.0225	0.0057	0.0169
3	0.0007	0.0020	0.0034	0.0053	0.0297	0.0099	0.0224
4	0.0020	0.0029	0.0047	0.0075	0.0227	0.0071	0.0185
5	0.0016	0.0023	0.0057	0.0080	0.0302	0.0089	0.0270
6	0.0047	0.0049	0.0040	0.0098	0.0231	0.0067	0.0195
7	0.0009	0.0010	0.0033	0.0043	0.0324	0.0099	0.0215
8	0.0001	0.0009	0.0046	0.0056	0.0248	0.0069	0.0123

As it is well known, expenditure surveys are done alone very short periods of time and therefore household usually report zeroes in most commodities. This fact introduces a sort of measurement errror problem when using expenditure or income to measure consumption (see, for example, Meguir and Robin, 1992, among others). In Table 3 we present the percentage of zeroes found in each commodity.

Table 3: Percentage of Zeros in each commodity for each subsample							
Subsample	Camping1	Camping 2	Recreation	Env1	Electricity	Gas	Car
1	0.9425	0.9425	0.7241	0.7126	0.0345	0.2299	0.4483
2	0.9712	0.9353	0.7482	0.7194	0.0432	0.3237	0.6547
3	0.9683	0.9457	0.7579	0.7376	0.0633	0.2353	0.5090
4	0.9434	0.9150	0.7407	0.7015	0.0784	0.2026	0.6405
5	0.9694	0.9611	0.6611	0.6472	0.0194	0.1722	0.4222
6	0.9284	0.9079	0.7724	0.7136	0.0409	0.1969	0.5934
7	0.9638	0.9548	0.7692	0.7376	0.0136	0.1900	0.4932
8	0.9851	0.9505	0.7525	0.7277	0.0495	0.1485	0.6733

The number of zeroes is particularly important in some commodities, such as Camping2 or Recreation. Notice, however, that in many applications this fact is not usually considered.

ESTIMATION RESULTS

In this section we present the results of estimating the income elasticities by di¤erent methods. Our basic question is whether the income elasticity is seriously a¤ected, in terms of qualitative conclusions, by the application of these di¤erent methods.

The working hypothesis is that the household appreciation of the environment can be deduced from the expenditure on some environmental commodities, i.e. these goods are considered as proxies to the environment.

In the …rst place, we observe that there are serious di¤erences in the estimated income elasticity depending on the estimation method considered. Both, the OLS method and the IV method tend to overestimate the income elasticity. Remember that these two methods lead to inconsistent estimates in the presence of measurement error. On the other hand, the Hausman et al. and Lewbel methods lead to very similar results in all cases.

In the Table 4 the estimates of the elasticity of the Recreation good are presented, using the four estimate procedures: OLS, IV, Lewbel and Hausman. In the Appendix A the estimates for the rest of the selected goods are shown. For each group are carried out the estimates using different samples: the first, second and third income quartiles.

Table 4: Expenditure elasticity in recreation[2]

	OLS			VI			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	1.1622	1.097	1.1597	0.3348	1.0207	1.2705	2.0683	1.3894	1.4936	1.3950	1.1240	1.1386
	2.0707	0.5560	0.6757	1.9936	0.6297	0.5744	5.6338	0.8350	0.7741	5.6338	0.3488	0.5796
2	3.1887	2.3235	3.0197	4.6275	2.1319	2.2480	1.8104	1.3045	1.3808	3.6528	2.0961	2.4432
	2.2915	0.6429	0.7056	3.7794	0.6840	0.9160	1.3520	0.1676	0.2525	1.3520	0.5957	0.6907
3	4.0609	2.0283	1.5977	3.5476	2.3010	1.9846	2.3756	1.5054	1.3159	2.2850	1.6419	1.4810
	1.2345	0.3207	0.2538	1.1006	0.4304	0.3208	3.4870	0.4850	0.2082	3.4870	0.3451	0.3041
4	6.2912	2.0622	1.6849	6.5704	2.1419	1.7458	2.9859	1.8035	1.6810	6.3769	2.1411	1.7606
	3.5165	0.1525	0.0890	4.0465	0.1847	0.1123	2.3245	0.1558	0.0512	2.3245	0.1626	0.0924
5	1.1333	1.8817	2.9717	1.1062	1.8903	3.0102	-0.073	0.8745	1.4388	1.3976	1.7312	2.4393
	0.6846	0.6834	1.2782	0.5336	0.5939	0.8880	0.5842	0.3384	0.3285	0.5842	0.4384	0.7620
6	2.2553	2.0330	1.7403	2.1333	2.0001	1.7436	-0.667	0.9147	1.4492	2.4943	1.9890	1.6133
	0.3191	0.2359	0.1867	0.3305	0.2458	0.1888	0.4587	0.1556	0.1324	0.4587	0.2562	0.1861
7	1.8788	1.8924	2.8410	1.7046	1.6782	2.3624	0.9545	1.0147	1.0904	2.1225	1.5567	1.5727
	0.3837	0.5264	1.2342	0.5277	0.3530	0.7726	1.1913	0.6828	0.8907	1.1913	0.2679	0.8475
8	2.9810	2.2555	1.8949	3.1060	2.2062	1.8045	5.3383	3.0760	2.1901	2.5833	2.0368	1.7534
	0.5387	0.2672	0.1766	0.6714	0.2818	0.1840	16.546	4.1374	1.4628	16.5460	0.3628	0.1982

[2] Estimations for the first income quartile are generally not significant, however they have been included in the tables.

It is interesting to highlight two types of results: first the influence of the estimation method in the estimated value of the elasticities, particulaty since these estimates are used in policy design. Second, the focus on the differences in the elasticities for different groups of the population. This would be equal, in a traditional approach, to determine the significance of the different variables that were used to form the subsamples in the explanation of the values taken by the elasticity.

The main hypothesis is that the preferences of the individuals for the environment can be deduced from the expenditures they make in certain goods. These goods (services and camping site products, recreation, etc.) are considered proxies of the environment. At first the environment was generally considered a luxury good. Kriström and Riera (1996) resume the discussion, sketching the more or less predominant opinion and trying to show that the empirical evidence in certain countries has not matched this hypothesis. In a recent study of Costa (1997) for USA, she finds elasticities for recreation goods greater than one, but with the interesting result that this elasticities fall in an important way in the last hundred years (from a value of two at the beginning of century to not much more than one at the present time).

Kriström and Riera (1996) using estimates for different European countries of the willingness to pay for environmental goods (Finland, France, Norway, Holland, Spain and Sweden), find, in most cases, that it the hypothesis that the environmental goods are necessary goods cannot be rejected (income elasticity less than one).

In the case of Uruguay, Pereyra and Rossi (1998) using different functional forms of Engel curves, using parametric methods and keeping in mind the selectivity bias (the variables used as proxies for the environment are the same ones used in this work) corroborate the traditional hypothesis that environmental goods constitute a luxury one.

In this work we specially emphasize non parametric methods and the existence of differences stemming from the methods of estimation. The first conclusion is that in many cases the di¤erences in the estimated elasticities are substantial. To put it in another way, the results obtained on the value of the elasticities are not neutral to the estimation procedures.

The following expected result is obtained: the estimates of the elasticities in the …rst income quartile are larger than the estimates in the second one and these are larger those of the third quartile. These results are independent of the estimation method that is used.

The non parametric estimates con…rm the hypothesis that the environmental constitutes a luxury good in Uruguay.

Complementarily to the estimate of elasticities of those goods considered proxies of environmental goods, the elasticities of goods of possible negative impact in the environment (electricity, gas and car) were also considered.

For electricity and gas elasticities smaller than unity were observed and for car the elasticity is higher than one. This shows that during the process of growth it is important the design of policies to control the negative externalities of cars.

CONCLUSIONS

The two main conclusions of this study are:

In the …rst place, we observe that there are serious di¤erences in the estimated income elasticity depending on the estimation method considered. Both, the OLS method and the IV method tend to overestimate the income elasticity, then the results obtained on the value of the elasticities are not neutral to the estimation procedures.

Second, the non parametric estimates con…rm the hypothesis that the environmental constitutes a luxury good in Uruguay.

APPENDIX A

Table 4a: Expenditure elasticity on camping1											
	OLS			IV		Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q25	Media	Q75	Q25	Media	Q75
1	13.647	1.860	1.1644	13.1965	1.9199	1.3298	0.9031	0.9321	1.9659	1.1301	1.0515
	39.952	0.2490	0.1191	38.9746	0.3114	7.1706	0.5182	0.2197	7.1706	0.2320	0.1025
2	4.2068	1.1032	0.2518	6.6041	1.2917	1.0062	0.9697	0.9405	0.8320	0.9023	0.8633
	6.9743	0.2767	0.4035	12.5376	0.2613	1.1138	0.3618	0.3751	1.1138	0.1861	0.4004
3	4.2595	2.9293	3.0847	-6.3810	3.5435	0.7534	0.9304	0.9447	3.2264	1.3614	1.1400
	6.6462	1.7485	0.9266	55.0152	6.0714	17.342	3.9570	2.4899	17.3425	0.5923	0.9860
4	1.7232	1.9217	1.8161	1.1243	1.6728	1.3980	1.2955	1.1447	0.4902	0.6866	0.9082
	0.6046	0.6114	0.4484	1.0493	0.6735	0.3410	0.2319	0.1286	0.3410	0.2969	0.2429
5	2.9125	2.1421	1.9920	2.7028	2.1549	1.1980	1.1331	1.1221	3.3550	1.8797	1.5345
	1.5505	0.7022	0.5959	1.0810	0.9559	4.2510	1.2749	0.7276	4.2510	0.5777	0.4690
6	3.3462	3.1541	9.0606	13.0808	2.1538	10.986	2.0086	2.7457	9.4314	2.1193	3.5426
	5.6507	1.0069	5.5327	28.0289	0.4617	116.27	1.3107	5.9499	116.270	0.4859	1.8239
7	4.7871	3.2529	7.8584	-8.6958	4.0816	1.1188	1.4036	2.2945	5.7519	1.8665	3.2505
	25.662	2.2592	4.1587	135.670	4.1087	19.892	1.2022	10.511	19.8920	2.0908	10.3480
8	30.628	2.4676	2.4353	35.8501	2.6002	3.0555	1.0504	1.0004	4.1874	1.0374	0.9220
	209.89	0.6280	0.8302	189.758	0.4256	28.933	0.1556	0.1746	28.9332	0.2115	0.3146

Note: smaller numbers are the standard deviations

Table 4b: Expenditure elasticity in camping2												
	OLS			IV			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	13.333	1.8593	1.1641	12.8937	1.9186	1.2127	1.3178	0.9024	0.9318	1.9428	1.1291	1.0510
	37.874	0.2487	0.1191	36.9451	0.3110	0.1481	6.9009	0.5194	0.2202	6.9009	0.2313	0.2313
2	6.3065	1.5416	0.9404	9.7544	1.5885	0.4136	0.9333	0.9361	0.9093	1.1191	1.0317	1.0300
	13.363	0.4501	0.5098	22.4534	0.3635	0.3040	3.6146	0.8232	0.7388	3.6146	0.1964	0.4553
3	5.8762	3.1389	3.4836	-6.3780	3.4222	4.5152	-1.513	1.1724	1.3585	8.0870	1.7002	1.5140
	23.403	1.8965	1.1250	79.323	3.1588	1.8140	48.968	0.8603	0.4335	48.9685	0.6565	0.6525
4	2.4066	1.9252	1.6216	1.8269	1.7555	1.6537	1.6517	1.3289	1.1522	1.3584	1.1216	1.0029
	0.8249	0.4445	0.3340	1.2700	0.5139	0.3866	0.5527	0.2274	0.1111	0.5527	0.3125	0.1778
5	5 2.7405	2.0229	1.5375	2.6538	2.1129	1.6428	1.1868	1.0803	1.0301	2.8699	2.0747	1.5549
	0.9180	0.5010	0.3212	0.8159	0.6796	0.4587	0.1468	0.0838	0.0533	0.1468	0.5410	0.3441
6	4.9208	2.6166	5.9247	9.8881	2.0292	2.4695	-3.108	0.6531	0.7946	7.8748	1.9597	2.7384
	5.2819	0.6059	2.8097	15.5182	0.4729	1.5934	22.333	0.7701	0.8338	22.3331	0.3961	1.2053
7	6.5659	3.2971	8.7256	-7.3174	3.9805	12.795	-0.634	1.3783	2.5632	7.2233	2.2082	4.6877
	39.854	1.9699	5.1944	117.858	3.4783	8.2914	130.76	1.1372	12.868	130.765	2.4950	16.4741
8	7.6139	1.7419	1.2457	7.3837	1.6431	1.1189	1.8361	1.0702	0.9928	3.6542	1.1633	0.8808
	14.449	0.3590	0.3261	13.3088	0.2638	0.2094	2.0191	0.1251	0.1276	2.0191	0.0940	0.1259

Table 4c: Expenditure Elasticity on commodity Env1												
	OLS			IV			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	3.8064	1.4581	1.1632	3.0636	1.4459	1.2267	0.6798	0.7836	0.8207	1.1623	1.0487	1.0312
	4.5884	0.3555	0.1779	4.3253	0.3981	0.1974	9.1826	0.7947	0.2856	9.1826	0.230	0.1627
2	3.9282	2.1027	2.3384	5.8409	1.9783	1.6471	3.4492	1.4267	1.2009	3.6667	1.8673	1.9651
	2.7793	0.5018	0.5985	4.8460	0.5168	0.7002	15.915	1.1413	0.9834	15.9155	0.5294	0.6313
3	4.3041	2.4356	2.2194	2.2146	2.7122	2.8188	2.8069	1.9395	1.8455	3.6139	2.3930	2.2623
	2.2366	0.6431	0.4911	0.9961	1.0252	0.7255	10.278	1.0952	0.4644	10.2783	0.4784	0.3275
4	3.4652	2.0099	1.6645	3.1191	1.9943	1.7161	2.4380	1.8052	1.6358	2.7704	1.7909	1.5526
	1.0181	0.1906	0.1130	1.3474	0.2309	0.1414	1.1113	0.2020	0.0708	1.1113	0.2129	0.1054
5	1.5460	1.9215	2.2632	1.5035	1.9529	2.3345	0.1217	1.0740	1.5294	1.8741	1.9719	2.1938
	0.5157	0.5037	0.6443	0.4944	0.4599	0.5109	0.3633	0.2906	0.1992	0.3633	0.4657	0.4691
6	2.7439	2.5201	3.5053	4.3281	1.9729	1.9215	2.4866	1.5005	1.5435	4.1414	1.9801	1.9936
	0.8710	0.4874	0.5160	1.4418	0.2842	0.4601	8.4396	1.0862	0.8894	8.4396	0.2740	0.3849
7	2.0152	2.2259	4.0585	1.4474	2.2252	4.5209	0.7872	1.0179	1.2310	2.3229	1.9888	3.0543
	0.4340	0.6006	1.3965	0.6236	0.6643	1.5994	1.8993	0.7268	0.9406	1.8993	0.6527	1.9674
8	3.2958	2.1719	1.8164	3.3961	2.1143	1.7215	6.6169	3.2473	2.2534	2.7364	1.9016	1.6357
	0.6410	0.2358	0.1676	0.7580	0.2402	0.1689	5.3394	1.0709	0.4249	5.3394	0.3182	0.1841

Table 4d: Expenditure Elasticity on Electricity												
	OLS			IV			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	0.7429	0.6353	0.4755	0.8476	0.7440	0.5870	0.8680	0.7925	0.6788	0.8654	0.7529	0.5813
	0.0961	0.0932	0.1709	0.0939	0.1013	0.2048	0.1222	0.1084	0.0871	0.1222	0.1036	0.2182
2	0.8060	0.6742	0.3608	0.8467	0.6593	0.2246	0.6595	0.6295	0.5314	0.6937	0.6807	0.6236
	0.1314	0.1108	0.2570	0.1453	0.1399	0.3375	0.1370	0.2417	0.5954	0.1370	0.1511	0.3895
3	0.7023	0.6536	0.5655	0.7553	0.6969	0.6004	0.6439	0.6510	0.6316	0.7002	0.6829	0.6358
	0.1123	0.0694	0.0537	0.1286	0.0711	0.0708	0.0918	0.0680	0.0494	0.0918	0.0635	0.0612
4	0.8737	0.8080	0.7231	0.9615	0.8609	0.7282	0.8134	0.7948	0.7734	0.8586	0.8507	0.8427
	0.0809	0.0617	0.0694	0.0899	0.0635	0.0826	0.1223	0.1381	0.1613	0.1223	0.0670	0.0705
5	0.6162	0.6798	0.7277	0.7070	0.7522	0.7852	0.6961	0.7803	0.8542	0.6468	0.7450	0.8312
	0.0917	0.0604	0.0572	0.1113	0.0646	0.0668	0.0400	0.0348	0.0322	0.0400	0.0616	0.0599
6	0.5843	0.6045	0.6365	0.5980	0.6161	0.6452	0.5636	0.6118	0.6826	0.5747	0.6290	0.7080
	0.0749	0.0540	0.0571	0.1180	0.0634	0.1060	0.0257	0.0268	0.0438	0.0257	0.0565	0.0810
7	0.6233	0.6239	0.6293	0.7117	0.6931	0.6715	0.5795	0.6234	0.6878	0.6148	0.6994	0.8185
	0.0975	0.0731	0.0837	0.0973	0.0731	0.1123	0.0588	0.0429	0.0482	0.0588	0.0883	0.1025
8	0.8116	0.7349	0.6533	0.8385	0.7587	0.6714	0.7084	0.7088	0.7283	0.8008	0.7768	0.7604
	0.0882	0.0772	0.0860	0.0921	0.0809	0.0890	0.0583	0.0508	0.0382	0.0583	0.0820	0.0756

Table 4e: Expenditure Elasticity on gas												
	OLS			IV			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	0.1532	0.2511	0.2093	0.1530	0.1976	0.0233	0.5373	0.5040	0.2785	0.0020	-0.009	-0.354
	0.2698	0.2181	0.2339	0.3165	0.2491	0.2862	0.7662	1.0745	2.9898	0.7662	0.6373	1.1867
2	0.2430	0.5302	0.9483	0.0756	0.4356	0.9627	-0.433	-0.172	0.1147	-0.140	0.2377	0.7707
	0.3182	0.2224	0.5118	0.3475	0.2122	0.6210	0.2362	0.1673	0.1498	0.2362	0.3321	0.4543
3	0.6257	0.4792	0.2551	0.5950	0.4429	0.2108	0.3276	0.3034	0.2858	0.4833	0.4021	0.2879
	0.1150	0.0915	0.0858	0.1449	0.1054	0.0974	0.0311	0.0262	0.0429	0.0311	0.1012	0.1046
4	0.4363	0.4222	0.3891	0.3768	0.4012	0.4119	0.5220	0.5120	0.4737	0.3538	0.3931	0.4268
	0.0968	0.0832	0.0781	0.1160	0.0944	0.0883	0.0230	0.0371	0.0788	0.0230	0.0823	0.0873
5	0.5192	0.4658	0.3520	0.5124	0.4658	0.3604	0.3886	0.4049	0.3723	0.4605	0.4563	0.4027
	0.1283	0.0894	0.0651	0.1406	0.0942	0.0693	0.0283	0.0240	0.0148	0.0283	0.0797	0.0648
6	0.8045	0.6197	0.2727	0.7905	0.5819	0.1900	0.5885	0.5424	0.4710	0.7114	0.6330	0.4946
	0.0952	0.0813	0.1252	0.1232	0.0856	0.1538	0.0321	0.0263	0.0745	0.0321	0.1118	0.1673
7	0.7481	0.5358	0.1854	0.8119	0.5842	0.2115	0.6963	0.5686	0.3523	0.7140	0.5606	0.3038
	0.1771	0.1220	0.1100	0.1850	0.1221	0.1353	0.0804	0.0587	0.1314	0.0804	0.1443	0.2087
8	0.5285	0.5308	0.4739	0.5205	0.5117	0.4381	0.3809	0.4162	0.3871	0.4495	0.4758	0.4426
	0.2020	0.1518	0.1229	0.2259	0.1653	0.1211	0.0921	0.0800	0.0680	0.0921	0.1293	0.1276

Table 4f: Expenditure Elasticity on car												
	OLS			IV			Lewbel			Hausman		
	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75	Q25	Media	Q75
1	1.7913	1.4473	1.2111	1.8026	1.4040	1.1420	1.4300	1.1841	1.0292	1.5849	1.2988	1.1100
	0.2430	0.1706	0.1574	0.2967	0.2005	0.1943	0.9703	0.4241	0.1831	0.9703	0.1755	0.1979
2	1.5979	1.5306	1.5949	1.8636	1.8699	2.0040	5.8415	2.4655	1.8554	2.5027	1.8014	1.7504
	1.3454	0.2633	0.2212	1.4167	0.3274	0.3483	9.6083	1.0341	0.4807	9.6083	0.2888	0.2569
3	2.2244	1.7574	1.5491	2.3221	1.8990	1.7083	3.0736	2.2338	1.8603	2.1719	1.8547	1.7101
	0.2145	0.1176	0.1194	0.2562	0.1448	0.1573	2.3400	0.9768	0.5623	2.3400	0.1481	0.1326
4	2.0017	1.6925	1.3741	2.1489	1.7773	1.4025	1.9681	1.7163	1.4350	2.0578	1.6387	1.2502
	0.2314	0.1667	0.1248	0.2450	0.1863	0.1488	0.2442	0.1311	0.0602	0.2442	0.0658	0.0613
5	2.0739	1.5497	1.3615	2.3022	1.6816	1.4634	3.1813	1.9835	1.5112	1.9589	1.4235	1.2099
	0.1987	0.0851	0.0893	0.2345	0.1012	0.1114	0.5831	0.1622	0.0838	0.5831	0.0727	0.0802
6	2.6503	1.6976	1.3295	2.8823	2.0212	1.6625	2.9975	2.0801	1.6984	2.4051	1.8814	1.6459
	0.3604	0.1175	0.0902	0.3631	0.1603	0.1427	25.548	7.6724	3.3079	25.548	0.1917	0.1377
7	1.7849	1.6288	1.4233	2.2731	1.7657	1.3136	3.1357	2.2606	1.4909	2.0514	1.6270	1.2510
	0.2640	0.1935	0.1698	0.2792	0.2201	0.2276	0.7532	0.3295	0.1472	0.7532	0.1635	0.1924
8	2.9516	1.8768	1.5414	3.1327	2.0217	1.6700	3.6633	2.1261	1.6517	2.4795	1.7572	1.5247
	0.5386	0.1851	0.1409	0.5971	0.2203	0.1660	1.5784	0.3343	0.1462	1.5784	0.2274	0.1656

APPENDIX B

In this appendix we briefly present the Hausman et al. (1995) and Lewbel (1996) methods for estimating an Engel equation in a context of measurement errors.

The Hausman et al. (1995) method is based in the following specification. Let the Engel equation be

$$w_k^* = g(C; \beta_k) + \varepsilon_k$$

where $g(C;\beta_k) = \sum_{s=0}^{S} \beta_{sk} C^s$; w_k^* is the budget share of good k, C is total consumption and β_k are the parameters of interest. It is assumed that there is a reduced equation for total consumption given by

$$C = V'\alpha + \xi;$$

where the parameters α are unknown and ξ and V are statistically independent with $E(\xi) = 0$ y $E(\varepsilon_k \mid V) = 0$. Also, the observable variables are total expenditure, G, and expenditure share on good k; w_k; which are used to approximate the unobservable variables C and w_k^*: It is assumed that

$$G = C + U$$

and

$$w_k = w_k^* + \varpi_k$$

with $E(\varpi_k \mid V; \varepsilon_k; \xi) = E(U \mid V; \varepsilon_k; \xi) = 0$:

The estimation method proposed by Hausman et al. (1991, 1995) is based on the following three moment conditions

$$\begin{aligned} E(w_k \mid V) &= \int g(V'\alpha + \xi; \beta_k)\, dF_\xi \\ E(Gw_k \mid V) &= \int (V'\alpha + \xi)\, g(V'\alpha + \xi; \beta_k)\, dF_\xi \\ E(G \mid V) &= V'\alpha \end{aligned}$$

where F_ξ is the distribution function of the error term in the instrumental variable equation (Miles, 1998; Hsiao and Whang, 1996; Newey, 1992). From the last condition an estimator of α is obtained, and from the first two we can recover β_k: In Miles (1998), simulations of this method are presented which show the appropriate performance of this method under the assumptions it was built.

Lewbel (1996) argues that the problem with Hausman et al. (1995) method is given by the fact that it does not consider a nonlinear measurement error in the dependent variable, which is the case in the estimation of Engel curves. Lewbel proposes a method for consistently estimating the parameters of Engel curves under the presence of nonlinear measurment errors in both, the dependent and the independent variables. His method is based in recovering the distribution function of the measurement error using its sequence of moments, and using this distribution to correct the biases introduced by measurement error.

Let the Engel equation be

$$w_k^* = \beta_{0k} + \beta_{1k} \ln(C) + \beta_{2k} \ln(C)^2 + \varepsilon_k \quad k = 1, \ldots, K. \tag{A.1}$$

and $G = \sum_{k=1}^{K} G_k$, $w_k = G_k / G$ are, as before, the observable total expenditure and expenditure share in good k.

Then, if $E(G_k \mid C) = E(C_k \mid C)$, the measurement error in good k is given by

$$G_k = C_k + \upsilon_k C$$

with $E(\upsilon_k \mid C) = 0$. If $G = CU$, then

$$w_k = (w_k^* + \upsilon_k)/U. \tag{A.2}$$

which implies that the measurement error of the dependent variable can not be additively separated, as it is common in the classical context.

Substituting $(A.2)$ in $(A.1)$, and multiplying by VG^q, where V is a vector of instrumental variables, assumed to be statistically independent of u_k, υ_k, and G^q is the total expenditure raised to power q, we get

$$\begin{aligned} VG^q w_k &= \beta_{0k} V^q C^q U^{q-1} + \beta_{1k} V^q C^q \ln(C) U^{q-1} \\ &\quad + \beta_{2k} V^q C^q \ln(C)^2 U^{q-1} + V^q C^q U^{q-1} u_k + V^q C^q U^{q-1} \upsilon_k, \end{aligned}$$

or

$$\begin{aligned} E[VG^q w_k] &= \beta_{0k} E[VC^q] E\left[U^{q-1}\right] + \beta_{1k} E[VC^q \ln(C)] E\left[U^{q-1}\right] \\ &\quad + \beta_{2k} E\left[VC^q \ln(C)^2\right] E\left[U^{q-1}\right] + E[VC^q] E\left[U^{q-1}\upsilon_k\right]. \end{aligned} \tag{A.3}$$

Using the relationship $G^q = C^q U^q$, we can solve for $E[VC^q]$, $E[VC^q \ln(C)]$ and $E\left[VC^q \ln(C)^2\right]$ to get

$$E[VG^q w_k] = \alpha_{1kq}E[VG^q] + \alpha_{2kq}E[VG^q \ln(G)] + \alpha_{3kq}E\left[VG^q \ln(G)^2\right], \tag{A.4}$$

with

$$\begin{aligned}
\alpha_{1kq} &= \Bigg(\beta_{0k} - \beta_{1k}\frac{E[U^q \ln(U)]}{E[U^q]} \\
&\quad + \beta_{2k}\left(2\frac{E[U^q \ln(U)]^2}{E[U^q]^2} - \frac{E\left[U^q \ln(U)^2\right]}{E[U^q]}\right) \\
&\quad + \frac{E[U^{q-1}\upsilon_k]}{E[U^{q-1}]}\Bigg)\frac{E[U^{q-1}]}{E[U^q]} &\text{(A.5)}\\
\alpha_{2kq} &= \left(\beta_{1k} - 2\beta_{2k}\frac{E[U^q \ln(U)]}{E[U^q]}\right)\frac{E[U^{q-1}]}{E[U^q]} &\text{(A.6)}\\
\alpha_{3kq} &= \beta_{2k}\frac{E[U^{q-1}]}{E[U^q]}. &\text{(A.7)}
\end{aligned}$$

If, in (A.5)-(A.7) $q = 1$, with $E[U^q] = 0$ for $q = 0, 1$, we get

$$\begin{aligned}
\beta_{0k} &= \alpha_{1kq} + \alpha_{2kq}E[U \ln(U)] + \alpha_{3kq}E\left[U \ln(U)^2\right] &\text{(A.8)}\\
\beta_{1k} &= \alpha_{2kq} + 2\alpha_{3kq}E[U \ln(U)] &\text{(A.9)}\\
\beta_{2k} &= \alpha_{3kq}. &\text{(A.10)}
\end{aligned}$$

From the last equation we see that β_{2k} is identified, but for recovering (β_{0k}, β_{1k}) we need to estimate $E[U \ln(U)]$ y $E\left[U \ln(U)^2\right]$.

For this, we first estimate the alphas' using equation

$$G^q w_k = \alpha_{1kq}G^q + \alpha_{2kq}G^q \ln(G) + \alpha_{3kq}G^q \ln(G)^2 + \varepsilon_{kq}.$$

Second, with the $\alpha_{kq} = (\alpha_{1kq}, \alpha_{2kq}, \alpha_{2kq})'$ we use condition (A:7) to recover the moments of the distribution function of the measurement error, U. Fom this condition, if $\mu_q = E(U^q) < \infty$, for $q > 1$, we get

$$\mu_q = \alpha_{3k1}^{q-1}\prod_{j=2}^{q}\left(\alpha_{3kj}^{-1}\right),$$

which is the sequence of moments of the distribution of the measurement error. Then, Lewbel assumes that the distribution of the measurement error is log-normal, so we have that $E(U_h \ln(U_h)) = \ln(\alpha_{3k1}/\alpha_{3k2})/2$ and $E\left(U_h \ln(U_h)^2\right)$ $= \ln(\alpha_{3k1}/\alpha_{3k2})\left(1 + \ln(\alpha_{3k1}/\alpha_{3k2})/2\right).$

Finally, the method developed by Miles (1998) is based on the following specification of the Engel curve,

$$w_k^* = g(C; \beta_k) + \varepsilon_k$$

where $g(\cdot)$ is any theory consistent specification, $w_k^* = C_k/C$, is the true budget share proportion of good k and C is total consumption. Also, we have the following instrumental variable equation for total consumption

$$C = V'\alpha + \xi$$

such that V and ξ are statistically independent. We do not observe C nor w_k^*, but instead we observe expenditure in good k G_k and total expenditure, G, with the following measurement errors,

$$G_k = C_k + U_k$$

$$G = C + U$$

such that $E(U_k \mid V) = E(U \mid V) = 0.$

Miles (1998) proposes a method based on two of the three moment restrictions in which is based the Hausman et al. (1995) method. Based on

$$\begin{aligned} E(G_k \mid V) &= \int (V'\alpha + \xi)\, g(V'\alpha + \xi; \beta_k)\, dF_\xi \\ E(G \mid V) &= V'\alpha \end{aligned}$$

if we denote $q(V'\alpha + \xi; \beta_k) = (V'\alpha + \xi)\, g(V'\alpha + \xi; \beta_k)$, we could write the Taylor expansion around the mean of ξ, getting

$$E(G_k \mid V) = q(V'\alpha; \beta_k) + \sum_{j=2}^{\infty} \frac{q^j(V'\alpha; \beta_k)}{j!} \int \xi^j\, dF_\xi \qquad (1)$$

where $q^j(V'\alpha;\beta_k) = j g^{j-1}(V'\alpha;\beta_k) + (V'\alpha) g^j(V'\alpha;\beta_k)$ is the $j-$th derivative of $q(C;\beta_k)$ evaluated at $V'\alpha$. If $E\left(\nu^j\right) < \infty$, for $j > 1$, (Lewbel, 1996), then we could rewrite

$$E(G_k | V) = q(V'\alpha;\beta_k) + \lim_{J\to\infty}\sum_{j=2}^{J}\gamma_j\frac{q^j(V'\alpha;\beta_k)}{j!} \tag{2}$$

where $\gamma_j = \int \nu^j dF_\nu$. Note that if $q(V'\alpha;\beta_k)$ is linear in β_k, then also the derivatives, $q^j(V'\alpha;\beta_k)$, will be linear. Therefore, the expansion will be a linear specification where the dimension of the parametric space will depend on the order of the expansion. If it is assumed that the order of the expansion depends on the size of the sample, $J = J(n)$, such that $J(n) \to \infty$ when $n \to \infty$, then the parametric space will depend on n. Mammen (1993) has proposed an F based test, whose distribution is approximated by bootstrap, for testing the dimension of the parametric space, and hence, the order of the expansion to be considered.

REFERENCES

Banks, J. Blundell R and Lewbel, A. (1997) "Quadratic Engel curves and consumer demand" The Review of Economics and Statistics, 79,9

Costa, Dora (1997), Costa Less of a Luxury: the rise of recreation since 1888 National Bureau of Economics Research #6054.

Curiel, F. (1997) "La elasticidad de la renta del gasto en recreacion ambiental", manuscript, Universidad Autonoma de Barcelona.

Deaton, A. and Muellbauer, J. (1980) Economics and Consumer Behaviour, Cambridge,

Cambridge University Press.

Flores, N. and Carson, R. (1995) "The relationship between the income elasticities of demand and willingness to pay", manuscript University of California, S. Diego.

Fry, V. and Pashardes, P (1992) "An almost ideal quadratic logarithmic demand system for the analysis of microdata" IFS-WP.

Hausman,J., Newey, W, Ichimura, H. and Powell, J. (1991) "Identi…cation and estimation of polynomial errors in variables models", Journal of Econometrics, 50, 273-95.

Hausman, J. Newey, W, and Powell, J. (1995)"Nonlinear errors in variables estimation of some engel curves", Journal of Econometrics, 65, 205-33.

Jorgenson, D. Lawrence, J. and Stoker, T. (1983) "The trascendental logarithmic model of aggregate consumer behaviour" in Basman,R. and G.

Kriström, B. and Riera, P. (1996) Is income elasticity of environmental improvements less than one? Environmental Resource Economics.

Kriström, B. and Riera, P. (1997) Income distribution and willingness to pay for environmental goods: some empirical evidence, manuscript.

Lewbel, L (1996) Demand Estimation with expenditure measurement errors on left and right hand side, The reveiw of economics and statistics, 718-25.

Meghir, C. and Robin, J.M (1992) "Frequency of purchase and estimation of demand systems" Journal of Econometrics, 53, 53-85.

Miles, D. (1998) Especi…cation e Inferencia en Modelos Econométricos de Curvas de Engel, Unpublished PhD dissertation, Universidad Carlos III, Spain.

Newey, W, (1992) "Distrubion free simulted moment estimatio of nonlinear error-in-variablers model" manuscript, MIT

Phlips, L (1983) Applied consumption analysis. Advanced textbooks in economics, North holland.

Pereyra y Rossi (1998), Los bienes ambientales ¿constituyen un bien de lujo? Working Paper 13/98 Universidad de Uruguay.

Pollak, R. and Wales, T. (1992) "Demand System Speci…cation and

Estimation" Oxford, Oxford University press.

Robles, Advances in Econometrics, JAI PRESS