Engel Curves, Household Characteristics and Low-User Tariff Schemes in Natural Gas

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Abstract

We explore the relative importance of income and household characteristics (such as family size) in explaining differences in household consumption of natural gas and LPG. In a simple model of vertically (willingness to pay) ordered households we posit that the relative importance of the income elasticity of demand (vs. the family-size elasticity) depends positively on the price faced by households. Thus, very low prices tend to depress the across households income elasticity of demand in favor of the characteristics-elasticity and the opposite holds for under high prices. We test this hypothesis using, for the first time in Argentina, data from the household expenditure survey on Natural gas and LPG and compare the cross-section consumption equations for both fuels, which have quite different price regimes. Finally, we explore welfare implications for low-user tariff scheme reforms in natural gas.

JEL class. numbers D12, L11, Q41,
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1 Introduction

The role of income vs. household characteristics in explaining household consumption of natural gas and electricity seems relevant in the design of so-called social tariff schemes in those sectors. While there have been historical antecedents, in both theory and practice, of tariff schemes that differentiate blocks by observed consumption[1], recent criticisms of this practice, to address income

[1] This paper is part of a project on social tariff issues in infrastruture services in Argentina held at FIEL (www.fiel.org/tarifasocial). I thank Pedro Hancevic for excellent research assistance and comments.

[1] See for example Phlips (1983, Chapter 5) for the description of an early social tariff scheme in Belgium since the layte 50s and Armstrong, Cowan and Vickers (1994) for a discussion of low-user schemes with applications to telecommunications. Navajas and Porto (1990) is

differentials and subsidies to the poor, points to the weak relationship between consumption and income, and instead to the much larger dependency on household characteristics such as family size and the like. Thus, any policy based on an assumed steep engel curve, i.e. a strong and monotonically increasing relationship between consumption and income, is deemed to have very low effectiveness in the attainment of subsidizing the poor. If relatively poor families are larger than rich ones then household consumption may become too weakly related to per capita or even household income. Thus, low user schemes type of subsidies are neither effective to reach the poor nor robust to avoid unwanted transfers to the rich.[2]

Argentina is an ideal environment for the study of this issue in the natural gas sector. The country has been an early mover towards natural gas consumption since the discoveries of large reservoirs in the late 70s. Natural gas has been progresively reaching households in a country with large a urban population, along with strong penetration in industry, electricity generation and even transport. Large quantities were also started to be exported to Chile through several pipelines. This very dynamic environment suffered a setback in recent times after a combination of a sluggish supply and a contractual crisis (due to a a huge real devaluation followed by strong price controls) led to a serious imbalance between demand and supply and to a suspension of exports to Chile.[3] The required adjutments of energy prices, set today at about half way to the level of neighboor countries, with a still large part of the population with low income levels, suggest that some form of social tariff scheme will have to be implemented somehow. Design or even discussion of the topic have been delayed for political reasons[4], but point to the likely use of some form of differentiation by blocks of consumption along with other characteristics.[5] While this policy issue can be addressed with conventional two part tariff menu design, there are at least two important califications of such a strategy. First, as stated above quantity-based tariff discounts cannot be effective if houselhold per-capita income is only loosely correlated with aggregate houselhold consumption (the observed variable for pricing purposes). Second, incomplete access of households to the infrastructure service imply that many households (relatively poor compared to those with natural gas) have to rely on an alternative fuel

an early reference of some issues of two-part tariff design in theory and in Argentina. Of course, models of multiblock tariffs in monopoly pricing (e.g. Wilson, 1993) need not rely on distributive concerns and simply reflect demand structures with different price elasticities across customers, that normally ignore income diiferences effects.

[2] See for example Komives et.al (2005) and, for Argentina, Foster (2003).

[3] See Navajas (2007) for an account of the broken exchanges in natural gas bewteen Argentina and Chile.

[4] See Navajas (2006) for an explanation of some stilized facts of tariff structure behavior after macroconomic crisis and an assessment of the lack of reform after 2002.

[5] By the end of 2002 the Ministry of the Economy in Argentina, along with the regulatory body ENARGAS, put forward to the executive an opening up of the residential (i.e. household) tariff category in natural gas, so as to cushion a proposed increase in the tariff level. The increase was finally blocked by the judiciary power, but the segmentation of the residential (so called "R") category was openned (and remained latent, with the same pricing) in three subcategories (R1, R2 and R3) according to consumption levels

(LPG) to satisfy energy services. The price of LPG is set in (albeit imperfectly) competitive markets with border price (export parity) references and with corresponding higher values than regulated (or rather over controlled) natural gas prices.

This paper looks at the problematic issue of the relatively poor correlation of income and consumption of natural gas and its implication for social tariff design. Section 2 draws on a simple two-part tariff model with household preferences that allows vertical differences, to derive a result on the relative magnitude of income and characteristics in explaining household consumption. We posit a hypothesis that this relative magnitude depends on the price regime in place, that is, when prices are relatively low household consumption is less reactive to income and more on the characteristics of the household. Section 3 attempts to empirically look at this hypothesis for the case of Argentina, with an econometric testing of the determinants of natural gas and LPG consumption, with quntities retrieved from the last available Household Expenditure Survey for the metropolitan region of Buenos Aires. This allows us to test household demand behavior in two different price regimes, one considered "low" and the other "high". We find evidence on the relative magnitude of income and family size elasticities that matches the hypothesis derived from the previous model. In section 4 we move to discuss the implications of these results for a reform towrads so-called social (i.e. low user scheme) two-part tariff exercises such as those that are bound to be propossed in Argentina. Finally section 5 concludes and suggest further related research topics.

2 Household demand: income vs. family size and the price level

The demand for natural gas can be derived in a framework were the demand for alternative forms of energy are derived from two stage budgeting procedures and considering the equipment or connection available to households.[6] In this paper, and given our main focus and data restrictions to estimate such a model, we simplify the setting to directly assume household preferences for a single good that adopt a simple and standard specification used in vertical differentiated models of two-part tariff monopoply pricing (see for example Tirole, 1988, Ch. 3) in non-linear pricing analysis in regulated industries (see for example Armstrong et.al., 1994, Ch. 2).[7] Utility U is given by

$$U = Y.V(x, z) - T \tag{1}$$

[6] See, for example, Baker et.al. (1989).

[7] This specification is kept simple to develop the argument in a simple and manageable fashion. See Wilson (1993, chapter 7) for rigorous analysis of nonlinear pricing models in the case when heterogeneity across households concerning income are allowed. The structure of preferences in his example 7.3 is similar to the above one in the sense that income determines the type of the household, except that the relationship between income and price electicities is more flexible that the one postuilated here and no allowance or explicit treatmet of household characteristics is introduced.

if the quantity of the good $x > 0$ and $U = 0$ if $x = 0$. Where Y is a willingness-to-pay parameter represented by household income, $V(.)$ is a subutility function assumed concave in x, and z is a parameter representing a household characteristic, such as family size or number of members. T is an outlay or expenditure for consuming x, represented by a two-part tariff, i.e.

$$T = A + p.x \tag{2}$$

if the quantity of the good $x > 0$ and $T = 0$ if $x = 0$, where A is a fixed charge or fee and p is the marginal price. Household face schedule T and chose x to maximize (1) leading to first order condition (for an interior solution)

$$Y.V_x(x, z) = p \tag{3}$$

where V_x is the partial $\partial V/\partial x$. From this we can write the household demand for x as

$$x^* = V_x^{-1}(\frac{p}{Y}, z) = g(\frac{p}{Y}, z) \tag{4}$$

In this setting, price and income elasticities are equal, i.e. $\eta_{x,p} = -\frac{g_1}{g}.\frac{p}{Y} = \eta_{x,Y}$ where g_1 is the partial derivative of g with respect to its first argument. Both elasticities are increasing in p if $-g_1/g$ is non-decreasing in price p, a condition that depends on the form of equation (4).[8] At the same time, the characteristic-elasticity of demand is $\eta_{x,z} = \frac{g_2}{g}.z$, which can be increasing or decreasing in price depending on wheter g_2/g is increasing or decreasing in price.[9]

Further, and central to our hypothesis, the ratio

$$\frac{\eta_{x,Y}}{\eta_{x,z}} = -\frac{g_1}{g_2}.\frac{p}{Y.z} \tag{5}$$

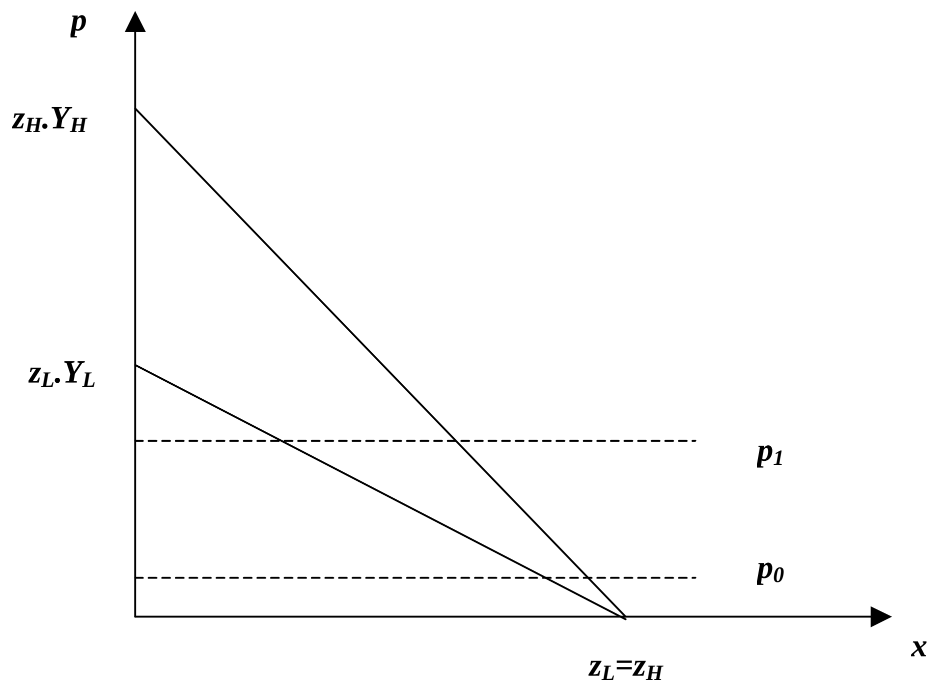
can be increasing in price if $-g_1/g_2$ is non-decreasing in price. Thus, the model allows for the empirical (and very likely) posibility that the relative magnitudes of household income (Y) and characteristic (z) elasticities of demand depend upon the price level faced by consumers.

This pattern can be represented for instance in the linear demand case. Starting from a cuadratic specification of utility, such as, $V(x, z) = \frac{1-(z-x)^2}{2}$, where $V_x = z - x$, we obtain $x^* = g(.) = z - \frac{p}{Y}$. In this linear case, we have that $g_1 = -1 = -g_2$, and $-g_1/g = Y/(Y.z - p) = g_2/g$, both increasing in price. Thus the income-elasticity $\eta_{x,Y}$ and the characteristic-elasticity $\eta_{x,z}$ are both increasing in price with the ratio $\frac{\eta_{x,Y}}{\eta_{x,z}} = \frac{p}{Y.z}$ being less than one and increasing in price. Figure 1 illustrates this linear demand case where it is shown that when prices are zero, the quantity consumed by high-income (H)

[8] The condition will hold for concave (i.e. $g_{11} < 0$), linear and weakly convex demands . In notation, $\frac{d(-g_1/g)}{dp} = Y^{-1}.\left[(\frac{g_{11}}{g})^2 - \frac{g_{11}}{g}\right]$. Of course, convex demands of the constant-elasticity (in price) type have, by definition, constant elasticity

[9] For this elasticity to be increasing in price it is sufficient that $g_{21} \geqq 0$, while it is necesary to have a $g_{21} < 0$ and large to see the opposite. In notation, $\frac{d(g_2/g)}{dp} = \frac{g_{21}}{g.Y} - \frac{g_2.g_1}{g^2.Y}$.

Figure 1: Linear Demand Case



and low-income (L) households depend only on household characteristics, such as family size. Thus, for low-price regimes (p_0) consumption across households will be almost only related to characteristic differentials such as family size and therefore very poorly related to income differences, while por high-price regimes (p_1) income differences become more visible as a explanatory variable.

3 Cross-section estimates of parameters

Panel data of household energy consumption is not available in Argentina, precluding a formal testing of wide energy demand models (e.g. Parker et.al. (1989) and Berkhout et.al. (2004)). In fact, the database of the country demand analysis is comparatively poor, since household expenditure surveys are sporadic (every decade or so) with the last one (2005-06) not yet available and a complete absence of energy consumption surveys. Even so, in this section we proceed to estimate a cross-section demand for gas to obtain relevant parameters to the previous analysis. The estimation is, to our knowledge, the first to be performed with micro-data obtained from the national household expenditure survey (NHES) 1996-97 in Argentina. The reason for this lack of estimates is probably due to the aggregated format of the data publicly available, which aggregates in "fuels for the household" many items (natural gas, LPG, kerosene, wood, etc) and therefore precludes a separate measurement of each fuel expenditure. Our access to the disaggregation of the items[10] allow us to proceed with the estimation of the cross section equation of the household consumption of natural gas and LPG, which we find relevant for testing the relative magnitudes of income-elasticities and characteristic-elasticities under diffrerent price regimes, given the sizeable differences (about 2.5 to 1 in 1996-97 in favor of natural gas) between the -calorific content equivalent- of both forms of fuels (used for cooking, producing hot water and heating). The data set obtained is restricted to the metropolitan area, that is Buenos Aires City and the Great Buenos Aires Area.

The NHES surveyed, between february 1996 and march 1997, 4905 households living in Buenos Aires City (1287 households) and in the Great Buenos Aires Area (3558 households). Of these, 4845 households reported living in houses and appartments (the rest in other dwellings such as hotels, guest houses and the like) and 4640 reported to consume either natural gas (3376 households) or LPG (1264 households). Given that the NHES reports expenditures and not quantities consumed, we retrieved the implicit quantities embeded in the household answers to the survey. This was not troublesome given the available detailed information of the pricing and tax structure observed at that time for both Buenos Aires City and the Great Buenos Aires Area. In the case of natural gas, retrieved quantities from observed expenditures were obtained from applying tariff schedule (2) and solving for the implied quantities. In the case of LPG, expenditures were simply divided by (uniform) prices and converted into calorific-equivalent (to natural gas) units. [11] The resulting quantities were inspected to eliminate negative values in the case of natural gas (121 households, or 3.5% of the sample), presumably due to errors in the survey and the presence of a very small discount scheme for pensioners.

Table 1 shows the definition and source of variables used in the estimation.

[10] The disaggregated dataset for household fuels was obtained from a special request to the statistical office INDEC in 1999 while using the NHES 1996-97 for the study of the distributive impact of relative price changes; see Navajas (2003).

[11] Actually computations should proceed in the Argentine case from a more general formulae for the tariff outlay $T = \left[\frac{A}{(1+t_1)} + \frac{p.x}{(1+t_1)} + \frac{\sum_i \alpha_i.t_2/FC}{(1+t_1)}\right].\Pi_{i=1}^{3}(1+\tau_i)$ where $(t_1, t_2, \tau_1, \tau_2$ and $\tau_3)$ are taxes (t's are on sales affecting the value chain, and the τ's are value added, provincial and -average- municipal taxes), α_i is a share of the gas field from where the natural gas is transported and FC is a capacity charge factor for residential consumers. Values of A and p were obtained from the regulatory agency (ENARGAS) and are weighted averages of the values for the three firms that operate in the area (actual tariff differences are small, anyway). In the case of LPG the formula was much simple given uniform pricing and only ad-valorem taxes (mainly VAT). The end-user price of LPG was obtained from a survey perfomed by FIEL for LPG suppliers at that time.

Table 1
Definition and source of variables

Household variable	Definition	Source
expenditure of natural gas or LPG	Total household expenditure divided by the number of household members	National Household Expenditure Survey 1996/97 (ENGH 96-97)
members	Total number of household members	(ENGH 96-97)
rooms	Number of rooms excluding bathrooms, kitchen, study, garage, play,garden, etc. Leaves basically bedrooms, dinning and liiving rooms	(ENGH 96-97)
house	Binary variable, =1 when the household lives in a house.	(ENGH 96-97)
Appartment	Binary variable, =1 when the household lives in an appartment.	(ENGH 96-97)
Apt from 0 to 4 floors	Binary variable, =1 when the appartment is in a building from 0 to 4 floors.	(ENGH 96-97)
Apt from 5 to 10 floors	Binary variable, =1 when the appartment is in a building from 5 to 10 floors.	(ENGH 96-97)
Apt of more than 10 floors	Binary variable, =1 when the appartment is in a building of more than 10 floors.	(ENGH 96-97)
Central Heating	Binary variable, =1 when the home has central heating.	(ENGH 96-97)
Fixed Appliances Heating	Binary variable, =1 when the home has heating through fixed appliances.	(ENGH 96-97)
Mobile Appliances Heating	Binary variable, =1 when the home has heating through mobile appliances.	(ENGH 96-97)
No Heating	Binary variable, =1 when the home has no heating.	(ENGH 96-97)
Appartment w. Central Heating	Binary variable, =1 when the household lives in an appartment with central heating.	(ENGH 96-97)
Elevator and Electric Porter	Binary variable, =1 when the building (house or appartment) has elevator and electric porter	(ENGH 96-97)
Security or Surveillance	Binary variable, =1 if the building has personel assigned to security or surveillance	(ENGH 96-97)
Pool or Sports area	Binary variable, =1 when the building has a (private or joint) swiming pool, playground or sports area.	(ENGH 96-97)
Bs.As. City	Binary variable, =1 when the building is located in Buenos Aires City.	(ENGH 96-97)

The set of variables includes expenditure of natural gas or LPG (from which quantities were obtained) and a list of characteristics that are available in the NHES and were considered relevant. "Members" refer to members of the household and "rooms" is a proxy for housing characteristics. Binary variables start with, house or appartment, which is a dimension to capture housing conditions relevant for energy consumption. The NHES allows to distinguish between the numbers of floors of the building where appartments are, and thus we included this dimension too, in order to capture possible different consumption patterns. The next dimmesion relates to the provision of heating, which is indeed relevant for gas consumption. Heating can be obtained in a central fashion, which for appartments in Argentina means a centralized provision provided for the whole building. The NHES also provides information on some characteristics of the housing services such as if the have elevator in the case of appartments, security and common ares for sport and or leissure. These dimmensions are related to income or wealth differentials and were included in the initial regressions but not reported due to their lack of significance in explaining consumption across households.

Descriptive statistics of the main variables are shown in Table 2, where we distinguish between natural gas and LPG and between Buenos Aires City and Great Buenos Aires. As shown in the Table, LPG consumers, i.e. those that do not have access to natural gas distribution pipeline have lower incomes, live mostly in houses, in the Great Buenos Aires Area, have more members, live in smaller houses and use mobile appliances for heating, relatively to those who have access to natural gas. As for natural gas users, they live mostly in houses in the Great Buenos Aires and predominantly in appartments in the Buenos Aires City. They use fixed appliances for central heating but in Buenos Aires City there is also a significant proportion with central heating corresponding to those that live in appartments.

Table 2

Descriptive Statistics

		Natural Gas			Liquified Petroleum Gas	
Household Variables	All Sample	Bs.As. City	Greater Bs.As.	All Sample	Bs.As. City	Greater Bs.As.
Income per cap ($, 2 months)						
Mean	804.2	1076.4	640.7	328.9	618.7	313.4
St. Dev.	621.1	715.5	488.9	287.8	521.2	261.1
Consumption (m3, 2 months)						
Mean	156.0	150.6	159.2	34.9	36.5	34.8
St. Dev.	154.6	163.4	149.1	24.2	18.9	24.4
Nº of members						
Mean	3.2	2.9	3.4	4.4	4.1	4.4
St. Dev.	1.7	1.6	1.7	2.2	2.5	2.2
Nº of rooms						
Mean	3.2	3.1	3.2	2.7	3.0	2.6
St. Dev.	1.1	1.2	1.0	1.0	1.1	1.0
		Shares				
House	58.9%	24.1%	79.9%	93.4%	50.1%	95.8%
Appartment	41.1%	75.9%	20.1%	6.6%	49.9%	4.2%
0 to 4 levels	18.8%	24.2%	15.5%	5.4%	29.4%	4.1%
5 to 10 levels	13.4%	31.7%	2.4%	0.8%	11.8%	0.2%
more than 10 levels	8.9%	20.0%	2.2%	0.4%	8.7%	0.0%
Central Heating	9.6%	22.4%	2.0%	0.5%	6.0%	0.2%
Fixed Appliances Heating	68.7%	57.8%	75.3%	11.7%	15.8%	11.5%
Mobile Appliances Heating	14.2%	12.2%	15.4%	60.3%	52.6%	60.7%
No Heating	7.4%	7.6%	7.2%	27.2%	23.7%	27.4%
Appartment w. Central Heating	8.2%	20.9%	0.7%	0.3%	6.0%	0.0%

We estimate equations in logaritm form for measued variables and include control variables as dummies in binary form. The general form to be estimated is the following:

$$\ln(x) = \alpha_0 + \alpha_1 . \ln(Y) + \alpha_2 . \ln(Members) + \alpha_4 . \ln(Rooms) + \underline{\gamma} . Controls + u \quad (6)$$

The results on the pattern of natural gas consumption across hosuholds is show in Table 3. In the first column we report results for the whole sample of 3207 households selected from the survey that consume natural gas. All regressions were estimated by weighted OLS. We tested for non-linear terms equation (7) and interactions bewteen dummy variables. Results reported do not include non-significant variables (such as housing amenities (see Table 1). P-values associated with robust standard errors (that take account of heteroscedasticity) are reported below each regression coeficient and similarly robust F values are reported at the bottom of the table along with adjusted R^2s. Columns (2) and (3) show corresponding results for Greater Buenos Aires and Buenos Aires City samples.

Table 3: Natural Gas Consumption Across Households

Dependant variable: ln(household consumption of natural gas)

	Sample		
	(1)	(2)	(3)
Regresors	All	Great Bs.As.	Bs.As. City
ln(household income)	0.218	0.229	0.194
	0.000	0.000	0.000
ln(members)	0.262	0.274	0.243
	0.000	0.000	0.000
ln(rooms)	0.300	0.265	0.351
	0.000	0.000	0.000
Apt from 0 to 4 floors	-0.036	-0.037	-0.062
	0.395	0.461	0.443
Apt from 5 to 10 floors	-0.163		-0.164
	0.006		0.049
Apt of more than 10 floors	-0.091		-0.146
	0.171		0.119
Apt of more tha 5 floors		-0.110	
		0.181	
Central Heating	0.037	-0.010	0.013
	0.805	0.931	0.964
Mobile Appliances	-0.191	-0.188	-0.198
	0.000	0.000	0.013
No Heating	-0.237	-0.299	-0.135
	0.000	0.000	0.153
Central Heating x Apt	-0.481		-0.456
	0.003		0.125
Bs As City	0.079		
	0.049		
Constant	2.572	2.517	2.806
	0.000	0.000	0.000
R^2	0.18	0.16	0.22
F(k,n-k-1)	54.15	47.51	22.13
Prob>F	0.00	0.00	0.00
Observations	3207	2127	1080

Household income elasticity is close to 0.22 and relatively constant for different areas. It is lower for Buenos Aires City , due to the presence of appartments that have central heating provision, as commented below. In turn, household characteristics such as household or family size (members) is quantitatively more important than income in explaining consumption differences, with an elasticity around 0.26. Also number of rooms, a proxy for the house size is also significant and more important than income. Appartments dummies related to the floors numbers were introduced to capture probable diffrences in consumption due to building conditions and the like and tend to suggest lower consumption due to better housing insulation (see on this Baker et.al. (1989) and Barkhout et.al. (2004)). But also because we found, early on in our research, that the interactive dummy of "central heating and appartmets" showed a sizeable reduction in the consumption of natural gas (-0.481 in column (1)) that reflects errors in the measurement associated with the NHES in Argentina. The fact is that households leaving in Appartments report expenditures of natural gas according to their bill. But billing procedures in Argentina have an individual bill for what is consumed in the appartment (e.g. appliances for cooking) and a separate, collective bill for the whole building (so called consortium). This later item is classified in "expenses" paid by households and associated with the building maintenance. As expected, this effect is due to Apartments in Buenos Aires City. Finally, households that report heating themsleves with mobile appliances consume less natural gas, presumably since some of these are electric appliances.

According to the simple model used in the previous section, the relative magnitude of income and characteristics elasticities should change in a high-price regime. Even though prices of natural gas in Argentina are currently (and due to the frezze in place since 2002) much lower than they were in the 90s and at the time of the NHES, there is plently evidence that natural gas for households was relatively cheap at that time[12]. Even when natural gas was in a rather low-price regime in the 90's, a natural test for the hypothesis developed in section 2 would be to compare estimates of elasticities then and now, given the huge drop in real prices since 2002 (with CPI inflation accumulanting more than 100% and end-user prices of natural gas being much the same). This will not be possible until the new NHES is made available.

Nevertheless, we argue that an indirect way of testing the hypothesis of section 2 is to compare results for natural gas and for LPG, the alternative fuel when NG is not available to households. LPG has a quite different price regime, with prices beign determined in (imperfect) competitive markets and with international or cross-border arbitrage. At the time of the NHES used in this study, the ratio (in calorific equivalent terms) between LPG and natural gas end-user prices (with taxes) was about 2.5 to 1. Thus, LPG demand was in effect facing a high-price regime and it is not surprising to observe that consumption of LPG per household is much lower even controlling for income and characteristics differentials.

The results for the consumption of LPG are reported in Table 4.

[12] This evidence comes not only from the relative magnitude of natural gas expenditures in houselhold expenditures (or even in energy household expenditures) in Argentina, but also if an international benchmarking of residential prices is made; see Navajas (2000).

Table 4: Consumption of LPG across households

Dependant variable: ln(consumption of LPG)	
Regresores	All Sample
ln(household income)	0.223
	0.000
ln(members)	0.078
	0.005
ln(rooms)	0.157
	0.000
Apt of more than 5 floors	-0.062
	0.708
Fixed Appliances	0.066
	0.248
No Heating	0.005
	0.896
Bs. As. City	-0.015
	0.850
constant	1.609
	0.000
R^2	0.15
F(7,1246)	28.96
Prob > F	0.00
Observations	1254

The income-elasticity is about the same magnitude as in the case of natural gas, while the characteristic elasticities related to both family size (Members) and house size (Rooms) are much lower. The ratio of the income to the family size elasticities, i.e. expression (5), is in this case 2.86, much higher than the the ratio 0.83 obtained for natural gas. The data seems to reject the linear demand model insofar as the behavior of elastities across low-price and high-price regimes is not consistent with predicted changes in these elasticities after an increase in prices (i.e. the income -elasticity remains constant rather than being increasing in price and the characteristic-elasticity falls raher than being increasing too).[13] But for the purposes of the hypothesis, the results show that the relative magnitude of income and characteristics in explaining the differences of consumption across households is indeed quite sensitive to the price regime. Income differences are more than three time important relative to characteristics in the high-price regime of LPG compared to the low-price regime of natural gas.

Results obtained in Tables 3 and 4 can be integrated in a single equation for gas that takes account of the differential effects of the explanatory variables according to the type of fuel being used by households. This is performed in Table 5, column (1), where regression results correspond to the whole sample of gas users. Columns (2) and (3) test the robustness of the results by restricting

[13] Another feature of the results is that the magnitude of the implicit price-elasticity of demand (equal to the income elasticity, according the previous model specification) is of a magnitude consistent with empirical (e.g. time-series) estimates for Argentina (see, for example, World Bank (1990) and FIEL (1995)).

the sample to households with income that are in the domain of the income of households that consume LPG (equation (2)) and besides live in houses (equation (3)). This allows to avoid the criticism that previous comparisons of natural gas and LPG equations come from different income-type of households. In other words, looking at a subsample of households with relatively lower income, the results remaing reasonably solid.

Table 5: Consumption of Gas across households

Dependant variable: ln(household consumption of natural gas or LPG)

Regresors	(1)	(2)	(3)
ln(household income)	0.220	0.196	0.221
	0.000	0.000	0.000
ln(household income) x LPG	-0.004	0.025	0.000
	0.898	0.558	0.999
ln(members)	0.260	0.290	0.292
	0.000	0.000	0.000
ln(members) x LGP	-0.178	-0.221	-0.221
	0.000	0.000	0.000
ln(rooms)	0.312	0.282	0.172
	0.000	0.000	0.031
ln(rooms) x LPG	-0.163	-0.149	-0.027
	0.007	0.044	0.761
Apt from 0 to 4 floors	-0.023	0.033	
	0.540	0.430	
Apt of more than 5 floors	-0.127	-0.022	
	0.015	0.770	
Central Heating	0.046	0.123	0.137
	0.754	0.511	0.469
Mobile Appliances	-0.182	-0.194	-0.174
	0.000	0.000	0.002
No Heating	-0.179	-0.185	-0.195
	0.000	0.000	0.000
Ceantral Heating x Apt	-0.475	-0.320	
	0.003	0.131	
Mobile Appliances x LPG	0.039	0.048	0.025
	0.502	0.449	0.726
Bs As City	0.068	0.034	0.027
	0.070	0.441	0.654
LPG	-0.731	-0.887	-0.838
	0.001	0.001	0.005
Constant	2.538	2.687	2.636
	0.000	0.000	0.000
R^2	0.48	0.51	0.53
F(k, n-k-1)	324.90	258.26	263.12
Prob > F	0.00	0.00	0.00
Observations	4461	3359	2668

(1) All Sample

(2) Reduced Sample 1: Only households with income similar to LPG users

(3) Reduced Sample 2: Similar to (2) but only for houses.

4 Welfare effects of low-user tariff scheme reforms

Starting from the previuos setting, one can evaluate the social welfare change of a tariff reform that proposes an introduction of a low-user tariff scheme in natural gas. Of course, this proposal need not, and in general will not, be superior to a scheme concentrating on LPG users or to other schemes that use additional information on household characteristics. Rather, the topic issue of this paper is to address the power of a scheme based solely on observed consumption and its dependance on observed engel curves that in turn may depend on the price regime. A low user tariff scheme can be defined as a modification of an original two-part tariff that changes both A and p in expression (2), below and above a given quantity level $x = \widehat{x}$. That is, the reform consist of a new tariff schedule:

$$T_1 = A_1 + p_1.x \quad \text{if } x \leq \widehat{x} \quad \text{and} \quad T_2 = A_2 + p_2.x \quad \text{if } x > \widehat{x} \tag{7}$$

This change from the original duple (A, p) may in principle include both the case of a conventional menu of two two-part tariff that must satisfy self-selection constraints, and the case where household segmentation is feasible and two different bundles are offered or imposed to households.

Replacing demand equation (4) into the utility function (1) allows us to write the maximum value function:

$$U^* = U(p, Y, z, A) = Y.V(x^*(\frac{p}{Y}, z), z) - A - p.x^*(\frac{p}{Y}, z) \tag{8}$$

Ordering households $h = 1, ..., H$ according to its per-capita income $y^h = Y^h/z^h$ we can write social welfare as:

$$W = \sum_h \beta^h(y^h).U^{h*}(p, Y, z, A) + \Pi(p, Y, z, A) \tag{9}$$

where β^h is the social marginal utility of income of household h (which depends negatively on y^h)[14] and $\Pi(.)$ are profits from the sale of x which in the initial (before reform) two-part tariff (2) can be written as:

$$\Pi(p, Y, z, A) = H.A + (p - c). \sum_h x^{h*}(\frac{p}{Y^h}, z^h) \tag{10}$$

where c is the marginal (assumed constant, without loss of generality) cost of x. Starting from (7) which is based on the schedule defined by the duple (A, p) and considering small changes, a low-user tariff scheme reform is a differentiation of both fixed charge A and marginal price p, for consumption values lower or higher than $\widehat{x}$. We assume changes in T for households that consume $x \leq \widehat{x}$ ($x > \widehat{x}$) such that $dT \leq 0$ ($dT > 0$). That is, denoting "1" ("2") the changes in the new schedules for quantities less (greater) than $\widehat{x}$, we have that $dT_1^h = dA_1 + dp_1.x^h \leq 0$ (assuming, by construction, that $dT_1^h = 0$ for $x = \widehat{x}$) and $dT_2^h = dA_2 + dp_2.x^h > 0$. That is, consumers with low (defined relative to $\widehat{x}$) consumption will receive a tariff reduction and those with high consumption will see an increase in their bills.

[14] Private marginal utility of income is constant and unitary in the model of section 2. Thus, the β are social weights contained in the welfare function $W(.)$

Since the reform is assumed to be neutral in profits, starting from a situation where the firm earns a fair rate of return[15], we have that changes in W in expresion (9) are explained by changes in the sum of weighted utilities of households. Totally differentiating expression (9) with respect to A and p for $x \leq \widehat{x}$ and $x > \widehat{x}$, and given that from the envelope theorem $\partial U^{h*}/\partial A = -1$ and $\partial U^{h*}/\partial p = -x^{h*}$ we have (given that $d\Pi = 0$):

$$dW = -\sum_h \beta^h(y^h).dT_1^h.I^h(x^h \leq \widehat{x}) - \sum_h \beta^h(y^h).dT_2^h.I^h(x^h > \widehat{x}) \tag{11}$$

where $I^h(.)$ is an indicator function that takes value 1 when the expression within brackets holds and zero otherwise. Expression (11) says that the welfare dominance of a low-user tariff scheme reform requires that the socially weighted sum of transfers to the beneficiaries of the low-user scheme must be greater than the equivalent transfers from the the rest of households. Given that transfers for low-user scheme beneficiaries and from the rest of households dT (with $-dT_1^h, -dT_2^h$) are by construction decreasing in x (albeit not necesarily continuous functions), a crucial determinant of the positive sign of expression (11) is that $\beta^h(y^h)$ is decreasing across x. For this to hold it is required that x^h be increasing in y^h, i.e. total household consumption must be increasing in household per-capita income.

This condition is implied by the nature of the engel curve obtained from the demand structure of the model of section (2). Starting from demand equation (4) and assuming that demand is homogeneous of degree k in household income y and family size z, we can write:

$$x^* = g(\frac{p}{Y}, z) = z^k.g(\frac{p}{y}, 1) \tag{12}$$

Differentiating (12) with respect to y and considering that z changes across y [16]we have that the total income elasticity of demand, that expresses the relationship between observed consumption and household per capita income in the data ca be written as:

$$\frac{dx^*}{dy}.\frac{y}{x^*} = \eta_{x,y} - \eta_{x,z}.\eta_{z,y} \tag{13}$$

where $\eta_{x,y}$ and $\eta_{x,z}$ are per capita income and family size elasticities and $\eta_{z,y} = -\frac{\partial z}{\partial y}.\frac{y}{z}$ is an elasticity of family size with respect to per capita income. From expressions (11) to (13) and the assumptions there in (dT decreasing in x, β decreasing in y) a necesary and sufficient condition for a low user tariff scheme

[15] We assume that the original tariff $T(A, p)$ has already solved the regulatory problem and that the introduction of a low-user scheme must keep profits at the same level. This allow us to separate the evaluation of the (social) tariff structure associated with a low-user scheme from the setting of the right regulated price level.

[16] z was not taken as an explicit funtion of income in the specification of demand equation (4) since family size is not modelled here, and to separate income and characteristics elasticities of demand. The same result could have been obtained by specifying $z = z_0 + z_1(y)$.

refom to be weakly welfare enhancing, i.e., $dW \geq 0$ is that expression (13) is non negative. On the other hand, the condition says nothing about the "power" (i.e. the magnitude of the welfare gain) of a low-user scheme tariff refom in itself or vìs-a-vìs other potential schemes that better discriminate using observables.

Computing (13) for the empirical study done in section 3 requires a respecification of regresion equations so as to estimate previous elasticities. This is done in Table 6, that follows the specification for all gas users adopted in Table 5 -except that income is expressed in per capita terms-, and shows qualitatively similar results.

Table 6: Consumption of Gas Across Households (per capita income)

Variable Dependiente: ln(household consumption of gas)

Regresors	(1)	(2)	(3)
ln(household per capita income)	0.220	0.196	0.221
	0.000	0.000	0.000
ln(hous per cap income) x LPG	-0.004	0.025	0.000
	0.898	0.558	0.999
ln(members)	0.480	0.487	0.512
	0.000	0.000	0.000
ln(members) x LPG	-0.183	-0.196	-0.221
	0.000	0.000	0.000
ln(rooms)	0.312	0.282	0.172
	0.000	0.000	0.031
ln(rooms) x LPG	-0.163	-0.149	-0.027
	0.007	0.044	0.761
Apt from 0 to 4 floors	-0.023	0.033	
	0.540	0.430	
Apt of more than 5 floors	-0.127	-0.022	
	0.015	0.770	
Central Heating	0.046	0.123	0.137
	0.754	0.511	0.469
Mobile Appliances	-0.182	-0.194	-0.174
	0.000	0.000	0.002
No Heating	-0.179	-0.185	-0.195
	0.000	0.000	0.000
Central Heating x Apt	-0.475	-0.320	
	0.003	0.131	
Mobile Appliances x LPG	0.039	0.048	0.025
	0.502	0.449	0.726
Bs As City	0.068	0.034	0.027
	0.070	0.441	0.654
LPG	-0.731	-0.887	-0.838
	0.001	0.001	0.005
constant	2.538	2.687	2.636
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R^2	0.48	0.51	0.53
F(k, n-k-1)	324.90	258.26	263.12
Prob > F	0.00	0.00	0.00
Observations	4461	3359	2668

(1) All Sample

(2) Reduced Sample 1: Only households ith income per capita similar to LPG

(3) Reduced Sample 2: Similar to (2) but only for households in houses.

Using the estimates from Table 6 along with the estimated elasticity of family size with respect to per capita income, which is 0.30 for household that use natural gas (0.33 for LPG users)[17], we find positive estimates of the total

[17] The elasticity was estimated by OLS with a simple double log specification of members

elasticity in expression (13) and values of 0.076 for natural gas and 0.147 for LPG. Empirical values therefore suggets that a low user tariff scheme reform for natural gas in Argentina would satisfy conditions for improving welfare, even though the value of the estimated (total) elasticity of consumption with respect to per capita income suggests that the magnitude of the welfare gain can be rather small. Following the hypothesis posited in this paper, the magnitude would be dependant on the price level from which the reform is undertook.

5 Final Remarks

This paper was motivated by queries about the rather poor relationship between consumption and income in energy infrastructure markets such as residential electricity and natural gas and its implication for the desirability of low user tariff schemes. We derived some results from a simple model of demand that accomodates income and characteristics effects across households that suggest that the price level or price regime is relevant for the relative magnitude of these effects. In a very intuitive way, very low prices tend to depress the across households income elasticity of demand in favor of the characteristics-elasticity and the opposite holds for high prices. We further use a microdata base from the consumption of natural gas and LPG in Argentina to estimate consumption equations and characteristic-augmented engel curves which, appart from obtaining interesting results on the determinants of gas consumption in the metropolitan area of Buenos Aires, allow us to indirectly test the hypothesis derived from the model, as we use LPG as a proxy for a high-price regime compared with the low-price regime represented by natural gas. Finally we address the issue of the welfare effects of low user scheme tariff reforms in an original two part tariff and obtain conditions for welfare enhancing reforms in natural gas in Argentina. The results of this paper point to some main points to conclude and qualify the extent of the results.

First, the evaluation of low-user scheme tariff reforms, insofar as the impact on different households is concerned, should not performed at initial, observed prices if the reform is going to follow a large increse in the tariff level, as is likely to be the case in environments were prices are too low. This is to say that evaluations should not be based on parameters or patterns of consumption observed in very low-price regimes, where characteristics will dominantly explain observed consumption across households. This is a relevant point for the pending reform in Argentina, both for natural gas and electricity.

Second, low-user tariff schemes can be welfare enhancing, but the magnitude of the welfare gain may be marginal, i.e. the power of the reform for relieving the burden of tariff increases on low income households can be small. In the case of Argentina, this may not only be due to the fact that LPG users are normally excluded (which in itself calls for a priority treatment of that group) but also from the evidence of the degree of correlation between consumption and income. Recent segmentation proposals of the residential consumers tariff category in

against per capita income of household.

Argentina are therefore going to have low welfare effects if a differentiation of tariffs according to consumption levels is to be introduced. Even if prices were to jump substantially above the 1990s levels, results do not suggest that welfare gains are going to turn to be substantial.

Third, results call for applied research on richer schemes that will have to introduce observed attributes that may dillute errors of exclusion (of low income) and inclusion (of high income) households in the group that will benefit from the subsidies. Nevertheless it is unlikely that quantities consumed will be excluded as a usable attribute for designing a so called social tariff, for at least two reassons. First, quantities consumed are indeed shown to be positively correlated with income and therefore the value of information (related to the household type) to be included is positive. Second, limits to the subsidies beyond some consumption level is going to be desirable not only to avoid undue subsidization or for budgetary reasons but also if inefficient energy consumption is going to be avoided.

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