Prepaid Meters in Electricity. A Cost-Benefit Analysis

Ariel A. Casarin[†]
Luciana Nicollier[#]

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Abstract

Prepaid meters have being widely adopted by utilities in different countries. Yet, its practice is still controversial. This paper uses cost-benefit analysis to assess the adoption of prepaid meters in a local district. The analysis highlights how the role of tariffs, the cost of start-up investment and the socio-economic characteristics of the population affect system performance. Several simulation exercises examine the sensitivity of results to changes in some distinctive elements of policy implementation. The paper also summarizes the results of a survey conducted among local electricity users. Results indicate that prepaid meters lead to an increase in welfare. They also indicate that the advantages of the system are linked to the reduction of arrears in accounts receivables and of operational and financial costs on the part of the service provider and to a better allocation of resources for the user. Consumer evidence, however, suggest that the main arguments against prepayments relate to the possibility of self disconnection by low income consumers.

Keywords: Cost-benefit analysis; prepayment meters; regulation; electricity

[†] Corresponding author. IAE Business School, Universidad Austral. Mariano Acosta s/n y Ruta Nac 8. Casilla de Correo 49. B1629WWA Pilar, Buenos Aires. Argentina. Tel: +54 2322 481000. FAX: +54 2322 481050. ACasarin@iae.edu.ar.
[#] University of Warwick – Department of Economics. Coventry, CV4 7AL. United Kingdom. L.A.Nicollier@warwick.ac.uk

1. Introduction

The social dimension of utility reforms in less developed countries involves at least two clearly related problems. The first is to improve access to infrastructure services, a challenge that has spurred industry restructuring, private sector involvement and consequential regulatory reforms. The second challenge, which originates in the economic efficiency goal of establishing cost-reflective tariffs, is to ensure that consumers can afford the cost of utilities services. These concerns have motivated firms and regulators to identify technological and regulatory options aimed at encouraging access and making easier for consumers to pay for their services. In both cases, Latin America has pioneered the adoption of innovative mechanisms. In the first case, higher access rates have been encouraged with the identification and imposition of connection targets, the creation of community involvement and micro credit programs, and the use of new technologies. In the second case, higher levels of affordability have been sought for with the use of instruments that ease the burden of bills via cost and tariff cutbacks and the introduction of alternative payment means.

Indeed, most of the efforts oriented towards securing higher levels of affordability have consisted of mechanisms aimed at reducing the cost of services, either by affecting their quality or by reducing their demand. Other efforts have been targeted, however, towards the adoption of various subsidy schemes, either directly or through tariff structures (Gómez-Lobo and Contreras, 2004). In general, experiences with policies that adopt alternative payment methods for utilities have been scarce. The simplest alternative, which is often suggested, consists of increasing the frequency of billing to low income users.[1] However, a disadvantage of this mechanism is that it would increase administrative collection costs, which would ultimately result in higher tariffs (Estache et al. 2000).

Over the last few years, however, prepayment meters – either in electricity, water or piped gas – have been proposed as an innovative solution aimed at facilitating affordability and reducing utilities' cost. This mechanism essentially requires that users pay in advance for the delivery of goods or services, before their consumption. In this way, consumers hold a credit and then use the service until the credit is exhausted. Prepayment systems have been introduced for the first time in South Africa but are now widely used in the UK, Turkey and India (Tewari and Shah, 2003). Yet, their use is still controversial. On the one hand, those that

[1] This system has been adopted, for example, in the concession of water services in La Paz-El Alto. In this case, the utility opened commercial offices in low-income areas to facilitate payment of services, so that users could cancel the cost of their consumption at least once a week.

support the diffusion of prepaid meters claim that they benefit both consumers and utilities because they help users to consume more efficiently and to improve the management of their budget, while allowing firms to reduce financial, operational and bad debts' costs. On the other hand, those that are against to prepaid meters argue that their adoption is expensive for firms and risky for low income consumers, as the insecurity and volatility of their income may force little service usage or, ultimately, involuntary self-disconnection. None of these arguments have been comprehensively examined before.

This paper uses cost-benefit analysis to evaluate the implementation of prepaid electricity in Carmen de Areco, the first municipality to have adopted them in Argentina. Indeed, the district's electricity distribution utility offers prepaid meters to all users since 1996, which creates a data rich experiment to apply cost-benefit techniques to evaluate the adoption of prepayment systems. The study thus contributes to the analysis of policies oriented to ease affordability for at least two reasons. First, because it conducts a complete analysis that factors in the end results of prepaid meters implementation in respect of users, the utility and the government. Second, because it makes possible to identify the components of the results – i.e. where gains and losses come from – and through this process to help establish regulatory definitions concerning prepaid meters, which in many cases have yet to be made. The empirical evaluation is complemented with an examination of the results of a survey that explores the perception of users about prepaid meters.

The rest of the paper is organized as follows. Section 2 describes the main features of prepayment meters in electricity. Section 3 examines the socio-economic features of the local district under study and contrasts the districts' indicators against those of other areas. Section 4 presents the cost-benefit model, its implementation and the data used in the analysis. Section 5 presents and examines the main findings. This section also reports the results of several simulation exercises that explore the sensitivity of results to changes in the implementation of prepaid meters. Section 6 summarizes the main findings of a survey carried out among the district's electricity users. The last section concludes.

2. The technology and economics of prepaid electricity

Prepayment systems refer to the outlay made by a consumer for using a good or service before consumption. In the case of electricity, the distinctive feature of the prepayment system is the reversion of the conventional commercialization system: whereas in the latter consumers hold a consumption credit because they pay for their energy bills periodically and after consumption, in the prepayment system such credit is not available because the purchase and payment of energy are made prior to consumption. Thus, prepaid systems allow users to consume energy only when they have credit in an electricity account, as supply is discontinued when such credit is exhausted.

The prepayment technology was initially developed in South Africa in the late 1980s with the objective of supplying energy to a large number of low-income and geographically dispersed users. The system was initially geared to minimizing the difficulties arising from users' irregular incomes and to overcoming the limited development of the infrastructure required for the dispatch and reception of credit slips. By the late 1990s, prepayment systems were very popular in India and in some OECD countries (Estache *et al.*, 2000), and had probably reached their highest development in Great Britain (Waddams *et al.*, 1997). In Argentina, prepayment meters were firstly introduced in 1993, when Energía Mendoza Sociedad del Estado (EMSE) put a few running in small shops at the Mendoza Bus Central Station.[2] The experience was soon extended to other communities in the country.

From a technological point of view, the prepayment system consists of three well differentiated components. The first is a service meter installed at the unit where energy will be consumed, such as a household dwelling or a store. In general, these meters are of the "two-gang" type and consist of a user's interface unit and a current measuring set. The interface unit is a device installed inside the building, which allows the user to "interact" with the meter. The metering unit, on the other hand, is the intelligent component that stores credit and consumption information and it makes up the element that either clears or switches off electricity supply. The second component of the system is the so-called credit dispensing unit, which is the vending machine where consumers can purchase electricity credit. In general, these sales outlets are located at the utility's commercial offices as well as in stores with long opening hours. The third component is the supporting device that links the various sales outlets to the utility's management system.

The way the system works for the user is simple. The user purchases energy at the sales outlet and, as part of the operation, receives a credit slip and a supporting device that identifies the operation, which may be a voucher with an identification code or another with a magnetic support. The user then utilizes the device to add on her new consumption credit, either by

[2] EMSE was privatized in 1998. This first experience consisted of the installation of 100 meters to commercial users only.

entering a code or inserting the magnetic medium into the interface unit, which in both cases will be possible only if the device identification matches that of the meter.[3] The measuring unit then clears consumption of the amount of energy purchased and also displays, in real time, the available credit remaining for consumption. The meter switches off when credit is exhausted, and it switches on again only when the device corresponding to a new purchase is inserted.

From an economic perspective, the reversion of the commercialization system as implied by prepaid meters translates into changes in the cash flow of the utility and in consumers´ behavior. In the case of the firm, prepayment systems may result in a decrease in metering, billing and disconnection and reconnection costs. The fact that payment is made prior to consumption implies both a significant improvement in the collection of revenues and a reduction of working capital. Moreover, prepaid systems may constitute a way to provide more flexible payment options to users with minimal or unreliable income streams without increasing transactional costs to the firm. From the consumer's perspective, prepayment systems may result in a better understanding of how much energy is being consumed, inducing more control of energy use and budget management (Tewari and Shah, 2003). However, these apparent improvements are not cost free: not only the change from conventional to prepaid electricity imply a change in consumption habits, which may reduce the utility of consumers, but also it may result in too few electricity consumption or in the self-disconnection of poorer groups of consumers.

3. The adoption of prepaid meters: the case of a local district

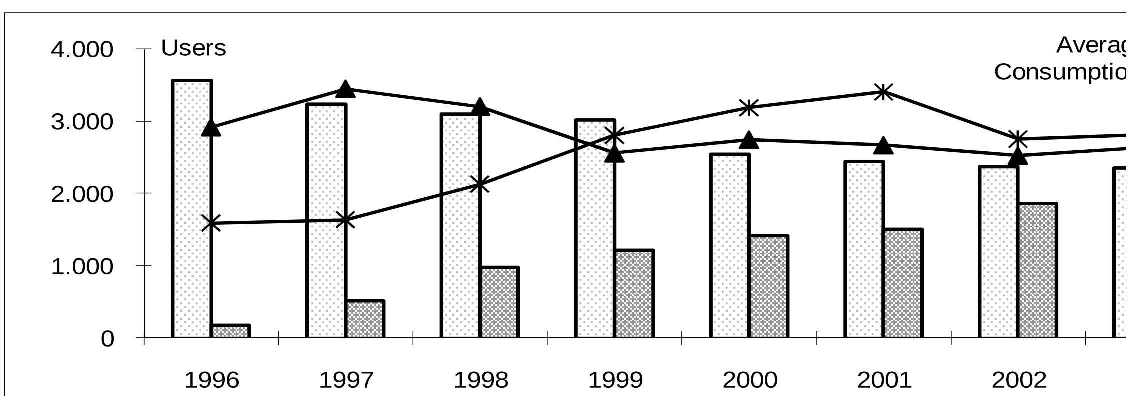
The prepayment system in electricity was adopted for the first time in Argentina in 1996, when CELCA[4], the power distribution company of Carmen de Areco – a small municipality of the Buenos Aires Province – made optional to all consumers within its franchise area the use of prepaid meters. CELCA was created in 1945 and is one of the almost 200 municipal electricity distribution utilities operating in the Province of Buenos Aires. These utilities – most of which are organized as cooperatives – were traditionally allowed to set their own tariffs until 1996, when privatization of the then vertically integrated electricity operator of the provincial state – called ESEBA – resulted in the creation of independent power producers, three new regional electricity distribution utilities – in whose exclusive franchise

[3] In this way, theft or loss of bills already paid can be avoided.
[4] CELCA stands for Cooperativa de Electricidad de Carmen de Areco

areas municipal utilities operate – and a new provincial regulatory authority, named as Organismo de Control de Energía Eléctrica de la Provincia de Buenos Aires (OCEBA). Following privatization, local electricity distributors purchase energy from one of the three regional utilities at OCEBA's regulated tariffs.[5] This agency also regulates the final tariffs local distributors charge to final consumers.

Table 1 summarizes some economic indicators for CELCA before and after the implementation of prepaid meters. By 1996, when the system became available, the utility had 4,888 users, three quarters of which were residential. A total of 134 users switched to prepayment during 1996. The series show that average demand have remained roughly stable except for those using prepaid meters, which have increased theirs since 1996. Figure 1 complements because it shows that, by 2003, average demands of residential users of prepayment converged to those of the conventional system. It also illustrates that the number of residential users of prepaid meters increased steadily, reaching to about 45% of total residential users by 2003.

Figure 1
Residential Users of Energy and Mean Annual Consumption
CELCA. By type of system; 1996-2003



Source: Own estimates based on CELCA's Annual Reports.

Table 1 also summarizes performance indicators of the utility. The data show that the average tariff increased 40% between 1992 and 1996, since when it has reduced slightly. CELCA encouraged the prepayment system by granting those that switch a 5% discount on unit charges, despite that fact that switchers had to pay for the new meter and its installation cost. The data show that revenues, assets and the firm's equity all increase much faster between 1992 and 1996 than between 1997 and 2003, when prepaid meters were in use. It is interesting to contrast, however, the composition of the firm's asset structure before and after

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[5] Alternatively, local electricity distributors can purchase power from the Wholesale Electrical Market (MEM), in which case a transportation cost should be added. By 2003, about 20% of local distributors were members of MEM.

implementation of prepaid meters. The data show that liquid assets and investments notably increased since adoption of the prepayment, reversing the deteriorating trend that prevailed before. Moreover, the figures display that the upward trend of accounts receivable was reversed, to the extent of allowing the firm to significantly reduce the total amount of unpaid bills.

Table 1
Major Economic Indicators
CELCA. Various years

	1992	1996	2003	Δ Annual Average 1992-1996 (%)	Δ Annual Average 1996-2003 (%)
Conventional Users					
Residential	3,197	3,563	2,360	2.7	-5.7
Industrial	50	110	84	21.8	-3.8
Other (1)	1,197	980	931	-4.9	-0.7
Prepayment Users					
Residential	0	184	1,974	268.3	40.4
Industrial	0	3	11	31.6	20.4
Other	0	48	302	163.2	30.0
Total	**4,444**	**4,888**	**5,662**	**2.4**	**2.1**
Average Annual Consumption (kW)					
Conventional Users					
Residential	1,214	1,458	1,322	4.7	-1.4
Industrial	22,213	54,605	56,723	25.2	0.5
Other	5,374	5,040	4,887	-1.6	-0.4
Prepayment User					
Residential	0	795	1,407	431.0	8.5
Industrial	0	25,343	62,595	1.161.7	13.8
Other	0	2,671	4,324	618.9	7.1
Average Tariff	**0.10**	**0.14**	**0.13**	**8.2**	**-0.8**
Revenue	**1,814,343**	**2,392,419**	**2,871,011**	**7.2**	**2.6**
Assets	**2,192,814**	**3,615,308**	**3,689,441**	**13.3**	**8.7**
Cash and equivalents	29,987	21,580	85,662	-7.4	21.8
Investments	20,123	14,040	118,712	-8.6	35.7
Accounts Receivable	602,681	1,235,519	813,840	19.7	-5.8
Fixed Assets	1,183,528	2,034,615	2,201,509	14.5	1.1
Inventories	245,012	248,463	414,948	0.3	7.6
Other Assets	111,484	61,090	54,769	-13.9	-1.5
Equity	**853,761**	**2,303,861**	**2,974,780**	**28.2**	**3.7**

Source: Own estimates based on CELCA's Annual Report and Balance Sheet.
Note: (1) Includes business and rural users, the waterworks firm and other government agencies as well as non-paying users and the utility's own consumption.

Table 2 summarizes demographic and socioeconomic features of the district and collates them with those of other Buenos Aires' districts and the national total.[6] The data show that Carmen de Areco has almost 14,000 inhabitants, a population considerably smaller than the average of 46,000 of those provincial districts beyond the Greater Buenos Aires area, which are about

[6] The Buenos Aires province is divided into 134 districts. The Greater Buenos Aires is the urban sprawl including the City of Buenos Aires – a separate federal district - and 24 surrounding districts of the Buenos Aires province.

eight times larger.[7] Population density in Carmen de Areco is remarkably lower than the provincial average, though similar to that of the country as a whole. Socio-economic statistics show that the district's unmet basic needs and unemployment are not very different from the provincial average, though both figures are higher than those of the Greater Buenos Aires and the rest of the country.[8] In general, the data show that the district's working population has an educational level that is below the average of both the Buenos Aires Province and the country.

The last rows of Table 2 present information related to consumer's access to basic services. The statistics indicate that coverage of sewerage services in Carmen de Areco is higher than in the rest of the province and the country, whereas water coverage is not. They also suggest that the district is poorly covered by the natural gas grid. This is not the case of electricity, as virtually all households in the district are covered by this service. All in all, it becomes then apparent that the utility's difficulties with electricity services provision relate to users' affordability problems than to coverage challenges. The next section details the economic model used to examine whether prepaid meters alleviate this problem and contribute to economic welfare.

4. The model

We examine the adoption of prepaid electricity using cost-benefit analysis techniques. This method consists of comparing the performance of the electricity distribution system in the local district after the adoption of prepaid meters (the factual scenario) with what that performance would have been had prepayment meters not been adopted (the counterfactual scenario). Thus, we construct for the utility a counterfactual scenario that serves as our control. The welfare gains (or loss) that we estimate below are then the difference between the level of welfare in the factual and counterfactual scenarios. The basic notion behind this partial cost-benefit analysis is thus very simple: adoption of prepayment meters should be encouraged if benefits exceed those of the best available alternative, which is represented by the counterfactual, but not adopted in the opposite case.

[7] Carmen de Areco's surface area is 1,080 sq. km, most of which is devoted to agriculture. Other activities include the manufacture and repair of agricultural implements, cheese making and meat-packing plants.

[8] The National Statistics Bureau (INDEC) defines households with unmet basic needs as those where (1) there are more than three residents per room; (2) there is no privy; (3) at least one of the residents is a school-age child who does not attend school; (4) there are four or more persons for each employed household member and the household head has not completed the third year of primary school

Table 2: Demographic and socioeconomic data for the district of Carmen de Areco

Comparison with Buenos Aires Province and National Total; 2001.

	Carmen de Areco	Greater Buenos Aires				Rest of Buenos Aires Province				Total
		Max.	Min.	Average	Total	Max.	Min.	Average	Total	National
General Characteristics										
Population	13,876	1,255,288	118,807	361,852	8,684,437	560,666	1,709	46,086	5,142,766	36,260,130
Households	4,211	333,688	29,561	99,337	2,384,089	177,019	487	13,968	1,536,507	10,075,814
Population density (inhabitants / km2)	13.0	163.6	10.068.5	4.213.7	2.394.4	654.8	0.9	60.2	16.9	13.0
Unmet basic needs (%)										
Households	9.0	26.7	4.3	14.7	13.0	26.3	4.8	10.1	11.0	14.3
Population	10.0	30.4	4.8	17.2	16.0	30.0	4.3	11.3	13.0	17.7
Unemployed[1] (%)	23.4	35.6	13.5	25.71	36.4	42.7	14.2	23.5	27.0	28.5
Retired heads of household (%)	18.3	24.6	10.1	17.24	18.3	28.9	0.2	21.0	21.0	18.9
Education (%)										
Illiteracy	2.4	2.6	0.5	1.5	1.6	3.9	0.6	1.9	1.6	2.6
Educational Level of Employed Population										
Without schooling or unfinished primary school	15.5	15.8	2.9	9.7	9.5	24.5	4.7	12.5	10.1	12.4
Finished primary school or unfinished secondary school	55.6	58.4	23.1	46.1	45.4	59.4	32.7	51.5	46.4	42.2
Finished secondary school or unfinished secondary school/university	18.6	43.5	20.3	31.3	31.9	38.1	13.2	22.9	27.9	29.6
Tertiary Education Completed	6.5	10.5	3.8	6.3	6.4	11.9	3.8	7.7	7.6	7.2
University Education Completed	3.9	19.8	1.7	6.5	6.7	16.8	1.4	5.4	8.0	8.5
Public Services (%) [2]										
Sewage	61.0	98.4	4.3	14.7	50.0	87.3	1.9	53.5	50.3	54.8
Running water	74.4	100.0	9.3	65.3	75.0	99.4	24.0	79.9	75.1	84.6
Electricity	97.7	99.7	9.3	97.2	97.0	99.2	64.4	93.3	96.8	95.5
Piped Gas	50.2	98.6	44.0	82.0	78.0	93.6	1.1	63.1	78.5	65.5
Pavement	76.2	99.1	67.6	86.1	82.0	96.9	35.2	69.2	81.7	72.8
Public Transportation	11.5	98.9	80.0	92.5	84.0	89.5	2.5	44.2	86.9	79.3
Garbage Collection	85.8	99.6	88.9	95.5	94.0	99.7	49.5	86.6	93.7	89.8

Source: National Population, Households and Housing Census, 2001. Notes: (1) Population 14 years old or older. (2) This refers to households where the service is available.

The model is based on the assessment of social welfare for each scenario and its distribution among groups. The model requires discerning the difference between two results: the social value of the system under the prepayment system and its social value if that innovation had not been adopted. The net effect on social welfare can thus be estimated adding up the net welfare changes of each group. These changes can all be expressed as $\Delta W = \lambda_c \Delta C + \lambda_\pi \Delta\pi + \lambda_G \Delta G$, where ΔW represents the total net social welfare change, ΔC the changes in consumers' welfare, $\Delta\pi$ the changes in the firm's profits, ΔG the changes in the government's income, and λ the weighing of each component on welfare.[9] Thereby, the cost-benefit analysisl requires constructing a simple model for each of the groups involved and then to calculate the changes in each one's welfare. The aggregated results for each group leads to a final outcome for all groups.

4.1 Changes in consumers' welfare

Consumers switching from the conventional to the prepayment system face two types of cost. One refers to the direct monetary cost, while the other refers to differences in habits that result from replacing a post-consumption and single monthly payment with more frequent payments, which occur prior to consumption.[10] The main direct monetary effect is the cost of the new meter and its associated opportunity cost, which we proxy using the interest rate for savings accounts deposits. Other direct monetary effect includes possible changes in the cost of electricity due to tariff differentials. In this case, however, users benefit from a 5% discount on the final unit price of electricity consumed. Finally, users also pay the opportunity cost arising from advance payment of consumption, which was estimated relating consumers' average expenditure to a rate capturing the opportunity cost of money.

Periodical purchases of electricity imply a change in consumer habits, because they have to incur the extra costs associated to the time spent on additional buys. The extent of this cost would vary with the periodicity of energy reloads (it would be neutral if reloads occurred once a month, as this would demand an effort similar to that incurred when paying the conventional monthly bill) and it would be directly dependent on the user's salary; it is possible to presume that the higher an individual's salary, the higher the opportunity cost of her time. We therefore estimate this cost by firstly computing an average hourly cost that we approximate using census income data for the district, and then multiplying that cost by both the estimated

[9] This formulation allows each group to carry a different weight, which may stem either from efficiency or equity considerations (thus, the existence of taxes or other distortions may imply that one additional dollar of government revenue may displace more than one consumption dollar).

[10] The results of these changes could be examined with an econometric estimate of the users' indirect utility function, which in this case was not possible because the number of observations was insufficient to obtain reliable results.

duration of each reload and the average number of yearly purchases made by each household using the prepayment system.[11]

4.2 Changes in utility's profits

The effects of introducing the prepayment meters on the firm's profits were estimated as $\Delta\Pi = \Delta R - \Delta C - r^F\Delta F - r^V\Delta V$, where ΔR sums up income changes, ΔC the change in operating costs, $r^F\Delta F$ the changes in the cost of fixed capital F at a r^F rate, and $r^V\Delta V$ those in net working capital V invested in electricity distribution at a rate r^V. Economic profits differ from accounting profits because r^F includes not only depreciation and the cost of debt, but also the expected return of shareholders, and it is also different from accounting profits because it factors in the opportunity cost of the net working capital ($r^V V$).

Income changes ΔR_t for each year t were obtained by breaking them down into its price P and quantity Q components for each user category i registering prepayment users using the formula $\Delta R_{it} = \Delta P_i \cdot Q_{t-1} + \Delta Q_i \cdot P_t$. Then, $\Delta R_t = \sum_i \Delta R_{it}$. Income changes were then computed using tariff and demand data for each user category that come from the firm's annual reports. The prepayment system may impact the firm's operating cost associated to meter readings, dispatch of correspondence, collection costs, invoice claims and disconnecting service. Cost changes could be obtained through an econometric estimation of the firm's cost function, which in this case was not possible because of the limited number of observations. Therefore, cost changes ΔC were estimated by linking an estimation of the amount of inputs applied in those activities to their cost, which were estimated with data from the firm financial statements (see Ofgem (1999) for a similar approach).

Cost changes due to bad debts were estimated collating for each year a rate for bad debts for each scenario, which was then multiplied by total sales. For the factual scenario, the bad debts rate was obtained from the quotient between the costs of bad debts (resulting from the sum of all charges to profit and loss in concept of allowances for this concept plus court costs) and sales, while in the case of the counterfactual scenario they were projected using average rates over the years prior to the adoption of the prepaid system (1992-1996).

Changes in working capital ΔV were estimated for each scenario by applying an opportunity cost rate r^V to the difference between the product of each year's sales and the cash conversion

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[11] Unfortunately, the unavailability of data at the household level precluded us to account for income differences across households to estimate this cost.

cycle. In the factual scenario, the latter was obtained by multiplying the sum of the inverse of the rates of cash turnover, accounts receivable and accounts payable times 365.[12] The counterfactual scenario was projected using average rates over the years prior to the adoption of the prepaid system (1992-1996). Opportunity costs for both scenarios were approximated by the average rate for current account advances to the private sector. However, if the cash conversion cycle was positive, the opportunity cost for each year was estimated by the average rate for saving account deposits. All series come from the Central Bank.

Changes in fixed assets ΔF are of two types. The first consists of the cost of new prepayment meters, which in this case affects the firm only as regards to depreciation charges, as meter costs are incurred by users, although replacement cost at the end of their useful life is considered as the utility's responsibility. The second type of changes is associated with the new equipment needed to operate the system (the equipment to issue vouchers for reloading at the sales outlets and to link this information to the utility's operation systems). These costs stem from the incorporation of computer equipment, and their magnitude was obtained during interviews held with the firm's management. Estimations assume the useful life of such assets to be of 7 years, which together with an opportunity cost r^F equivalent to 14% results in an annual cost for their use equivalent to 30% of their value.

4.3 Changes in government revenue

Changes in government revenue result from the effects that adoption of the prepayment system cause on fiscal revenues at the various levels of government. Tax receipts are affected not only because consumption of electricity is variously taxed but also because the sale of prepayment meters implies an increase in the collection of value-added and income taxes.

Federal taxes on power consumption are the Value Added Tax (VAT) and the Santa Cruz Provincial Fund (Law 23681) tax. The tax rate of the former is 21%, while the latter's – aimed at financing the works of interconnection to the national grid and to subsidize the cost of electricity in Santa Cruz Province – is 0.6%. Provincial levies, on the other hand, are the Special Fund for Major Provincial Power Projects (Law 9038), the Province's Electrical Power Development Fund (Law 7290), the Law 9226 Fund, and the Law 11969 Tax.[13] The former two are applicable to residential users only, with rates of 5.5% and 10%, whereas the

[12] The cash flow was obtained for each year by dividing sales by average cash balance; the accounts receivable turnover was calculated as the quotient between sales and the average balance of such accounts; and the accounts payable turnover was estimated dividing the cost of sales and the running costs by the average balance of the accounts payable.

[13] Receipts of the Special Fund for Major Provincial Power Projects and the Province's Electrical Power Development Fund are intended to expand the service and finance investment related to electricity generation, while revenue from the other two taxes is assigned, in the latter case, to the collecting municipality, and in the former, to the province's treasury department.

other two are applicable to all users (except municipal distribution utilities and public lighting) with rates of 6% and 0.6%, respectively. Electricity consumption is also taxable for the Provincial Rate Equalization Fund, which with a 5% rate seeks to balance final prices in the Buenos Aires province by compensating cost differences among suppliers. Changes in government revenue were thus estimated by applying the aforementioned rates to the changes in the utility's income, as explained above. Changes in receipts relating to the sale of prepayment meters were estimated by applying, respectively, the value-added and income taxes to sales and the supplier's estimated profit.

5. Results

Table 3 summarizes the results (in 1996 constant pesos) of the cost-benefit analysis of the adoption of prepaid meters, and the distribution of net welfare changes across consumers, the firm and the government. The rows in the table distinguish each element that was considered to compute net welfare changes. The series also show the distribution of these results over time, and distinguish those of the 1996-2003 period from those projected for future periods, which consist of adding the results projected for each year between 2004 and 2008 to those projected for the years following 2008, which in turn were obtained by calculating the present value of a perpetuity that assumes 2008 values will remain constant.[14]

[14] Present values were computed using a 6% discount rate. The computations assume that all λ's equal 1.

Table 3

Distribution of Profit and Loss in the Prepayment Electricity System

Concept	1996-2003 A	2004-2008 B	Perpetuity C	Projection Subtotal D = B + C	Total Present Value E = A + D
Prepayment Users					
Tariffs	123,681	130,234	644,564	774,798	898,479
Taxes	53,471	57,623	286,107	343,731	397,202
Reloading time	-19,471	-16,699	-64,036	-80,735	-100,206
Advance payment	-9,488	-9,393	-46,534	-55,926	-65,415
Meters	-531,463	-100,878	-372,619	-473,497	-1,004,960
Subtotal	**-383,270**	**60,887**	**447,483**	**508,370**	**125,100**
Utility					
Revenue	-123,681	-130,234	-644,564	-774,798	-898,479
Running costs	131,369	109,464	413,619	523,083	654,452
Working capital	106,322	47,037	230,763	277,801	384,122
Bad debts	-77,227	94,880	465,481	560,361	483,134
Bad debt taxation	-37,610	46,207	226,689	272,896	235,286
Fixed assets	-81,771	-70,010	-267,453	-337,462	-419,233
Subtotal	**-82,598**	**97,345**	**424,535**	**521,880**	**439,282**
Government					
Fiscal revenue	-21,309	-54,360	-274,513	-328,873	-350,182
Subtotal	**-21,309**	**-54,360**	**-274,513**	**-328,873**	**-350,182**
System Total	**-487,177**	**103,872**	**597,505**	**701,377**	**214,200**

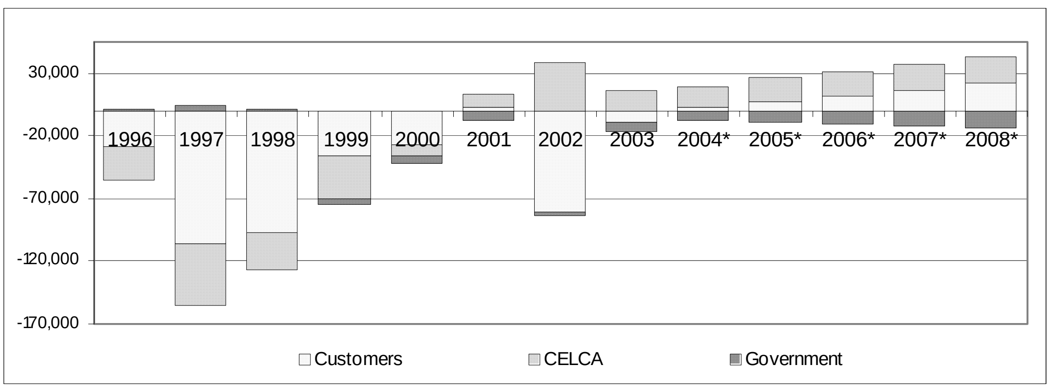
Results suggest that the policy leads to an increase in overall welfare equivalent to $a 214,200, or $a 38 per user.[15] Results differ across groups, as users and the firm both benefit from implementation of the system, whereas the government does not. Data in the first column show that, until 2003, the policy did not result in improvements for any group. A breakdown of results indicates users bore the largest losses, as the benefits of those using prepaid meters originated from tariff discounts and tax savings were not sufficient to make up for the meters' costs. The following columns show, however, that this result is overturned when one takes into account the projections. In the case of users, projections indicate that the benefits from lower prices and associated taxes exceed the costs associated with the advanced payment of electricity, the time incurred to recharge the meter, and the meter cost.[16] Thus, the last column shows that adoption of the system results in a total benefit to consumers of $a 125,000, or $a 55 per user. In the case of the utility, projections indicate that loses of tariffs discounts are overturned by the benefits incurred in the reduction of operating and financial

[15] $a refer to Argentinean pesos
[16] Projections consider that the proportion of users in the prepaid system will remain constant at 2003 values.

costs. The net benefit for the firm is $a 439,000, or $a 78 per user. The last column indicates that the utility benefits the most. Finally, the table shows that government losses in all cases.

Figure 2 completes because it breaks down the net benefits for each group across years. In the case of users, the figure shows that investment in meters generated losses in the first years that gradually decreased until 2001 but for 2002, when they picked up again – and remarkably – when that year's crisis seemed to have prompted many users to opt for the prepayment. The series indicate that, as from 2004, users obtained benefits from using the prepayment. Estimates also show that the evolution of the firm's net benefit is similar, as original losses linked to investment in assets and tariff discounts are followed by benefits arising from the decrease in bad debts and from lower running and finance costs, which originate from improvements in working capital.

Figure 2
Evolution of Costs and Benefits - Prepayment System
Period 1996-2003 and projections



Note: present values at 1996; (*) projected values.

Results also indicate that the implementation of the prepayment system generates losses for the government, as the increase in revenues associated with the sale of meters do not compensate for the decrease in revenues linked to tariff discounts. The data in Table 3 make evident that some results come from transfers between different groups. Thus, user benefits generated by lower tariffs and taxes (both totaling $a 1,295,600) are equivalent to the losses carried on by both the firm and the government.

It is also possible to examine the sensitivity of these results vis-à-vis changes in some parameters and distinctive features of the policy. A few simulation exercises were conducted for this purpose. The aim of the first simulation was to identify the discount rate at which the implementation of this policy makes no change at an aggregate level, while the second simulates the discount rate. The third scenario conjectures that the use of the prepayment system is not associated with a tariff discount, while the fourth envisages the provider of the service bearing the cost of the meters. The fifth scenario explores the options regarding the latter two in conjunction. The exercises for scenarios six and seven therefore assume that the utility bears the cost of the meters and seeks a tariff discount that makes the adoption of the policy for the users in one case, and the utility in the other, economically neutral. Table 4 shows the results of those simulation exercises.

The data show that the elements of the model are sensitive to the discount rate employed to standardize each year's results. Results from the first exercise indicate that there are no benefits when a 6.5% discount rate is used to standardize the basic scenario's annual operating statements, while results from the second show the importance of decline in social welfare when an 8% rate is used. The third scenario makes it clear that the users' benefit depends on tariff discounts only. These results show that, in the hypothesis that users were obliged to use the prepayment system without the benefit of a discount, they would suffer a loss, although both the utility and the government would obtain substantial benefits. The results of the fourth scenario differ from the previous one because it shows that, when the firm bears the cost of the meters, it incurs net losses but the users benefit to a considerable extent. This situation is reversed in the case of the fifth scenario as the firm bears the cost of the meters but does not grant tariff discounts.

Table 4

Results for Alternative Scenarios

Prepaid electricity system; Carmen de Areco

Concepts	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Parameters to be simulated								
Discount rate	5%	6,5%	8%	5%	5%	5%	5%	5%
Tariff discount	5%	5%	5%	0%	5%	0%	0,64%	3,09%
Who pays the meter?	Users	Users	Users	Utility	Utility	Utility	Utility	Utility
Prepayment Users								
Tariffs	898.479	641.836	494.851	0	898.479	0	114.849	555.230
Taxes	397.202	283.361	218.185	0	397.202	0	50.773	245.457
Reloading time	-100.206	-73.766	-58.371	-100.206	-100.206	-100.206	-100.206	-100.206
Advance payment	-65.415	-46.852	-36.210	-65.415	-65.415	-65.415	-65.415	-65.415
Meters	-1.004.960	-833.867	-729.218	-1.004.960	0	0	0	0
Subtotal	**125.100**	**-29.287**	**-110.763**	**-1.170.581**	**1.130.060**	**-165.621**	**0**	**635.066**
Utility								
Revenue	-898.479	-641.836	-494.851	0	-898.479	0	-114.849	-555.230
Running costs	654.452	483.182	383.329	661.429	654.452	661.429	660.537	657.117
Working capital	384.122	290.340	236.033	384.122	384.122	384.122	384.122	384.122
Bad debts	483.134	302.275	200.153	483.134	483.134	483.134	483.134	483.134
Bad debt taxation	235.286	147.208	97.475	235.286	235.286	235.286	235.286	235.286
Fixed assets	-419.233	-309.585	-245.954	-419.233	-1.204.430	-1.204.430	-1.204.430	-1.204.430
Subtotal	**439.282**	**271.584**	**176.184**	**1.344.739**	**-345.915**	**559.542**	**443.801**	**0**
Government								
Fiscal revenue	-350.182	-242.298	-180.930	47.020	-350.182	47.020	-3.753	-198.437
Subtotal	**-350.182**	**-242.298**	**-180.930**	**47.020**	**-350.182**	**47.020**	**-3.753**	**-198.437**
System Total	**214.200**	**0**	**-115.509**	**221.178**	**433.963**	**440.941**	**440.049**	**436.629**

The last two exercises identify implementation alternatives whose results may benefit a given group but without disturbing the welfare of another's. The sixth scenario thus indicates the minimum discount that leaves users' welfare unchanged, with the utility bearing the cost of the meters. Results show that, in such a case, a tariff discount lower than 1 % is enough for the policy to make no difference to users, for the utility to obtain profits, and for overall welfare changes to be positive, albeit with losses for the government. The last scenario indicates that, if the firm bears the cost of the meters, any tariff discount above 3.1% will generate a welfare loss. The government position, on the other hand, will be similar to that of the utility, in that any tariff discount will be translated into a decrease in its welfare. The simulations highlight the importance of tariff discounts and of payment for meters in the distributive effects from implementing the system since, although in almost all scenarios a net increase in social welfare occurs, the distribution of benefits and costs associated with the system is different from one scenario to the other.

6. The perception of consumers

The results of the cost-benefit analysis seem to suggest that adoption of prepaid meters leads to a welfare increase, not only to users adopting the system but also to those that do not. Such economic analysis ignored, however, how consumers evaluate the system. The views of consumers are thus relevant not only because they might be highly correlated with changes in their welfare – and so they might give additional support to the findings of the economic model – but also because they become a relevant factor behind the success of prepaid systems.[17]

Still, previous studies indicate that prepaid meters are not necessarily a well-received innovation in some segments of societies to the extent that, in some cases, the society as a whole is reluctant to the implementation of the system (Tewari and Shah, 2003). In this section we therefore summarize the results of a survey conducted in November 2004 among residential electricity users in Carmen de Areco. The survey was aimed at examining the main characteristics of households that switched to prepaid meters and at exploring their satisfaction with the system. A total of 90 users were surveyed: 47% stated that they had

[17] Indeed, some observers argue that a key potential of prepaid systems is that their implementation in small communities help reduce the level of confrontation between the local utility and consumers (USAID, 2004).

adopted prepaid meters, while the rest indicated they have remained with the conventional system.[18]

Table 5 summarizes some socioeconomic features of households that use prepaid meters and that do not. The data show that households that adopted the prepayment system have, on average, both a larger number of members and of minors and that such differences are statistically significant. The data also indicate that adoption of prepaid meters does not differ, statistically, according to the occupation of household heads except for unemployed households, retirees and beneficiaries of social plans, as most of them had opted for remaining within the conventional system. It is then possible to speculate that the argument that the lower or more unstable the family income, the stronger the tendency to use prepaid meters might hold,[19] but up to a point where income instability makes the prepayment to increase the chance of self-disconnection, in which case consumers seem to prefer the conventional system and to expose themselves to a disconnection triggered by the utility.

The table also displays some variables that can be considered as imperfect approximations of households' income such as ownership of the household's dwelling, the availability of a fixed telephone line and of air conditioning equipment, and the number of bathrooms in the residence. Results indicate that the use of prepayment in electricity varies according to housing tenure. Households owning their home are more inclined to remain within the prepayment system, whereas households renting their home are more prone to use prepaid meters (probably because of the imposition of property-owners, as prepaid meters reduce the risk of unpaid bills). Average distance to outlets where regular bills can be paid or electricity be purchased is similar to most consumers. The data show that ownership of a fixed telephone line and of air conditioning equipment is not statistically different between the two groups. This result contrasts, however, with the fact that the proportion of houses with more than one bathroom – a variable that is suspected to be positively correlated with the dwelling's total built size – is statistically higher among users of prepaid meters. These findings may suggest that the potential existence of a direct relationship between household income and use of prepaid meters is not conclusive.[20]

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[18] These proportions are similar to those observed for the district's residential population in 2003. The size of the sample n was estimated with the formula n = (N*Z 2*p*q) / [d2*(N-1)* Z 2*p*q] where N is the size of the population, Z the level of confidence, d the level of accuracy and p and q the proportion of the users' population with and without the prepaid system. The values employed were N = 4.34 (the number of residential users), Z = 1.96, d = 0.10, p = 0.46 and q = 0.54.

[19] This is usually the case when minimal or unreliable income streams make it hard to make a monthly payment (USAID, 2004)

[20] This finding should be interpreted with caution because it could result form the reduced dispersion of households' income within the district.

Table 5

Socioeconomic Features of Residential Users

Carmen de Areco District.

Status	Prepayment Users	Conventional Users	Mean Difference Test (1)
Number of household members (average)	4.1	3.3	**
Number of minors (average)	1.3	0.6	**
Occupation of household head (%)			
Worker or employee	48.8	35.4	
Self-employed	31.7	25.0	
Manager or employer	4.9	2.9	
Other (2)	14.6	37.5	**
Housing tenure (%)			
Owner	77.5	89.6	**
Rented	20.0	6.2	*
Other (3)	2.5	4.2	
Distance to top up / payment center (4)	6.11	7.57	
Telephone (%)	80.5	68.1	
Air conditioning (%)	9.8	14.9	
Number of bathrooms in dwelling (%)			
One	63.4	82.9	**
Two	34.1	14.9	**
More than two	2.4	2.1	

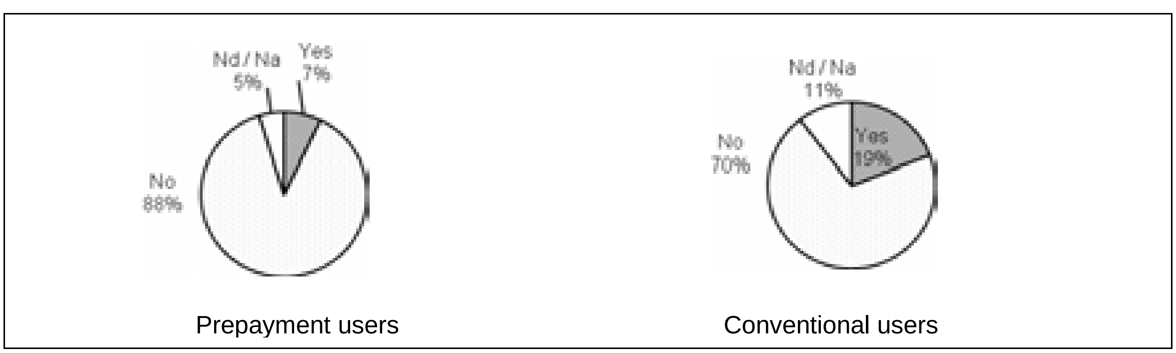
Source: Own elaboration based on survey results.
Notes: (1) The symbols * and ** indicate that differences are statistically significant at 1% and 5% significance levels, respectively. (2) It includes retirees, beneficiaries of social plans and unpaid workers; (3) It includes company-owned homes and other unspecified options. (4). Average distance, in number of blocks.

Survey results also suggest the presence of an apparent equilibrium between the number of users of the prepayment and conventional systems, as most users manifest a strong preference to remain with their system. Figure 3 shows that 88% of prepaid meter users are not willing to switch back to the conventional system, whereas 70% of conventional meter users are not willing to switch; only 19% of the latter would consider switching to prepayment.

Figure 3

Willingness to Switch

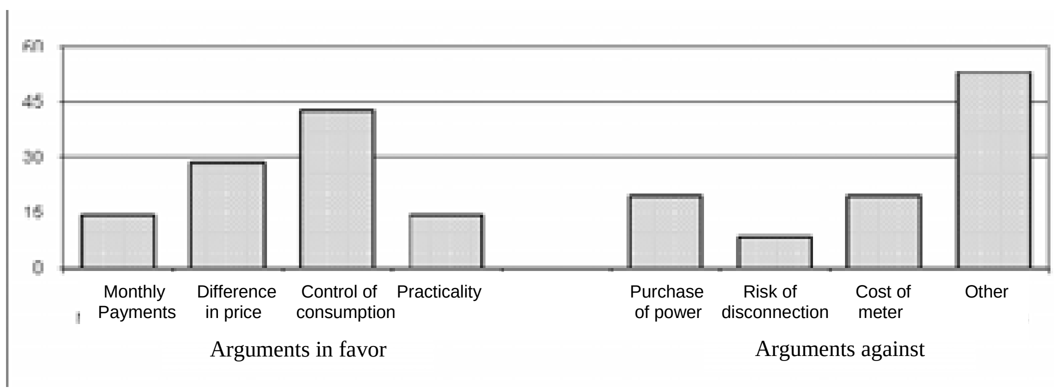
Percentage of total users for each system



Source: Own elaboration based on survey results.

Figure 4 summarizes the reasons that would motivate users of the conventional system to remain in this system or to switch to prepayment. In the first case, the survey data indicate that the inconvenience involved in the advanced purchase of electricity and the cost of the meter are important reasons for not switching. Other arguments against switching include the fact that tariff discounts are not large enough – given consumption level – as to warrant switching and that advance payment for a utility is not a sound practice. In the second case, reasons that favor switching include the possibility to exert a better control on consumption and the perception that the prepayment involves lower expenditures. Results suggest that over 70% of users interested in switching to prepaid meters would do so for reasons associated with the cost of electricity. In addition, almost 15% of users willing to switch consider that the prepayment is practical and convenient – a percentage that is higher than the proportion of users who prefer the conventional system owing to the risk of being left without electricity.

Figure 4
Switching to Prepayment System
Arguments in favor and against switching



Source: Own elaboration based on survey results.

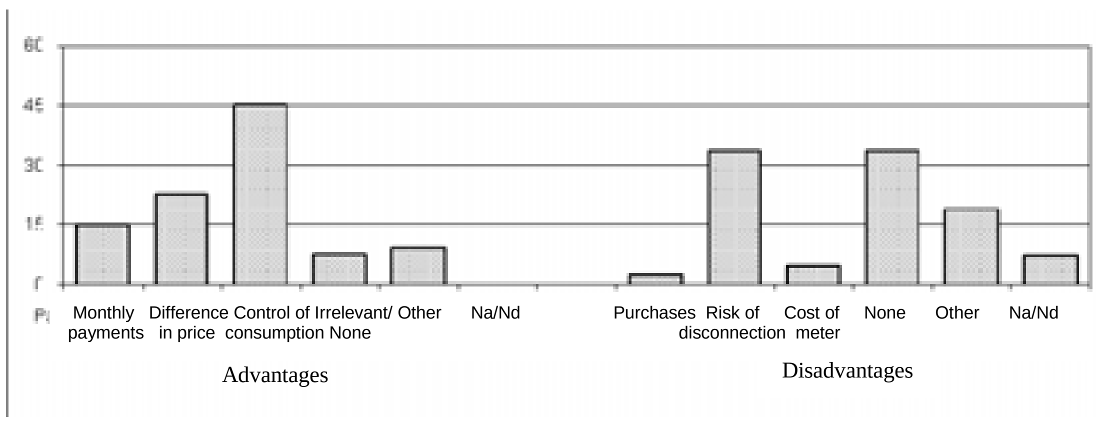
Survey data also reveal the advantages and disadvantages of prepaid meters as identified by users. Figure 5 summarizes these results. The main advantages refer to electricity expenditure, as the tariff differential between the two systems is considered an advantage by more than 20% of prepayment users, while 45% value the opportunity of a better control of consumption. Indeed, more than a half of prepayment users consider that their electricity consumption has decreased since they adopted the system at their homes.[21] Other advantages include the possibility to purchase electricity according to the availability of money, which is closely linked to the advantage of not having to make fixed monthly payments. It becomes

21 This relationship between the prepayment and a low demands contradicts the average demand data reported in Section 3.

apparent that the advantages identified by users are very similar to the reasons cited for having installed prepaid meters: more than 70% of users had adopted prepaid meters because they expect to reduce their expenditure in electricity.

The main disadvantage reported by one third of users refers to the possibility of disconnection. The data also underline the low relevance prepayment users attach to the cost of the meter as well as to the necessity of making more frequent payments, despite the fact that 23% of users report toping up electricity at least once a week (recall that average distance to electricity retail outlets is about 7 blocks).[22] It is notorious that a high proportion of prepaid meter users find no disadvantages of the system whatsoever.

Figure 5
Prepayment Electricity System
Advantages and Disadvantages



Source: Own elaboration based on survey results

The risk of disconnection does not seem to be too much of a problem. Results in Table 6 indicate that 45% of prepayment users report to have been disconnected at least once during the last year. The data also show that 62% of users that disconnected, the lack of energy lasted less than seven hours; in 80% of the cases, disconnection occurred due to user neglect. The opposite situation occurs, however, in the case of disconnections over periods longer than seven hours, for which the main cause is the lack of money to reload the meter.

[22] This result differs from those of other communities where prepayment meters have been installed. For example, many users in Johannesburg have declared that it is "a big hassle to buy electricity frequently" (Tewari and Shah, 2003).

Table 6
Lack of Electrical Power for Prepayment Users
Frequency and Reasons

	Number of Users (%)
Lack of Electricity	
During the last year	45.2
During the last month	16.7
During the last week	7.1
Reasons for Lack of Electricity	
Less than seven hours	62.0
- Not enough money	16.7
- Neglect	83.3
More than seven hours	42.0
- Not enough money	66.7
- Neglect	33.3

Source: Own elaboration based on survey results

7. Conclusions

Prepayment systems have been proposed as an innovative solution to the problem of affordability in utilities services. In spite of being a popular system in European and African countries, the use of such mechanisms is still controversial. Among the main arguments in favor of its dissemination are advantages concerning lower costs of arrears, running costs and finance charges for the service provider and the better allocation of resources it implies for users. The arguments against prepaid meters are based on the higher cost of the technology and the possibility of self-disconnection of low-income users. This paper contributes to the debate because it uses cost-benefit analysis to examine the adoption of the prepayment electricity system in the first local district that has adopted them in Argentina.

The case study makes it possible to identify the change in aggregate welfare resulting from the adoption of the prepayment system as well as in each of the groups concerned. The figures show that the adoption of this system involves a favorable change in social welfare, which expressed in 1996 constant prices reaches $a 38 per user of electrical power. The increase in social value is not distributed in a constant way among the various groups involved as, while the distribution utility and the users obtain a net profit, the government sustains an important loss generated by lower tax revenues related to changes in electricity consumption. In addition, the increase in social welfare exhibits an evolution over time which is typical of investments with high sunk costs, because the results show that in the first years of implementation the system generated losses owing mostly to the high cost of the technology involved. These results are however reversed and more than compensated for when the period of analysis is longer.

The analysis was complemented with those corresponding to the model's sensitivity to changes in some distinguishing parameters and features of policy implementation. In general, the simulations confirmed the system's potential as a mean to increase social welfare, highlighting at the same time the role of tariff discounts and payment for meters in the distribution of the generated benefits. The importance of those simulations for regulatory purposes is due to, at least, two reasons. On the one hand, because the possibilities of replicating the policy depends on the positive results of its implementation being maintained under different scenarios; and on the other hand, because the definition of regulatory policies in respect of prepayment systems should be based not only on the added welfare change but also on the identification of winners and losers.

The analysis is also complemented by the results of a survey conducted among residential users of electrical power in Carmen de Areco. The data show a generalized level of satisfaction among prepayment users, and highlight the importance of the variables linked to the cost of the service, both directly through lower tariffs and indirectly by way of the enhanced control of consumption as allowed by the prepayment system's technology. The survey also indicates that, at least in the case of Carmen de Areco, self-disconnection does not seem to be a major issue. However, it is important to point out that, even if the results of this work highlight the potentialities of the prepayment systems as a tool to facilitate the affordability of public services and enhance social welfare, they partially depend on the particular socioeconomic characteristics of the context of the study. Further studies remain to be conducted in the future on the extension of this analysis to different locations.

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