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Distributional Effects of Water Tariff Reforms – An Empirical Study for Lima, Peru

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Abstract

This study analyzes the affordability and distributional implications of water tariff reforms for poor water customers under means-tested tariffs in comparison to increasing block tariffs (IBTs) using volumetric targeting. For this purpose, we employ a unique data set for Lima, Peru. Our analysis reveals that from a pro-poor perspective, the performance of means-tested tariffs is mixed. On the one hand, they distribute more income to poor households than the IBTs, given the assumption that the overall revenue to the water supplier remains constant. On the other hand, the share of poor customers who actually benefit from water subsidies declines with means-testing. Nevertheless, means-tested tariffs clearly outperform IBTs in terms of excluding non-poor customers from being subsidized. These findings should be generalized with care as the performance of the tariff crucially depends on the cut-off value for cross-subsidies and the block prices chosen under volumetric targeting and on the design of the means-test. Our analysis further suggests that a proper assessment of individual welfare effects should take household size into account and rest on a broad set of affordability and distributional indicators. Interestingly, our results are relatively insensitive to the price elasticity of water demand.

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1 Introduction

The individual welfare effects of water tariffs and corresponding reforms are an important concern of public policy in developing countries (UN, 2000; WMO, 1992). Especially, affordability of water supply is often understood as a precondition for making (necessary) increases in average tariff levels politically feasible (Batley, 2004; Fankhauser and Tepic, 2007; Kaimowitz, 1996).[2] The classical economic intuition advises against differentiating the price signal for the sake of distributional and affordability concerns.[3] Instead, such concerns should be addressed by non-distorting income transfers which increase the ability-to-pay of poor households (see, e.g., Griffin, 2001). However, this strategy may not be implementable in developing countries, in which social transfer systems are often either absent or deficient (World Bank, 2000). Consequently, tariff discrimination is the major means to safeguard affordability in many countries throughout the world. The dominant approach are increasing block tariffs (IBTs) (Komives et al., 2005; OECD, 2009), with which the marginal price of water supply increases step-wise with the quantity of water consumed. This tariff scheme seems appealing for pro-poor targeting at first sight as water consumption is usually assumed to be linearly related to household income. Nevertheless, IBTs are nowadays commonly criticized for being insufficiently targeted to the poor. Inter alia, this is due to the fact that the relationship between water consumption and income may be less clear-cut in developing countries, where poor families are often significantly larger than wealthier ones and in many cases share connections with a joint meter. Moreover, IBTs also subsidize non-poor water users, for example, if these turn out to have low consumption levels or if the size of the first block is beyond subsistence consumption (Bithas, 2008; Boland and Whittington, 2000; Dahan and Nisan, 2007; Estache et al., 2002; Foster and Yepes, 2006; OECD, 2009; Whittington, 1992). As a response to these deficits, means-tested tariffs are increasingly proposed and have been implemented in some countries, such as Chile. They are expected to be better targeted to poor customers as the tariff discriminates on the basis of individual

[2] For the sake of brevity, we will refer to the entire process of water extraction, transportation, and purification as well as of wastewater collection and treatment as water supply throughout our paper.

[3] Affordability of water supply may not only be warranted for distributional concerns but also for efficiency reasons if water consumption produces positive externalities in terms of improved health outcomes, reduced incidence of epidemics or reduced time spent on fetching water. In this case, the subsidized provision of a subsistence level of water supply may be economically first-best (Agthe and Billings, 1987; Hajispyrou et al., 2002). For a broader discussion on pricing water supply see, for example, Griffin (2001).

welfare means (Foster et al., 2002a; Foster and Yepes, 2006; Gómez Lobo and Contreras, 2003). However, the empirical evidence on the actual performance of means-tested tariffs is still limited.

This study provides a quantitative assessment of the distributional effects of means-tested tariffs as compared to IBTs. We aim at examining how well the different tariff options are actually targeted to the poor and whether this affects affordability. For this purpose, we use a unique data set for the Metropolitan Area of Lima and Callao in Peru. It combines administrative data of the state-owned water and sanitation company SEDAPAL with socio-economic data for the roughly 9 million people living in Lima obtained from a recent expenditure survey by the Peruvian Statistical Office. We compare the effects of the existing IBT to four alternative tariffs using different affordability and distributional measures and distinguishing between short-run and long-run effects. The latter take demand adjustments of households in reaction to price changes into account. Evaluating the effects of price reforms is particularly important in Lima where water supply is extremely scarce. Subsidizing households via water tariffs and thereby deviating from full-cost pricing, which a priori reflects scarcity, should be done - if so at all - with extreme care.

Our analysis adds to the limited literature on distributional effects of water tariffs. A major strand of this literature bases its assessment on a consumer theory approach (Diakité et al., 2009; Garcia and Reynauld, 2004; Groom et al., 2008; Hajispyrou et al., 2002; Renzetti, 1992; Rietveld et al., 2000; Ruijs, 2009; Ruijs et al., 2008). Using water demand estimates, these studies examine changes in consumer surplus for different consumer groups and for alternative tariff options. Their focus lies on a comparison of IBTs and tariff schemes that are closer to the efficient pricing rule (uniform pricing combined with a fixed fee in most cases). The overall finding is that IBTs reduce overall social welfare but may increase the consumer surplus of poor customers (even though to different extents). A main problem of this literature with respect to our research question is that the data used rarely offers appropriate indicators to identify poor households. It also remains often at a highly aggregate level and uses, e.g., district average consumption levels of different income groups to quantify the effects. What is more, using the consumer theory approach for a developing country analysis is often difficult due to a lack of appropriate data needed for regression analysis (Nauges and Whittington, 2010). This constraint also applies to our analysis, so that we cannot compute surplus variations. We rely on a second strand of literature which proposes affordability and distributional measures assuming inelastic elasticity of demand to analyze the effects on poor customers (Angel-Urdinola and Wodon, 2007; Foster et al., 2002a, b; Gómez Lobo and Contreras, 2003; Komives et al., 2006; Komives et al., 2007; Walker et al., 2000). Interestingly, these studies attenuate the above results, which attest a relatively good pro-poor performance of IBTs by allowing for more detailed insights into the redistribution of income than aggregated surplus variations. Our study goes beyond these analyses in several respects. First, we compare an IBT to (simulated) means-tested tariffs for the same water supplier, SEDAPAL, not across different utilities with different existing tariff schemes (Foster et al., 2002a is the only exception). This allows us to reduce the distortion of our results by contextual factors and to examine a variety of alternative means-tested tariffs. Second, we apply a much broader set of indicators, including not only distributional measures but also affordability measures. Thereby, we are able to discuss methodological issues related to measuring affordability and distributional impacts. Third, we do not only look at impacts at the household level but also take household size and per capita figures into account. This step confirms many hypotheses on the poor performance of IBTs from the literature based only on household level analysis. Finally, we analyze to what extent our results are contingent on the assumed price elasticity of demand and hence try to close at least somewhat the gap to the surplus variation analysis.

The remainder of the paper is organized as follows: Section 2 introduces the affordability and distributional measures used. Section 3 describes the current situation in the Metropolitan Area of Lima and Callao. Section 4 presents the data we use and the calibration of the different tariff options. Section 5 presents and discusses our results. Section 6 concludes and offers policy recommendations.

2 Measuring the Impact of Water Tariffs on Individual Welfare

When it comes to measuring the impact of water tariffs on individual welfare, a general distinction can be made between affordability and distributional measures. Affordability measures aim at identifying who is poor in terms of water consumption and in need of being subsidized to be able to pay for water consumption. Distributional measures determine to what extent eligible households actually benefit from subsidies. Thus, they assess whether the direction of income redistribution is appropriate given that there are eligible customers. Both types of measures rest on normatively set poverty lines, either to define affordability or to define eligibility for subsidies.

2.1 Affordability Measures

The most commonly used affordability measure is the Conventional Affordability Ratio (CAR) (see, e.g., Fankhauser and Tepic, 2007). The corresponding burden ratio r_i for a household i relates expenditures for water supply, which compute as the (average) price of water p times the consumed quantity q_i, to a household's budget b_i, which may be interpreted as total income or total expenditures of the household:

$$r_i = pq_i\,/b_i.$$

The CAR may also be computed on a per capita basis relating individual water consumption to individual expenditures. An affordability issue arises when this ratio exceeds some normatively set threshold, which is typically set between two to five percent (Komives et al., 2005). Gawel et al. (2013) show that this approach has important conceptual shortcomings as it does not account for relative preferences for water and other commodities and also neglects that even poor households may consume more water than necessary.

To correct for these deficiencies, the Potential Affordability Ratio (PAR) is suggested (e.g., Foster and Yepes, 2006). To calculate the burden ratio r_i^p, actual water consumption q_i is replaced by a normatively set standard subsistence level q^*:

$$r_i^p = pq^*/b_i.$$

Typically, values for q^* vary between 20 and 100 litres per capita and day (e.g., Howard and Bartram, 2003). The PAR traces affordability problems back to income constraints, i.e. only poor customers can have an affordability problem. The use of this second ratio may be difficult if political affordability concerns are not only motivated by concerns about poverty but more broadly by potential public resistance against water tariff reforms. In this case, the overall burden of water expenditures (as represented by the CAR) may be more relevant than the burden associated only with subsistence consumption (as represented by the PAR) (Gawel and Bretschneider, 2011).

2.2 Distributional Measures

Distributional measures rest on some exogenous welfare indicator based on income or a more complex welfare index, for which a poverty line is determined (e.g. the lowest quintile of the income distribution is defined as poor). They analyze whether and to what extent those water customers identified as poor by the poverty line actually benefit from the subsidies implicit in the tariff scheme. If one assumes that poor customers are more likely to have an affordability problem, distributional measures provide insight into whether a tariff mitigates affordability issues. Distributional measures can be assessed on a household or per capita basis. The simplest measure is the absolute subsidy received or paid, which compares a household's actual water expenditure to the true value of water consumption based on the average cost of water supply c:

$$s_i = cq_i - pq_i$$

Based on these individual measures, simple aggregated indicators of *beneficiary incidence* can be constructed (Foster et al., 2002b; Komives et al., 2007). For this purpose, the total number of households H connected to the network is divided into poor customers P and non-poor customers NP. Likewise, the total number of subsidy beneficiaries B (i.e. those households with $s_i > 0$) is distinguished into poor B_P and non-poor B_{NP}. The error of exclusion EE specifies which share of the poor does not benefit from the subsidy:

$$EE = 1 - B_p/P$$

To put this value into perspective, it may also be worthwhile to relate the number of the benefiting poor to the entire (connected and unconnected) poor population:

$$\widehat{EE} = 1 - B_P/P_{tot}$$

This ratio additionally includes the error of exclusion associated with the lack of network access. Moreover, the number of excluded poor customers may also be related to the total connected population to learn about the overall importance of the error of exclusion:

$$\widetilde{EE} = \left(P - B_p\right)/H$$

The error of inclusion EI illustrates which share of the subsidy beneficiaries is non-poor:

$$EI = B_{NP}/B$$

Here, it may again be insightful to relate the number of non-poor beneficiaries to the entire connected population to illustrate how universal or not the subsidy is:

$$\widetilde{EI} = B_{NP}/H$$

Errors of exclusion and inclusion provide an idea of which households benefit but not of the actual extent of those benefits (Coady et al., 2004). This deficiency can be overcome by indicators of *benefit incidence*. The leakage rate assesses which share of the total volume of the positive subsidies goes to non-poor water costumers (Foster et al., 2002b):

$$LR = 1 - S_P^+ / S^+$$

where $S_P^+ = \sum_{i=1}^{P} s_i$ with $s_i > 0$ denotes the aggregated positive subsidies received by the poor and $S^+ = \sum_{i=1}^{H} s_i$ with $s_i > 0$ overall positive subsidies received by all households.

The benefit indicator Omega, Ω, assesses whether the average subsidy received or paid by one population group is lower ($\Omega < 1$) or larger ($\Omega > 1$) than the average subsidy received or paid by the population as a whole.[4] In contrast to Angel-Urdinola and Wodon (2007), we distinguish Omega for positive and negative subsidies as well as for poor and non-poor customers. Table 1 provides the full definition of these Omegas.

Distribution of	**Population group under consideration** Poor	Non Poor
positive subsidies	$\Omega_P^+ = S_P^+ / S^+ \cdot H/P$	$\Omega_{NP}^+ = S_{NP}^+ / S^+ \cdot H/NP$
negative subsidies	$\Omega_P^- = S_P^- / S^- \cdot H/P$	$\Omega_{NP}^- = S_{NP}^- / S^- \cdot H/NP$

Table 1: Definitions of Omegas

$S_P^- = \sum_{i=1}^{P} s_i$ with $s_i < 0$ denotes negative subsidies to the poor. The aggregated positive and negative subsidies for non-poor customers, S_{NP}^+ and S_{NP}^-, compute correspondingly. If Omega is equal to one, subsidies are distributed as if randomly to the population. An Omega larger than one for positive subsidies qualifies the redistribution mechanism as progressive (regressive) when assessed for the poor (non-poor). The reverse holds true for the Omega for negative subsidies. Distinguishing between Omega for positive and negative subsidies allows detecting redistribution of income, which would not show up with an Omega for net subsidies if positive and negative subsidies within one group cancel out.

[4] A further indicator is the Gini coefficient, which measures to what extent the distribution of a subsidy deviates from equal distribution (see, e.g., Foster et al., 2002b). We abstain from computing this indicator here as the resulting information of progressivity or regressivity of a subsidy is similar to that of the Omega.

3 Water and Waste Water Tariffs in Lima

The monopolistic, state-owned water and waste water firm SEDAPAL serves 1.81 million customers or roughly 90 percent of Lima's population through its network. The remaining population is supplied by decentralized means of water supply, including water tankers and semi-centralized networks. Table 2 provides an overview of the tariff valid for SEDAPAL customers in 2011, the starting point of our analysis. The tariff has a two-part structure with a fixed and a variable charge. The variable charge is differentiated for drinking water and wastewater. The total amount billed in both categories is based on the volume of water consumed by each connection, i.e. the waste water quantity is assumed to be the same as the drinking water volume. The overall price per cubic meter is the sum of drinking and waste water price. Further, the variable charge distinguishes between customer types and volume categories. Private households, which account for 78 percent of SEDAPAL's water consumption, are classified as residential customers. Non-residential customers include industrial, commercial, and government entities. The social tariff is paid, for example, by operators of public standpipes or poorhouses. Domestic, commercial, and industrial customers disposing of a water meter pay an IBT. Under this tariff, a customer's monthly expenditures e_i for water supply are computed as follows:

$$e_i = f + p_{j-1} * u_{j-1} + p_j * (q_i - l_j) \text{ with } l_j < q_i \leq u_j \text{ and } u_{j-1} = l_j$$

where f is the fixed charge, p_j is the price for block j, and l_j and u_j are the lower and upper consumption bounds of block j. That is, despite the four blocks, each consumer only faces two block prices: the price of the block into which the total consumption level falls and the price of the block below. Customers without a water meter, around 12.3 percent of all connected units, are assigned a fixed amount of consumption based on their class and category, the continuity of supply (in hours per day) and their place of residence (the wealthier the district they live in, the higher the assigned consumption). They thus pay a monthly flat rate for their water consumption.

Fixed charge in PEN per month and connection:	4.740

Variable charges:

Customer class	Customer category	Range in m³ per month	Drinking water tariff in PEN per m³	Waste water tariff in PEN per m³
Residential	Social	>0	0.940	0.411
	Domestic	0-10	0.940	0.411
		10-25	1.091	0.477
		25-50	2.414	1.055
		>50	4.095	1.789
Non-residential	Commercial and industrial	0-1000	4.095	1.789
		>1000	4.392	1.919
	State	>0	2.294	1.002

Table 2: Water tariff valid in Lima from 6 June 2011 to 6 May 2012

The water tariff in Lima is set by the *Superintendencia Nacional de Servicios de Saneamento* (SUNASS), the regulatory authority of the water sector. SUNASS calculates an average price which is supposed to cover average long-term costs of SEDAPAL. The current average price, or long-term average cost per cubic meter, is 2.57 for all customer types.[5] Without the fixed charge per connection of 4.74 PEN, it is 2.48 PEN/m³. Considering just domestic customers, the variable average cost per cubic meter reduces to 1.74 PEN. As we focus on the distributional impact of pricing water for private households, 1.74 PEN/m³ is the benchmark for the following tariff analysis. Accordingly, all but the customers whose overall consumption volume falls into the fourth block get subsidies for at least part of their consumption.

4 Empirical Approach

4.1 Calibration of Tariff Options

We analyze the individual welfare effects of five different tariff options for domestic customers. The calibration of these tariffs rests on several assumptions. First, we assume that the fixed charge as well as the tariffs for the social, commercial, industrial, and state

[5] The long-term average unit cost covers investment by SEDAPAL and maintenance costs accruing from the SEDAPAL network. Apart from SEDAPAL, different bodies also invest into water and waste water infrastructure. These are, however, not included in the cost formula by SUNASS. The long-term average cost is thus not the true long-term average cost one would like to consider to understand whether the water tariff is financially sustainable.

categories remain constant throughout all options. Second, the overall level of revenue from water supply is assumed to be constant throughout all tariffs. Revenue sufficiency is an important concern of water suppliers and acceptance of tariffs reducing their revenue is hardly conceivable. Additionally, keeping revenue from domestic consumption constant allows comparing the distributional effects of the different tariffs as the sum of available subsidies is always the same. Overall monthly revenues of SEDAPAL amount to PEN 88.25 million in 2011. The billed monthly volume of consumption is 34.37 million m^3. Finally, we assume that individual consumption levels do not vary if tariffs change, i.e. consumption is perfectly inelastic to marginal price changes. Even though this assumption may seem very restrictive at first sight, empirical studies find that the price elasticity of water demand is usually below 1 in developing countries (Nauges and Whittington, 2010). We therefore feel reasonably safe to assume inelastic demand at least in the short run. We will relax this assumption later on.

The tariffs we compare are summarized in Table 3 (note that drinking water and waste water tariffs are aggregated). We choose the options such that we can analyze a heterogeneous set of tariff designs and discuss possible trade-offs between distributional concerns and other criteria, such as economic efficiency and administrative simplicity.

<table>
<tr><th>SISFOH</th><th>Block</th><th>m³</th><th>IBT current</th><th>IBT rev</th><th>IBT dif</th><th>Uni 35</th><th>Uni 0</th></tr>
<tr><td rowspan="5">Non Poor</td><td>1</td><td>0-10</td><td>1.351</td><td>1.184</td><td rowspan="2">1.509</td><td rowspan="5">1.910</td><td rowspan="5">1.988</td></tr>
<tr><td>2</td><td>10-25</td><td>1.568</td><td>1.743</td></tr>
<tr><td>3</td><td>25-50</td><td>3.469</td><td>3.469</td><td>3.866</td></tr>
<tr><td>4</td><td>50-100</td><td rowspan="2">5.884</td><td rowspan="2">5.884</td><td>4.825</td></tr>
<tr><td>5</td><td>>100</td><td>5.884</td></tr>
<tr><td rowspan="4">Poor</td><td>1</td><td>0-10</td><td>1.351</td><td>1.184</td><td>1.240</td><td rowspan="8">0.620</td><td rowspan="2">0.000</td></tr>
<tr><td>2</td><td>10-25</td><td>1.569</td><td>1.743</td><td>1.509</td></tr>
<tr><td>3</td><td>25-50</td><td>3.469</td><td>3.469</td><td>2.481</td><td rowspan="2">1.988</td></tr>
<tr><td>4</td><td>>50</td><td>5.884</td><td>5.884</td><td>4.825</td></tr>
<tr><td rowspan="4">Extremely Poor</td><td>1</td><td>0-10</td><td>1.351</td><td>1.184</td><td>0.943</td><td rowspan="2">0.000</td></tr>
<tr><td>2</td><td>10-25</td><td>1.568</td><td>1.743</td><td>1.240</td></tr>
<tr><td>3</td><td>25-50</td><td>3.469</td><td>3.469</td><td rowspan="2">2.233</td><td rowspan="2">1.988</td></tr>
<tr><td>4</td><td>>50</td><td>5.884</td><td>5.884</td></tr>
</table>

Table 3: Overview of tariff options (tariffs in PEN per m^3)

- *IBT current* is the tariff which was in place in Lima in 2011. It only incorporates volumetric price discrimination. All households which consume in the first, second or third block pay less than average costs in the domestic category (1.7426/m^3) for either their total consumption (first and second block consumers) or for the first 25 cubic meters (third block consumers). Only households consuming more than 50 cubic meters pay more than average costs for their whole consumption.

- *IBT rev* is a revised version of the existing tariff. The price for the second block is increased to the average costs of water supply in the domestic category. To maintain overall revenues constant, the price of the first block is slightly reduced. Thus, under this option, only consumption in the first block is subsidized. This option is included to compare the effect of setting different cut-off values for subsidies (25 m^3 under *IBT current* and 10 m^3 under *IBT rev*).
- *IBT dif* is an increasing block tariff differentiated by individual welfare means. It combines volumetric and means-tested targeting. This tariff is currently discussed within SUNASS for a revision of SEDAPAL's existing tariff. It is meant to provide for a better consideration of distributional concerns at the household level. The decision to propose such a hybrid tariff – instead of switching directly to purely means-tested tariff discrimination – may seem surprising at first sight. Volumetric targeting commonly is understood as an appropriate targeting mechanism if there is no other way to identify eligible households. If another targeting mechanism, such as a means-tested poverty indicator, is available at reasonable costs, economic rationale would advise to discriminate (if so at all) using different prices according to the means test. The decision by the Peruvian government and regulatory agency, however, may be explained politically. Radical tariff reforms may produce concerns and consequently opposition among stakeholders: The water utility may fear that it eventually ends up with less income. Water customers may be afraid that the tariff reform is employed to conceal tariff increases. Against this background, a hybrid tariff may be understood as a means to make gradual transition from an IBT to a purely means-test tariff discrimination politically feasible.

In addition, we analyze a set of two uniform tariff options which primarily discriminate on the basis of individual welfare means:

- *UNI 35* allows for a rebate for customers classified as poor or extremely poor. They pay only around 35 percent of the average domestic tariff. The tariff for non-poor customers is beyond the average tariff to recover the subsidy to poor and extremely poor customers.

- *UNI 0* exempts poor and extremely poor customers for the first 25 m^3 from any charge and charges all poor and extremely poor customers with larger consumption volumes the same price per additional cubic meter as non-poor customers. It is the second hybrid tariff we analyze.

In order to calibrate the alternative tariff options, we use a data set compiled for SUNASS by the Argentinian consultancy Centro de Estudios de Transporte e Infraestructura S.A. (CETI, 2008). It matches SEDAPAL's commercial database for September 2010 with the database of the *Sistema de Focalización de Hogares* (SISFOH), which provides the so-called SISFOH index for all connections. The means-tested income index SISFOH distinguishes between non-poor, poor, and extremely poor households and therewith identifies the three income groups which are part of the above tariff designs. SISFOH was created in 2004 by the Peruvian government as a monitoring tool to identify eligible persons for various social transfer programs administered by the government. It has been implemented since 2007 and identifies households using means-tested criteria based on household characteristics. SUNASS and SEDAPAL are now considering using it also for pro-poor targeting in water tariff design. Due to data constraints, SEDAPAL and SISFOH data could not be matched on an individual customer but only on a census block basis. That is, a customer's poverty indicator is contingent on the classification of the block she lives in.[6] We use the SEDAPAL data to calibrate the tariff schemes. Using administrative data for this step allows us to be sure that revenue neutrality is met. However, SEDAPAL's commercial data set only gives information on the quantity consumed, the total payment per month, and the SISFOH category of each connection.

4.2 Data for the Analysis of Distributional Effects

In order to analyze the distributional impact of different tariff scenarios, we use the expenditure survey *Encuesta Nacional de Hogares* (ENAHO) published by the national statistical office of Peru (INEI). It contains inter alia monthly expenditure data for drinking water for 2570 representative households in Lima in 2010. It enables us to calculate the quantity of water consumed per household using the SEDAPAL tariff scheme from 2010. Even though this information is also included in the commercial database provided by SEDAPAL, using ENAHO data has several advantages. First, we can link the volume of water consumption to the individual characteristics of the households, e.g. household size,

[6] The full methodology used to match the two datasets is provided in CETI (2008).

which are not available from administrative data. Our study is the first to quantify the distributional effects at the individual level. Second, we are able to calculate two different income classifications from ENAHO data which allow analyzing the distributional effects of means-tested pricing and clarifying the crucial role of the choice of the poverty measure for the success of pro-poor pricing. The first income classification is the official poverty line of INEI distinguishing (as the SISFOH index) between "extremely poor", "poor", and "non-poor" households. The second is the SISFOH index introduced above. Even though both indices use the same category names, the households identified to belong to each group are different for the two indices. While the SISFOH index is a means-tested indicator, poverty lines classify households according to income, or because data availability is often better, according to household expenditure. For Lima, the per capita poverty line for monthly expenditure are 159.62 PEN (extremely poor, 56.4 US$ in 2010) and 325.17 PEN (poor, 114.9 US$ in 2010).[7] This corresponds to 2 US$ a day per capita for extremely poor persons, and 4.1 US$ a day per capita for poor persons. The poverty line of extreme poverty lies within the first decile of the income distribution (0-306 PEN per capita and month) and the poverty line of non-extreme poverty lies within the second decile of the income distribution (306-376 PEN): In 2010, only 0.55 percent of the population in Lima had monthly incomes below the extreme poverty value, and only 12 percent had incomes below the non-extreme poverty line. The fact that we can find the SISFOH categories for each household from the ENAHO data allows us to apply the means-tested pricing schemes to the representative household data from ENAHO.[8] We use monetary poverty as the "true" poverty indicator and discuss means-tested pricing of drinking water and waste water services referring to monetary income categories as reference groups. The choice of a specific poverty indicator to evaluate tariffs is purely normative, as is the choice of the indicator used to target subsidies, and we could have chosen any other index as a benchmark to evaluate means-tested pricing. Most studies mentioned in the introduction consider households in the lowest part of the income distribution to be poor (10-40 lowest percent of income distribution) and use this as a reference category to evaluate subsidy scheme performance. The cut-off value we choose for Lima is far lower. We discuss the implications of this choice for our results in section 5.2.

[7] We use the exchange rate of 2.83 PEN/US$ published by the World Development Indicators 2010. The routine to calculate the poverty lines is provided by INEI with the 2010 version of ENAHO.

[8] See Appendix 1 for the methodology, questionnaires, and weighting for the SISFOH index calculation.

Whereas combining administrative and expenditure data allows a more precise analysis with respect to the determinants of redistributive performance of different tariff schemes, it is not free of problems. One potential source of impreciseness is that the calculation of the consumption volumes rests on the assumption that all water bills are based on metering as we use the 2010 SEDAPAL tariff to calculate the quantities from the total amount paid registered by the household expenditure survey. We cannot distinguish from the EHANO data between metered and non-metered households. As mentioned above, 13.2 percent of all water and waste water connections in Lima are not metered. Our analysis is therefore based on the ideal case of universal metering.[9] Another problem may be that we cannot identify exactly the same households with ENAHO data that were identified by the matching of the administrative data with the SISFOH-categories. As explained above, this matching was done block-wise and not individually for each household, whereas we identify SISFOH-categories individually from ENAHO data. Further, but minor differences between the SISFOH procedure and ours are explained in the Appendix. Overall, we are confident that our identification comes close to reality: In the administrative data, 82.67 percent of the connections are categorized as non-poor, 16.44 percent as poor, and 0.88 percent as extremely poor. The equivalents of our SISFOH identification based on ENAHO data result in 88.18, 11.37 and 0.46 percent of total households, respectively.

As we are interested in the redistribution effects of SEDAPAL tariffs, we restrict the original sample of around 2.21 million households to the 1.93 million households consuming drinking water from SEDAPAL for most of the following analysis. Except for the calculation of errors of exclusion and inclusion, we exclude all user groups that do not use an individual access point using SEDAPAL drinking water because we cannot calculate consumption volumes for shared or non-SEDAPAL connections. First, we exclude tank users. Even though tanks are usually under the concession of SEDAPAL, tank water is charged differently. Second, we exclude users who have access through a shared connection within their building as there is no information available about how users share their bill. Third, users getting their water from their neighbors are excluded as well. Presumably, neighbors sell their water at their own, probably much higher price. We include users of public fountains as the fountains are operated by SEDAPAL and only registered families are allowed to use them at prices of the first block. With these restrictions of the data set, 67.5 percent of the extreme poor and 73.8

[9] Missing meters and therefore systematic assignment of consumption volumes applies to 89.2, 80.5 and 92 percent of non-poor, poor and extremely poor connection units, respectively.

percent of the poor (according to INEI poverty lines) remain in our data set. 90.1 percent of the non-poor population are also connected individually to the SEDAPAL network. That is, the majority of the poor and non-poor would be affected by changes in the tariff structure.

5. Results

5.1 Is water poverty an issue at all?

Table 4 illustrates that affordability of water supply is an issue if a relatively low threshold ratio (2 percent in our case) is chosen.[10] If alleviating affordability via pro-poor pricing is a political goal, tariff discrimination may be justified in this case. However, for a threshold ratio of 5 percent, affordability problems almost disappear. As one would expect, affordability problems are much more prevalent among poor and extremely poor customers. However, at least according to the CAR, water may also be unaffordable for a significant share of non-poor customers. Moreover, the comparison of the PAR to the CAR yields interesting results. We chose 70 liters per day and per person as the minimum consumption volumes necessary to cover daily hygienic, drinking and cooking routines (see e.g. Breed & Breed, 2011). Affordability issues aggravate for extremely poor customers (with all of them facing a problem under some tariff options), while they are mitigated for poor customers and become irrelevant for non-poor customers. This implies that many extremely poor customers consume below subsistence levels and may therefore be identified as having no affordability constraint by the CAR. In contrast, many poor and non-poor customers over-consume and may therefore be identified as having an affordability problem under the CAR. The next sections inter alia analyze in how far affordability problems may be a result of distributional effects of different tariffs.

[10] We display results at the household and the per capita level. With respect to affordability, results are more or less the same from the two perspectives. We discuss the role of household size for affordability and distributional effects separately in chapter 5.4.

		IBT current	IBT rev	IBT dif	Uni 35	Uni 0
	CAR (r_i)	Share of households facing affordability problems				
	> 2%	0.21	0.20	0.22	0.29	0.30
	> 5%	0.02	0.02	0.02	0.02	0.03
by SISFOH						
Extremely poor	>2%	0.64	0.64	0.64	0.50	0.50
Poor	>2%	0.41	0.37	0.40	0.44	0.44
Non-poor	>2%	0.19	0.19	0.20	0.27	0.29
	PAR (r_i^p)	Share of households facing affordability problems				
	> 2%	0.14	0.02	0.02	0.04	0.05
	> 5%	0.01	0.00	0.00	0.00	0.00
by SISFOH						
Extremely poor	>2%	0.94	0.94	1.00	0.55	0.55
Poor	>2%	0.29	0.16	0.22	0.44	0.50
Non-poor	>2%	0.12	0.00	0.00	0.01	0.01
	CAR (r_i)	Share of individuals facing affordability problems				
	> 2%	0.18	0.17	0.19	0.25	0.26
	> 5%	0.01	0.01	0.01	0.01	0.02
by SISFOH						
Extremely poor	>2%	0.59	0.59	0.59	0.50	0.50
Poor	>2%	0.37	0.34	0.37	0.41	0.42
Non-poor	>2%	0.16	0.15	0.16	0.22	0.24
	PAR (r_i^p)	Share of individuals facing affordability problems				
	> 2%	0.14	0.02	0.02	0.04	0.04
	> 5%	0.01	0.00	0.00	0.00	0.00
by SISFOH						
Extremely poor	>2%	0.90	0.90	1.00	0.55	0.55
Poor	>2%	0.25	0.13	0.22	0.44	0.50
Non-poor	>2%	0.12	0.00	0.00	0.01	0.01

Table 4: Share of connected water customers with affordability problems (share of water expenditures exceeds CAR/PAR of 2%/5%). Own calculations.

5.2 How well are tariffs targeted to the poor?

Distributional effects by any given pro-poor pricing will be driven by the targeting mechanism chosen to channel cross-subsidies to poor households. The tariff reforms we propose either imply volumetric targeting (*IBT current, IBT rev),* means-tested targeting (*UNI 70, UNI 35*), or hybrid targeting involving both mechanisms (*IBT dif, UNI 0*).

Volumetric targeting as currently employed for Lima's water tariff (*IBT current*) rests on the assumption that water consumption increases with income. An analysis of average consumption in the three INEI income groups indicates that this assumption may actually hold in Lima: The extremely poor consume on average 10.92 m^3 per month and household, the poor 12.72 m^3, and the non-poor 16.71 m^3, according to monetary poverty groups. This observation is at odds with most of the developing countries literature, which finds no major differences in consumption patterns for poor and non-poor households. Thus, at a per household basis and from a pro-poor perspective, IBT tariffs could a priori lead to better redistributive results in Lima than in other cities or countries in the developing world. This may be indicated by the relatively low error of exclusion (see Table 5): Only 10 percent of the connected poor customers (which corresponds to only 1 percent of all connected customers) do not receive a subsidy. However, the downside to this finding is the very high error of inclusion: 91 percent of the subsidy beneficiaries are non-poor. These constitute 78 percent of the connected population. This result can be explained by the high cut-off line for subsidies of 25 m^3, which dominates a potential progressive effect of the IBT structure that would in principle be possible in Lima. Figure 1 shows that most of the population in Lima lives in households consuming total volumes below 25m^3 per month (block 1 and 2). This is not only true for the extremely poor and poor population, but also for the non-poor population. This part of the population only receives from the cross-subsidy scheme. Only 0.84 percent of the non-poor persons live in households that do not receive any subsidies (block 4). Subsidy coverage is thus almost universal, the exact coverage only depending on the consumption levels of the 19.46 percent of population consuming between 25 and 50m^3 (block 3). Figure 2 shows what happens in block 3 in the tariff *IBT current*. Consumers in this block get subsidies for the first 25m^3 and pay into the system for all following cubic meters. Ultimately, households consuming more than 27.49m^3 per month are net subsidy payers because from this volume on, negative subsidies net out positive subsidies. This compensating effect is a function of the price for the second and third block, or more generally of the prices for the two blocks around the cut-off. The errors of inclusion and exclusion effectively summarize the targeting performance with respect to net subsidies and are, in the case of IBTs, composed by targeting and pricing effects.

	IBT current	IBT rev	IBT dif	Uni 35	Uni 0
Errors per household					
Error of Inclusion Receivers (EI)	0.91	0.91	0.92	0.751	0.751
Error of Inclusion Total ($\widetilde{EI}$)	0.78	0.71	0.80	0.067	0.067
Error of Exclusion Eligible (EE)	0.08	0.12	0.05	0.722	0.722
Error of Exlusion Eligible nonSeda ($\widehat{EE}$)	0.33	0.36	0.30	0.798	0.798
Error of Exclusion Total ($\widetilde{EE}$)	0.01	0.01	0.00	0.058	0.058
Errors per capita					
Error of Inclusion Receivers (EI)	0.89	0.88	0.89	0.659	0.659
Error of Inclusion Total ($\widetilde{EI}$)	0.74	0.68	0.75	0.053	0.053
Error of Exclusion Eligible (EE)	0.10	0.14	0.08	0.745	0.745
Error of Exlusion Eligible nonSeda ($\widehat{EE}$)	0.34	0.36	0.30	0.812	0.812
Error of Exclusion Total ($\widetilde{EE}$)	0.01	0.01	0.01	0.079	0.079

Table 5: Beneficiary incidence. Own Calculations.

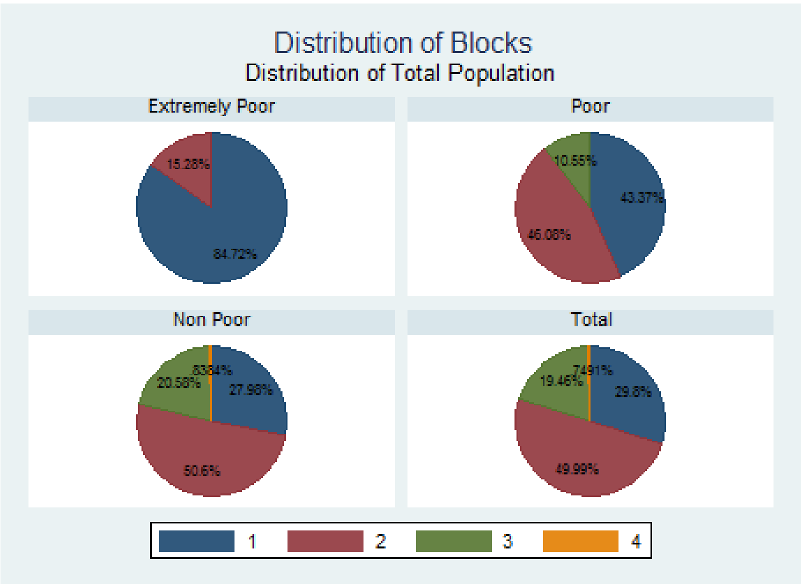

Figure 1: Distribution of users over pricing blocks in Lima, Peru. Source: own calculations.

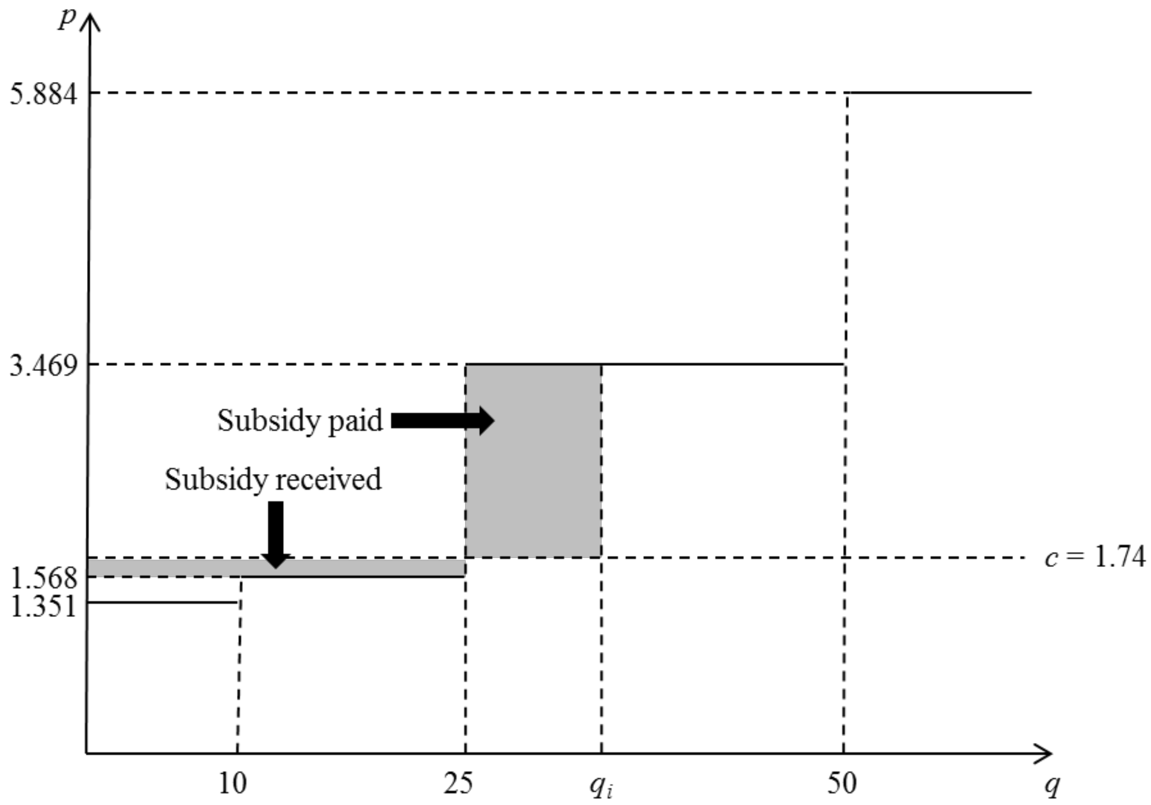

Figure 2: Compensating effect for water users consuming in the third block

To correct for almost universal coverage, tariff *IBT rev* lowers the cut-off value to a subsistence level of 10m³, which has been proposed by the literature as an appropriate lifeline (Foster et al., 2006).[11] In contrast to what one would expect, however, this modification hardly affects the performance of the IBT in terms of beneficiary incidence. The explanation is again linked to the compensation effect which is now materializing immediately in the third block. All non-poor households in block 1 and 2 are still in the numerator of the errors of inclusion. Consumers in block 2, however, do not get subsidies anymore. All households consuming in the third block but below 27.49m³ also become net payers. Only the share of those customers who are non-poor is however excluded from the errors of inclusion. As expected, the error of inclusion with respect to total connected households decreases somewhat. Since the numerator and denominator of the error of inclusion in total receivers are both affected by the change and the denominator decreases more than the numerator, this error even increases somewhat. This effect appears as long as the volumetric targeting excludes poor households from receiving net subsidies and not only non-poor customers.

[11] This comes close to the 70 liters per day and capita that we assumed above: An average poor household in Lima with 6 members consumes 12.6m³ if this minimum volume is applied.

However, an increase of the error of inclusion in such a situation gives a confusing signal with respect to what the indicator should measure: Effectively, more non-poor customers are excluded from receiving net subsidies than before. This is adequately reflected by the error of inclusion in total population, which, however, misses the fact that the share of non-eligible customers in total receivers has increased. It is thus important to consider both errors together in order to fully understand the targeting effect of volumetric targeting. Both errors of exclusion increase as the poor in the third block now also become net payers. However, this share is too small to affect the errors of exclusion significantly. The CARs in Table 4 show that decreasing the lifeline while reducing the first block price and setting the second block price equal to average costs does not increase the affordability problems of the poor and extreme poor at current consumption levels.

Table 5 illustrates that switching to a purely means-tested targeting mechanism (*UNI 35*) brings about a clear trade-off: On the one hand, the error of inclusion is significantly reduced compared to *IBT current*. On the other hand, the error of exclusion drastically increases. This trade-off is directly linked to the suitability of the welfare index in place to target the poor and extremely poor as uniform tariffs don't bring about compensating effects. Table 6 shows that the SISFOH index (MT, Means-tested poverty) and the INEI index (Monetary poverty) mostly overlap for the non-poor population: 93 percent of the non-poor (INEI) are also identified as non-poor by the means test. 6.52 and 0.18 percent of the individuals classified as non-poor by monetary considerations receive subsidies according to means-tested targeting, suggesting relatively low errors of inclusion. For the two poor categories, poor and extremely poor individuals, targeting is less accurate. 19.78 percent of the extremely poor and 66.30 percent of the poor cannot be reached by means-tested targeting. These facts are also illustrated by the affordability measures (see Table 4). In fact, the extremely poor still benefit (in terms of CAR as well as PAR) from switching to a means-tested tariff. In contrast, the result for the poor is either indifferent (CAR) or significantly worse (PAR). This suggests that the increased exclusion from subsidies is primarily to be faced by the poor, not by the extremely poor. In comparison to the IBT effects on the PAR, it gets clear that the poor suffer from the high prices under uniform tariffs even if consumption volumes are reduced to the strict minimum of 70 liters per day and capita. This goes back to the missing attenuating effect of volumetric targeting. Under an IBT tariff, a poor customer who is not correctly identified by the cut-off value still benefits from lower prices in the lower blocks as long as her total consumption volume does not fall into the fourth block. That is, a mismatch in targeting hits the poorer harder under means-tested uniform tariffs.

MT Poverty	**Monetary Poverty**			
	Extr. Poor	Poor	Non Poor	*Total*
Non Poor	0.11	8.90	90.99	100
	19.78	66.30	93.30	**89.65%**
Poor	4.16	39.24	56.60	100
	76.47	32.85	6.52	**10.07%**
Extr. Poor	9.20	36.03	54.77	100
	4.74	0.85	0.18	**0.28%**
Total	**0.55%**	**12.03%**	**87.43%**	
	100	100	100	

Table 6: Income Categories and Water Consumption in Lima, ENAHO (2010): own calculations.

Lastly, we find that the hybrid approaches do not perform any better in terms of targeting. The hybrid approach of *IBT dif* hardly affects the errors of exclusion and inclusion as compared to *IBT current*. This seems to indicate that the bias of volumetric targeting (high cut-off value) dominates the attenuating effect that means-tested targeting would introduce to this tariff. In fact, poor and extremely poor customers with consumption levels above $25m^3$ are barely existent (10.5 percent of the poor), and price reductions for volumes below $25m^3$ are rather small. Also with the second hybrid tariff, *UNI 0*, the targeting effect of the main targeting mechanism, means-tested targeting in this case, dominates. As most of the poor and extremely poor consume in blocks 1 and 2 and the compensating effect above $25m^3$ only emerges for extremely high consumption levels, which are basically not realized by poor and extremely poor households, the volumetric component effectively has no impact on the errors.[12]

Summing up the discussion of targeting mechanisms and beneficiary incidence, we can say that, given the price and targeting design chosen in this study, volumetric targeting leads to almost universal subsidization because of the high lifeline. Means-tested pricing performs better in this respect because its targeting excludes most of the non-poor from receiving net

[12] The errors of exclusion that we present here are calculated for the population of SEDAPAL clients. That is, persons living in households without access to an official SEDAPAL connection are not taken into account. Including poor and extreme poor persons without access increases the errors of exclusion (share in eligible households): 0.34, 0.37, 0.33, 0.79, 0.79, 0.79 (in the order of the table). These values take into account who has access to water connection and who has not - this may be a function of the pricing system at hand, but may also be related to other factors, such as prohibitively high uptake costs or missing access to the grid at the place of residence.

subsidies. However, it also excludes most of the poor and extremely poor users from any subsidies. Interestingly, the two hybrid schemes and the tariff with the lower lifeline do not perform better.

5.3 How strongly is income redistributed among poor and non-poor?

Table 7 illustrates the pattern of income redistribution via tariff reforms distinguishing between the pattern of contributions to and benefits from the system of cross-subsidies. As we have discussed targeting problems linked to missing access above, we focus on customers connected to the SEDAPAL network in this section.

With respect to the benefits from the system (Ω^{+}), all tariffs but the current IBT are progressive with respect to extremely poor and poor households. The means-tested tariffs, however, redistribute more strongly towards both groups.[13] With respect to the contributions to the system (Ω^{-}), all tariffs again fulfill progressive redistribution, however, this time the means-tested tariffs perform worse. Due to the targeting issues discussed above, especially with the means-tested tariffs, not all poor and extremely poor households are exempt from contributing to the system. Interestingly, all tariff options are relatively neutral to the non-poor households. That is, the share of subsidies contributed to the system by the net payers among the non-poor households is almost as big as the share that the net receivers among the non-poor households get from the system. Additionally, the share of the non-poor subsidies in total positive or negative subsidies is almost of the same size, compared to their share in population, i.e. the redistribution among them is as if random. Only the means-tested tariffs reduce the share received by non-poor households. This result is also underpinned by the leakage rate. Around 90 percent of the positive subsidies are allocated to non-poor households with IBT tariffs, 62 percent with the means-tested tariffs. This reflects the high errors of inclusion of all targeting mechanisms. Lastly, the pattern of income redistribution is not affected by the hybrid pricing schemes. *IBT Dif* performs clearly better than the other two IBTs but does not reach the redistribution implemented by the means-tested tariffs. *UNI 0* again has no differential effect.

[13] Note that the nominator of the Omegas is always composed by the share of subsidies of those receiving (or paying) net subsidies, whereas the denominator contains the whole population in the subgroup. If extreme poor receive 1.5 times as much subsidies as their share in total population, this only affects those extreme poor who effectively receive net subsidies. The errors of exclusion still apply and not all poor benefit from this share in total subsidies.

	IBT current	IBT rev	IBT Dif	Uni 35	Uni 0
Omegas per household					
Receiver of subsidies					
Extremely poor (Ω_{EP}^{+})	1.15	1.40	4.87	11.78	11.84
Poor (Ω_{P}^{+})	0.98	1.06	1.48	4.55	4.52
Non-poor (Ω_{NP}^{+})	1.00	0.99	0.96	0.67	0.67
Payers of Subsidies					
Extremely poor (Ω_{EP}^{-})	0.00	0.00	0.00	0.28	0.28
Poor (Ω_{P}^{-})	0.24	0.30	0.24	0.64	0.64
Non-poor (Ω_{NP}^{-})	1.07	1.06	1.06	1.03	1.03
Omegas per capita					
Receiver of subsidies					
Extremely poor (Ω_{EP}^{+})	0.80	0.97	3.10	8.19	8.24
Poor (Ω_{P}^{+})	0.73	0.80	1.11	3.42	3.40
Non-poor (Ω_{NP}^{+})	1.03	1.02	0.98	0.69	0.69
Payers of Subsidies					
Extremely poor (Ω_{EP}^{-})	0.00	0.00	0.00	0.20	0.20
Poor (Ω_{P}^{-})	0.18	0.22	0.18	0.48	0.48
Non-poor (Ω_{NP}^{-})	1.10	1.09	1.09	1.06	1.06
Leakage Rate (LR)	0.92	0.91	0.89	0.62	0.62

Table 7: Benefit Incidence. Own Calculations.

Table 7 shows the materiality of the tariffs which completes the analysis of benefit incidence. The fact that the average net subsidy per household received by the non-poor is positive for the IBTs further underlines that they heavily redistribute towards non-poor households. The hybrid *IBT Dif* allocates by far the largest net subsidies to all three income groups. The means-tested tariffs, in contrast, take on average from the non-poor households, which reconfirms the positive Omegas below 1 and the negative Omegas above 1 in Table 7. As with the affordability ratios and negative Omegas, the average net subsidies of poor households under means-tested tariff schemes show that these tariffs favor the extreme poor more than the poor.

5.4 What is the impact of household size?

One aspect that we have not discussed so far is the impact of household size on our results. Several of the indicators that we present show that taking household size into account considerably attenuates the results with respect to the progressivity of the different tariff options.[14] Most importantly, the two purely volumetrically targeted tariffs (*IBT current*, *IBT rev*) are clearly regressive or close to neutral at the per capita level with respect to the distribution of positive net subsidies (Table 8). The other tariff options remain in the same order from the pro-poor perspective, however, they all lose some of their progressivity. All positive Omegas decrease by roughly the same percentage (30 percent for the extremely poor, 25 percent for the poor), so that household size does not affect the distributional effects of the tariffs differently (Table 7). The only exception is the *IBT Dif* indicator which decreases by 36 percent for the extremely poor. The two pure IBTs were already close to neutral at the

	IBT current	IBT rev	IBT dif	Uni 35	Uni 0
Average net subsidies per household (s_i)					
Extremely poor	3.97	5.32	23.64	6.68	10.43
Poor	2.90	3.29	6.50	1.22	1.99
Non-poor	1.34	1.07	1.62	-2.23	-3.23
Poor/Non-poor	*2.16*	*3.07*	*4.02*	*-0.55*	*-0.62*
Extremely poor/Non-poor	*2.96*	*4.96*	*14.63*	*-2.99*	*-3.23*
Average net subsidies per capita (s_i)					
Extremely poor	0.68	0.92	3.62	1.15	1.80
Poor	0.54	0.61	1.17	0.23	0.37
Non-poor	0.34	0.27	0.40	-0.57	-0.82
Poor/Non-poor	*1.57*	*2.24*	*2.93*	*-0.40*	*-0.45*
Extremely poor/Non-poor	*2.00*	*3.35*	*9.06*	*-2.02*	*-2.18*

Table 8: Average net subsidies in PEN per month. Own Calculations

household level and are therefore the first here to change into a regressive pattern. This result is further reinforced by the average net subsidies per capita (Table 8). We calculate the ratio of average net subsidies of poor (extremely poor) to average net subsidies of non-poor.[15] This ratio decreases with all three IBT tariffs from the household to the per capita level. Again, the

[14] Average household size per monetary poverty group is 6.17 in extremely poor households, 5.98 in poor households and 4.66 in non-poor households.

[15] Note the change of interpretation of this indicator with its change in sign. A positive ratio shows how many times the poor or extreme poor receive what the non-poor receive. A negative ratio, however, can be read as how much the poor or extreme poor receive what the non-poor contribute.

decreases are equal for all tariffs (32 percent for the extremely poor, 27 percent for the poor) but *IBT Dif* (38 percent for the extremely poor, 27 percent for the poor). Overall, the per-capita analysis reinforces the results at the household level and importantly adjusts the picture with respect to *IBT current* and *IBT rev*. The fact that the *IBT Dif* indicators decrease by even more than the other tariffs highlights the complexity of the targeting structure at work with this tariff. The loss of progressivity under IBT can be due, in total, to three different factors: the price level, the cut-off volume and (for *IBT Dif*) the means test. The means test or the combination of the means test and one or both of the two other factors interact with the pattern of consumption levels for different household sizes under *IBT Dif*, so that the reduction is larger with *IBT Dif*. Importantly, it would be wrong to conclude that it is only the means test that acts against larger poor households here. The change in price levels from *IBT current* to *IBT Dif* in combination with the means tests or the means test in combination with the cut-off value can also exclude poor families from subsidies. The uncertainty about the exact underlying reason for this effect highlights the complexity of the combination of different targeting mechanisms within one tariff and generally speaks in favor of simple tariff schemes where the effects are clearly understandable just from the design of the tariff.

5.5 What is the impact of price elasticity of demand?

So far, we assumed that demand is inelastic with respect to price changes. However, this might not be true in the long run. Nauges and Whittington (2010) review the evidence on price elasticities estimated with data from developing countries and find that estimated elasticities vary between -0.3 and -0.6 for private connections. In the following, we simulate the quantity adjustment to price changes from the current IBT to the *UNI 35* tariff assuming elasticities of -0.3 and -0.8 in order to find out whether the assumption of inelastic demand determines our results. As the change in the average affordability and distributional indicators discussed above is quite small for -0.3, the latter value is higher than the upper bound from the literature to provoke sizeable changes. Table 9 shows the price changes in percent and the resulting quantity adjustments per block and income group. Even though the size of some of the changes seems quite unrealistic, no change leads to dramatic changes in the indicators. Table 10 shows the results for the distributional indicators and the conventional affordability rates at a per capita basis.[16]

[16] The errors of inclusion and exclusion are not affected by the quantity adjustments, the potential affordability ratios deliberately ignore quantitative adjustments.

SISFOH	m³	IBT current	Uni 35	Price change (%)	Quantity change (%, -0.3)	Quantity change (%, -0.8)
Non Poor	0-10	1.3511	1.9101	41.37	-12.41	-33.10
	10-25	1.568		21.82	-6.55	-17.45
	25-50	3.469		-44.94	13.48	35.95
	50-100	5.884		-67.54	20.26	54.03
	>100					
Poor	0-10	1.3511	0.6201	-54.10	16.23	43.28
	10-25	1.569		-60.48	18.14	48.38
	25-50	3.469		-82.12	24.64	65.70
	>50	5.884		-89.46	26.84	71.57
Extremely Poor	0-10	1.3511		-54.10	16.23	43.28
	10-25	1.568		-60.45	18.14	48.36
	25-50	3.469		-82.12	24.64	65.70
	>50	5.884		-89.46	26.84	71.57

Table 9: Price change when switching from IBT current to Uni 35 and resulting quantity changes for different price elasticities of demand. Own calculations.

		IBT current	Uni 35	Uni 35 Ela -0.3	Uni 35 Ela -0.8
Affordability	**CAR (r_i)**	**Share of individuals facing affordability problems**			
	> 2%	0.18	0.25	0.24	0.23
	> 5%	0.01	0.01	0.01	0.02
by SISFOH					
PE	>2%	0.59	0.50	0.50	0.63
P	>2%	0.37	0.41	0.38	0.34
NP	>2%	0.16	0.22	0.22	0.21
Average net subsidies per capita (s_i)					
Extremely poor		0.68	1.15	1.37	1.73
Poor		0.54	0.23	0.33	0.47
Non-poor		0.34	-0.57	-0.56	-0.54
Poor/Non-poor		1.57	-0.40	-0.59	-0.88
Extremely poor/Non-poor		2.00	-2.02	-2.46	-3.21
Omegas per capita					
Receiver of subsidies					
Extremely poor (Ω_{EP}^{+})		0.80	8.19	8.15	8.33
Poor (Ω_{P}^{+})		0.73	3.42	3.44	3.45
Non-poor (Ω_{NP}^{+})		1.03	0.69	0.69	0.68
Payers of Subsidies					
Extremely poor (Ω_{EP}^{-})		0,00	0.20	0.18	0.15
Poor (Ω_{P}^{-})		0.18	0.48	0.46	0.44
Non-poor (Ω_{NP}^{-})		0.10	1.06	1.07	1.07

Table 10: Comparison of affordability and distributional indicators for different price elasticities of demand. Own calculations.

The simulated quantity reaction of a household to price changes is simply the product of past consumption volumes, the price change and the elasticity of the respective block and income group of the household in question. Obviously, this is a very pragmatic way to interpret average estimates of point elasticities. Additionally, the estimation of elasticities under IBT pricing schemes brings about some methodological issues that further handicap the simulation of quantity reactions. These need to be kept in mind when analyzing the results. First, the usual assumption for estimation is that the marginal prices of all blocks increase equally by 1 percent (Olmstead et al., 2007). It is obvious from Table 9 that this is not true for the tariff switches considered in this study. Even if this was the case, the average price change over all blocks would need to be taken into account for simulation as well. It would lead to a change in virtual income, which would reduce the estimated reaction to price decreases as income elasticity estimates are usually estimated to be positive.[17] However, the impact of a change in virtual income may be small here, as income elasticity estimates are even smaller than price elasticities and mostly insignificant in most studies from developing countries (Nauges and Whittington, 2010). Second, there is evidence that price elasticities differ according to the price scheme studied. Under uniform pricing, elasticity seems to be somewhat lower than under IBT schemes (Olmstead et al., 2007); note that we consider a switch from one type to the other. A third complication results from the fact that even though there are estimators and methodologies to estimate unconditional elasticities for IBT schemes (see e.g. Olmstead et al., 2007), these are not applied in developing countries' studies due to a lack of data. That is, the elasticity range of [-0.3,-0.8] only applies to quantity adjustments conditional on remaining within the same consumption block. This is another assumption that does not hold for all households in our study. Due to these issues, the correct use and interpretation of the results of the large literature on elasticity estimation is difficult if not unfeasible in the absence of own panel data. Nevertheless, if considered with caution, the simple simulation provides some insights.

Only the (SISFOH) non-poor households consuming below 25m³ face price increases. This leads to decreasing affordability problems at the two percent expenditure threshold in general, as this group is the majority of the customers, but also in the specific group as such. The price increase seems to be netted out by quantity adjustments. This result either materializes because of or is reinforced by the mistargeting of the means test which applies to

[17] See Nataraj and Hanemann (2011) for a short but very recent discussion of whether households react to marginal price changes of "their" block or of the blocks below or to average price changes of all blocks at once.

around 9 percent of the non-poor customers. Affordability problems at the 2 percent level for extremely poor households increase strongly, the opposite is true for poor households, who see their affordability problems decrease. In the two groups of extremely poor and poor customers, the matching of the two poverty indicators is worse. Hence, the effect of quantity and price changes is even more biased by mistargeting, which leads to price increases for poor and extremely poor households classified as non-poor. The average net subsidies for the extreme poor and poor increase with the quantity adjustment. Again, the poor benefit most: their average net subsidy increases by (rounded) 43 percent (-0.3) or 104 percent (-0.8), whereas the average net subsidy of the extremely poor increases by 19 or 50 percent, respectively. The sharp increase for the poor is reflected by the fact that with an elasticity of -0.8, the poor now receive more than the non-poor contribute to the cross-subsidizing system at the household level (not shown). However, at the per capita level the poor still receive less than the non-poor contribute. This again highlights the role of per capita considerations, even though, as above with inelastic demand, the ranking of the tariffs is not affected by the switch from household to per capita levels. The last indicator that is affected by the quantity adjustments is the distributional incidence (Omega).[18] It is surprising that the changes in the average indicator are very small, even negligible, even though the changes at the individual level discussed beforehand are quite dramatic. This means that the overall increase of for example positive subsidies in the system is divided relatively equally into increases of positive subsidies for the three income groups (here the increase is around 16-17 percent of the total subsidies with the original *UNI 35* tariff). Another interesting result is that the negative effects on poor customers that we found in the inelastic analysis are attenuated by the quantity reactions.

6. Conclusion

We examine the individual welfare effects of water tariff reforms. Our particular interest lies in understanding affordability and distributional implications for poor water customers under volumetric and means-tested targeting. For this purpose, we compare five tariff options for

[18] Note that the per household and per capita Omegas will change exactly by the same percentage as the denominator is the only difference between Omega per household and Omega per capita. The denominator, the share of households (individuals) in total households (population), does not change in this simulation. We only display the Omega per capita.

water supply in Lima, Peru, which either apply one or a combination of the two targeting mechanisms.

It is not entirely clear which tariff performs best. First, under any of the tariff options, affordability is an issue for between 20 to 30 percent of the households if the critical share of total water expenditures in income is set at 2 percent. At a 5 percent threshold, there is no problem for all of the tariffs. If only the expenditures for subsistence consumption are considered (instead of total expenditures), our analysis highlights that the affordability problem only remains for extremely poor households as they are subject to true budget constraints. Second, also the distributional results provide an ambiguous picture from a pro-poor perspective – even though all tariffs except the current IBT and its slightly adjusted variation are progressive. On the one hand, uniform means-tested tariffs clearly perform better in terms of a progressive redistribution of income: The non-poor contribute to the system, the poor and extremely poor benefit, and the latter more so. On the other hand, a hybrid approach combining the currently existing IBT with means-tested targeting clearly redistributes the largest average subsidy to the extremely poor. However, it also allocates the largest average subsidy to non-poor customers. Generally, all tariffs allow for important redistribution among non-poor customers, which is clearly inefficient and scales down the potential scope for pro-poor pricing. The means-tested tariffs partly address this problem, the hybrid IBT is worst in this respect. Third, it is important to bear the errors of exclusion and inclusion in mind. When volumetric targeting is replaced by means-tested targeting, the share of non-poor customers receiving subsidies declines while the share of poor customers excluded from subsidies increases. This leads to the highlighted advantage of means-tested uniform tariffs in terms of redistribution among those who are still in the system, but also puts this gain into perspective as the share of those eligible *and* benefiting decreases. Lastly, the performance of hybrid approaches combining both targeting mechanisms hinges on the questions which mechanism dominates. Thus, they only do as good (or bad) as the dominant targeting approach on its own.

Overall, the analysis makes clear that one should be careful with generalizing any of these findings speaking against or in favor of one particular tariff scheme. First of all, the specific details of designing the targeting mechanism, i.e. the cut-off value for cross-subsidies, the block prices, the means test and the decision how to combine these within one tariff scheme, are decisive for the actual income redistribution. What is more, the results also crucially depend on the consumption pattern of consumers. These are a function of local environments.

In our context, household size has proven to be especially decisive, and our study is the first to show this effect quantitatively. However, this is the only (actionable) result from the literature about consumption patterns that informs the debate about pro-poor tariff design so far. Further research is clearly needed. A generalizable result is that understanding and, most important for policy advice, predicting the effects of IBTs is clearly more complex than with uniform means-tested tariffs because IBTs combine most of the aforementioned design factors. The interplay of tariff design and local consumption patterns may even make IBTs unusable for clear-cut policy measures.

Our analysis yields some further methodological results. Some of the indicators frequently used have to be interpreted with care. For example, the interpretation of the error of exclusion under volumetric targeting is ambiguous as it is a function of the cut-off value and the price structure chosen for an IBT (compensating effect). Therefore, the error does not only say something about targeting alone but also about price effects. In addition, using only the error of inclusion in total receivers can also be confusing as it can increase even if the share of non-eligible households getting subsidies decreases. These findings highlight the necessity to always employ a broad set of indicators to provide a comprehensive analysis of the performance of tariffs from a pro-poor perspective. This is further reinforced by the ambiguous results discussed above. Evaluating the distributional measures without the errors of exclusion and inclusion would point to another conclusion than considering just the errors or the distributional measures. Ultimately, it is a policy decision to weigh the results against each other and to decide what is more important as a policy goal in the specific country or city in question. Further, we propose to closer analyze redistribution within and not only across groups, as well as to separate access factors from targeting analysis. These two aspects have not been taken into account by previous literature and lead to important additional insights. Finally, the price elasticity of demand hardly affects the average affordability and distributional performance of tariffs in our case, even though the changes at the individual level in terms of price and quantity changes faced by the customers are huge. This aspect clearly needs more research as our case study is the first to clearly demonstrate the dichotomy of results.

Deriving policy recommendations for tariff design in Lima against this background is challenging. From a pro-poor perspective, it is ambivalent whether it is preferable to make more poor and extremely poor customers receive subsidies (as under volumetric targeting with the current IBT tariff) or to increase the transfers to those poor actually subsidized to effectively mitigate affordability problems (as under a means-tested tariff). However, it is clear that a simple means-tested tariff will outperform the IBT tariff as soon as the underlying welfare indicator is improved, i.e. as soon as the SISFOH approach is replaced by an indicator better reflecting customers' true income situation. Moreover, the fact that a means-tested tariff reduces the error of inclusion may be beneficial from a pro-poor perspective in the long term. It provides that a higher share of the population faces stronger incentives to reduce water consumption and water scarcity may be mitigated. Thus, the long-run costs of water supply may be lower than under a scenario with rather universal subsidization as with the current IBT. The analysis of the means-tested tariffs further shows that differentiating prices between poor and extremely poor household brings about undesirable results especially for the poor as the means test cannot clearly distinguish between the two in Lima. Combing an IBT with means-testing – as currently proposed by Peru's regulatory agency – does not bring about significant benefits for poor and extremely poor customers. Even if it may be true that such a tariff is politically easier to implement than a direct switch to a uniform means-tested tariff, this is clearly not due to the real effects of the tariffs. Eventually, if deviation from efficient pricing is deemed to be absolutely necessary to help the poor and extremely poor to afford their daily water consumption, promoting an improved means-test as the better pro-poor element in combination with a uniform tariff is warranted.

Appendix

A.1 Questionnaire for SISFOH categorization (Ficha Socioeconómica Unicá, FSU) (CETI, 2008)

The FSU (see figure below) is part of the identification of poor and extremely poor households in Peru. The whole identification process consists of three parts (CETI, 2008). The first step identifies poor neighborhoods from census data (currently Census 2005) according to the dominant features of housing in the neighborhood (housing material, water and sanitation services, household size per room). In a second step, a survey following the FSU is completed for all neighborhoods which could not be identified as clearly poor by the criteria in the first step. Households who think that they are poor but live in a census district classified as rich can apply for re-categorization. In the third, households are allocated weighted points according to their answers and the FSU weighting scheme (see below). Households are then put into the seven different SISFOH categories according to their total points in the questionnaire. SISFOH 1 and 2 correspond to the category Extremely Poor and are composed by the first two deciles of the FSU point distribution, SISFOH 3 to 5 correspond to the categorie Poor (deciles 3 to 5) and SISFOH 6 and 7 (deciles 6 to 10) correspond to Non-poor.

As all the items of the FSU questionnaire are also questions within the ENAHO expenditure survey, we can construct the SISFOH categories without having access to the original FSU survey. As we miss the first step, our procedure rests on the assumption that all poor households in rich census districts were re-catogerized after the initial identification. We cannot correct for rich households categorized as poor or extremely poor in the first step by the original SISFOH procedure who probably won't apply for re-classifcation. Using ENAHO data, these households will be identified as non-poor for our analysis. Unfortunately, official figures for the classification in Lima are not available, so that we cannot compare our results to the ones by the official procedure.

VARIABLES Y CATEGORIAS	Puntaje a la Respuesta	Peso de la Pregunta	Puntaje Total por Pregunta
Hacinamiento (miembros por habitación)			
Más de 6	-1,7890	0,3790	-0,6780
Más de 4 miembros, hasta 6	-1,7890	0,3790	-0,6780
Más de 2 miembros, hasta 4	-1,0600	0,3790	**-0,4010**
Más de 1 miembro, hasta 2	0,3960	0,3790	0,1500
Un miembro o menos	1,1730	0,3790	0,4440
Nivel Educativo del Jefe de Hogar			
Ninguno	-1,2770	0,4933	-0,6300
Inicial	-1,2770	0,4933	-0,6300
Primaria	-0,9360	0,4933	-0,4610
Secundaria	0,0030	0,4933	0,0010
Superior No Universitaria	0,9330	0,4933	**0,4600**
Superior Universitaria	1,9430	0,4933	0,9580
Postgrado	1,9430	0,4933	0,9580
Combustible que usan en el hogar para cocinar			
No cocinan	-1,3240	0,6805	-0,9010
Otro	-1,3240	0,6805	-0,9010
Leña	-1,3240	0,6805	-0,9010
Carbón	-1,3240	0,6805	-0,9010
Kerosene	0,7450	0,6805	0,5070
Gas	0,7450	0,6805	**0,5070**
Electricidad	0,7450	0,6805	0,5070
Tenencia de teléfono Fijo			
No	-0,6300	0,6116	**-0,3853**
Si	1,6040	0,6116	0,9811
Tenencia de Cocina a gas			
No	-1,4250	0,6421	-0,9150
Si	0,6960	0,6421	**0,4470**
Tenencia de Refrigeradora			
No	-0,8990	0,6952	**-0,6250**
Si	1,1140	0,6952	0,7740
Tenencia de TV a color			
No	-1,1960	0,6839	-0,8180
Si	0,8330	0,6839	**0,5700**
Tenencia de equipo de música			
No	-1,5230	0,5364	**-0,8170**
Si	0,6510	0,5364	0,3490
Número de artefactos en el hogar			
Ninguno	-1,6150	0,7480	-1,2080
1 artefacto	-1,0870	0,7480	-0,8140
2 artefactos	-0,2830	0,7480	-0,2110
3 artefactos	0,5060	0,7480	0,3780
4 artefactos	1,1870	0,7480	**0,8880**
5 artefactos	1,7430	0,7480	1,3040
6 artefactos	2,1160	0,7480	1,5830
Material que predomina en las paredes			

VARIABLES Y CATEGORIAS	Puntaje a la Respuesta	Peso de la Pregunta	Puntaje Total por Pregunta
Otro	-1,828	0,5914	-1,081
Estera	-1,614	0,5914	-0,955
Madera	-1,49	0,5914	-0,881
Piedra con barro	-1,417	0,5914	-0,838
Quincha	-1,384	0,5914	-0,819
Adobe o tapia	-1,027	0,5914	-0,607
Ladrillo o bloque de cemento	0,837	0,5914	**0,4950**
Material que predomina en los pisos			
Otro	-1,617	0,7019	-1,135
Tierra	-1,37	0,7019	-0,962
Madera (entablados)	-0,669	0,7019	-0,469
Cemento	0,357	0,7019	**0,2510**
Laminas asfálticas, vinílicos	1,622	0,7019	1,139
Losetas, Terrazos o similares	1,622	0,7019	1,139
Parquet o madera pulida	2,145	0,7019	1,505
Material predominante en los techos			
Otro	-1,381	0,5807	-0,802
Paja, hojas de palmera	-1,284	0,5807	-0,746
Caña o estera con torta de barro	-1,01	0,5807	-0,587
Plancha de calamina	-0,788	0,5807	-0,458
Tejas	-0,687	0,5807	-0,399
Madera	-0,374	0,5807	-0,217
Concreto armado	1,234	0,5807	**0,7170**
Abastecimiento de agua en el hogar			
Otro	-2,6	0,4819	-1,253
Río, acequia	-1,99	0,4819	-0,959
camión, tanque cisterna	-1,79	0,4819	-0,862
Pozo artesanal	-1,677	0,4819	-0,808
Pilón	-1,542	0,4819	-0,743
Fuera de la vivienda	-1,106	0,4819	-0,533
Dentro de la vivienda	0,543	0,4819	**0,2620**
Tipo de servicio higiénico			
No tiene	-1,982	0,6216	-1,232
Sobre acequia	-1,363	0,6216	-0,847
Pozo ciego o negro	-1,285	0,6216	-0,798
Pozo séptico	-1,089	0,6216	-0,677
Red pública fuera de la vivienda	-0,67	0,6216	-0,417
Red pública dentro de la vivienda	0,687	0,6216	**0,4270**
Tipo de alumbrado			
Ninguno	-3,601	0,4427	-1,594
Otro	-3,601	0,4427	-1,594
Vela	-3,601	0,4427	-1,594
Kerosene, petróleo	-3,601	0,4427	-1,594
Generador	-3,601	0,4427	-1,594
Electricidad	0,264	0,4427	**0,1170**

Figure 3: FSU questionnaire and weighting scheme (CETI, 2008)

A.2 Comparison of SISFOH and INEI poverty identification

Means-tested poverty categories and monetary poverty lines reflect completely different concepts of how to measure poverty and also imply different processes and costs. Calculating expenditure for each and every household as it is done to classify households according to the INEI poverty lines for the representative ENAHO sample is by far more complex than the means testing SISFOH approach. Poverty lines use very detailed expenditure data to calculate household expenditure. This includes pricing self-production of goods and services a priori not valued by market prices and comparing expenditure levels to the expenditures needed to satisfy basic nutritional needs in the specific area where the household lives. Because of the complexity of these processes, interviews are only done with a small and representative sample of households. Means-tested approaches as the SISFOH indicator have been introduced to enable an administratively easier and cheaper identification of eligible households for social programs. As detailed above, the SISFOH indicator is constructed by using interview information from each and every household. The items asked include the type of housing (walls, floors), the set of public services accessed by the household (water, waste water collection, electricity, insurance), and other household characteristics decisive for its means to avoid poverty (education, employment, age, etc). Even if the list includes around 20 questions and several answer options for each question, the questions are easy to answer and the answers easy to verify by the interviewer. It is obvious from this that a means-tested procedure is more realistic in terms of costs and time needed in order to identify potential beneficiaries of social benefits. It is, however, debatable what variables should compose the means test and how they should be weighted. Comparing the procedures that have been discussed in Peru (detailed e.g. in MEF (2010) and CETI (2008)) gives an idea of the complexity of this highly normative issue. Valderrama Torres and Pichihua (2011) discuss how to bring the targeting performance of the current SISFOH index closer to that of the monetary poverty lines for the case that this were desirable.

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