Perceived Water Prices and Estimated Water Demand in the Residential Sector of Windhoek, Namibia. An Analysis of the Different Water Market Segments

Working Paper

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Abstract

We develop a demand model for the water market of Windhoek, Namibia, and segment the market by income. The model uses the perceived price concept developed by Shin (1985). Results confirm the Shin hypotheses that consumers don't know actual prices, but respond to perceived prices. The average price and covariates have the expected signs. However, marginal price (MP) coefficient is positive. Shin's perception parameter (*k*) is negative in two of three income segments. In the Shin model, this implies that consumers respond to MP (through perceived prices). Ambiguities about prices warrant further investigation.

1. Introduction

Namibia is among the most arid countries in Sub-Saharan Africa and the world. Water demand in the already water short capital city of Windhoek and other urban areas intensified with an influx of people to the cities after independence and continues to grow. On the other hand, prospects for new water supplies are dim and so policy efforts have turned increasingly to demand control approaches. While per person water consumption rates are relatively low (140 l/c/d) for urban populations around the world (see Table I in the appendix), water demand continues to grow and shortages still loom.

Another challenge facing the city and municipality of Windhoek is the fact that there are considerable differences among citizens in terms of access to water and incomes. These differences create both inequities in access to water and differences in what might be the best demand control policy. It is a reasonable, but unexplored, hypothesis that different water demand policies will be needed to address the needs of different water demand segments in order to meet the two policy goals of controlling water demand and improving equity in access to water.

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The water market can be divided into the following segments. (i) in-house meters connected to individual houses; (ii) outside meters connected to individual houses; (iii) public stand pipes where groups of households share common pool water resources and (iv) group standpipes where a group of households use prepaid metered cards to access common pool water resources. Geographical location and housing characteristics, such as income, living standards and housing structures, also segment the water market. The municipality of Windhoek has made efforts to meet the demand for water in this diverse market by implementing a number of economic and conservation policies. Impacts of the municipal efforts must be examined according to each market segment, in order to assess the effectiveness of each policy on individual or segmented groups of consumers. In addition, a simultaneous framework of such policies would enable the municipality and policy makers to assess the comprehensive demand management program aimed at all water consumers in Windhoek.

Therefore, the objective of this paper is to empirically examine the factors that affect water demand using a price perception approach. We adopt a water demand estimation model to determine whether consumers react to average price or to marginal price (MP). In the current model, we use the reported average price (RAP) as a proxy for the average price. This paper addresses the issue of water market segmentation, something other studies did not consider and unique of its kind to be applied to an arid developing country, like Namibia. Another unique feature of the paper is its application of the price perception model to the different water market segments, which tests whether consumers respond to average or marginal price when demanding a commodity like water. According to Shin (1985), the perceived price specification is superior to existing models, which use average price or marginal price only, since it allows estimation of the price to which consumers respond.

Section Two of the paper reviews some of the issues concerned with water demand estimation. Section Three presents the sample and the data used. Section Four presents a theoretical framework of the Shin model. Section Five addresses the empirical water demand model. Section Six analyzes the results and Section Seven concludes with some policy implications.

2. Review of Water Demand Estimation

Several different models have been used in the literature to estimate water demand under different block pricing structures. These range from the original model by Nordin (1976) to the latest application of instrumental variables as a way to improve the estimates given by ordinary least squares (OLS) estimation. Nordin suggested the use of marginal price and an additional variable called the "difference variable" that accounts for intramarginal effects of price on water demand under block pricing regimes

The difference variable, which is also referred to as the rate structure premium or the income subsidy, is broadly defined as the total water bill minus what the water bill would have been if all units were charged the marginal price (Renwick and Green, 2000; Nieswiadomy and Molina, 1989). The Taylor-Nordin specification has been applied extensively in the literature. Various studies (Nieswiadomy and Molina, 1989; Renwick and Green, 2000; Jones and Morris, 1984; Agthe and Billings, 1986) could not confirm the prediction by Nordin that the coefficient of the difference variable should be equal in magnitude and opposite in sign to the income coefficient. Some researchers found the difference variable to have both the wrong sign and the wrong magnitude (Nieswiadomy and Molina, 1989; Renwick and Green, 2000). Others, for example, Jones and Morris, found the difference variable to be significant and have the correct sign, but not the same magnitude as the income variable.

Under block pricing structures, the price of water determines and is determined by water consumption. Therefore, the use of OLS could be problematic since price may be endogenous. . However, some studies found OLS results that were not fundamentally different from an instrumental variables approach (Jones and Morris, 1984), while others found improvement in the results by using instrumental variables (Nieswiadomy and Molina, 1989; 1991). Others have used instrumental variables in order to deal with the simultaneity problem (Renwick and Green, 2000; Nieswiadomy and Molina 1989; 1991) or adopted other demand estimation techniques, such as the least squares dummy variable (LSDV) approach (Shin, 1985).

Most studies found that income has a significant positive impact on water demand (Renwick and Green 2000; Jones and Morris, 1984; Moncur, 1987; Agthe *et al*., 1986; and Lyman, 1992). In general, factors such as income, price, household size, household age distribution, weather variables and conservation dummies were used in the literature and in most cases the variables had the expected signs. A study on water values, prices and water management in Botswana[1] concluded that economic factors play an important role in water management (Arntzen, *et al*., 2000). They identified average household income, household size, rainfall, house rent, and proportion of government consumption and water price to be the main determinants of water consumption in the capital, Gaborone. Arntzen, *et al*., (2000) found that water tariffs, rainfall and government consumption did not have significant impacts on household water consumption. While these variables often had the expected signs, for policy the size of the impact matters. Since it is not always clear that water price is sufficiently inelastic, the use of price as an effective policy tool should be treated with caution, particularly if one wishes to impose relatively small burdens on low-income households.

[1] Botswana and Namibia has similar climatic conditions and each country has a population of about 2 million people.

Table 1 below shows a summary of previous findings of water demand estimation by others.

Table 1: Summary of Some Studies in Residential Water Demand

Author(s)	Dep. Variable	Explanatory Variables	Estimation Technique	Data
Renwick and Green (2000)	Q_{it}, MP DMP.	MP, DMP, Info, Retro, Rebate, Ration, Restrict, Comply, Outdoor, Inc, Lot, BlockP, Prec, Temp	2SLS	Time Series
Jones and Morris (1984)	Q_{it}	AP, MP, Infra, Inc, Hhsize,	OLS – three functional forms	Cross section
Moncur (1987)	Q_{it}	Adjustm.factor, Qit-1, P, Inc, Rain, Hhsize, Restriction-D	OLS Dynamic (SR, LR)	Pooled
Lyman (1992)	$Q_{it\ (LR)}$	Qt, FCt-1, MPt-1, Pt, Inc, Hvalue, AvAge, HhSize, Heat, AgeHouse, TotBath, Sprinkler, LawnS, Shade, Prec, PeakD, SpringD, PSDummy, Flower, Veg, CoolDays, Temp,	OLS Dynamic Peak, off-peak demand	Pooled
Nieswiadomy (1992)	Q_{it}	Inc, MP, AP/MP, Rain, Temp, PubEd, Hhsize, %Homes, Occup, Conserve	OLS	Cross-Section
Nieswiadomy and Molina (1989); 1991	Q_{it}	Inc, MP, AP/MP, Rain, lawnsize, Income, weather, HHsize, Block-P1, -P2, -P3	OLS, IV 2SLS	Time Series
Dandy et al. (1997)	Q_{it}	Qit-1, PropV, P, QAllowance, HhSize, Climate,	2SLS	
Timmins (2003)	Q_{it}	AD, MP, Houses, Rain, Inc,	Nonlinear Dynamics	Panel
Nauges and Thomas (2003)	C_{it} P_{it}	PM, FC, Socio-demographics, system Features, Actual Consumption	OLS Nonlinear Dynamics	Panel
Shin (1985)	Q_t, P^*_t (Electricity)	Inc, GasP, HDD, CDD, AP, MP, Q_{t-1}, AP/MP,	LSDV IV	Pooled Panel

Note: For detail definition of the variables, see references

3. Sample and Data

The target population includes all private households in Windhoek, excluding the institutions and homeless people. According to the Census Office in the Central Bureau of Statistics (CBS) of Namibia, a household is a unit consisting of one or more persons, related or unrelated, who live together with common dining arrangements and are answerable to the same head of household. Given the time limit for the survey, the dwelling units were treated as the households. Following the Census Office's sampling procedures, we stratified the sample by three levels of living (high, middle and low) based on housing characteristics and geographic location. The choice of Windhoek for the sample is based on its importance as the capital and largest city in Namibia and on its accessibility for survey logistics relative to smaller cities and rural areas.

The paper uses primary data on a sample of 216 households from Windhoek, collected during the summer of 2004. Historically, colonial segregation by color ensured that different income groups were located in different areas of the city. What is referred to today as the high-income area of Windhoek was previously inhabited mainly by whites, and located a distance of 10 to 20 km away from the middle income black and coloreds' neighborhoods. Since differences still exist, we found it necessary to treat the different water users as distinct water market segments[2] as follows. The high-income group consists of 53 households from town and the middle-income group consists of 49 households from Khomasdal and 114 from Katutura.

Data on all the variables used in the model were collected from the individual households in face-to-face interviews. The data on marginal prices were collected from the rate schedule of the Windhoek municipality as presented in the Government Gazette of 1 July 2004. An interesting and challenging feature of the sample is that about 97% of the households used water within the first block and only 3% used water in the second block. Hence, there is no difference between MP and the actual average price paid by 97% of the sample. The data on plot size were collected from the individual respondents, but for missing data on this variable, we used secondary data from the municipality. The missing data for the income variable were filled in by the estimated value of income, using the respondent's education level and property such as television or car. Table 2 presents the different variables used in the paper.

[2] The different suburbs from Katutura are: Herero location, Gemeente, Golgota, Soweto Luxury-Hill, Single quarters, Goreangab formal area and Grysblok. The suburbs from Khomasdal are Khomasdal Park-Foods, Khomasdal Rossing Foundation and Otjomuise. The suburbs from town include Academia, Olympia, Eros, Windhoek North and Rocky Crest

Table 2: Variable Definition

Variable	*Description*	*Expected Impact or Sign*
Q_d	Household monthly water use in cubic meters	
Access	The mode of access to water Access = 1 if outside = 0 if inside	Negative – The further the access the less the water use, and hence the lower the price
RAP	Perceived average price per cubic water per month in N$, reported by respondent.	Negative – The higher the RAP, the less the demand for water as a normal good.
MP	Marginal price per cubic per month in N$	Positive – In an OLS analysis Negative – In a system analysis
Income	Household monthly income as reported by respondent	Positive – Income elasticity of demand for water as a normal good
Location	Dummy variable indicating geographical location of households Location = 1 for high income household = 0 for middle income households	Positive – the higher the location, the higher the demand for water and hence, the price of water
Childsize	The number of children in a household	Positive – But, an empirical issue
Adults	The number of adults in a household	Positive – according to Literature
PlotuseE	An interaction of plot size in square meters and a dummy variable indicating daily water use in the evening Daily water use_E[3] = 1 for more use in the evening = 0 otherwise	Positive – The larger the Plot the higher the demand for water, when we use plot size alone, but the interaction dummy depends on when water is used most
Qualpay	An interaction of a dummy indicating problems with water quality and a dummy indicating payment default at month-end Qualpay = 1 for quality problems and default = 0 otherwise	Negative – people who have problems with water quality are expected to use less water, but payment default is an empirical issue.
RainuseL	A dummy variable indicating less water use during rainy season Rainuse_L = 1 for less water use = 0 otherwise	Negative – People are expected to use less water during rainy season, especially those with gardens
Qsatis	A dummy variable indicating satisfaction with the amount of water used by household Qsatis = 1 if satisfied = 0 otherwise	An empirical issue
Minwalk	The number of minutes the consumer takes to walk to the water pump outside the house	Negative – The longer it takes to walk, the less the water demanded
Ration	A dummy variable indicating that the municipality is rationing water during peak and dry periods	Negative – When water is rationed, one expect consumption to go down
Info	A dummy variable indicating that households receive public education on water scarcity from the municipality	Negative – the more the information, the less they should consume
k	Perception parameter used to determine whether households respond to MP or to AP of water	Negative – implies that people react to MP in an Increasing Block (IB) situation Positive – implies that people react to AP in an IB situation

4. Theoretical Framework for Perceived Water Prices

Shin (1985), argues that it is costly for consumers to determine the actual rate schedule they pay for consumption. First, a consumer may not be aware of the block pricing structure of water, such that it is difficult for her to know the difference and recognize the impact of average

[3] The E in plotuse changes to M or D indicating water use in the morning or in daytime respectively.

or marginal price on her consumption. Secondly, even in cases where the consumer is aware of the rate structure, she may not adjust consumption until the impact of changes in the rate are reflected in the next water bill. Thirdly, the consumer often faces the difficulty of distinguishing water prices from the other components of a combined utility bill since the bill (like the one for Windhoek) is often part of a total municipal bill, which may include a charge for water, sewerage collection, electricity and other municipal fees. Differences in language between customers and the official or business language, like the case of Windhoek where the official language is English, could become a fourth difficulty facing the consumer in understanding the water bill.

The underlying concept of the Shin model is that the consumer will weigh the marginal costs and marginal benefits of determining the actual MP, and “guestimate,” and respond, to a perceived price that may not perfectly reflect the actual prices. According to Shin (1985), if the expected marginal benefit of determining the true marginal price is less than the cost, the consumer may not respond to marginal price, but may determine her consumption based on other price information, like an *ex post* average price. However, if the expected marginal benefit of the information is greater than the cost of obtaining it, the consumer is likely to determine the actual marginal price and adjusts her consumption accordingly. On the other hand, if the marginal benefit of determining the actual rate schedule is equal to the marginal cost, the consumer will stop searching for information and the perceived price may lie between marginal and average price, since the perceived price is designed to capture the effect of the rate structure premium on price perception (Shin, 1985; Nieswiadomy, 1992). According to Shin (1985), the perceived price, P* is constructed as a function of the MP, the average price (AP), and a price perception parameter k[4] as follows:

$$P^{*} = MP(AP/MP)^{k} \qquad (1)$$

[4] In this study, k is treated as a fixed parameter, assuming that all the factors that affect MP do not have a net effect on k over time. However, if price perception changes over time, k is expected to change over time (Shin, 1985).

The price ratio computed as the ratio of AP to MP is designed to capture the effect of the difference variable on price perception. It is for this reason that the difference variable does not enter the Shin demand model directly; rather it is captured through the price ratio (Shin, 1985; Nieswiadomy, 1992). The price perception parameter *k* is expected to be nonnegative. The parameter *k=0* if the consumer responds only to MP, and *k=1* if the consumer responds only to AP. If P^* lies between MP and AP, then $0<k<1$. In the case where *k* is greater than 1 or less than 0, the interpretation of *k, is less clear and* differs according to the pricing structure (Nieswiadomy, 1992). In an increasing block rate structure, like the one for Windhoek, $k>1$, implies that $P^*<AP<MP$, and k<0 implies that $P^*>MP>AP$. The reverse is true for a decreasing rate structure. Since the consumer's knowledge about the true MP depends on the marginal costs and benefits of acquiring the information, the proper choice of a price variable remains an empirical issue (Shin, 1985). (Nieswiadomy and Molina (1989) were the first to apply the model of perceived prices developed by Shin.)

5. Empirical Water Demand Model

Consider a water demand equation

$$\ln Qd_i = b_0 + a \ln PMP_i + ?'\mathbf{Z}_i + e_i , \qquad (2)$$

where Qd_i is water quantity demanded by household *i*, PMP_i is the (unobserved) perceived marginal price, and

$$?'\mathbf{Z}_i = b_3 \ln Income_i + b_4 \ln Adults_i + b_5 PlotuseE_i + b_6 PlotuseM_i + b_7 Qualpay_i + b_8 RainuseL + b_9 Qsatis_i + b_{10} Minwalk.$$

Because PMP_i is unobserved, we apply Shin's (1985) model to define a perceived marginal price (PMP) as in equation 1, but we use Reported Average Prices (RAP) as a proxy for the actual average price by the respondents as follows:

$$PMP = MP\left(\frac{RAP}{MP}\right)^k, \qquad (3)$$
$$\ln PMP = (1-k)\ln MP + k\ln RAP.$$

Equation (3) is then used as the price variable[5] in the demand model given by equation (3).

$$\begin{aligned}\ln Qd_i &= b_0 + a\ln PMP_i + \textbf{?}'\mathbf{Z}_i + e_i \\ &= b_0 + a\left[(1-k)\ln MP + k\ln RAP\right] + \textbf{?}'\mathbf{Z}_i + e_i \\ &= b_0 + b_1\ln MP_i + b_2\ln RAP_i + \textbf{?}'\mathbf{Z}_i + e_i \qquad (3)\end{aligned}$$

where and $b_1 = a(1-k)$, $b_2 = ak$. Given Shin's model, the estimable parameters b_1 and b_2 allow us to estimate Shin's parameter k as $k = b_2/(b_1 + b_2)$. The variables used in equation (3) are defined in table 2 and they vary according to the different market segments, the subscript *i* represent the number of households and *e* stands for the error term.

RAP is used as an instrument in determining quantity demanded in the second stage and Qd is used as an instrument in estimating RAP in the first stage of the demand model, given the simultaneity that exists between the two variables. RAP is estimated as a function of water quantity, actual AP, minwalk, location and child size. We only present the second stage preliminary results in the current paper.

Nieswiadomy and Molina (1989; 1991) analyzed demand for increasing and decreasing block rate structures, using OLS and instrumental variables. The current paper adopts a similar model using full information maximum likelihood (FIML) to estimate water demand for three different water market segments[6] in Windhoek. Theoretically FIML is preferred in estimating path parameters in non-recursive models because it takes the entire model into account, whereas

[5] While we used instruments of RAP in equation (3), MP enters equation (3) as an exogenous variable, given lack of variability in the MP data, even though it was found to be endogenous.
[6] The segments are connected (the total sample of 216 middle and high-income households who have inside and outside meters); middle-income segment (all 163 households who have inside and outside meters, but are located in Katutura or Khomasdal); and high-income segments (all 53 households who have inside meters only and they are located in town only).

2SLS estimates are computed based on partial information of the model at a time. Assuming that the disturbances are normally distributed, the FIML estimator is efficient among all consistent estimators (Greene, p. 693).

6. Interpretation of Results

6.1 General Test Results

Since the paper uses cross-sectional data, we tested for heteroscedasticity for all the water market segments. A test of homoscedasticity of the variance for each segment is not rejected, which implies that there is no problem of heteroscedasticity in this paper. Using White's heteroscedasticity test, the chi-squared statistics for the various segments were as follows: a chi-square statistics of 50.12 for 36 degrees of freedom for the connected segment; 22.54 for 18 degrees of freedom for the high-income segment; and 18.70 for 18 degrees of freedom for the middle income segment, all shows that we do not have enough evidence to reject the hypothesis of homoscedasticity at the 5% level.

Using the Hausman test of simultaneity, we found simultaneity between RAP and the quantity demanded for all the segments. The t-statistics for the residual values of *Qd* in estimating RAP were -8.02 for the connected; -2.31 for the high-income; and -5.23 for the middle-income segments respectively. This shows that the hypothesis of simultaneity between RAP and Qd is rejected for the inside and the outside segments and we do not have enough evidence to reject that hypothesis for the other three segments. Therefore, the non-recursive models for the connected, high- and middle-income segments are estimated using the FIML.

6.2 Preliminary Results of the Water Demand Model

Table 3: Preliminary Results of Water Demand in Windhoek

	Connected	High Income Segment	Middle Income
Variable	Q_d	Q_d	Q_d
Intercept	-2.409	4.813	-3.093
	(-1.07)	(0.87)	(-1.61)
LnMP	1.911	-0.771	1.649
	(1.98)	(-0.38)	(1.55)
lnRAP	-0.247	-0.593	-0.591
	(-1.25)	(-1.42)	(-1.73)
lnIncome	0.104	-0.745	0.334
	(2.77)	(-1.69)	(3.05)
lnAdults	0.132	0.195	0.123
	(1.80)	(1.45)	(1.18)
PlotuseE	0.0001	0.0002	
	(2.84)	(1.39)	
PlotuseM	0.0001	0.0003	
	(1.59)	(3.08)	
lnPlot			0.283
			(1.76)
RainuseL	-0.169		
	(-2.36)		
Qualpay	-0.540		-0.735
	(-2.65)		(-2.40)
Qsatis	0.572	1.704	
	(2.88)	(4.49)	
Info	-0.059	-0.034	-0.198
	(-0.68)	(-0.15)	(-1.62)
n	216	53	163
k	-0.15	0.44	-0.56

note: *t*-statistics are presented in parentheses

In the estimated water demand equation model, most of the variables have the expected signs as indicated in table 2 -- except income for the high-income segment and MP for all the segments. The negative impact of income on water demand for the high-income segment could be as a result of investments in water-saving devices, so that demand decreases with an increase in income – given that a major income effect has been accounted for by segmentation of the market. . The results of the RAP variable can be used to calculate the price elasticity of demand, which is -0.25 for the connected and -0.60 for each of the other two segments. This implies that consumers respond relatively more to a price change when treated as distinct segments, compared to when they are treated as a homogeneous group.

The public information dummy has a negative sign, which shows that water consumers reduced their demand as the municipality increases its public information campaigns on water scarcity. However, the information dummy results show that the municipal efforts on scarcity campaigns are not effective, and there is room for improvement on scarcity campaigns for this policy to become an effective conservation tool.

Results show that the price perception parameter is negative for the connected and the middle-income segments, which means that consumers appear to respond to MP for these segments in our current model. Nieswiadomy and Molina (1991) found similar results (k=-0.43) for increasing block rate structures and concluded that water consumers responded to MP. In contrast, a price perception parameter for the high-income segment is found to be positive (k=0.44), which implies that high-income consumers respond to AP when demanding water. Nieswiadomy and Molina (1991) found k=1.55, which was in line with findings by Shin (1985) and they both concluded that consumers respond to AP in a decreasing rate structure. For this reason, a positive k (in an increasing rate situation) for the high-income segment needs further investigation.

7. Conclusions and Policy Implications[7]

With the exception of the high-income segment when it is considered by itself, empirical results support the hypothesis that Windhoek consumers respond to MP. This is an important contribution of the paper and it confirms findings by others. Thus, Nieswiadomy and Molina (1991) found that consumers respond to MP in an increasing block rate structure, while Shin

[7] These results are preliminary and we are in the process of conducting more tests, which could modify the final results. Caution should be exercised when quoting these results.

(1985) found that electricity consumers responded to AP in a decreasing rate structure. However, it is also true that MP is constant and equal to AP for most consumers in this survey, and that the empirically estimated MP is positive.

In summary, some of the price results suggest that the use of price as a conservation policy could be effective. Thus, RAP is negative and significant for most of the segments as expected. Also, we found that the price elasticity of water shows that consumers respond relatively more to a change in price when treated as distinct water markets, compared to when they are treated as a homogeneous group, implying that targeted policies might be effective. However, the finding that MP is consistently positive for all the segments, except the high-income segments, is contrary to the usual and expected results for demand equations.

The price results could suggest the difficulties consumers face in determining the price they pay as advocated for by Shin (1985). Most of the other variables used as determinants, such as income, household size, plot-use, water quality, rain use, quantity satisfaction, distance, rationing and public information on scarcity had the expected signs. The information dummy results suggest that the municipal efforts on scarcity campaigns are not effective, which is a challenge to the Windhoek municipality.

The results show that policy variables, such as price, could have an impact in water conservation efforts as initiated by the municipality. Windhoek consumers consistently respond by reducing their water demand as RAP increases. However the impact of MP on water demand is positive, according to our current model. If it were true, this would tell policy makers to reject the block pricing schedule. However, we doubt it is true, and future models will attempt to better understand the nature of the pricing variables in this data set.

Our findings regarding marginal prices are somewhat disturbing for economic theory as well as being ambiguous for policy makers. However, the inference that Namibian water consumers increase their water demand as MP increases is probably wrong. More likely the result stems from the reverse causality: the fact that increased water use puts the user in a higher block. That is, the behavior of MP in this paper could be attributed to the fact that, although it is clearly an endogenous variable, MP is treated as exogenous due to data problems. We hope to sort out these ambiguities in ongoing work.

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APPENDIX

Table I. Average Daily Per Capita Water Consumption (l/c/d)

Income Group	Windhoek Population	Windhoek l/c/d	Grootfontein l/c/d	SA Design Guideline (l/c/d)
Informal	35,250	20	N/A	N/A
Low Income	85,590	80	114	60-120
Middle Income	58,400	140	185	80-160
High Income	17,650	309	658	120-350

Sources: Kaumbi (2000) - the first two columns and Van der Merwe (1998) the last two columns. Grootfontein is another city in Namibia and SA stands for South Africa