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ORIGINAL ARTICLE

The effect of cigarette price increases on cigarette consumption, tax revenue, and smoking-related death in Africa from 1999 to 2013

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Abstract
Objectives This study investigates the effects of price hikes on cigarette consumption, tobacco tax revenues, and reduction in smoking-caused mortality in 36 African countries.
Methods Using panel data from the 1999–2013 Euromonitor International, the World Bank and the World Health Organization, we applied fixed-effects and random-effects regression models of panel data to estimate the elasticity of cigarette prices and simulate the effect of price fluctuations.
Results Cigarette price elasticity was the highest for low-income countries and considerably lower for other African economies. The administered simulation shows that with an average annual cigarette price increase of 7.38%, the average annual cigarette consumption would decrease by 3.84%, and the average annual tobacco tax revenue would increase by 19.39%. By 2050, the number of averted smoking-attributable deaths (SADs) will be the highest in South Africa, followed by the Democratic Republic of Congo, Madagascar, and Ethiopia.
Conclusions Excise tax increases have a significant effect on the reduction of smoking prevalence and the number of averted smoking-attributable deaths, Low-income countries are most affected by high taxation policies.

Keywords Cigarette consumption · Price increases · Price elasticity · Smoking-related deaths · Africa

Introduction

In 1964, the Advisory Committee of the Surgeon General of the Public Health Service released a report that is best known for the conclusion that smoking is a cause of lung cancer. Since then, a number of other diseases have been linked to tobacco consumption, and smoking-caused mortality has subsequently emerged as an important issue in public health around the world (Samet 2014; Yach and Bettcher 2000).

The 2011 World Health Organization (WHO) report on the Global Tobacco Epidemic highlighted that tobacco consumption is responsible for the deaths of nearly six million people each year (World Health Organization 2011), and if not curbed, the death toll will reach 8 million each year in 2030, of which 80% will be from developing countries (Eriksen et al. 2012).

Although in most African countries the smoking rate and consumption have been lower than in other parts of the world (Mackay and Crofton 1996; Thun et al. 2012), in recent decades, multinational tobacco companies have been vigorously developing African markets to compensate for losses in developed countries (Warner 2000; Oluwafemi 2003; Doku 2010), leading to a high smoking prevalence in countries without tobacco prevention and control policies and aggravating the situation in countries that have already suffered from various deadly diseases.

Tobacco taxation is an effective single intervention to reduce the demand for cigarettes (Chaloupka et al. 2000).

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Unlike other tobacco control policy tools, taxation not only increases tax revenues for the state, but also effectively reduces the smoking population (Ahmad and Franz 2008). Previous studies have suggested that cigarette price increases are more effective in reducing consumption in low-income countries than in high-income countries, because cigarette affordability in the latter countries is higher than in low-income countries (World Health Organization 2011). Thus, cigarette price elasticity in mid- or low-income countries ranges between −0.5 and −1.05, whereas in high-income countries much lower figures (−0.25 to −0.5) have been reported (Chaloupka et al. 2000; Gallet and List 2003). As for African countries, estimates of cigarette price elasticity are rarely reported since research has focused on a restricted number of countries. That is, most studies have been time-series analysis on South Africa, reporting price elasticity figures ranging from −0.16 to −1.52 (Boshoff 2008; Reekie 1994; Van Der Merwe and Annett 1998; Van Walbeek 1996, 2000).

Income growth can offset the effect on consumption from a price rise, especially in countries with high growth rates. Previously reported income elasticities tend to range somewhere between 0 and 1 with figures for developing countries generally being higher than in developed countries (Blecher 2008; Nelson 2003). For the African region, estimates are available for only a few countries. Income elasticity figures for South Africa, for example, lie between 0.37 and 0.73 (Boshoff 2008; Reekie 1994; Van Walbeek 1996, 2000), and for Morocco between 0.87 and 1.04 (Aloui 2003).

The main contribution of this study is to estimate the price elasticity of cigarette demand in 36 African countries applying panel data analysis. If compared with time-series or cross-sectional studies, panel data analyses allow researchers to control for unobservables that threaten causal inference in observational studies and offer more opportunities to explore patterns of causal relationships over longer time spans (Halaby 2004; Hsiao 2014).

To ensure comparability between the 36 African countries, country-specific data analysed in this study were extracted from the same databases and for GNI per capita in purchasing power parity (PPP) international dollars were used (Jowell 1998).

According to World Bank statistics, GNI per capita has steadily increased in most African countries since the early 1990s and growth rates have been higher than the global average after 2001 (Sala-i-Martin and Pinkovskiy 2010), possibly affecting cigarette consumption behaviour and subsequently altering price elasticity patterns. Comprehensive cross-country investigations into the impact of price hikes on cigarette consumption would thus be instrumental in formulating future smoking prevention and tobacco taxation policies.

In 2003, the World Health Organization introduced the "Framework Convention on Tobacco Control" (FCTC) to reduce the supply and demand for tobacco products in the world. In 2008, it proposed six tobacco control policies (MPOWER) to effectively reduce tobacco consumption. Levy et al. (2013) found that if 41 countries in the world had implemented at least one MPOWER measure at the highest level of achievement during 2007–2010, the smoking population would have dropped by 14.8 million, and 7.4 million people would have not died of smoking.

In the past, assessments of tobacco control policies in Africa have rarely been conducted. Husain et al. (2016) in their study analysed tobacco control and prevention policies in 23 African countries and found large variations in the overall FCTC implementation rates, ranging from 9% in Sierra Leone to 78% in Kenya. Winkler et al. (2015) assessed the impact of tobacco control policies in 13 West African countries and found that smoking cessation plans, graphics and texts of health hazard warnings on cigarette smoking and cigarette price hikes had negative correlations with smoking prevalence and that smoking cessation plans had a higher impact on reducing smoking prevalence in males.

In this study, we applied fixed-effect and random-effect regression models of panel data to estimate price elasticity figures and the effects of cigarette price hikes on cigarette consumption for each of the observed 36 African countries. Based on the regression results, we also estimated tobacco tax revenues and the number of averted deaths.

In the final part of this study, we used the predicted effects of income, the number of MPOWER measures at the highest level of achievement and the rural/urban divide on cigarette consumption to discuss tobacco prevention and control policies for the region.

Methods

Measures

In this study, data regarding cigarette prices, cigarette consumption, gross national income (GNI) and the number of MPOWER measures at the highest level of achievement of 36 African countries were collected. Cigarette prices and consumption data were from the 1999–2013 market research database released by Euromonitor International (Euromonitor International 2014).

The average real retail price of a pack of cigarettes (20 cigarettes) was calculated by first dividing the total annual post-tax retail revenue by the total annual retail volume and then deflating the result using purchasing power parities (PPP).

Annual per capita cigarette consumption was calculated by dividing the total annual retail sales volume of cigarettes (pack of 20 cigarettes) by the number of people aged 15 years and older. Figures for cigarette sales used in the study did not include illegal cigarettes. Population data were obtained from the medium variant of the UN Population Division's World Population Prospects database (United Nations 2015).

The GNI data were abstracted from the World Bank's database and converted into gross national income (GNI) per capita in international dollars at purchasing power parity (PPP). Rural population in this study refers to the number of people living in rural areas as defined by the National Statistical Offices. In this study, the ratio of the rural population to the total population was used in the analysis.

The number of MPOWER measures at the highest level of achievement included six measures. That is, monitoring tobacco use and prevention policies (monitor), protecting people from tobacco smoke (protect), offering help to quit tobacco use (offer), providing warnings about the dangers of tobacco (warn), enforcing bans on tobacco advertising, promotion and sponsorship (enforce) and raising taxes on tobacco (raise). MPOWER figures for each country and details on the employed methodologies are available in the 2013 WHO report on the global tobacco epidemic (World Health Organization 2013a). The MPOWER indicator used in this study equalled the accumulated number of MPOWER measures at the highest level of achievement each country had obtained by the end of each respective year. Data on tobacco taxation, such as tobacco products consumption tax, value-added tax and health tax, were obtained from the WHO report and the market research databases of Euromonitor International (World Health Organization 2013b).

The model

To estimate cigarette price elasticity, a cigarette demand structure model was constructed using cigarette consumption as the dependent variable and cigarette price, gross national income (GNI), rural population, and the number of MPOWER measures at the highest level of achievement as explanatory variables.

According to World Bank data on GNI per capita in 2014 (Atlas method), countries can be divided into four groups with different income levels. As for the African region, there are only two high-income countries. Thus, this study distinguishes between three different income groups: low-income countries with a GNI per capita of US$1,045 or less; low–middle income countries with a GNI per capita between US$1,046 and US$4,125; and middle–high income countries with a GNI per capita of US$4,126 or more.

The cigarette price elasticity was estimated for three different income groups applying fixed-effect and random-effect regression models of panel data.

The baseline cigarette demand structure model of the African countries is as follows:

$$\ln C_{it} = \beta_1 + \beta_2 \ln P_{it} + \beta_3 \ln \mathrm{GNI}_{it} + \beta_4 \mathrm{MP}_{it} + \beta_5 \mathrm{Rural}_{it} + \varepsilon_{it} \quad (1)$$

where C_{it} is the annual cigarette consumption per capita in the population aged 15 years and older in country i in year t (1999–2013), P_{it} is the cigarette real retail price per pack of 20 cigarettes in country i in year t, GNI_{it} is per capita gross national income in country i in year t and MP_{it} is the number of MPOWER measures at the highest level of achievement in country i in year t. MPOWER measures included the monitoring of tobacco use and prevention policies, protecting people from tobacco smoke, offering help to quit tobacco use, providing warnings about the dangers of tobacco, enforcing bans on tobacco advertising, promotion and sponsorship, and raising taxes on tobacco. Rural_{it} is the rural population as percentage of the total population in country i in year t.

Equation (1) forms the basis of the empirical analysis in this study. Price endogeneity must be considered for the regression analysis to avoid biased estimates. We addressed this issue by using cigarette price and per capita GNI in periods $t-1$ and $t-2$ as well as rural population in periods $t-1$ as instruments for cigarette price, per capita GNI and rural population. This is however based on the assumption that the unobserved errors are not correlated with the instrument variables (Angrist and Pischke 2009). A Sargan test, a test for overidentifying restrictions validity, was thus administered to probe if residuals were correlated with the instrument variables (Arellano and Bond 1991). Furthermore, to rule out endogeneity, a test for price endogeneity was performed (Wilkins et al. 2007).

A Hausman test was applied to determine which model should be used for the equation estimation. A rejection of the test is taken to mean that the key random-effects assumption is false and in such case the fixed-effects estimates should be used (Wooldridge 2009).

To determine the effects of cigarette price hikes on cigarette consumption, cigarette consumption in 2013 was set as the baseline for this study. Maximum and mean increments in cigarette prices during 1999–2013 were applied to simulate changes in future cigarette consumption based on the cigarette price elasticity estimated in this study. Changes in tobacco tax revenues were calculated based on changes in consumption due to price increases.

Percentages of price increases were calculated using the yearly mean and maximum price increases between 1999 and 2013.

Applying the relevant changes in cigarette consumption to the number of smokers, we calculated the reduction in smokers. The number of deaths averted was estimated using an algorithm based on Doll et al. (1994, 2004), who concluded that half of all regular cigarette smokers would eventually be killed by their habit. As similar figures have been reported in other studies (Taylor et al. 2002; Kenfield et al. 2008), the suggested 50% probability was applied to smokers who had quit as a result of price increases to estimate the deaths averted (Levy et al. 2013).

Results

Descriptive statistics

Data on 36 countries of the African region were included in this study. Tables 1 and 2 exhibit for each African country the cigarette taxes as percentage of retail price, the average retail price for a pack of 20 cigarettes (including taxes and deflated using purchasing power parities (PPP), the annual per capita cigarette consumption in packs for people aged 15 years and older and the GNI per capita in PPP (current international $).

The structural composition of taxes on tobacco products in the observed countries is shown in Table 1. Total taxes include four types: specific excise, *ad valorem* excise, value-added tax/sales tax and import duties. *Ad valorem* and value added/sales tax were the most common types. According to the 2015 WHO report on the global prevalence of tobacco products, the total amount of taxes levied in 2014 was the highest in Madagascar (80.45%), followed by Seychelles (79.71%), Mauritius (72.52%) and Botswana (62.68%), whereas taxes accounted for less than 60% in the remaining countries. Benin had the lowest total tax rate (8.74%), followed by Togo (13.41%) and Ethiopia (18.77%).

Table 2 summarizes changes in retail prices, per capita consumption and per capita GNI. In 2013, the average retail cigarette price in South Africa was the highest at US$3.36 per pack, followed by that in Mauritius at US$2.87. Considering the fluctuation of real retail prices of cigarettes between 1999 and 2013, cigarette prices across the African continent generally showed a rising trend, with the Seychelles showing the fastest increase (129.7%), followed by South Africa (81.6%), Cameroon (72.9%) and Ethiopia (67.2%), while cigarette prices in Ghana, Nigeria and Gabon decreased by 53.7, 33.1 and 21.2%, respectively. In 2013, the annual per capita cigarette consumption of people aged 15 years and older was the highest in Algeria with 38.1 packs, followed by the Seychelles (22.9 packs), South Africa (20 packs), Equatorial Guinea (19.7 packs), Cabo Verde (18.1 packs) and Gabon (16.8 packs). The annual per capita consumption in other African countries was below 15 packs. With the exceptions of Kenya, Algeria, Nigeria, Ethiopia and Chad, where cigarette consumption increased by 89.5, 43.2, 13.6, 10 and 2.6%, respectively, consumption in other African countries assumed a downward trend with Mauritius showing the greatest decrease (76.4%), followed by Rwanda (70%).

As for changes in annual per capita GNI, with the exceptions of Central African Republic (−13.4%), there was an upward trend in all the other observed African countries between 1999 and 2013, with Ethiopia showing the largest increase (197.8%), followed by Equatorial Guinea (195.3%), Angola (180.3%), Mali (158.0%), Rwanda (156.7%), and Mozambique (154.8%), respectively.

Regression results

Results of the administered Hausman test t showed that the models were statistically significant at the 5% level for the full sample of countries, for low-income countries and for middle–high income countries, indicating that the fixed-effect model should be administered for the full sample, low-income, and middle–high income group of countries, while the random-effect model could only be used for the lower-middle income group (Table 3). We thus applied the fixed-effects model for all four samples. These instruments are valid in all the four sample models because the p values of the Sargan test are not significant at conventional levels, showing that there is no evidence of instrument misspecification (Arellano and Bond 1991). Moreover, the administered test for price endogeneity (Wilkins et al. 2007) established that price is exogenous in the model. In addition, the overall F statistic for each of the four regression models was statistically significant at the 5% level, indicating a very good model fit.

Elasticity estimates

Four panel regression models were used in this study to estimate the elasticity of demand for cigarettes. The cigarette consumption, cigarette price and income variables were all logarithmically transformed, indicating that the estimated parameter value was the elasticity. The results of the analysis showed differences in the cigarette price elasticity among the four clustered samples of African countries (Table 3). The price elasticity of demand for cigarettes was −0.496 in the full sample. Cigarette price elasticity was the highest at −0.562 for low-income countries (GNI per capita of

Table 1 Cigarette taxes in Africa as of 2014

Countries	Taxes as percentage of retail price					
	Specific excise (%)	Ad valorem excise (%)	Value added tax/ sales tax (%)	Import duties (%)	Other taxes (%)	Total tax (%)
Low income						
Benin	0.00	5.38	2.42	0.00	0.94	8.74
Burkina Faso	0.00	16.95	15.25	0.00	0.00	32.20
Burundi	27.5	0.00	15.25	0.00	0.00	42.75
Central African Republic	0.00	16.81	15.97	0.00	0.00	32.77
Chad	0.00	20.0	11.88	0.00	2.09	33.97
Democratic Republic of Congo	13.55	10.21	13.79	10.21	0.00	47.76
Ethiopia	0.00	13.9	4.87	0.00	0.00	18.77
Gambia	30.0	0.00	6.56	2.29	6.9	45.75
Guinea-Bissau	0.00	3.28	13.04	2.07	0.72	19.11
Madagascar	0.00	63.78	16.67	0.00	0.00	80.45
Malawi	14.53	0.00	4.09	2.06	0.00	20.68
Mali	0.00	6.70	6.80	5.07	0.63	19.20
Mozambique	16.33	0.00	14.53	0.00	0.00	30.86
Niger	0.00	11.11	15.97	0.00	0.83	27.91
Rwanda	0.00	17.42	5.23	0.00	0.00	22.64
Togo	0.00	8.26	4.79	0.00	0.36	13.41
Uganda	35.00	0.00	10.08	0.00	0.00	45.08
Lower-middle income						
Cabo Verde	0.00	12.32	9.24	0.00	0.31	21.87
Cameroon	0.00	6.69	6.44	6.18	1.34	20.65
Congo-Brazzaville	6.67	14.19	15.25	0.00	4.76	40.87
Côte d'Ivoire	0.00	15.18	10.93	0.00	0.00	26.11
Ghana	0.00	13.20	14.89	0.00	0.22	28.31
Kenya	0.00	35.00	13.79	0.00	0.00	48.79
Mauritania	0.00	8.26	12.28	3.58	0.55	24.67
Nigeria	0.00	15.87	4.76	0.00	0.00	20.63
Senegal	0.00	25.00	15.25	0.00	0.00	40.25
Swaziland	33.14	0.00	20.00	0.00	0.00	53.14
Zambia	0.00	20.00	1.36	0.00	0.00	21.36
Middle–high income						
Algeria	38.14	0.00	12.56	0.00	0.00	50.79
Angola	0.00	0.00	22.9	0.00	0.76	23.66
Botswana	42.44	9.53	10.71	0.00	0.00	62.68
Gabon	0.00	19.56	15.25	0.00	0.00	34.81
Mauritius	59.47	0.00	13.04	0.00	0.00	72.52
South Africa	36.52	0.00	12.28	0.00	0.00	48.80
Equatorial Guinea	0.00	22.06	8.6	13.24	0.44	44.35
Seychelles	66.67	0.00	13.04	0.00	0.00	79.71

US$1,045 or less). It reached −0.489 among middle–high income countries (GNI per capita of US$4,126 or more) and was the lowest at −0.486 for low–middle income countries (GNI per capita between US$1,046 and US$4,125). The income elasticity of demand for cigarettes was −0.229 in the full sample. In the other sample categories of countries, the income elasticity of demand for cigarettes ranged between −0.343 and −0.041.

The number of MPOWER measures at the highest level of achievement had a negative and statistically significant

Table 2 Cigarette consumption, retail prices and GNI per capita in Africa (1999–2013)

Countries	Real retail price per pack, PPP (USD)			Tax/price (%)	Per capita consumption (pack)			GNI per capita in PPP (current international $)		
	1999	2013	Changes % (1999–2013)		1999	2013	Changes % (1999–2013)	1999	2013	Changes % (1999–2013)
Low income										
Benin	1.41	1.83	29.8	8.74	4.4	3.5	−20.5	1240	1920	54.8
Burkina Faso	1.91	2.47	29.3	32.2	7.8	5.8	−25.6	820	1560	90.2
Burundi	0.77	1.25	62.3	42.75	8.9	2.9	−67.4	560	750	33.9
Central African Republic	0.92	1.10	19.6	32.77	6.7	5.3	−20.9	670	580	-13.4
Chad	0.62	1.02	64.5	33.97	3.9	4.0	2.6	800	1980	147.5
Democratic Republic of Congo	0.85	1.39	63.5	47.76	4.8	2.2	−54.2	400	630	57.5
Ethiopia	0.61	1.02	67.2	18.77	2.0	2.2	10.0	460	1370	197.8
Gambia	1.29	1.70	31.8	45.75	6.3	4.5	−28.6	1140	1610	41.2
Guinea-Bissau	1.54	1.83	18.8	19.11	6.4	5.1	−20.3	900	1380	53.3
Madagascar	0.90	1.46	62.2	80.45	13.1	6.3	−51.9	1090	1370	25.7
Malawi	0.85	1.39	63.5	20.68	7.1	2.3	−67.6	670	1090	62.7
Mali	1.81	2.33	28.7	19.20	9.7	6.1	−37.1	810	2090	158.0
Mozambique	1.16	1.48	27.6	30.86	4.3	2.4	−44.2	420	1070	154.8
Niger	0.59	0.77	30.5	27.91	3.8	2.6	−31.6	620	890	43.5
Rwanda	0.77	1.15	49.4	22.64	5.0	1.5	−70.0	600	1540	156.7
Togo	1.54	2.01	30.5	13.41	9.9	7.2	−27.3	1020	1130	10.8
Uganda	0.95	1.35	42.1	45.08	3.4	1.1	−67.6	820	1700	107.3
Lower-middle income										
Cabo Verde	1.70	2.20	29.4	21.87	22.4	18.1	−19.2	2590	6120	136.3
Cameroon	0.59	1.02	72.9	20.65	7.8	5.9	−24.4	1750	2780	58.9
Congo-Brazzaville	0.23	0.32	39.1	40.87	17	8.9	−47.6	2400	4670	94.6
Côte d'Ivoire	0.33	0.44	33.3	26.11	16	13.9	−13.1	2290	2900	26.6
Ghana	1.75	0.81	−53.7	28.31	4.6	3.7	−19.6	1700	3860	127.1
Kenya	0.98	1.19	21.4	48.79	3.8	7.2	89.5	1680	2830	68.5
Mauritania	1.67	2.20	31.7	24.67	6.5	4.0	−38.5	2250	3630	61.3
Nigeria	1.78	1.19	−33.1	20.63	4.4	5.0	13.6	2325	5360	130.5
Senegal	0.82	0.98	19.5	40.25	20.1	14.2	−29.4	1450	2220	53.1
Swaziland	0.62	1.00	61.3	53.14	31.8	14.1	−55.7	5600	7470	33.4
Zambia	1.36	1.72	26.5	21.36	8.9	4.6	−48.3	1520	3580	135.5
Middle–high income										
Algeria	1.00	1.44	44.0	50.79	26.6	38.1	43.2	7360	13,520	83.7
Angola	0.75	1.08	44.0	23.66	28.6	13.6	−52.4	2280	6390	180.3
Botswana	1.03	1.41	36.9	62.68	26.2	15.8	−39.7	7620	15,150	98.8
Gabon	0.85	0.67	−21.2	34.81	32.9	16.8	−48.9	12,630	16,990	34.5
Mauritius	1.96	2.87	46.4	72.52	43.6	10.3	−76.4	8100	17,950	121.6
South Africa	1.85	3.36	81.6	48.80	36.9	20.0	−45.8	7390	12,540	69.7
Equatorial Guinea	1.41	1.83	29.8	44.35	25.3	19.7	−22.1	6620	19,550	195.3
Seychelles	1.11	2.55	129.7	79.71	47	22.9	−51.3	13,650	24,360	78.5

GNI per capita gross national income, *PPP* purchasing power parity

Table 3 Results of fixed-effect and random-effect regression models of panel data, African countries (2009–2013)

	Dependent variable: (lnC_{it})							
	Full sample		Low-income countries		Low–middle income countries		Middle–high income countries	
	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Independent variables								
Constant	2.712** (0.29)	1.863** (0.28)	0.967** (0.37)	1.856** (0.37)	3.232** (0.59)	2.961** (0.53)	4.189** (0.64)	3.577** (0.50)
ln P_{it}	–0.496** (0.05)	–0.626** (0.05)	–0.562** (0.08)	–0.601** (0.08)	–0.486** (0.08)	–0.473** (0.08)	–0.489** (0.13)	–0.412** (0.10)
$lnGNI_{it}$	–0.229** (0.06)	0.102* (0.06)	–0.041** (0.09)	0.108 (0.09)	–0.286** (0.12)	–0.229** (0.11)	–0.343** (0.13)	–0.206** (0.11)
MP_{it}	–0.019** (0.008)	–0.028** (0.01)	0.040** (0.01)	0.030** (0.13)	0.019 (0.01)	0.016 (0.01)	–0.082** (0.01)	0.083** (0.01)
$Rural_{it}$	–0.485** (0.19)	0.035 (0.17)	1.547** (0.27)	0.598** (0.24)	–0.006 (0.32)	0.117 (0.28)	–0.043 (0.52)	0.117 (0.22)
Observations	504	504	238	238	154	154	132	132
Number of countries	36	36	17	17	11	11	8	8
F test	118.6**		114.7**		254.7**		28.2**	
Hausman test		240.1**		69.7**		3.23		1767.7**
R^2	0.967	0.269	0.901	0.376	0.962	0.386	0.684	0.403
J test (*p* value)	0.599	0.081	0.511	0.612	0.309	0.257	0.682	0.558

ln natural logarithm, C_{it} the annual cigarette consumption per capita in the population aged 15 and older in country *i* in year *t*, P_{it} the cigarette real retail price per pack of 20 cigarettes in country *i* in year *t*, GNI_{it} per capita gross national income in country *i* in year *t*, MP_{it} the number of MPOWER measures at the highest level of achievement in country *i* in year *t*, $Rural_{it}$ the rural population percentage in country *i* in year *t*

* and ** Statistically significant at 10 and 5%, respectively. Standard errors are shown in parentheses. Low-income countries (GNI per capita of US$1,045 or less): Benin, Burkina Faso, Burundi, Central African Republic, Chad, Democratic Republic of Congo, Ethiopia, Gambia, Guinea-Bissau, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Togo, Uganda; Lower-middle income countries (GNI per capita between US$1,046 and US$4,125): Cabo Verde, Cameroon, Congo-Brazzaville, Côte d'Ivoire, Ghana, Kenya, Mauritania, Nigeria, Senegal, Swaziland, Zambia; Middle–high income countries (GNI per capita of US$4,126 or more): Algeria, Angola, Botswana, Gabon, Mauritius, South Africa, Equatorial Guinea, Seychelles

Table 4 Impact of real retail cigarette price increases in African countries between 1999 and 2013 on cigarette consumption per capita, tax revenue, reduction in the number of smokers and reduction in smoking-attributable deaths

Countries	Annual max and mean increase % in real retail cigarette price		Annual max and mean decrease % in per capita cigarette consumption		Annual max and mean increase % in cigarette tax revenue		Reduction in no. of smokers due to cigarette price increase		Max and mean reduction in SADs	
	Max (%)	Mean (%)	Max (%)	Mean (%)	Max (%)	Mean (%)	Max	Mean	Max	Mean
Low income										
Benin	13.73	5.59	7.72	3.14	133	57	32,089	13,065	16,045	6532
Burkina Faso	14.14	6.08	7.95	3.42	33	15	80,211	34,490	40,106	17,245
Burundi	55.23	2.84	31.04	1.60	58	5	296,769	15,260	148,384	7630
Central African Republic	9.50	4.55	5.34	2.56	22	11	11,945	5721	5973	2861
Chad	37.60	10.44	21.13	5.87	66	23	112,743	31,304	56,371	15,652
Democratic Republic of Congo	58.38	13.24	32.81	7.44	27	11	953,467	216,237	476,733	108,118
Ethiopia	37.60	10.44	21.13	5.87	135	46	460,875	127,966	230,437	63,983
Gambia	15.09	5.45	8.48	3.06	22	8	11,696	4224	5848	2112
Guinea-Bissau	13.73	5.03	7.72	2.83	59	23	5435	1991	2717	995
Madagascar	57.57	12.96	32.35	7.28	16	8	601,652	135,442	300,826	67,721
Malawi	58.38	13.24	32.81	7.44	154	51	351,892	79,806	175,946	39,903
Mali	15.16	5.37	8.52	3.02	64	24	75,235	26,650	37,618	13,325
Mozambique	8.89	4.62	5.00	2.60	22	12	84,369	43,845	42,185	21,923
Niger	8.67	3.03	4.87	1.70	25	9	21,537	7527	10,768	3763
Rwanda	34.81	14.36	19.56	8.07	102	49	121,590	50,159	60,795	25,079
Togo	14.38	6.95	8.08	3.91	94	47	21,568	10,424	10,784	5212
Uganda	10.59	5.17	5.95	2.91	16	8	103,882	50,715	51,941	25,357
Lower-middle income										
Cabo Verde	14.38	6.53	6.80	3.09	54	26	1663	755	832	378
Cameroon	26.64	8.33	12.60	3.94	98	34	105,630	33,029	52,815	16,515
Congo-Brazzaville	10.41	6.57	4.92	3.11	19	12	10,053	6345	5026	3172
Côte d'Ivoire	13.12	6.91	6.21	3.27	41	22	72,198	38,025	36,099	19,013
Ghana	11.67	3.93	5.52	1.86	34	12	34,936	11,765	17,468	5883
Kenya	13.79	7.24	6.52	3.42	20	11	167,434	87,906	83,717	43,953
Mauritania	16.32	5.58	7.72	2.64	53	19	21,523	7359	10,761	3679
Nigeria	5.98	2.90	2.83	1.37	25	12	108,144	52,444	54,072	26,222
Senegal	11.19	3.81	5.29	1.80	21	8	29,435	10,022	14,717	5011
Swaziland	54.80	12.91	25.92	6.11	50	17	16,173	3810	8086	1905
Zambia	9.53	5.80	4.51	2.74	39	24	45,915	27,944	22,958	13,972
Middle–high income										
Algeria	15.64	5.76	7.65	2.82	21	8	223,377	82,267	111,689	41,133
Angola	10.96	5.39	5.36	2.64	38	19	54,014	26,564	27,007	13,282
Botswana	9.33	5.59	4.56	2.73	10	6	8690	5206	4345	2603
Gabon	14.39	4.75	7.04	2.32	31	11	8114	2678	4057	1339
Mauritius	18.83	10.19	9.21	4.98	14	8	16,536	8949	8268	4474
South Africa	54.27	17.43	26.54	8.52	55	24	1,480,417	475,468	740,209	237,734
Equatorial Guinea	13.73	5.56	6.71	2.72	22	10	2771	1122	1385	561
Seychelles	36.41	11.22	17.80	5.49	20	8	1905	587	953	294
All countries	22.91	7.38	12.06	3.84	47.58	19.39	159,886	48,252	79,943	24,126

SAD smoking-attributable death

impact on cigarette consumption in the full sample as well as in the middle–high income countries. However, in low-income countries, the number of MPOWER measures at the highest level of achievement showed a positive impact on cigarette consumption. In addition, living in rural areas had a positive and statistically significant impact on cigarette consumption in low-income countries. However, living in rural areas had a negative and statistically significant impact on cigarette consumption in the full sample.

Effect of cigarette prices on cigarette consumption, tobacco tax revenue and deaths from smoking-caused diseases

To determine the effects of cigarette price hikes on cigarette consumption, cigarette consumption in 2013 was set as the baseline for this study. The maximum and mean annual increments in cigarette prices during 1999–2013 were used to simulate changes in future cigarette consumption based on price elasticity estimated in this study. In both scenarios, increases in cigarette prices (mean and maximum) reduced cigarette consumption the most in South Africa (price mean and max: 17.43 and 54.27%; consumption mean and max: 8.52 and 26.54%), followed by Rwanda (price mean and max: 14.36 and 34.81%; consumption mean and max: 8.07 and 19.56%). The other countries with a large reduction in cigarette consumption were the Democratic Republic of Congo (mean: 7.44%, max: 32.81%), Malawi (mean: 7.44%, max: 32.81%) and Madagascar (mean: 7.28%, max: 32.35%). The simulation result also suggests that with an average annual cigarette price increase of 7.38% during the observed period of 1999–2013, the average annual cigarette consumption would decrease by 3.84% in the 36 African countries (Table 4).

Tobacco tax revenue in 2013 was used as the baseline to predict future effects of mean changes in cigarette prices on tobacco tax revenue. The simulation result shows that the average annual tobacco tax revenue would increase by 19.39%. Benin had the highest percentage increase in tax revenue (mean and max increase: 57 and 133%), followed by Malawi (mean and max increase: 51 and 154%), Rwanda (mean and max increase: 49 and 102%) and Togo (mean and max increase: 47 and 94%).

The largest number of smoking-attributable deaths (SADs) was averted in South Africa, Democratic Republic of Congo, Madagascar and Ethiopia. Our model predicts that by 2050, the number of averted SADs will be the highest in South Africa (averted SADs mean and max: 237,734 and 740,209), followed by the Democratic Republic of Congo (108,118 and 476,733), Madagascar (67,721 and 300,826) and Ethiopia (63,983 and 230,437) (Table 4).

Discussion

In general, previous studies were in favour of raising cigarette taxes to hike cigarette prices as a fair policy intervention to help improve the health and economic benefits of citizens, even in cases in which the effects of cigarette price hikes were different due to the differences in economic and cultural environments among the countries (Jha and Chaloupka 2000; Goodchild et al. 2016; WHO 2013b). The present study estimated that the price elasticity of demand for cigarettes in the African countries was approximately −0.486 and −0.562, lower than what had been estimated previously (Boshoff 2008; Reekie 1994; Van Der Merwe and Annett 1998; Van Walbeek 1996, 2000), suggesting that consumers were less responsive to price increases in the earlier years and that elasticity increased as prices rose, following the general pattern that elasticity tends to increase along the demand curve.

Our study found that when GNI per capita was US$1,045 or less, cigarette price elasticity was the highest at −0.562. Thus, in low-income countries, such as Rwanda, Malawi and the Democratic Republic of Congo, a cigarette price hike in the future would have the greatest impact on reducing cigarette consumption. Levy et al. (2013) suggested that when total tobacco taxes accounted for over 75% of the retail price, the smoking population and deaths from smoking-caused diseases dramatically decreased in Argentina, Italy, Romania and Turkey. However, only few African countries have had such high tax rates in recent years. During the observed 1999–2013 time frame, the average total tax rate was the lowest at 36.2% in the final year, which is a further indication that tobacco taxes in the majority of African countries are too low and that there is a large space for cigarette price hikes in the future to reduce cigarette consumption and mortality from smoking-derived diseases. Higher tobacco tax revenues could also be instrumental in financing other tobacco prevention and control programs.

Moreover, this study found that the estimated price elasticity of demand for cigarettes in the African countries were between −0.486 and −0.562. That is, the absolute value of the estimate of price elasticity was significantly greater than the value of the estimate income elasticity, indicating that the effect of cigarette price hikes in African countries on reducing cigarette consumption would not be offset by income growth. Therefore, it is recommended that cigarette prices should be increased substantially in countries with low cigarette prices. As the tobacco industry often willingly bears the increased cost of cigarette tax hikes to enhance sales, other tobacco control policies, such as monitoring the use of tobacco products, assisting smokers to quit, creating tobacco-free environments,

providing warning of the dangers of smoking and banning tobacco product advertising and promotion, should be applied in combination with tax adjustments.

If compared with other parts of the world, the African continent had the lowest number of MPOWER measures at the highest level of achievement and their effect on cigarette consumption was rather limited in low-income countries. Therefore, the implementation of MPOWER measures at the highest level of achievement needs to be further strengthened, especially in the least developed African countries. Economic Research Council (ERC) (2010) data on smoking prevalence exemplifies the urgent need to implement smoking prevention measures in poorer countries: During 1990–2010, the cigarette consumption in South Africa decreased by 46%, whereas demand in other African markets increased by 68%. The reason for this discrepancy is that in South Africa successful tobacco control policies reduced cigarette consumption, while at the same time the tobacco industry rigorously explored and expanded other markets in Africa, especially in poorer countries of the continents (Warner 2000; Oluwafemi 2003; Doku 2010).

Although smoking prevalence levels are still comparatively low and the negative impacts on society are thus less visible, the consequences of rising consumption are expected to have a dramatic impact on the health and welfare of the people in the near future (Blecher and Ross 2013; Eriksen et al. 2012). Moreover, as poorer countries are unable to obtain internal funds by levying tobacco taxes to support smoking prevention and control due to low smoking prevalence and incomplete tobacco tax mechanisms, there should be an attempt to acquire external funds to finance smoking prevention and control programs.

The limitations of this study include the possible effects of socio-demographic variables, such as educational attainment, and illicit tobacco trade not being accounted for in the analysis. Moreover, the study is based on observations from mostly sub-Saharan African states and might not be representative for Northern Africa, which is more closely tied to Southwestern Asia and constitutes a major part of the Muslim world. These issues should be addressed in future research on cigarette price elasticity and tobacco control in Africa.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This article does not contain any studies with human participants performed by any of the authors.

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