Benefits of regulation vs. competition where inequality is high: The case of mobile telephony in South Africa*

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Abstract

We test for the distributional effects of regulation and entry in the mobile telecommunications sector in a highly unequal country, South Africa. Using six waves of a consumer survey of over 134,000 individuals between 2009-2014, we estimate a discrete-choice model allowing for individual-specific price-responsiveness and preferences for network operators. Next, we use a demand and supply equilibrium framework to simulate prices and the distribution of welfare without entry and mobile termination rate regulation. We find that regulation benefits consumers significantly more than entry does, and that high-income consumers and city-dwellers benefit more in terms of increased consumer surplus.

Keywords: Mobile telecommunications; Competition; Entry; Discrete choice; Inequality

JEL Classification: L13, L40, L50, L96

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1 Introduction

South Africa is the most unequal country in the world, with a Gini coefficient of 0.63 in 2015 according to World Bank statistics. This is a consequence of apartheid-era racial discrimination policies (Leibbrandt et al., 2010). The top 10% of income earners earn thirty times more than the bottom 10%. As a result of these high levels of inequality, policymakers are under pressure to find means of reducing inequality. One such policy lever is reducing the prices of consumer services through greater competition and the regulation of firms with market power.

The mobile telecommunications sector is a prime example of an industry in which the number of competitors, and thus to some extent competition, is under state control. In partcular, the State assigns radio frequency spectrum licenses.[1] Despite competition between four network operators in South Africa, the prices of mobile services are high compared to other African and developing economies (Calandro and Chair, 2016).[2] Moreover, the regulation of termination rates, which are the prices mobile operators charge one another for inbound calls to their networks, has proved to be an effective way of reducing retail prices (see, for example, Genakos and Valletti, 2015). Recently, mobile termination rates (MTRs) have been reduced in many African countries, including in Botswana, Ghana, Kenya, Mozambique, Nigeria, South Africa, Tanzania and Zambia (Mothobi, 2017).

Competition policy and sector-specific regulation of industries such as telecommunications may help to reduce income inequality. This is because mobile telecommunications services account for up to 5% of the bottom income quartile's expenditure in South Africa, for example (see Figure 1).[3] But there are limits to the impact of competition and regulation. For example, mobile operators enter the most attractive local markets first, which are in general urban areas

[1]Typically, regulators make radio frequency spectrum available to licensees, via auctions or beauty contests, and therefore establish the market structure for the sector.

[2]This is reflected in recent political debates in South Africa which led to market inquiries into the cost of data services, launched by the South African Competition Commission in 2017 and the Independent Communications Authority of South Africa in 2018.

[3]Based on authors' computations using the National Income Dynamics Survey (NIDS), which is a nationwide survey of South African individuals and households collected by the Southern Africa Labour and Development Research Unit (SALDRU) at the University of Cape Town (UCT) in four waves: 2008, 2010/2011, 2012 and 2014/2015 (Southern Africa Labour and Development Research Unit, 2008-2016).

with higher average income levels. At the same time, since spectrum licences typically impose coverage obligations on firms, competition should eventually also spread to rural and other areas with lower income levels. These coverage obligations should guarantee that the majority of the population benefits from competition between mobile networks, but the reality may be different. Furthermore, regulators in general do not control how operators set their prices with respect to different market segments. In countries with a relatively small share of wealthy consumers and large numbers of poor consumers, firms may not be willing to lower prices enough to attract less profitable consumers.

In this paper, we use six waves of a South African survey of about 134,000 individuals collected between 2009 and 2014 to estimate the distribution of benefits across different segments of society resulting from the entry of new market players and the regulation of mobile termination rates.[4] South African society is multi-racial, multi-lingual and highly segmented with respect to income, which results in differences in the affordability of mobile telecommunications services. We estimate a discrete-choice model allowing for individual-specific price-responsiveness and preferences for network operators. Overall, we find that the price sensitivity of subscriptions to mobile networks is impacted by income directly and by factors which indirectly determine individual wealth and social group, such as race and language. We use the estimates of demand parameters and individual price-responsiveness to conduct counterfactual simulations. First, we simulate market outcomes in the absence of a new entrant, Telkom Mobile, which launched mobile services late in 2010, and in addition without Cell C, which launched services in around 2002. Second, we simulate a counterfactual situation without the regulation of termination rates which took place between 2010 and 2014.

Based on our equilibrium model, without the entry of Telkom Mobile and Cell C, we find that the adoption of mobile phones in South Africa would be lower by about two percentage points on average over the period 2011-2014. Thus, entry led to a relatively small increase in the total number of adopters, though this effect is higher for low-income consumers. Without

[4]We use data from the All Media Product Survey (AMPS) survey produced by the South African Audience Research Foundation (SAARF).

entry, mobile penetration among high-income consumers would have been two percentage points lower, while the reduction in penetration among low-income consumers would have been four percentage points. We also use the model to simulate changes in consumer welfare for different income groups and segments of society. In this way, we test whether poor or rich consumers benefit more from competition and regulation of firms with market power. We find that rich people benefited more from entry and regulation in terms of changes in consumer surplus. Thus, we find that entry does not reduce inequality but has the opposite effect. We also find that entry has a limited impact on consumer surplus. Furthermore, we find that regulation of MTRs results in significantly lower prices. Similarly, high-income consumers benefit from a larger increase in consumer surplus. In addition, we find that regulation has a greater effect than competition does on mobile penetration. In particular, absent regulation over the period between 2011 and 2014, mobile penetration would have been eight percentage points lower among low-income consumers compared to four percentage points among high-income consumers.

Our results provide important evidence on the distributional effects of competition and regulation, which can be of use to policy makers in South Africa and other countries.[5] We show that a 'rising tide lifts all boats', in that bringing about lower prices through competition and regulation benefits all consumers. However, the distribution of these benefits, measured by changes in consumer surplus, is skewed towards higher-income consumers and residents in towns and cities. Policymakers need to consider means by which new entrants could be encouraged to focus on low-income consumers and on rural areas.

The remainder of the article is organized as follows. Section 2 discusses relevant literature. Section 3 describes the market being analysed. Section 4 presents the data which we use in the estimation. Section 5 introduces the econometric framework. Section 6 presents the estimation results and finally, Section 7 concludes.

[5] Gruber and Koutroumpis (2011) show that higher penetration of mobile phones has a positive impact on economic growth. Other papers on the impact of mobile phones on market outcomes include Jensen (2007), Aker and Mbiti (2010), and Muto and Yamano (2009).

2 Literature review

Our paper contributes to various streams of the literature. First, we estimate demand for telecommunications using a discrete-choice model, a common approach used in previous research to estimate price elasticities and the effects of entry. For example, Train et al. (1987) use data from a US household survey and develop a nested logit model of consumer choices of telephone services. Price elasticities are estimated for a number of service options which vary based on distance. They find relatively high elasticities for monthly charges, which suggests that the service options are substitutes for one another. Pereira and Ribeiro (2011) use a mixed-logit model to estimate price elasticities for broadband Internet access using data from a household survey in Portugal. They then simulate the price effects of the structural separation of the incumbent dual-owner of DSL and cable broadband, and find substantial gains to consumers from doing so. In another paper, Grzybowski et al. (2014) estimate demand for fixed and mobile broadband services in Slovakia using a random coefficients model. They use their estimates of price elasticities to define markets, and conclude that fixed and mobile broadband are in the same market. However, we are aware of only one paper, by Björkegren (2018), in which a structural demand model is estimated for an African country, in Rwanda. In that paper, the author estimates changes in consumer welfare if taxes were shifted from handsets to usage of mobile phones. He finds, due to network effects in the adoption of mobile services, that welfare would have been 38% higher.

Second, we contribute to the literature on the impact of mobile telecommunications services on welfare and economic development using micro-level data. For example, Jensen (2007) analyses the impact of the rollout of mobile services in Kerala in India on the dispersion of prices for fish sold by fishermen at coastal markets. He finds that price dispersion decreased considerably and that this improved welfare for fishermen and consumers. In a related paper, Aker (2010) evaluates the effects of the expansion of mobile phone coverage in Niger on grain-price dispersion. She finds lower price dispersion between grain markets as mobile coverage expanded between 2001 and 2006, resulting in lower search costs.

Muto and Yamano (2009) use household panel data to analyse the effects of the expansion of mobile networks on the sale of agricultural commodities in Uganda between 2003 and 2005. They find that sales of perishable commodities (bananas) grew as a result of greater market participation by producing households due to expanded mobile coverage. In a related paper, Muto (2012) uses the same dataset to assess the effects of mobile phone ownership on individual choices to migrate in Uganda. He finds that mobile phone ownership results in a higher likelihood of migrating. Klonner and Nolen (2010) analyse operator and survey data to evaluate the effects of the rollout of mobile networks on unemployment in South Africa. Their results show significantly higher employment rates after an area receives mobile network coverage.

Aker and Mbiti (2010) survey the evidence on the impact of mobile telephony on economic development in Sub-Saharan Africa, and conclude that the expansion in mobile usage improves consumer and producer welfare. Finally, Hjort and Poulsen (forthcoming) assess the impact of the arrival of high-speed broadband via subsea internet cables on employment and productivity in African countries and find that they rise with access to high-speed broadband.

Third, our paper is also related to the literature on the impact of entry and regulation on prices and welfare in markets for telecommunications services. Nicolle et al. (2018) use hedonic price regressions to analyse the impact of regulation and investment on prices for mobile services in France. They find that quality-adjusted prices declined between May 2011 and December 2014 which was mainly due to new entry and investment in 4G networks. Economides et al. (2008) quantify the benefits of entry into local telecommunications service markets. They find that consumers benefit significantly, though rather than resulting in reduced prices, entry results in product differentiation and new plan introductions. In another paper, Genakos et al. (2018) study the impact of market concentration levels on prices and investment in 33 OECD countries in the years between 2002 and 2014. They report that prices and concentration are positively related and that increased concentration may lead to higher investment.

In respect of the impact of regulation on prices and welfare, gains from MTR regulation have been reported on previously such as in Genakos and Valletti (2015). However, as far as we are aware, there are no studies that comment on gains from MTR regulation in respect of consumer surplus in a structural framework. Stork and Gillwald (2014) discuss the impact of termination rate reductions in Kenya, Namibia and South Africa. They conclude that lower MTRs resulted in lower retail prices and greater expansion of mobile services to differing degrees. While prices fell rapidly in Kenya in response to lower MTRs, retail price reductions were slower in Namibia and South Africa. This paper is based on a qualitative approach, however.

Fourth, we contribute to the literature on the impact of competition on inequality and on welfare more generally. This is important in light of recent calls for a greater role for competition policy in reducing inequality (see Baker and Salop, 2015). In a seminal paper, Deaton (1988) proposes a methodology to estimate elasticities of demand using household survey data. The purpose of their analysis was to improve the design of taxes and subsidies for commodities in developing country governments, where the government is not able to raise general income taxes. Argent and Begazo (2015) show that reducing sugar and maize prices by 20% by making markets more competitive in Kenya could result in a reduction in poverty of between 1.5% (sugar) and 1.8% (maize). However, competition may not always benefit market participants belonging to different income groups equally, and thus can affect inequality. For example, Wodon and Zaman (2009) find that lower food prices would benefit higher-income consumers at the expense of poor producers.

In highly unequal economies, firms may enter the market and compete for high-income consumers, where they can earn higher margins, rather than provide services at low margins to masses of poor consumers. However, from a welfare perspective, poor consumers should benefit the most from access to telecommunications services, which may help them to get jobs and escape poverty. In this paper, we detail how entry and regulation impact the well-being of South African consumers in different income and societal segments. Our paper presents important evidence on the distributional effects of government policies towards competition and regulation in telecommunications markets in South Africa and other developing economies with high levels of inequality. We find that the regulation of MTRs is a more effective tool for reducing prices than competition by means of new entry.

3 Industry

There are two full-coverage mobile network operators in South Africa, MTN and Vodacom, and two partial-coverage networks, Telkom Mobile and Cell C. The latter two roamed on the MTN and Vodacom networks respectively in the sample period.[6]

Vodacom and MTN began rolling out their Global System for Mobile (GSM) networks in the mid-1990s, at around the same time that similar networks were being rolled out in other countries. Cell C entered the market in late 2001, while Telkom Mobile entered in late 2010. Cell C and Telkom Mobile focus largely on higher-income cities and towns. As a result of this, the newer entrants have largely captured higher-income consumers (see Figure 2). The newer entrants had poorer quality networks, due to the lack of seamless roaming and because 3G and 4G roaming was not available, at least in the earlier years in the sample period.

As a result of racial discrimination during apartheid, White consumers have significantly higher incomes compared to other racial groups. Indian and Coloured consumers were discriminated against during apartheid but benefited from having more access to public resources and from living in urban areas. Many Black people were forced to live in rural 'homelands' with substantially lower funding for education and healthcare. Indian and Coloured consumers therefore have lower incomes than White consumers though all three groups have higher incomes than Black consumers.

Based on our data, operator market shares vary by race and income group (see Figure 2). There are nine provinces in South Africa which have very different population groups. The provinces of the Western Cape and Gauteng have significantly more people living in urban areas, while the provinces of the Eastern Cape, KwaZulu-Natal, Limpopo, Mpumalanga and the North-West have large populations living in former 'homelands' which are largely rural areas. The Northern Cape is a sparsely populated province that has a relatively small population.

There are eleven official languages in South Africa which are, ranked by number of speakers:

[6]We dropped subscribers to Virgin Mobile, a Mobile Virtual Network Operator (MVNO), from the analysis due to its small market share which was much below 1% in 2014. In an alternative specification, we estimated a model with subscribers to Virgin Mobile and include this provider in the choice set of all consumers. The estimation results are comparable.

Zulu, Xhosa, Afrikaans, English, Northern Sotho, Tswana, Sesotho, Tsonga, Swazi, Venda and Ndebele. In the dataset, languages sharing common traits or a common geographic region are grouped together. Thus, Zulu is grouped with Swazi and Ndebele ('Zulu+'), while Sesotho, the main language spoken in the largest cities of Johannesburg and Pretoria is grouped together with Northern Sotho, Tswana, Tsonga and Venda ('Sesotho+').

Mobile network choices among language groups follow race group patterns.[7]

Cell C and Telkom Mobile have largely focused on urban areas, and their market shares are therefore relatively higher in cities and towns (see Figure 2). Low-income consumers based in rural areas have not taken up new entrant services, despite the new entrants having roaming agreements with the full-coverage networks.

Termination rates are an important cost factor for voice services on mobile networks, as they are the charges that each operator pays for calls to other networks. The government and Independent Communications Authority of South Africa (ICASA), the telecommunications sector regulator, began reducing mobile termination rates (MTRs) in 2010. At that stage Telkom Mobile, owned partly by government, complained about high MTRs due to their imminent entry.[8] Since then, MTRs have declined by 90% and retail voice prices have declined as a result of this, according to ICASA (see Figure 3).[9] There are separate ('asymmetrical') termination rates for large and small operators, as the regulations allow smaller operators to charge a higher MTR. There were separate peak and off-peak termination rates until 2013, when the regulations forced the MTRs to converge.

[7]Note that Indian consumers largely speak English, while approximately three-quarters of Coloured consumers speak Afrikaans.

[8]Dividends from Telkom appear on the budget in the telecommunications line ministry's annual report, and appear to account for the bulk of incoming funds into that ministry.

[9]ICASA reviewed the effects of lower MTRs in its bi-annual review of prices. See: ICASA, 2018, "Bi-Annual report on the analysis of tariff notifications submitted to ICASA for the period 02 January 2018 to 30 June 2018".

4 Data

We estimate a discrete-choice model using six waves of the All Media Products Survey (AMPS). AMPS is a survey of approximately 25,000 consumers each year between 2009 and 2014.[10] In total, the sample size is more than 134,000 observations. The AMPS dataset contains consumer choices of a range of products and services as well as personal and household characteristics.[11] As can be expected, low-income consumers account for the bulk of survey respondents and are disprorportionately less likely to be connected (see Table 1).

Prices were obtained from Research ICT Africa and Tarifica.[12] In addition, we used an online archive service, the Internet Archive's Wayback Machine, to complete the pricing database.[13] Prices were matched to consumers firstly by payment method (prepaid and postpaid).[14] Second, we matched prices using estimated usage of voice minutes. In this way, we arrived at a price per minute for each operator faced by each consumer.

Prepaid consumers, which account for 81% of the sample with a mobile service, belong to one segment. Postpaid consumers, which account for the balance, were divided into three groups: low, medium and high voice users according to their declared monthly cellphone spend. Low-usage consumers are assumed to have monthly bills in the range R1-R150 per month, medium-usage is in the range R151-500 and high-usage is above R500 per month.[15]

[10] An exception is the year 2013, when only half that number is available due to a questionnaire change halfway through the year. This meant that certain questions (such as cellphone spend) were not asked in the second half of the year, which means it was not possible to use those observations.

[11] This is an annual survey conducted by the South African Advertising Research Foundation (SAARF) on buyers of a range of products, in order to match media companies (such as newspapers, TV stations and radio stations) and advertisers of the various products surveyed.

[12] Research ICT Africa is a non-governmental organisation that collects data and conducts research on telecommunications in Africa. Tarifica is a market intelligence firm which collects information on prices of telecommunications services worldwide.

[13] The Internet Archive, whose website is archive.org, is a non-profit organisation that records snapshots of websites over time and makes these available to the public.

[14] In South Africa, most subscribers are on prepaid plans and are typically unable to choose between prepaid and postpaid because they do not meet the income and employment requirements for a postpaid contract. This is a result of low levels of employment and participation in the labour force. According to the "Quarterly Labour Force Survey" undertaken by Statistics South Africa (publication P0211), the employed population divided by the number of adults in South Africa (aged 15-65 years), i.e. the 'labour absorption rate', varied between 41% and 46% over the period between 2009 and 2014. The unemployment rate varied between 22% and 26% using the official definition (active job seekers) while the expanded definition (i.e. including discouraged work seekers) varied between 30% and 36%.

[15] The South African currency is highly volatile but as of December 2018 one US dollar was approximately

Next, we computed average prices per minute for the four consumer segments. Prices for prepaid and postpaid services are shown on Figure 3. We assumed different monthly usage volumes for each segment: 30 minutes for prepaid users (1 minute per day), 180 for low-usage postpaid consumers (6 per day), 540 for medium-usage postpaid consumers (18 per day) and 1,080 for high-usage postpaid consumers (36 per day).[16] In South Africa, prices differ depending on whether calls are on the same network (on-net), to other mobile networks (off-net) or are terminated on fixed lines. We assumed that 10% of minutes are terminated on fixed lines and 90% are terminated on mobile networks, for all consumers. Calls terminated on mobile networks are distributed according to operator market shares. We also assumed that 50% of calls are made in 'peak' periods and 50% were 'off-peak', for which there are different prices.[17] Using this call distribution pattern, we computed the average price per minute for all prepaid tariffs and picked the lowest for each operator in a given year. We assume that these are the prices that prepaid consumers face when choosing a service. In a similar way, we computed the average price per minute faced by postpaid consumers belonging to the three segments. We tested our results against different calling patterns and our estimates of elasticities are comparable in these different specifications. Usage profiles are a common means of modelling consumer decisions in telecommunications services as well as comparing prices across countries and over time.[18]

We tested the proposition that new entrants choose higher-income areas in towns and cities by

14.6 Rands. Classifying consumers into high, medium and low usage groups is a standard approach to segmenting telecommunications subscribers. The spending bands were selected to broadly reflect regular intervals and available mobile packages, and so as to ensure a large number of observations would fall within each category. Approximately 25% of postpaid customers fall within the first group, around 53% fall within the second category and the remaining 22% fall within the highest spend group. The second category has a greater proportion since almost 25% of postpaid customers spend between R271-R500 per month. Since there are many more packages advertised in the R151-R500 spend level than above R500, it made more sense to allocate the R271-R500 category to the medium-spend group.

[16]These usage categories are similar to the OECD mobile voice call baskets cited below, of 30, 100, 300 and 900 calls per month. The groups are also not far from minutes of use reported by Vodacom in its annual reports between 2009 and 2014, for example, for prepaid and postpaid customers. Prepaid customers on the Vodacom network used between 52 minutes and 116 minutes per month on average, depending on the year, while postpaid consumers used between 182 and 240 minutes per month.

[17]This is in line with the OECD usage baskets mentioned above, which assume that 46% of calls are made during the day, 27% are made during the evening and 27% over the weekend. In South Africa, weekend and evening calls are grouped together under the 'off-peak' period. Source: OECD, 2017, "Revised OECD Telecommunications Price Baskets".

[18]See, for example, the OECD basket methodology, cited above.

means of reduced-form regressions on a proxy for entry, the Herfindahl-Hirschman Index (HHI).[19] A lower HHI indicates a greater degree of entry. As we can expect, new entrants focus on areas that have a higher share of richer consumers (see Figure 4 and Table 2). Market concentration levels are lower in towns and cities, and among high-income consumers, whether measured by mean household incomes or the share of high-income individuals in a location. Income, race and language group are correlated in South Africa. Therefore, higher-income races (Coloured, Whites, Indians) experience lower levels of market concentration, and a similar pattern is found among higher-income language groups (English and Afrikaans-speakers). This suggests that new entrants target higher-income locations and population groups.

5 Econometric Model

5.1 Demand

5.1.1 Discrete-choice model

We estimate demand for mobile subscriptions by means of a discrete-choice model, where consumers choose the network operator that maximizes their utility function. We allow individuals $i = 1, ..., N$ to choose among network operators $j = 1, ..., J$. Individual utility depends on network and consumer characteristics. In what follows, we skip the time subscript for year t. We specify that individual i's utility for mobile network j is given by:

$$U_{ij} = x_j' \widetilde{\beta}_i - \widetilde{\alpha}_i p_{ij} + \epsilon_{ij}. \quad (1)$$

[19] The HHI is calculated as follows: $HHI = \sum_{j=1}^{k} (s_j * 100)^2$, where s_j is the market share of operator j. A monopoly results in an HHI of 10,000 (100^2). AMPS reports the locations of respondents in each year by province, by parts of the large cities of Cape Town, Durban, Johannesburg and Pretoria, by secondary cities and towns (Bloemfontein, Kimberley, Pietermaritzburg, Port Elizabeth, East London, Vaal) and by community size (metropolitan areas (250 000+), cities (100 000 - 249 999), large Towns (40 000 - 99 999), small towns (8 000-39 999), large villages (4 000- 7 999), small villages (500 -3 999), settlements (less than 500), non-urban (rural)). In total, there are 509 such location-years. We dropped location-years that had fewer than 50 observations, and arrive at a sample size of 420.

Here, x_j is a $J \times 1$ vector of network dummy variables interacted with individual characteristics and $\widetilde{\beta}_i$ is a $J \times 1$ vector of coefficients denoting the individual-specific valuations for each network, estimated relative to the base of having no mobile service. Furthermore, p_{ij} denotes the price paid by consumer i for making a call on network j, and $\widetilde{\alpha}_i$ is a coefficient for the individual-specific valuation of price. The construction of the price variable was discussed in Section 4. Finally, ϵ_{ij} is an individual-specific valuation for network j, i.e. the "logit error term". It is identically and independently distributed across mobile networks according to the Type I extreme value distribution.

The vector of coefficients $\widetilde{\beta}_i$ and the price coefficient $\widetilde{\alpha}_i$ may depend on observed individual characteristics and unobserved heterogeneity. More specifically, we define:

$$\begin{pmatrix} \widetilde{\beta}_i \\ \widetilde{\alpha}_i \end{pmatrix} = \begin{pmatrix} \beta \\ \alpha \end{pmatrix} + \Pi D_i + \begin{pmatrix} 0 \\ \sigma_\alpha \end{pmatrix} \nu_i \quad , \qquad \nu_i \sim N(0,1) \tag{2}$$

where (β, α) refers to a $(J+1) \times 1$ vector of mean valuations. The vector of observable individual characteristics, D_i, has dimension $d \times 1$. The matrix of parameters Π with dimension $(J+1) \times d$ captures the impact of individual characteristics on the valuations for the J network dummy variables, x_{jt}, and the price variable, p_{jt}. The randomly drawn vector from the standard normal distribution ν_i captures unobserved individual heterogeneity in respect of price. In addition, σ_α is a vector of standard deviations around the mean valuations.

The vector of observable characteristics D_i includes gender, age category ($15-25$, $26-50$, $51-65$, 66 and above), race, language, province, income group (below R$3,000$, R$3,000-7,999$, R$8,000-15,999$, R$16,000$ and above, per month), employment status, whether the person is self-employed and whether the person has a telephone at home or work.

In the special case, where $\sigma_\alpha = 0$, there is no unobserved individual heterogeneity and we obtain the conditional logit model. In a more general framework, we have a mixed or random coefficients logit model, which allows for unobserved heterogeneity between individuals. The utility function specified above allows for flexible substitution between network operators. This allows us to assess which network operators are closer substitutes at the level of the individual.

An individual i chooses a utility-maxmizing network j, i.e. $U_{ij} = \max_{k \in C_i} U_{ik}$, where C_i is individual i's available choice set. Hence, the probability that individual i with given coefficients $\widetilde{\beta}_i$ and $\widetilde{\alpha}_i$ chooses network j is given by:

$$\begin{aligned} l_{ijt}\left(\widetilde{\beta}_i, \widetilde{\alpha}_i\right) &= \Pr\left(U_{ij} = \max_{k \in C_i} U_{ik}\right) \\ &= \frac{\exp\left(x_j' \widetilde{\beta}_i - \widetilde{\alpha}_i p_{ij}\right)}{\sum_{k \in C_i} \exp\left(x_k' \widetilde{\beta}_i - \widetilde{\alpha}_i p_{ik}\right)} \end{aligned}$$

where the second line arises from the distributional assumptions of the logit error term ϵ_{ij}. In the random coefficients model we need to integrate the conditional choice probability $l_{ij}\left(\widetilde{\beta}_i, \widetilde{\alpha}_i\right)$ over the distribution of $\widetilde{\alpha}_i$:

$$P_{ij} = \int_{\widetilde{\alpha}} l_{ij}\left(\widetilde{\beta}_i, \widetilde{\alpha}\right) f(\widetilde{\alpha}) d\widetilde{\alpha}, \tag{3}$$

The distribution of $\widetilde{\alpha}_i$ was specified earlier in (2) and consists of an observable part and an unobservable component that is normally distributed, $\nu_i \sim N(0,1)$.

Assuming independence of individual choices, the log-likelihood function can be written as:

$$\mathcal{L}(\theta) = y_{ij} \sum_{i}^{N} \sum_{j} \log(P_{ij}). \tag{4}$$

Here, $y_{ij} = 1$ if individual i chose alternative j and $y_{ij} = 0$ otherwise, and θ is the vector of all parameters to be estimated. We use a simulation method to approximate the integral entering the choice probabilities P_{ij} in (3). Following Train (2009), we take R draws for ν_i from the standard normal distribution to obtain the average choice probability per individual:

$$\widehat{P}_{ij} = \frac{1}{R} \sum_{r=1}^{R} \frac{\exp\left(x_j'\beta - (\alpha + \sigma \nu_i^r) p_{ij} + (x_j', p_{ij}) \Pi D_i\right)}{\sum_{k \in C_i} \exp\left(x_k'\beta - (\alpha + \sigma \nu_i^r) p_{ik} + (x_k', p_{ik}) \Pi D_i\right)}. \tag{5}$$

In the special case of no unobserved individual heterogeneity ($\sigma = 0$), Equation 5 becomes the multinomial choice probability:

$$\widehat{P}_{ij} = \frac{\exp\left(x'_j\beta - \alpha p_{ij} + (x'_j, p_{ij})\Pi D_i\right)}{\sum_{k\in C_i}\exp\left(x'_k\beta - \alpha p_{ik} + (x'_k, p_{ik})\Pi D_i\right)}.$$

Substituting Equation 5 for P_{ij} in Equation 4, the maximum simulated likelihood estimator is the value of the parameter vector θ that maximizes the likelihood function $\mathcal{L}$.

5.1.2 Price Elasticities of Demand

We calculate own- and cross-price elasticities for voice calls on mobile networks in the following way. The effect of a one *percent* price increase by network k on the *level* of individual i's probability of choosing network j is:

$$\frac{\partial P_{ij}}{\partial p_{ik}}p_{ik} = \begin{cases} -\widetilde{\alpha}_i P_{ij}(1-P_{ij})p_{ij} & \text{if k=j} \\ \widetilde{\alpha}_i P_{ij}P_{ik}p_{ik} & \text{otherwise} \end{cases}.$$

This could be referred to as individual i's semi-elasticity of demand for j with respect to the price of k. Let the aggregate market share for network j be given by $s_j \equiv \sum_i P_{ij}/N$, where N is the number of consumers in the dataset in a given year. The aggregate elasticity of demand for subscriptions to network j with respect to the price of k may then be defined as:

$$\varepsilon_{jk} = \frac{1}{N}\left(\sum_i \frac{\partial P_{ij}}{\partial p_{ik}}p_{ik}\right)\frac{1}{s_j} = \begin{cases} \sum_i(-\widetilde{\alpha}_i)P_{ij}(1-P_{ij})p_{ij}/\sum_i P_{ij} & \text{if k=j} \\ \sum_i \widetilde{\alpha}_i P_{ij}P_{ik}p_{ik}/\sum_i P_{ij} & \text{otherwise} \end{cases}. \quad (6)$$

5.1.3 Consumer surplus

We use the estimated model to calculate changes in consumer surplus due to regulation or new entry. In discrete-choice models, the expected consumer surplus of consumer i is given by (see Small and Rosen, 1981):

$$E(CS_i) = \int_{\widetilde{\alpha}} \frac{1}{|\widetilde{\alpha}_i|} ln\left(\sum_j \exp(V_{ij})\right) d\widetilde{\alpha} + C_i$$

where α_i is the individual-specific price coefficient, V_{ijt} is the observed part of the utility function in Equation 1 and C_i is an unknown constant representing unmeasured utility. The change in consumer surplus due to an intervention, such as regulating termination rates or introducing new entrants, can be written as:

$$\Delta E(CS_i) = \int_{\widetilde{\alpha}} \frac{1}{|\widetilde{\alpha}_i|} \left| ln\Big(\sum_j \exp(V_{ij}^1)\Big) - ln\Big(\sum_j \exp(V_{ij}^0)\Big) \right| d\widetilde{\alpha} \tag{7}$$

where V_{ij}^1 denotes the utility after and V_{ij}^0 before the intervention.

5.2 Supply

We use both the demand and supply-sides to simulate how the entry of mobile operators Cell C and Telkom Mobile impact welfare and how consumer surplus is distributed across consumer segments. For the simulations, we consider marginal costs to be call termination costs, calculated using the termination rates in Section 3.[20] We also simulate the effect of no regulatory intervention. In order to do this, we compute marginal costs as though the pre-regulation (pre-2010) mobile termination rates applied throughout the period between 2011 and 2014. In this simulation we consider that mobile operators compete by setting call prices per minute in prepaid and post-paid market segments separately. Prepaid consumers choose between prepaid offers from different operators but they do not switch to post-paid offers, and similarly post-paid consumers from each usage segment: low, medium and high.

The profits of firm f are given by:

$$\Pi_f(\mathbf{p}) = (p_f - c_f)\, s_f(\mathbf{p}) L \tag{8}$$

where c_f is the marginal cost of firm f, and $s_f(\mathbf{p})$ is firm f's market share as a function of

[20] We computed the termination costs for each mobile operator as follows. First, we consider that 90% of calls are made to other mobile networks (the other 10% are to fixed networks) and that calls to other mobile networks are distributed according to market shares. We further consider that 50% of calls are made during peak hours and 50% are made off-peak, since termination rates were different for these two time slots. Using this information, we computed an average termination cost per minute paid by each mobile operator in each year.

the price vector. Market size is denoted by L. Assuming that firms choose prices to maximize profits, the first-order conditions that define the Bertrand-Nash equilibrium are then given by:

$$s_f(\mathbf{p}) + (p_f - c_f)\,\frac{\partial s_f(\mathbf{p})}{\partial p_f} = 0. \tag{9}$$

for products $j = 1, \ldots, J$. The choice probabilities and price derivatives of choice probabilities are computed at the individual level, and then an average is calculated for each of the four usage profiles (discussed in section 4) and for each operator and year. The FOCs can be written in vector notation as:

$$\mathbf{s}(\mathbf{p}) + (I \odot \mathbf{\Delta}(\mathbf{p}))\,(\mathbf{p} - \mathbf{c}) = 0. \tag{10}$$

where $\mathbf{p}$ and $\mathbf{s}(\mathbf{p})$ are $J \times 1$ price and market share vectors, $\mathbf{\Delta}(\mathbf{p}) \equiv \partial \mathbf{q}(\mathbf{p})/\partial \mathbf{p}'$ is a $J \times J$ matrix of own- and cross-price derivatives. A $J \times J$ block-diagonal identity matrix, I, represents ownership, and $\odot$ denotes element-by-element multiplication of two matrices.

The system of first-order conditions (Equation 10) can be used to perform counterfactual simulations. In the first simulation, we solve the system of equations after removing Telkom Mobile and Cell C from the market, which we do by setting their marginal costs (and equilibrium prices) to a very high number. The solution gives the counterfactual equilibrium price vector $\hat{\mathbf{p}}$, which contains only prices for the remaining mobile operators, Vodacom and MTN. In the second counterfactual, we use the pre-2010 termination rates as marginal costs. In the simulations, we calculate an average price per operator per year using the iterated best-response algorithm. We then use this price vector to compute the counterfactual market shares, $\hat{\mathbf{s}}$, and changes in individual consumer surplus given by Equation 7. These can then be aggregated for different population segments.

6 Results

When estimating the model we need to account for the endogeneity of the price variable. Consumer choices depend on price but are also determined by unobserved quality differences. At the same time, quality influences price. Following Petrin and Train (2010), we use the control function approach to account for this endogeneity.

In the first stage, we regress the prices on a set of controls. In particular, we use call termination charges to approximate the marginal cost of calls. Termination rates differ by destination and are zero for on-net calls. We compute the cost of termination based on the market shares of each operator. We apply the same split between calls to mobile (90%) and to fixed (10%), and between peak and off-peak (50% each), which we used in respect of usage profiles (Section 4). In the regression, we also use a set of dummy variables for operators and type of tariff, and their interaction terms. Our first-stage regression is shown in Table 3. The estimation results show that call termination costs have a significant impact on prices. An increase in termination cost by 1 cent increases the retail price by 1.3 cents. A positive relationship between call termination and retail prices was also found in earlier literature (see for instance Genakos and Valletti, 2015 and Hawthorne, 2018). We include the residuals from the first stage regression in our demand estimation to control for endogeneity.

The estimation results for the multinomial and random coefficients models are shown in Table 4. The price coefficient is highly significant and negative in both models. There is significant unobserved heterogeneity in responsiveness to price, shown by a significant standard deviation for the price variable. We also allow observable individual characteristics to determine price-responsiveness. Low-income consumers have a higher elasticity of demand than higher-income consumers. Black and Coloured consumers are less price-sensitive than White and Indian consumers, after controlling for income. Xhosa-speaking consumers are less price-sensitive.

Consumers who live in cities and towns are significantly more likely to choose Telkom and Cell C than Vodacom and MTN, after controlling for the quality of networks using operator dummy variables. Being employed, and self-employed in particular, as well as having a telephone at work and being young all make it more likely to take up a mobile service. Being older than 50 and having a landline telephone at home makes taking up a mobile service less likely. There is some variability in the uptake of mobile services depending on the province; living in the Eastern, Western and Northern Cape provinces is associated with a lower probability of taking up a mobile service than being in Gauteng. Consumers in the North West, Limpopo and Mpumalanga are more likely to take up a mobile service than consumers in Gauteng.

We use the estimates to compute individual-level price elasticities and then aggregate them using the equations shown in Section 5.1.2. The demand for mobile services is relatively elastic in respect of prepaid prices, shown in Table 5 but somewhat less so in respect of postpaid services 6. The own-price elasticities of demand are the highest for Telkom Mobile's services, equal to -1.77 in respect of prepaid services for example. Vodacom faces the lowest own-price elasticity of demand. These are average elasticities for the period 2011-2014, since Telkom Mobile was in the market in these years. The cross-price elasticities show relatively small differences in the degree of substitution between mobile operators.

We use our demand estimates and termination costs to compute prices under the assumption of Nash-Bertrand equilibrium using equation (10). The marginal costs, average prices and mark-ups are shown for prepaid prices in Table 7 and for postpaid prices (on average) in 8. Vodacom and MTN have the highest mark-ups (79%). Prices imputed from our model are similar to market prices. This means that our estimates of price elasticities are reasonable.

We then simulate how entry and regulation affect consumer welfare in different population segments, in the following three counterfactuals. First, we remove Telkom Mobile from the market. Telkom had a market share of around three percent by 2014, having entered in 2011, which suggests a very small impact on consumer welfare. In the second case, we also remove Cell C from the market, which leaves just two main competitors, MTN and Vodacom. Cell C had a market share of around sixteen percent in 2014 and therefore had a much bigger impact on consumer welfare. Third, we simulate a 'no regulation' scenario, in which termination rates remain as they were in 2009. The simulations are conducted for the period between 2011 and

2014 using the iterated best responses algorithm.

In the first scenario, we find that the entry of Telkom Mobile had minimal impact on equilibrium prices and consumer surplus. In the absence of Telkom, the average welfare loss per minute is approximately one cent, which is very little compared to the average price of a call, which was approximately one Rand per minute.

In the second scenario, the average loss in consumer surplus in the absence of Cell C and Telkom is estimated at almost sixteen cents per minute, as shown in Table 9. If we assume that customers on average make 30 minutes of calls per month, which is the usage profile for prepaid customers, at an average price of R1.15 per minute, then an average's customer's bill is R35 per month. In this case, the average gain from entry represents 14% of the bill and less than 1% of the average income of households (R9,758 per month). Overall, the consumer welfare effect of the entry of Telkom Mobile is close to zero while the welfare effect of the entry of Cell C is relatively small. The entrants did not price aggressively and were not able to acquire large market shares.

The increase in consumer surplus as a result of regulation was significantly larger at 26 cents per minute on average. Assuming, as above, a monthly average bill of R35 per month, regulation resulted in a consumer surplus gain of 23% of monthly bills but less than 1% of monthly incomes. While this gain is relatively small, the effect of regulation of termination rates resulted in a more meaningful impact than introducing new entrants. Previous research has also found gains from call termination rate regulation (such as by Genakos and Valletti, 2015). However, the effects on consumer surplus have not been quantified before as far as we are aware.

It is important to consider how consumer surplus from entry and regulation is distributed across income segments in the population. According to our estimates, the benefits of competition are not distributed equally in absolute terms. As shown in Table 9, the poorest consumers earning less than 3,000 Rands per month gained on average 12 cents per call. Consumers earning 16,000 Rands or more per month gained 18 cents per minute. Relative to usage intensity, since high-income consumers tend to use mobile services more intensively, they benefit even more. There are also differences in gains in consumer surplus across race groups, as shown in Table 9. Black people gain 17 cents per minute, Coloured people benefit on average 13 cents, Indian people gain 14 cents and White people gain 16 cents. We see a similar picture when computing changes in consumer surplus by language groups, as shown in Table 9.

There are substantial geographic disparaties in the benefits from entry and regulation, which reflects the distribution of income in South Africa. While consumer surplus among city-dwellers increases by 18 cents per minute from entry, consumers in rural areas benefit by only 11 cents per minute. These results are consistent with our reduced-form analysis, which shows that entrants target geographic areas that have higher-income consumers (see Section 4). There are also significant differences within race and income groups between geographic areas (see Table 10). For example, while low-income consumers benefit from an increase in consumer surplus of 12 cents per minute on average, in rural areas this falls to 9 cents per minute, less than half the benefit accruing to high-income consumers in cities (19 cents per minute).

The effects of regulation are also not evenly distributed. In the absence of regulation, consumer surplus among low-income consumers (earning less than R3,000 per month) declines by 21 cents per minute while those earning R16,000 or more per month lose 30 cents per minute. There are also differences in losses between race and language groups, as shown in Table 9. Again, the geographic differences are significant, since consumers in rural areas benefit by approximately 23 cents per minute while mobile users in the city benefit from regulation by 27 cents per minute. Geography has an even greater impact when comparing income groups (see Table 10). For example, while consumer surplus among low-income consumers in rural areas declines by 20 cents per minute without regulation, the decline among high-income consumers in cities is 30 cents per minute.

Next, we also use the model to simulate the impact of entry and regulation on mobile subscriptions in different population segments. We find that in the absence of Telkom, the uptake of mobile services over the period 2011-2014 does not change. In the absence of Telkom and Cell C, the penetration of mobile phones would be a bit lower, declining from 86% to 84%. As shown in Table 11, mainly poor people subscribed to mobile services after entry. Among people earning less than R3,000 per month, the lack of entry reduces penetration from 74% to 71%. At the same time, in the segment of people earning R16,000 and above, penetration declined from 95% to 93%. Entry also had divergent effects on subscriptions among people from different race and language groups. The increase in uptake as a result of entry (between 2 and 3 percentage points) was reasonably evenly spread across provinces and between urban and rural areas, likely as a result of the national pricing policies of the mobile operators. Therefore, competition introduced by new entrants to attract consumers in the towns and cities likely resulted in lower prices and greater uptake across South Africa.

While the changes as a result of entry and regulation may be evenly spread among geographies, it is important to note the large disparities within and between race and income groups in respect of uptake across geographies (see Table 12). Using model prices (the baseline scenario), 89% of Black people in cities are connected, which is close to connectivity among White people in cities, at 92%. However, only 79% of black people in rural areas are connected, while 92% of White people in rural areas are. This means that there are significant disparaties in connectivity between race groups and within historically disadvantaged racial groups, particularly once geography is considered. Competition and regulation have done little to reduce these inequalities.

The effects of regulation on the uptake of mobile services were more pronounced than the effects of entry, and again low-income consumers benefited more. Overall, mobile penetration absent regulation declines to 80% from 86% on average between 2011 and 2014. Without regulation, mobile penetration among low-income consumers would be 66% rather than 74%. Among high-income consumers, mobile penetration would have been 91% absent regulation rather than 95%. Thus, while high-income consumers benefit more from entry and regulation from a consumer surplus perspective, low-income consumers benefit more from a mobile uptake perspective. At the same time, high levels of inequality in the uptake of mobile services persist across geographic and racial lines. Our results suggest that introducing new entrants may be less important than direct interventions that support lower retail prices, such as lowering mobile termination rates.

7 Conclusion

We study the distributional welfare effects of entry and regulation in the mobile telecommunications sector in South Africa, which has the highest level of inequality in the world. We use six waves of South African survey data on 134,000 individuals collected between 2009 and 2014. We estimate a discrete-choice model allowing for individual-specific price-responsiveness and preferences for network operators. We find that the price-sensitivity of subscriptions to mobile networks is affected by income and by factors linked to individuals' wealth in South Africa, such as race and language. We use the estimates of the demand parameters and individual price-responsiveness to simulate market outcomes in the absence of a new entrant, Telkom Mobile, which launched mobile services in late 2010, and without Cell C, which launched services in around 2002. We then simulate the effects of eliminating the regulation of mobile termination rates, which are the prices that mobile operators charge one another for incoming calls.

Based on our equilibrium model of demand and supply, we find that the adoption of mobile phones in South Africa would be lower by about two percentage points on average over the period between 2011 and 2014, without the entry of Telkom Mobile and Cell C. Thus, entry led to a relatively small increase in the total number of adopters. On the other hand, the regulation of mobile termination rates had a more significant impact on uptake. Absent regulation, mobile penetration would have been six percentage points lower. The positive effect of entry and regulation on the uptake of mobile services is higher for low-income groups. Without entry, mobile penetration among low-income consumers would have been four percentage points lower, compared to a reduction of two percentage points for high-income earners. Without regulation, mobile penetration among low income consumers would have been eight percentage points lower, compared to four percentage points among high-income consumers. At the same time, substantial differences in the uptake of mobile services in rural areas and cities in South Africa persist, and these differences vary between race and income groups. For example, while 95% of high-income consumers in cities are connected, only 72% of low-income consumers in rural areas are connected. Greater competition and regulation have done little to narrow this 'digital divide'.

We also use the model to simulate changes in consumer welfare for different income groups and segments of society. We find that while a 'rising tide lifts all boats', in that all consumers benefit from entry and regulation, high-income consumers benefit more in respect of consumer surplus. These effects are particularly stark once geography is taken into account. Poor consumers in rural areas experience less than half the benefits from entry accruing to consumers in cities. This is consistent with our reduced-form analysis, which shows that new entrants target areas that have a higher proportion of richer consumers.

Our paper contributes to the literature by providing an equilibrium-based assessment of the distributional welfare effects of entry in the mobile telecommunications sector. We assess these distributional consequences in circumstances where income-inequality is extremely high. The mobile telecommunications industry is of particular importance in South Africa and other developing economies where there is limited fixed-line infrastructure to make phone calls and access the Internet. A growing dissatisfaction with the performance of the telecommunications industry in South Africa, including high prices and poor Internet infrastructure, resulted in market inquiries into competition being launched by the competition authority in 2017 and by the telecommunications regulator in 2018. Also, in 2017, the South African government put forward a proposition to award significant amounts of future high-demand spectrum to a regulated wholesale open-access network (WOAN) in which existing operators would be shareholders, instead of providing for new market entry or distributing the licences to current market players. This idea has received mixed responses from mobile operators and other stakeholders.

Our analysis is an important contribution to this discussion by demonstrating that the two latest market entrants were relatively ineffective in generating and distributing welfare among South African consumers. Wholesale price regulation had a greater effect on consumer surplus but also benefited higher-income consumers more than low-income consumers. There is an urgent need for solutions on rolling out networks in low-income urban and rural areas to bring more benefits to poor consumers and reverse the distributional welfare effects. The roaming agreements between small and large networks do not seem to be enough. Further wholesale regulation may be necessary.

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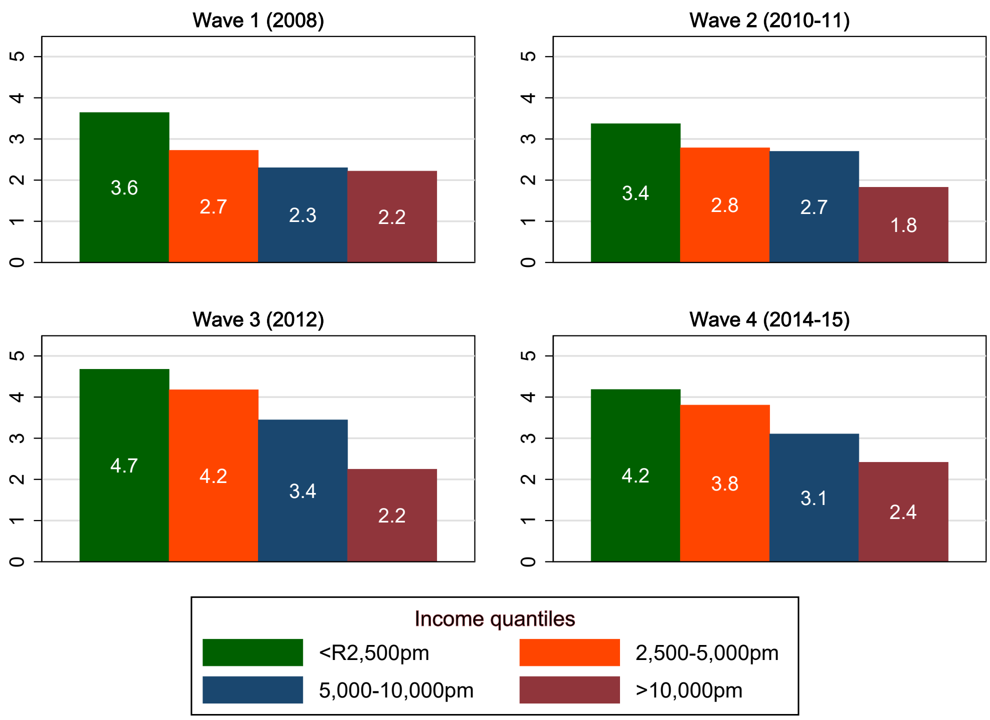
A Appendix

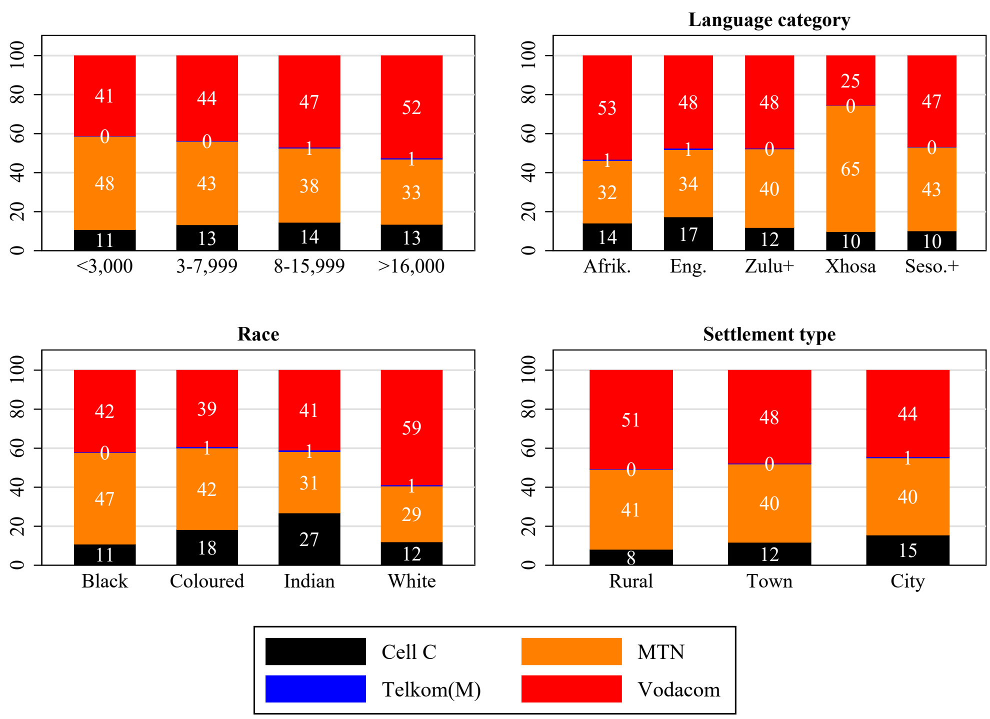
A.1 Figures

Figure 1: Share of spend on mobile by income segments (NIDS, 2008-2015)



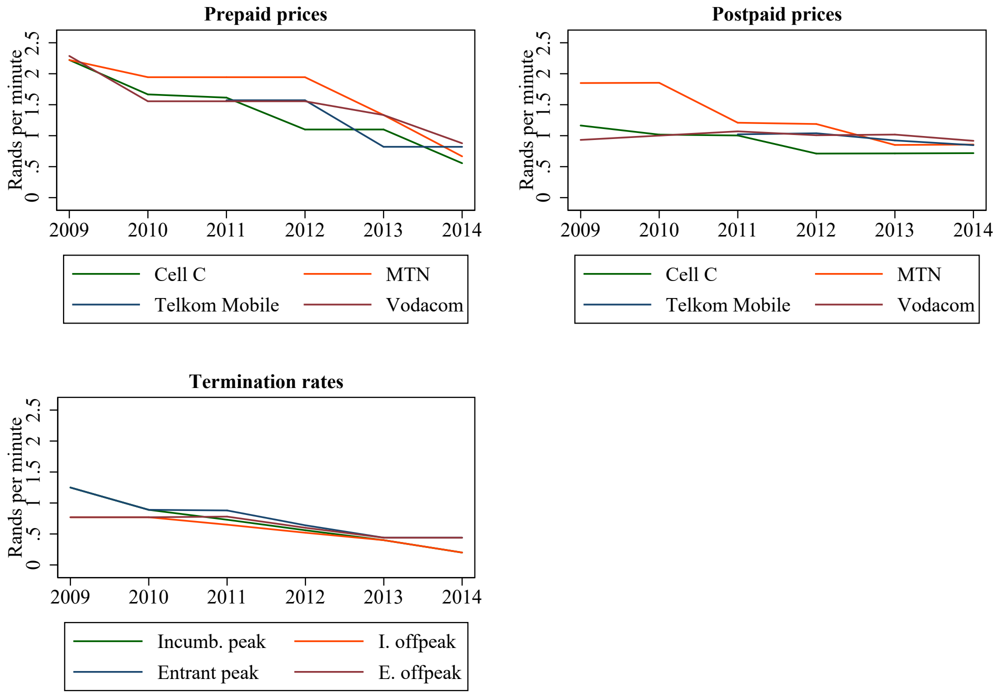
Source: NIDS survey waves 2008-2015. Net income levels per month are shown on the graph.

Figure 2: Operator market shares by demographic segments (AMPS, 2009-2014)



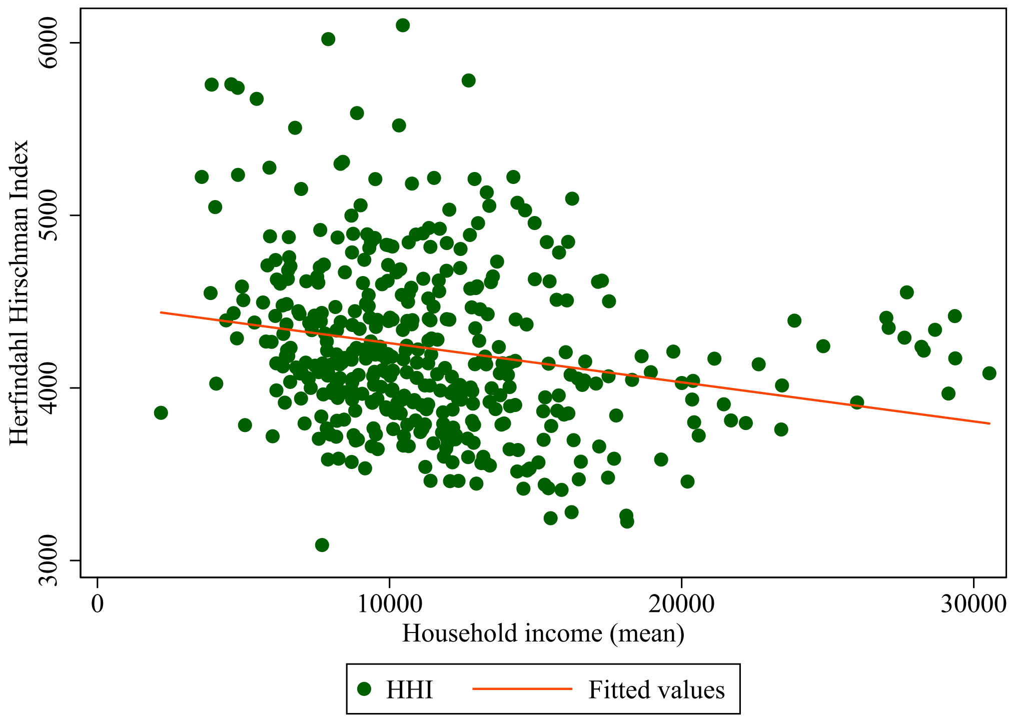
Source: AMPS survey market shares for all observations over the period 2009-2014.

Figure 3: Average operator prices and termination rates (2009-2014)



Note: Postpaid prices are an average for high, medium and low usage consumers. Sources: Prices from Research ICT Africa, Tarifica and the Internet Archive and termination rates from government gazettes.

Figure 4: Relationship between market concentration (HHI) levels and income (2009-2014)



HHI calculated from AMPS sample (N = 420).

A.2 Data tables

Table 1: AMPS demographic variables, by operator (entire sample)

Variable	None		Cell C		MTN		Telkom(M)		Vodacom		N
	N	%	N	%	N	%	N	%	N	%	
Income											
<R3,000	9,821	31	2,351	7	10,453	33	51	0	8,979	28	31,655
R3-7,999	7,274	19	4,160	11	13,425	35	114	0	13,676	35	38,649
R8-15,999	3,918	12	4,302	13	11,281	34	161	0	13,937	41	33,599
>R15,999	1,943	6	4,228	13	10,512	31	199	1	16,511	49	33,393
Race											
Black	12,244	17	6,368	9	27,641	39	177	0	24,717	35	71,147
Coloured	5,122	26	2,697	14	6,185	31	93	0	5,810	29	19,907
Indian	1,585	17	2,013	22	2,359	26	64	1	3,079	34	9,100
White	4,005	11	3,963	11	9,486	26	191	1	19,497	52	37,142
Language											
Afrikaans	6,935	19	4,278	11	9,715	26	172	0	16,125	43	37,225
English	4,073	13	4,804	15	9,559	30	197	1	13,187	41	31,820
Zulu+	3,306	16	2,121	10	7,223	34	63	0	8,514	40	21,227
Xhosa	3,618	23	1,205	8	8,002	50	20	0	3,140	20	15,985
Sotho+	5,024	16	2,633	8	11,172	36	73	0	12,137	39	31,039
Settlement type											
Rural	5,085	24	1,340	6	6,776	31	46	0	8,363	39	21,610
Town	8,334	18	4,485	10	15,354	33	148	0	18,265	39	46,586
City	9,537	14	9,216	13	23,541	34	331	0	26,475	38	69,100
Province											
Western Cape	3,337	18	2,335	13	6,167	34	86	0	6,479	35	18,404
Northern Cape	1,891	28	743	11	1,821	27	17	0	2,295	34	6,767
Free State	1,726	16	958	9	3,901	36	32	0	4,243	39	10,860
Eastern Cape	4,866	25	1,743	9	8,113	42	55	0	4,340	23	19,117
Kwazulu-Natal	3,992	16	3,867	15	8,045	32	101	0	9,178	36	25,183
Mpumalanga	786	11	485	7	1,812	26	21	0	3,962	56	7,066
Limpopo	1,303	17	585	7	2,042	26	20	0	3,897	50	7,847
Gauteng	3,870	11	3,737	11	11,173	32	180	1	15,741	45	34,701
North-West	1,185	16	588	8	2,597	35	13	0	2,968	40	7,351
Age category											
Age < 26 years	6,505	16	5,504	14	13,909	35	125	0	14,033	35	40,076
Age 26-50 years	7,158	12	6,631	11	21,850	36	289	0	24,885	41	60,813
Age 51-65 years	4,618	20	2,065	9	6,999	30	82	0	9,705	41	23,469
Age > 65 years	4,675	36	841	7	2,913	23	29	0	4,480	35	12,938
Additional											
Unemployed	18,228	22	8,941	11	25,954	31	276	0	29,244	35	82,643
Employed	4,728	9	6,100	11	19,717	36	249	0	23,859	44	54,653
Not self-empl.	21,998	18	13,678	11	41,229	33	448	0	46,881	38	124,234
Self-employed	958	7	1,363	10	4,442	34	77	1	6,222	48	13,062
No home tel.	17,186	17	10,945	11	35,415	35	331	0	37,681	37	101,558
Home telephone	5,770	16	4,096	11	10,256	29	194	1	15,422	43	35,738
No work tel.	22,216	18	13,195	11	40,600	33	450	0	46,342	38	122,803
Work telephone	740	5	1,846	13	5,071	35	75	1	6,761	47	14,493
Female	10,681	16	7,386	11	23,618	34	217	0	26,919	39	68,821
Male	12,275	18	7,655	11	22,053	32	308	0	26,184	38	68,475

Table 2: Relationship between market concentration (HHI) and income measures

	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Towns	-311.28***	-318.98***	-236.02***	-249.74***
	(68.77)	(68.46)	(62.45)	(62.64)
Cities	-408.07***	-424.06***	-276.15***	-221.09**
	(80.50)	(78.82)	(73.41)	(76.02)
Household income (mean)	-0.01*		-0.00	0.01+
	(0.01)		(0.01)	(0.01)
High income % of population		-360.27+		
		(183.39)		
Coloured % of population			-724.27***	
			(107.89)	
White % of population			-376.44*	
			(180.03)	
Indian % of population			-2074.03***	
			(239.04)	
English % of population				-1333.12***
				(138.78)
Afrikaans % of population				-402.52***
				(90.80)
Constant	4660.84***	4615.95***	4805.16***	4712.46***
	(75.63)	(66.47)	(72.83)	(76.20)
R-Square	0.11	0.11	0.29	0.28
Number of obs	420	420	420	420

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Note that the shares of race groups in the AMPS sample are as follows: Black (51.8%), Coloured (14.5%), Indian (6.6%), White (27%).

Table 3: Control function estimation results - voice services

		Coeff.	(STD)
Termination cost		1.30***	(0.16)
MTN		0.80***	(0.16)
Telkom		0.36*	(0.18)
Vodacom		0.50**	(0.16)
Prepaid		0.68***	(0.16)
Postpaid*	Medium	0.18	(0.16)
	High	0.44**	(0.16)
MTN*	Prepaid	-0.28	(0.22)
	Postpaid medium	-0.21	(0.22)
	Postpaid high	-0.22	(0.22)
Telkom*	Prepaid	-0.42+	(0.25)
	Postpaid medium	-0.21	(0.25)
	Postpaid high	-0.27	(0.25)
Vodacom*	Prepaid	-0.07	(0.22)
	Postpaid medium	-0.14	(0.22)
	Postpaid high	-0.19	(0.22)
Constant		-0.02	(0.14)
Number of obs	88		
R-squared	0.68		

+ $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 4: Estimation results

	Cond. logit		Mixed logit		Cond. logit		Mixed logit	
	Coeff.	**(STD)**	**Coeff.**	**(STD)**	**Coeff.**	**(STD)**	**Coeff.**	**(STD)**
Price	-2.14***	(0.08)	-2.00***	(0.09)				
SD Price			0.76***	(0.03)				
	Price interactions				**Mobile interactions**			
Income 3-7,999	0.14***	(0.03)	0.23***	(0.04)	0.26***	(0.06)	0.24***	(0.06)
Income 8-15,999	0.07*	(0.03)	0.20***	(0.04)	0.79***	(0.06)	0.82***	(0.07)
Income 16,000+	0.03	(0.04)	0.16***	(0.04)	1.27***	(0.07)	1.35***	(0.07)
Black	0.36***	(0.07)	0.50***	(0.08)	-0.89***	(0.13)	-1.15***	(0.14)
Coloured	0.26***	(0.04)	0.26***	(0.04)	-1.20***	(0.07)	-1.37***	(0.07)
Indian	-0.24***	(0.05)	-0.32***	(0.06)	-0.59***	(0.10)	-0.70***	(0.10)
Afrikaans	-0.10	(0.08)	-0.13	(0.08)	0.06	(0.14)	0.10	(0.15)
English	0.11	(0.07)	0.10	(0.08)	0.01	(0.13)	0.07	(0.14)
Zulu+	-0.03	(0.04)	-0.03	(0.04)	0.02	(0.07)	0.02	(0.08)
Xhosa	0.57***	(0.04)	0.62***	(0.05)	-0.90***	(0.08)	-0.93***	(0.08)
	Operator fixed effects				**Operator * Cities**			
Cell C	1.92***	(0.15)	2.08***	(0.17)	1.03***	(0.04)	1.11***	(0.04)
MTN	4.12***	(0.16)	4.14***	(0.17)	0.40***	(0.03)	0.49***	(0.03)
Telkom	-1.13***	(0.21)	-0.97***	(0.22)	1.16***	(0.16)	1.23***	(0.16)
Vodacom	4.04***	(0.15)	4.14***	(0.17)	0.26***	(0.03)	0.35***	(0.03)
					Operator * Towns			
CellC					0.62***	(0.04)	0.67***	(0.04)
MTN					0.27***	(0.03)	0.33***	(0.03)
Telkom					0.66***	(0.17)	0.71***	(0.17)
Vodacom					0.19***	(0.03)	0.25***	(0.03)
	Mobile interactions							
Age 26-50	0.05**	(0.02)	0.07**	(0.03)				
Age 51-65	-0.50***	(0.02)	-0.61***	(0.03)				
Age 65+	-1.25***	(0.03)	-1.55***	(0.04)				
Male	-0.35***	(0.02)	-0.43***	(0.02)				
Working	0.54***	(0.02)	0.68***	(0.03)				
Self-employed	0.25***	(0.04)	0.28***	(0.05)				
Telephone-home	-0.25***	(0.02)	-0.30***	(0.03)				
Telephone-work	0.53***	(0.04)	0.62***	(0.05)				
Western Cape	-0.05+	(0.03)	-0.08+	(0.04)				
Northern Cape	-0.42***	(0.04)	-0.51***	(0.05)				
Free State	0.01	(0.04)	0.03	(0.04)				
Eastern Cape	-0.46***	(0.03)	-0.59***	(0.04)				
KwaZulu Natal	-0.03	(0.03)	-0.04	(0.04)				
Mpumalanga	0.47***	(0.05)	0.57***	(0.06)				
Limpopo	0.09*	(0.04)	0.15**	(0.05)				
North West	0.07+	(0.04)	0.10+	(0.05)				
Control function	1.78***	(0.04)	1.47***	(0.04)				
Number of obs	636,891		636,891		636,891		636,891	
Log-likelihood	-166,357		-166,227		-166,357		-166,227	

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 5: Own-price & cross-price elasticities, by operator - prepaid (2011-2014)

Operator	Cell C	MTN	Telkom	Vodacom
Cell C	-1.44	0.77	0.01	0.76
MTN	0.19	-1.38	0.01	0.73
Telkom(M)	0.21	0.77	-1.77	0.75
Vodacom	0.19	0.76	0.01	-1.22

Table 6: Own-price & cross-price elasticities, by operator - postpaid (2011-2014)

Operator	Cell C	MTN	Telkom	Vodacom
Cell C	-1.13	0.59	0.01	0.81
MTN	0.21	-1.17	0.01	0.81
Telkom(M)	0.22	0.60	-1.64	0.81
Vodacom	0.21	0.60	0.01	-0.92

Aggregate elasticities are calculated for each year between 2011 and 2014 (when Telkom Mobile was present). The elasticities shown on the table are the average over the four year period.

Table 7: Operator prices, marginal costs and mark-ups - prepaid (2011-2014)

Operator	Marginal costs	Market prices	Market mark-ups	Model prices	Model mark-ups
	ZAR/min	ZAR/min	%	ZAR/min	%
Cell C	0.41	1.09	63	1.09	63
MTN	0.29	1.47	79	1.30	77
Telkom(M)	0.46	1.20	62	1.06	58
Vodacom	0.27	1.33	80	1.23	78

Table 8: Operator prices, marginal costs and mark-ups - postpaid (2011-2014)

Operator	Marginal costs	Market prices	Market mark-ups	Model prices	Model mark-ups
	ZAR/min	ZAR/min	%	ZAR/min	%
Cell C	0.41	0.80	48	1.09	64
MTN	0.29	1.07	72	1.22	76
Telkom(M)	0.46	0.98	53	1.04	57
Vodacom	0.27	1.03	74	1.29	80

We consider termination costs to be marginal costs. Model prices are simulated from these costs using iterated best responses. Simple averages of prepaid and postpaid prices over 2011-2014 are shown.

Table 9: Change in prices & consumer surplus after entry & regulation (2011-2014)

	Model price	**No Telkom, Cell C**		**No regulation**		**N**
		Price	ΔCS	Price	ΔCS	
Income						
Income <3,000	1.08	1.11	-0.12	1.30	-0.21	18379
Income 3-7,999	1.19	1.24	-0.15	1.45	-0.25	24610
Income 8-15,999	1.25	1.32	-0.17	1.53	-0.27	21638
Income >15,999	1.26	1.36	-0.18	1.56	-0.30	23080
Total	1.20	1.27	-0.16	1.47	-0.26	87707
Settlement type						
Rural	1.16	1.21	-0.11	1.40	-0.23	13840
Town	1.20	1.26	-0.14	1.46	-0.25	29105
City	1.21	1.29	-0.18	1.49	-0.27	44762
Total	1.20	1.27	-0.16	1.47	-0.26	87707
Race						
Black	1.23	1.29	-0.17	1.49	-0.26	45452
Coloured	1.09	1.12	-0.13	1.34	-0.23	12434
Indian	1.12	1.16	-0.14	1.40	-0.26	5925
White	1.22	1.30	-0.16	1.50	-0.28	23896
Total	1.20	1.27	-0.16	1.47	-0.26	87707
Language						
Afrikaans	1.15	1.21	-0.14	1.41	-0.25	23620
English	1.19	1.27	-0.17	1.48	-0.28	20475
Zulu, Swazi, Ndebele	1.25	1.32	-0.15	1.52	-0.26	13511
Xhosa	1.16	1.21	-0.21	1.40	-0.24	10137
Sth, Tsw, Tsn, Ven, Oth	1.25	1.31	-0.15	1.51	-0.26	19964
Total	1.20	1.27	-0.16	1.47	-0.26	87707
Province						
Western Cape	1.18	1.24	-0.16	1.44	-0.26	11882
Northern Cape	1.06	1.10	-0.12	1.31	-0.23	4307
Free State	1.22	1.29	-0.15	1.49	-0.26	6848
Eastern Cape	1.10	1.14	-0.17	1.34	-0.23	12172
Kwazulu-Natal	1.19	1.26	-0.15	1.47	-0.26	16042
Mpumalanga	1.29	1.36	-0.14	1.56	-0.28	4574
Limpopo	1.26	1.32	-0.13	1.52	-0.26	4998
Gauteng	1.25	1.33	-0.18	1.53	-0.28	22090
North-West	1.24	1.30	-0.14	1.50	-0.26	4794
Total	1.20	1.27	-0.16	1.47	-0.26	87707

Iterated best responses is used to simulate prices for each scenario in each year between 2011 and 2014. The simulations are run using termination costs as marginal costs, applying termination rates in 2009 for the whole period in the 'no regulation' scenario.

Table 10: Change in consumer surplus after entry & regulation by race, income & area (2011-2014)

	Rural	Town	City	Mean
No Telkom, Cell C				
Income <3,000	-0.09	-0.11	-0.16	-0.12
Income 3-7,999	-0.12	-0.14	-0.18	-0.15
Income 8-15,999	-0.13	-0.15	-0.18	-0.17
Income >15,999	-0.13	-0.16	-0.19	-0.18
Black	-0.11	-0.15	-0.20	-0.17
Coloured	-0.08	-0.11	-0.15	-0.13
Indian	-0.09	-0.13	-0.15	-0.14
White	-0.12	-0.14	-0.17	-0.16
No regulation				
Income <3,000	-0.20	-0.21	-0.23	-0.21
Income 3-7,999	-0.25	-0.24	-0.25	-0.25
Income 8-15,999	-0.27	-0.27	-0.28	-0.27
Income >15,999	-0.28	-0.29	-0.30	-0.30
Black	-0.23	-0.25	-0.27	-0.26
Coloured	-0.21	-0.22	-0.25	-0.23
Indian	-0.24	-0.26	-0.27	-0.26
White	-0.27	-0.27	-0.29	-0.28

Iterated best responses is used to simulate prices for each scenario in each year between 2011 and 2014. The simulations are run using termination costs as marginal costs, applying termination rates in 2009 for the whole period in the 'no regulation' scenario.

Table 11: **Impact of entry and regulation on mobile penetration (%, 2011-2014)**

	Uptake - model prices	No Telkom, Cell C	No regulation	N
Income				
Income <3,000	74	71	66	18379
Income 3-7,999	84	81	77	24610
Income 8-15,999	90	88	85	21638
Income >15,999	95	93	91	23080
Total	86	84	80	87707
Settlement type				
Rural	80	78	74	13840
Town	85	83	79	29105
City	89	86	83	44762
Total	86	84	80	87707
Race				
Black	85	83	80	45452
Coloured	79	76	72	12434
Indian	86	82	78	5925
White	91	89	86	23896
Total	86	84	80	87707
Language				
Afrikaans	85	82	78	23620
English	90	87	84	20475
Zulu, Swazi, Ndebele	87	85	82	13511
Xhosa	79	77	75	10137
Sth, Tsw, Tsn, Ven, Oth	87	84	81	19964
Total	86	84	80	87707
Province				
Western Cape	86	83	79	11882
Northern Cape	77	74	69	4307
Free State	87	84	81	6848
Eastern Cape	77	75	72	12172
Kwazulu-Natal	87	84	81	16042
Mpumalanga	91	89	86	4574
Limpopo	87	84	81	4998
Gauteng	91	88	86	22090
North-West	87	84	81	4794
Total	86	84	80	87707

Iterated best responses is used to simulate prices for each scenario in each year between 2011 and 2014. The simulations are run using termination costs as marginal costs, applying termination rates in 2009 for the whole period in the 'no regulation' scenario.

Table 12: Mobile uptake absent entry & regulation by race, income & area (%, 2011-2014)

	Rural	**Town**	**City**	**Mean**
Model prices (baseline)				
Income <3,000	72	74	77	74
Income 3-7,999	82	83	85	84
Income 8-15,999	89	90	90	90
Income >15,999	94	94	95	95
Black	79	86	89	85
Coloured	74	76	82	79
Indian	80	84	86	86
White	92	89	92	91
No Telkom, Cell C				
Income <3,000	69	70	72	71
Income 3-7,999	80	80	82	81
Income 8-15,999	87	87	88	88
Income >15,999	93	93	93	93
Black	76	83	86	83
Coloured	71	73	78	76
Indian	77	81	83	82
White	90	87	90	89
No regulation				
Income <3,000	64	66	69	66
Income 3-7,999	76	77	79	77
Income 8-15,999	84	84	85	85
Income >15,999	90	90	91	91
Black	72	81	84	80
Coloured	65	68	75	72
Indian	71	76	79	78
White	87	84	87	86

Iterated best responses is used to simulate prices for each scenario in each year between 2011 and 2014. The simulations are run using termination costs as marginal costs, applying termination rates in 2009 for the whole period in the 'no regulation' scenario.