Does ICT Benefit the Poor? Evidence from South Africa

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Abstract: We study the economic effects of the roll-out of mobile phone network coverage in rural South Africa. We address identification issues which arise from the fact that network roll-out cannot be viewed as an exogenous process to local economic development. We combine spatially coded data from South Africa's leading network provider with annual labor force surveys. We use terrain properties to construct an instrumental variable that allows us to identify the causal effect of network coverage on economic outcomes under plausible assumptions. We find substantial effects of cell phone network roll-out on labor market outcomes with remarkable gender-specific differences. Employment increases by 15 percentage points when a locality receives network coverage. A gender-differentiated analysis shows that most of this effect is due to increased employment by women. Household income increases in a pro-poor way when cellular infrastructure is provided.

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1 Introduction and Overview

Market imperfections are widely cited as a source of inefficiencies in low income countries and are thus believed to be a major obstacle to growth. One prominent such imperfection is lack of information. For example, farmers are not aware of market prices in other locations and laborers may not be able to respond to labor demand when there are information frictions. This gives rise to spatially segmented markets and creates scope for rents extracted by middlemen.

Around the world, over the past 15 years wireless communication has provided an economical means of affordable long-distance communication, which allows to spread information where this was not previously possible. Viewed as infrastructure improvement, mobile phone network roll-out is an especially interesting case as it is largely market-driven, financed by private enterprises, and for-profit. In contrast, most other infrastructure improvements (roads, electricity, dams) are undertaken by governments and funded from public sector budgets.

There is plenty of qualitative and quantitative micro evidence from low income countries that cell phones are widely used also by the poor (for farmers and fishermen, see the numerous citations in Jensen, 2007) and that the availability of wireless communication can increase the efficiency of markets (Jensen, 2007). In this vein, the International Telecommunication Union has argued that ICT (information and communication technology) may contribute to poverty reduction (ITU 2006).

On the other hand, recent anthropological studies point out that, in rural African contexts, cell-phones may be used primarily for consumption rather than productive purposes (conversation with relatives and planning of festivals), and potentially create tensions in traditional societies (Hahn, 2008). Thus, while cell phones may improve the functioning of markets and increase welfare for a select group of entrepreneurs, it is less clear whether there are positive effects on the economy at large. Moreover, even when markets function more efficiently and thus total surplus in the economy is increased, it is less clear how the gains are distributed. In particular, will the poor benefit? Or will most of the surplus be captured by a small elite?

There is, to the best of our knowledge, no solid evidence on the effects of ICT on an economy-wide scale. Some cross-country studies estimate substantial effects of communication infrastructure on GDP growth (Hardy, 1980, for landlines; Roeller and Waverman, 2001; Waverman, Meschi and Fuss, 2005). But the main empirical challenge in estimating the effects of large infrastructure projects is not addressed in these papers, the endogeneity of infrastructure placement. In the present context this issue amounts to the question: Are mobile phones promoting local development or is local development promoting the placement of mobile phone infrastructure?

In this paper, we estimate the effects of cell-phone network roll-out on labor market and welfare outcomes. We use spatially coded mobile phone antenna coverage data from 1995 to 2000 from South Africa's major cell phone provider as key explanatory variable. Measures of labor market outcomes and income at the individual level are obtained from spatially coded household force surveys.

We pay particular attention to the problem of endogenous placement of mobile phone antennas by the network company. We address this problem in two ways. First, the availability of panel data allows us to conduct fixed effects estimation, which takes care of antenna placement due to unobserved permanent differences across different locations. Second, we instrument actual network coverage by a predicted value of local network coverage which we construct from topographical terrain data.

In our analysis we focus on rural areas for two reasons. First, according with the existing micro literature on the issue, the improvements in information flows can be expected to be larger in rural than in urban areas as in the latter land line penetration has been much higher and short distances make the flow of information less costly. Second, our instrumental variable approach is less suitable for urban areas where high population densities appear to override any effects of topography in a company's decision to provide network coverage.

Our findings suggest that cell phone coverage has a substantial positive effect on employment in rural areas whereby the lion's share of this increase accrues to women. We also find a significant shift in occupational patterns: with the availability of cell phones, employment shifts away from agricultural occupations, especially among young men. On the other hand, we do not find significant shifts between self-employment and wage-employment with increased cellphone reception. We find no significant income effects in our sample on average, but substantial positive income effects for households with few children. The same pattern arises in an analysis of moderate poverty. In an analysis of extreme poverty, however, we find positive effects in the entire sample, suggesting that network rollout is pro-poor.

Methodologically, our study is related to Duflo and Pande (2007), who pioneered the use of topographical variables as an instrumental variable in estimating the economic effects of large dams in India, and Dinkelman (2008), who studies the effect of electricity network roll-out on time use patterns of rural households in the South-African province of KwaZulu-Natal.

The plan of the paper is as follows. In section 2 we informally discuss potential effects of cell-phone coverage on rural labor markets. In section 3, we introduce our empirical approach. Section 4 presents the data used. Results are in Section 5 and the final section concludes.

2 Analytical Framework

The focus of this paper is on the effect of cellphone network roll-out on employment, occupational choice and welfare. In the context of rural South Africa with very low land line penetration rates, we view cell phones primarily as an improvement in information flows. This has two major effects on the labor market. First, improved spatial integration of the market for wage labor and, second, better conditions for business startups through reduced fixed costs, lower cost of information, outreach to a broader customer base etc. The first effect will in general result in higher wage-employment while the second effect will result in more business startups and thus more self-employment.

If there is any effect on rural labor markets, we thus clearly expect an increase in employment. Whether and how the composition of employment (self vs. wage employment) is affected is left open by these theoretical considerations and depends on relative improvements in the two categories. These two questions, is there an increase in employment and how does the composition of employment shift, set the stage for the subsequent empirical analysis.

3 Empirical Approach

The main objective of this paper is to estimate the effect of mobile phone infrastructure, mp, on an economic outcome at the household or individual level, y say. In this study, we use data from several years during which the roll-out of the cell phone network took place. If households (indexed by i) in each year t were randomly sampled and the placement of new mobile phone infrastructure was random, a regression of the form

$$y_{it} = a_t + \beta \ mp_{it} + \varepsilon_{it} \tag{1}$$

where mp_{it} is a measure of mobile phone infrastructure available to household i in year t, e.g. the percentage extent of network coverage in the household's neighborhood.

Actual network roll-out, on the other hand, is driven by cost and earnings considerations of the cell phone provider. According to our conversations with engineers, locations with high per area unit (expected) demand for mobile telephony are more likely to receive coverage early on. Second, once an initial network is rolled out, non-covered locations close to already covered locations are ceteris paribus more likely to receive coverage because such expansions are cheaper for the provider. All of these factors, which are likely not entirely observed by the researcher, potentially also affect y in (1) through ε, thus introducing a correlation between the regressor of interest, mp, and the error term. If the factors just cited are time-invariant and affect only the level of y, a remedy is to conduct fixed effects estimation. With household panel data, one may estimate

$$y_{it} = a_i + b_t + \beta \ mp_{it} + \mathbf{x}_{it}\gamma + \varepsilon_{it},$$

where m indexes locations and $\mathbf{x}_{mit}$ is a vector of individual-specific controls. Here the fixed effect a_i absorbs unobserved factors affecting the level of y which are potentially correlated with mp.

The household data we use in this paper consists of repeated cross sections, in which each household is assigned to one of M locations. We can thus identify the effect of mobile phone infrastructure in a household's location on household outcomes by estimating

$$y_{mit} = a_m + b_t + \beta \ mp_{mt} + \mathbf{x}_{mit}\gamma + \varepsilon_{mit}, \tag{2}$$

where mp_{mt} is a measure of mobile phone infrastructure in the household's location.

The approach formalized in (2) seizes to capture the causal effect of mobile phone infrastructure, however, if a variable unobserved by the researcher systematically affects both the provider's decision to provide coverage and changes in y over time. An example are labor demand shocks in the form of greenfield projects. These will increase employment and, with the prospect of accelerated local development, potentially attract cellular network providers into the area. As a consequence, network coverage and the error term are correlated.

A remedy against this problem is instrumental variable estimation. To this end, a variable is needed which explains some of the variation in mp but which is at the same time uncorrelated with ε. In this connection, one observable factor driving the cost of providing coverage to a given location is the topography of the location. In particular, cell phone towers have a wider reach when the terrain features exposed - rather than only flat - sections. Our conversations with engineers suggest that there is essentially a U-shaped relationship between the terrain ruggedness of a location and the cost of providing coverage. Moderately rugged locations have a lower cost than both completely flat and very rugged locations. This is illustrated in Figure 1.

The topographical measure we will use captures the curvature properties of the terrain in location m. For ease of exposition, consider a scalar measure of curvature at the location level (the actual measure used will be discussed in more detail subsequently), $curv_m$ say. As topography is time-invariant, it will not as such suffice to identify β, which is estimated from time variation in mp. In the spirit of Duflo and Pande (2007), we therefore interact terrain curvature at the location level with coverage averaged over all locations in year t, $\overline{mp}_t$ say. The first stage regression then is

$$mp_{mt} = \alpha_m + \xi_t + \delta \; curv_m \overline{mp}_t + u_{mt}. \tag{3}$$

If the pace of overall network roll-out (manifested in $\overline{mp}_t$) is reasonably exogenous, predicted values of (3) include only that variation in mp which is due to differences in topography. More formally, the identifying assumption is that $curv_m \overline{mp}_t$ and ε are uncorrelated. Given that $\overline{mp}_t$ is strongly positively correlated with t, this will be the case if, conditional on other observables, terrain curvature does not have an effect on changes (over time) in y. To eliminate some of the time-varying components in ε which are based on observable baseline characteristics at the location level $\mathbf{w}_m$ and potentially correlated with our instrument, we will also condition on interactions of $\mathbf{w}_m$ and $\overline{mp}_t$. We will thus estimate regressions of the form

$$y_{mit} = a_m + b_t + \beta \; mp_{mt} + \mathbf{x}_{mit}\gamma + \overline{mp}_t \mathbf{w}_m \psi + \varepsilon_{mit}$$

and use $curv_m \overline{mp}_t$ as instrument for mp_{mt}.

4 Data

We employ four sources of data. For employment, income and poverty outcomes at the individual and household level we use two annual household surveys: the October Household Survey (OHS) from 1996 to 1998; and the September wave of the Labour Force Survey (LFS) for 2000 and 2001. The surveys are nationally representative and are designed to capture demographic and employment data. However, the income data is less than ideal. Household income can be calculated for the OHS for 1995-1998 but the income data on transfers from family members and for members of the household who are not present during the survey is poor. Household income cannot be calculated from the LFS. Therefore the poverty outcomes discussed will only use the data from 1996-1998 and should be interpreted with some care.

Our analysis will focus on the cellular roll-out in the rural areas of the country. Summary statistics and sample proportions from the rural areas are set out in Table 1. The average age in our sample is 24 years and roughly 54% of the sample is female. This higher percentage of females in the rural area is because of the history of migrant labour in the country, where men typically move to urban areas to work and send money back home. When looking at the household make-up we can see that almost half of the females live in households with more than 2 children under the age of 15. The sample is mostly African, 94%, 4% colored and 2% white. Of the people who are willing to take a job if an appropriate one is offered to them, 55% are unemployed. The definition of unemployment that we will use throughout this analysis is one where a person is considered to be in the labour force if he would take a job if an appropriate one is offered.[1] This definition stayed roughly constant over the years of analysis.

[1] This is referred to as the Expanded definition of unemployment by StatsSA; the main statistical agency in South Africa.

The definition on whether someone is self-employed did not stay constant. In the OHS a person was considered self-employed if he did work for his own business or on his family farm but in 2000 when the LFS replaced the OHS people were considered self-employed if they caught fish, searched for food, or did many other small tasks. Under both of these definitions of self-employed we have that only 12% of our sample is self-employed. Table one also shows that in rural areas almost 1 in every 3 people is employed in the agricultural sector and that 1 out of every 3 people has had no formal education.

A salient feature of our analysis is that the surveys also contain fairly detailed spatial information. In particular, we are able to assign each household in the survey to one of 83,148 enumerator areas. Enumerator areas have been chosen to have similar population figures in 1996 (around 100 households). The median area of an enumerator area is 0.3 square kilometers while the average size is 14.67 square kilometers. This reflects the enormous differences in population density between urban and rural areas. The sampling methodology of the surveys is stratified random sampling whereby in each year 1500-3000 enumerator areas are randomly selected and subsequently 10 households per enumerator area are interviewed.

For administrative purposes, the country is structured in 9 provinces which contain a total of 52 districts which in turn contain a total of 348 municipalities. With the survey sampling design, the probability that an enumerator area is sampled repeatedly within our time frame of six years is negligible. Therefore we will use a municipality as what we have referred to as "location" in the previous section, i.e. we will effectively only exploit information on the municipality in which a household in the survey data resides.

For cellular network coverage we use a unique dataset by Vodacom South Africa, the leading provider of cellular telephony in South Africa. Vodacom started to provide cell phone service in 1995, whereas competitors only one year later. Since then, Vodacom's market share in terms of customers has been steadily over 50% (56% in 2007). Over our sample period, Vodacom has had only one competitor. A third provider, Cell C, entered the South African Market only after 2001 and has managed to gain only 10% of the market share as of 2007. We do not have any detailed information on the coverage provided by this competitor, an issue to which we will return subsequently.

Vodacom's network roll-out proceeded quickly. In 1995, its network covered 43% of South Africa's population. While initial coverage was concentrated in urban areas, subsequent network expansion took place largely in rural areas. Ten years later, coverage was at 95% and by 2007 97.1% of households were covered. For the sake of comparison, landline coverage grew from 15% of households in 1995 to 26% of households in 2005. In the rural areas roughly 6% of households had landlines in 1995 and only 7% had landlines in 2001 whereas, over the same period, cell-phone ownership grew from 1% of households to 18% of household. Figure 2 illustrates the extent of Vodacom's coverage in 1995 and 2005 and Table 2 summarizes how cellular coverage, ownership, and landlines change in our sample.

For each year, our coverage data contain binary information (yes or no) on cellular coverage in squares of 0.04 square kilometers. Assigning the midpoint of each of these squares to the boundaries of enumerator areas in the survey data gives 7.5 grid points of coverage data for the median-sized enumerator area, which corresponds to 415 grid points per municipality.

We construct a population-weighted coverage measure at the municipality level as follows. We first calculate average coverage for each enumerator area, mp_{dme}, from those grid points of the Vodacom data set that are within that enumerator area's boundary. In particular we divide the number of such grid points with coverage by the total number of such grid points. We then calculate average municipality coverage as the arithmetic mean of enumerator area coverages. Since enumerator areas have roughly the same population (but vastly different areas), this measure approximates (as good as possible) the fraction of individuals in the municipality with cellphone coverage.

The instrumental variable considered in the previous section relies on terrain curvature in a location. To calculate terrain features, we use the digital elevation model (DEM) supplied online by NASA, which provides the altitude for each point on a grid spaced at 90 meters between any two points. Figure 3 is a map generated from these data. It is obvious from this map that South Africa features plenty of heterogeneity in terms of terrain. From the DEM, we calculate terrain curvature for each grid point as follows. For each grid point P say, we consider this point as well as its 8 adjacent neighbors. We then fit a quadratic polynomial through these 9 points and define the curvature at P as the negative of the trace of the Hessian matrix of that polynomial in P. In geography, this measure is known as "profile curvature" and it is useful for describing dynamics of flows (acceleration and deceleration) on surfaces. A positive value of this measure indicates that the surface is on average concave at P, a negative value that it is on average convex at P. Figure 4 is a curvature map of the country. In our instrumental variable analysis we seek to predict cellphone network placement by terrain curvature. As previously argued and illustrated in Figure 1, we expect a non-monotonic relationship between the curvature of a location and the cost of providing coverage at that location. As we do not want to impose a particular functional form on the relationship of terrain curvature and cost of providing network coverage, we will assign terrain curvature at each gridpoint to one of ten categories and ultimately model this relationship as a step function.

With the objective of calculating population-weighted terrain curvature measures at the municipality level, we proceed as follows. We calculate local curvature for the entire country, calculate the empirical distribution of curvature, and classify each grid point of the DEM into a decile of that distribution. Next, for each enumerator area, we calculate the fraction of grid points in each decile. To obtain the population-weighted fraction of grid points in a specific decile, we take the arithmetic mean of the corresponding fractions of all enumerator areas within that municipality. This gives, roughly, the population-weighted percentage of land within a given curvature decile in the municipality.

5 Results

In this section we estimate the effects of cellular network roll-out on various employment and welfare measures. Before we discuss those core results, however, we look at the penetration of cell phones in rural populations in response to cellular network coverage expansion. Of course, we only expect sizable effects of network roll-out if it results in more mobile phone use.

Based on the discussions in the preceding two sections, we start out with the derivation of our empirical specifications. Indexing districts by d, our empirical specification of interest is

$$y_{dmit} = a_{dm} + b_{dt} + \beta \; mp_{dm,t-1} + \mathbf{x}_{dmit}\gamma + \overline{mp}_t \mathbf{w}_{dm96}\psi + \varepsilon_{dmit}. \tag{4}$$

This specification straightforwardly extends (2) to a scenario with several districts. Moreover, we choose to use a one period lag of the cellular coverage measure as we expect effects to the local economy to occur with some delay. In particular, households first have to become accustomed to the new technology. Baseline characteristics at the municipality level $\mathbf{w}$ are taken at their levels in 1996.

We will estimate equations in the form of (4) both by OLS and instrumental variables where the set of instruments is $\{curv^2_{dm}\overline{mp}_{dt}, curv^3_{dm}\overline{mp}_{dt}, ..., curv^{10}_{dm}\overline{mp}_{dt}\}$. Notice that since the decile entries in each municipality sum up to one, we drop $curv^1_{dm}\overline{mp}_{dt}$ from the set of instruments. We do not identify off the difference in coverage between 1994 and 1995 as we do not want to impose that the initial setup of the network in 1995 had the same effects as the gradual expansion afterwards. We therefore use household data from only 1996 onwards (so the first year for coverage data is used is 1995).

In this econometric analysis,[2] the coefficients on different curvature categories are significantly different from one-another. Of particular interest is the large coefficient of the seventh decile which suggests that a moderate degree of concavity (recall that a high value of our curvature measure essentially implies concave terrain) in the terrain is particular favorable for providing coverage at a low cost.

Before we move to the employment results which are of most immediate interest, we first estimate the impact of coverage on cellphone ownership to get a sense of how cellphone penetration in the population, which will ultimately be responsible for any economic effects of this technology, is driven by the provision of local coverage. The results are set out in table 3. Surprisingly, the least squares estimate is indistinguishable from zero. However, the IV result suggests a 15 percentage point increase in cellphone ownership in response to moving a municipality from zero to one. Given that cellphone ownership in our sample was at just 10% in 1999 and 18% in 2000, coverage in fact explains the bulk of cellphone purchases in our sample.

The results pertaining to employment outcomes are in Table 4. The dependent variable is a dummy for being employed (self-employed or wage-employed) at the time of the survey interview. An observation is an individual and all individuals classified as in the labor force are included in this estimation. Columns 1 and 2 give OLS and IV results for the entire sample. The coefficient of cellphone coverage is positive and significant in both specifications. The OLS estimate of 0.054 implies that moving a municipality from no to full coverage results in an increase in employment of 4.7 percentage points one year later. Of course, as elaborated above, this estimate may suffer from a severe omitted variable bias. The IV estimate in column 2 is also positive and significant, and has 7 times the magnitude of the OLS estimate. Although it is

[2] Results not reproduced for considerations of space.

much less precisely estimated than the OLS coefficient, this indicates that the bias of the OLS estimation is downward. This implies that, on average, areas experiencing an expansion in coverage have ceteris paribus slower employment growth than areas with constant coverage over the sample period. This seemingly runs counter to the conjecture that the cellphone company expands preferably to regions with brighter economic growth prospects. We suspect, however, that this is due to the high average level of coverage during the period covered by our sample. In particular, with more than 50% of rural areas covered on average, for a "treatment municipality" with a substantial increase in coverage during the sample period the "comparison group" is a combination of already covered and uncovered municipalities.[3] If these already covered locations have substantially faster employment growth ceteris paribus (i.e. absent cellular coverage), we will see precisely a downward bias in the OLS treatment effects estimator. The fact that we do not capture the effects of the initial setup of the network in 1995, adds to this in that comparison groups are even more likely to be already covered areas for the period covered by our sample.

Most interesting are the results broken up by gender and age groups in columns 3 through 10. According to these, the entire effect in the pooled sample is due to positive employment effects enjoyed by women. While, according to both OLS and IV results, male employment is unaffected by coverage in the resident's municipality, women experience a to 4.5 percentage point higher likelihood of being employed for each 10 percentage point increase in cellphone coverage. We also disaggregate the results for women by number of children. According to column 10, women with more than two children contribute the lion's share to the increase in employment. The point estimate implies a stunning 64 percentage point increase in employment as a municipality moves from none to full coverage. As before, all IV point estimates are much larger than the OLS ones.

[3] See Table 2.

Other control variables included in these regressions have the expected signs. In the pooled sample, males are ten percentage points more likely to be employed. While coloreds are slightly more likely to be employed than blacks, perhaps surprisingly whites are not. The disaggregated results, moreover, show that, unemployment is higher among black women.

As elaborated in Section 3, the identifying assumption in our IV estimations is that changes (over time) in economic variables are independent of terrain curvature conditional on other baseline characteristics at the municipality level. We have therefore included interactions of municipality baseline characteristics and average district coverage over time, which is highly correlated with t. According to the results, conditioning on these additional interactions is important. In the IV regression of column 2, for example, areas with larger household sizes in 1996 have smaller employment growth ceteris paribus. It is important to condition on this variable when the average household size in 1996 is correlated with terrain features. We finally note that our estimates of the effects of network coverage is sensitive to inclusion of these controls, in particular for the subsequent results.

We now set out to explore changes in employment patterns in more detail. Micro studies such as Jensen (2008) suggest that cellular coverage is especially advantageous for small-scale entrepreneurs. We now seek to explore whether cellular coverage resulted in more self-employment in rural South Africa. As outlined within our conceptual framework above, we generally expect that cell-phone coverage improves self-employment (through potentially wider outreach) and wage employment opportunities (through fewer information frictions in the labor market). As we have noted above, self-employment is exceptionally low in South Africa, so a measurable effect of mobile phone coverage on self-employment would be an especially remarkable feature. We use a survey question on whether an individual is self-employed. We use the entire labor force as observations the following regressions.

The results are set out in Table 5. The disaggregation by gender and age groups is analogous to the previous table. Overall, we see little effect of cellphone coverage on self-employment. For the pooled sample, the coefficients are indistinguishable from zero both with OLS and IV estimation. If anything, the IV results point to negative effects for men. What this implies is that all positive employment effects which we previously manifested are to be attributed to wage employment.

We also explore effects of cell phone coverage on the sectoral composition of employment. In particular we consider the dependent variable "being employed in agriculture, hunting and related services" as dependent variable. With agricultural being the most traditional occupation, we would in general expect ICT to cause a shift away from the primary sector.

We use only employed individuals as observations in these regressions. The results are set out in Table 6. As expected, cellphone coverage results in a decrease in agricultural employment. For the pooled sample, OLS and IV estimates have a similar order of magnitude. Increasing network coverage from zero to one results in a 14.9 percentage point shift out of agriculture among the employed according to the IV results. Most of this shift appears to be due to males where we estimate a decrease of 22.7 percentage points. For females, on the other hand, we do not find any significant effects in the IV specifications.

While we found substantial effects on employment at the extensive margin, there is no evidence for changes in labor supply at the intensive margin. According to the estimates in Table 7, the number of hours worked among the employed does not respond to network rollout. The same applies to wage rates, which are not significantly affected by network rollout (Table 8).

We now turn to household income and poverty. According to Table 9, network coverage does not impact on income form employment. The same holds for other income source. Of particular interest here is that the OLS estimation suggests a large effect on income from other sources, but this finding is not confirmed by the IV methodology (Table 10).

According to Table 11, household income has a huge estimated elasticity in cellphone coverage. According to column 4, households with at most 2 children benefit the most. However, all coefficients are estimated with little precision by the IV methodology.

Tables 12 and 13 give results for poverty regressions, in which the dependent variable is a dummy for being under the poverty line. Table 12 considers extreme poverty: the poverty line is just a quarter of the World Bank's 1$ per day poverty line, while Table 13 is based on the 1$ per day standard. According to these two distinct poverty lines, the headcount ratio in our sample is at roughly 25 and 50%. According to Table 12, extreme poverty is relieved substantially in all specifications while moderate poverty (Table 13) shows no significant effect in any direction. To summarize, income growth triggered by cellphone infrastructure benefits the very poor significantly and we may thus understand the process of cellphone expansion as pro-poor.

We close this section by reflecting on our identification approach. By including interactions of local baseline characteristics and network coverage at the district level, we control for observed factors that impact on the evolution of economic variables over time. Our identification, however, is vulnerable to other, unobserved infrastructure projects whose roll-out is correlated with that of Vodacom's cellphone network and in its nature also subject to local topographical characteristics. In this connection, Dinkelman (2008) analyzes the effect of electricity network expansion that occurred at the same time. She demonstrates that steeper terrains have higher cost of electricity provision and uses terrain gradient as instrumental variable. While we use terrain curvature and find in fact a markedly non-monotonic relationship between terrain curvature and network expansion, terrain slope and curvature are highly correlated. An attempt to include interactions of terrain slope deciles and district coverage as controls in the second stage regression failed precisely because of collinearity with our instrument. With the specifications estimated here, the IV may thus suffer from a bias of unknown sign if our instrument in fact also explains part of the electricity network roll-out that occurred during the same period.

6 Summary and Conclusion

The effect of ICT on economic development is a vividly discussed topic among policy makers and academics. Compared to other forms of ICT such as the internet, mobile telephony is probably the technology which reached even remote areas of low-income countries at the most rapid pace. In this paper we have studied the labor market effects of the roll-out of mobile phone coverage in rural South Africa. We have dealt carefully with identification issues which arise from the fact that network roll-out cannot be viewed as an exogenous process to local economic development. We have combined spatially coded data from South Africa's leading network provider with annual labor force surveys. We have, moreover, used terrain properties to construct an instrumental variable that allows us to identify the causal effect of network coverage on economic outcomes under plausible assumptions.

We find substantial effects of network roll-out on labor market outcomes with remarkable gender-specific differences. Employment increases by 15 percentage points when a locality receives complete network coverage. A gender-differentiated analysis shows that most of this effect is due to increased employment by women, in particular those who are not burdened with large child care responsibilities at their homes. All of the employment gains accrue in wage employed occupations. Self-employment does not change significantly as network coverage becomes available. We also find a substantial sectoral shift among the rural employed. Agricultural employment decreases substantially, especially among males. To highlight our gender findings, mobile phone network roll-out has left employment for males unaffected but did result in a substantial sectoral shift out of agriculture while women experienced large gains in employment, albeit with no changes in the sectoral composition. Household income increases in a pro-poor way when cellular infrastructure is provided and the estimated decreases in extreme poverty are substantial.

It is interesting to compare our findings with those of Dinkelman (2008) who estimates the effects of electricity network roll-out on rural households in one province of South Africa. She argues that electricity connections for private households make home production less labor-intensive and thus affect female market labor supply in the first place. Accordingly, she finds most of the effect of electricity network roll-out to accrue to women with no or only a few children, i.e. a gender pattern of effects very similar to the one we find.

We think our results suggest a success story of ICT, especially given that cellphone coverage was facilitated through private sector efforts without large public expenditures, which are usually involved in other large-scale infrastructure projects. An important research project is to conduct cost-benefit analyses based on the findings of the present study. This is left for future research.

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Figure 1. Terrain Characteristics and Cell Phone Tower Placement

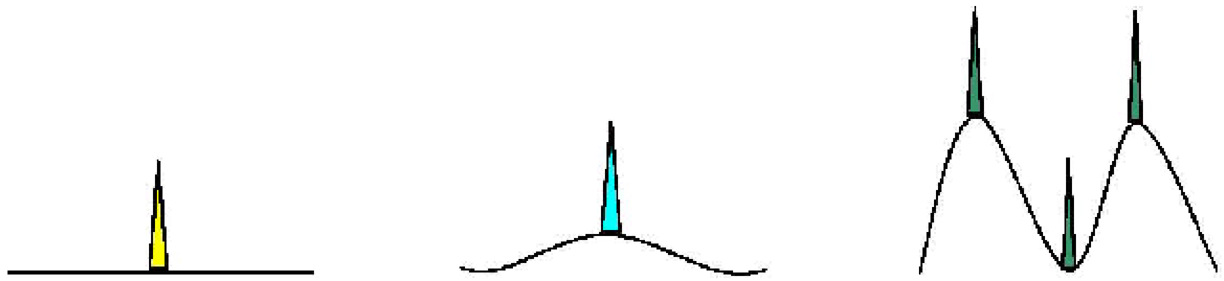
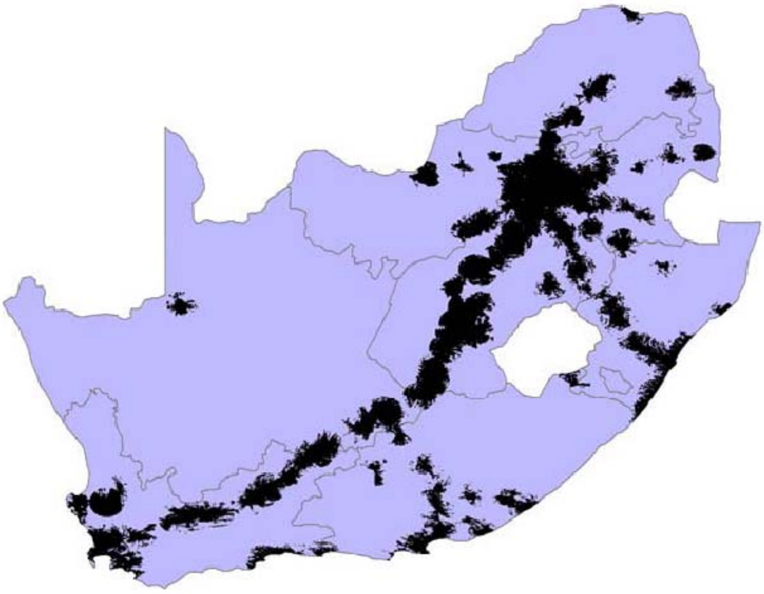


Figure 2

Panel A. Cell Phone Network in 1995 (covered areas in black)



Panel B. Cell Phone Network in 2005 (red: network expansion between 1995 and 2005)

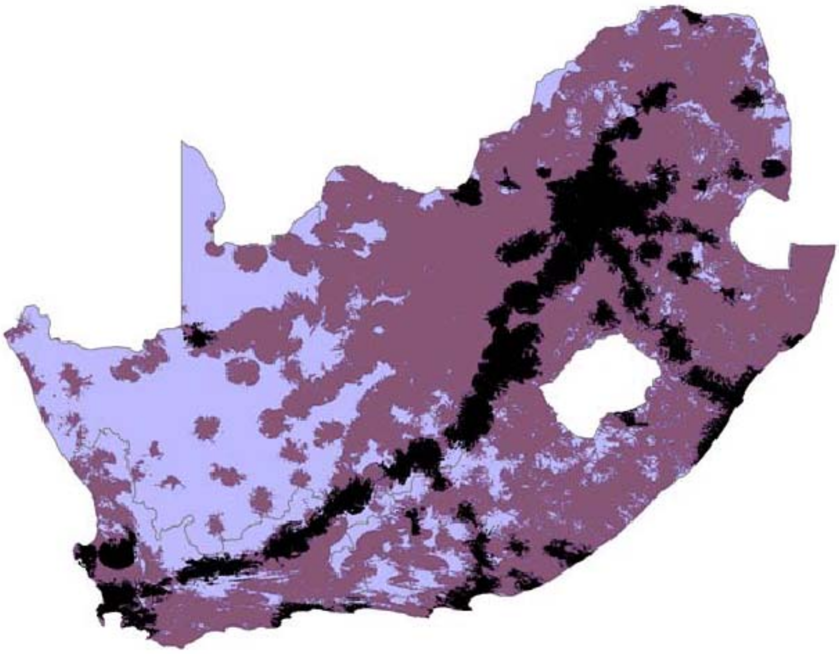


Figure 3. Digital Elevation Model and Province Boundaries. Enumerator area boundaries depicted for the three Nort-Eastern Provinces.

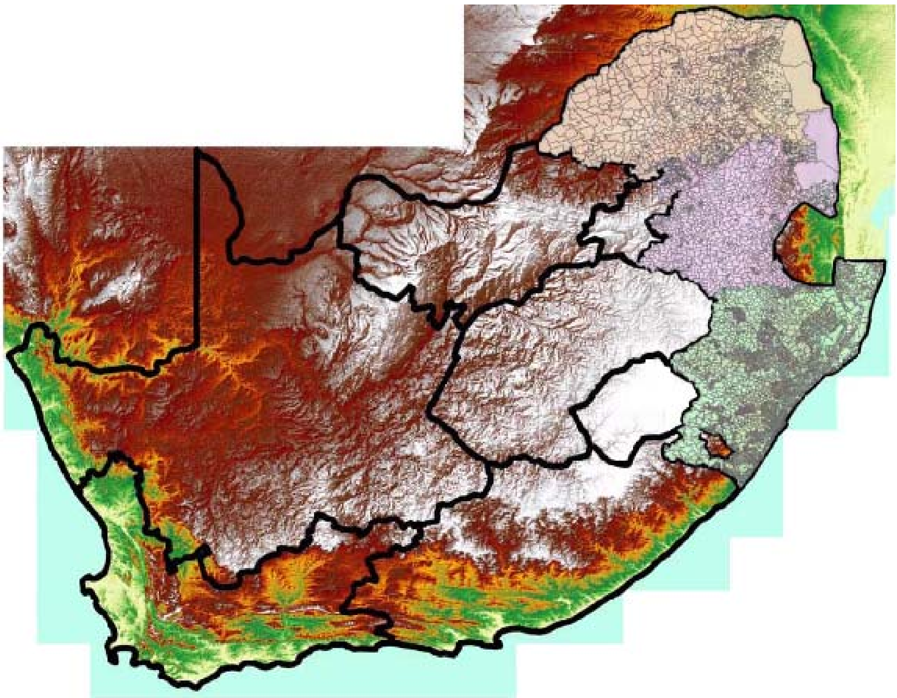
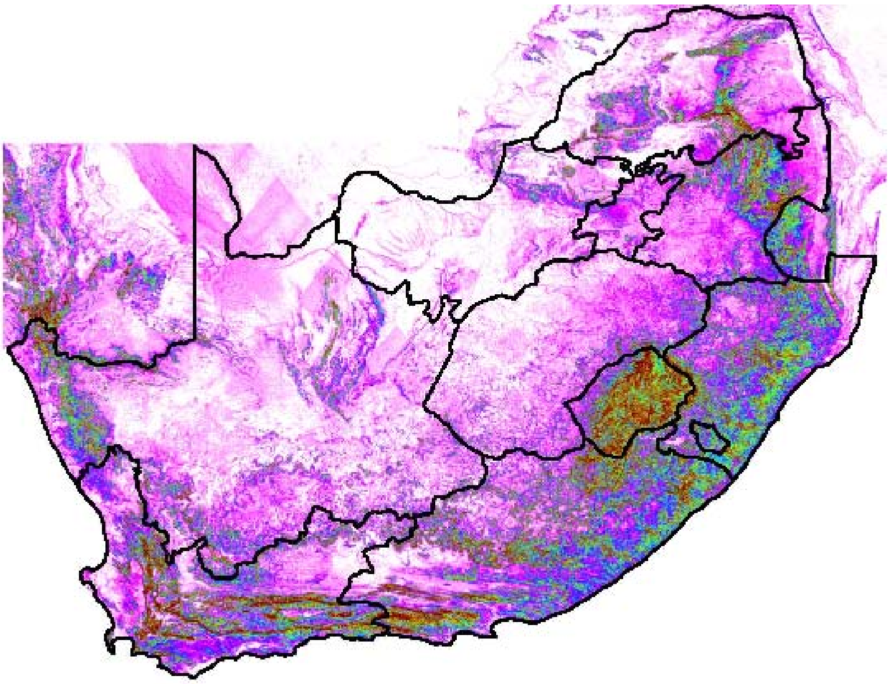


Figure 4. Local Terrain Curvature Calculated from the Digital Elevation Model.



Legend: small values (<0) are in green and blue, values close to zero white and purple, large values in red

Table 1. Individual and Household Characteristics

	MEAN	STD	MIN	MAX
Age	23.99	19.18	0	80
Male	0.46	0.50	0	1
African	0.94	0.23	0	1
Coloured	0.04	0.21	0	1
White	0.01	0.12	0	1
Employed	0.55	0.50	0	1
Of the Employed: Self-Employed	0.12	0.33	0	1
Of the Employed: in Agriculture	0.36	0.48	0	1
Monthly Salary (in year 2000 Rands)	1186.07	3717.07	0	449265
Hours worked per month (of the employed)	201.32	78.51	1	735.84
Wage per hour if Employed (in year 2000 Rands)	7.02	20.51	0	2501.75
Other income (in year 2000 Rands)	60.13	256.77	0	33000.00
Monthly household income (in year 2000 Rands)	1296.19	3523.64	1	115471
No Schooling	0.31	0.46	0	1
Attended High School	0.22	0.41	0	1
Higher Education with Degree	0.06	0.23	0	1

Table 2. Cellphone and Landline Ownership 1996-2001, Cell Phone Network Coverage 1995-2000 (Household Level)

YEAR		MEAN	STD	MIN	MAX
1996	Average Per Person Cellular Coverage in the Year Before	0.13	0.28	0	1
	Percent of Households that Have a landline	0.12	0.33	0	1
	Percent of Households that have a cellular phone	0.02	0.13	0	1
1997	Average Per Person Cellular Coverage in the Year Before	0.31	0.32	0	1
	Percent of Households that Have a landline	0.04	0.19	0	1
	Percent of Households that have a cellular phone	0.01	0.10	0	1
1998	Average Per Person Cellular Coverage in the Year Before	0.49	0.34	0	1
	Percent of Households that Have a landline	0.04	0.20	0	1
	Percent of Households that have a cellular phone	0.03	0.17	0	1
2000	Average Per Person Cellular Coverage in the Year Before	0.74	0.26	0	1
	Percent of Households that Have a landline	0.08	0.27	0	1
	Percent of Households that have a cellular phone	0.11	0.31	0	1
2001	Average Per Person Cellular Coverage in the Year Before	0.83	0.20	0	1
	Percent of Households that Have a landline	0.07	0.25	0	1
	Percent of Households that have a cellular phone	0.18	0.39	0	1

Table 3. Analysis of Cell Phone Pick Up (Household Level, Linear Probability Model)

Dependent Variable: Household Owns a Cellphone (=1)		
	(1)	(2)
Coverage in Municipality (lagged)	0.008	0.156***
	[0.008]	[0.037]
Percent of Household Male	0.004	0.004
	[0.004]	[0.004]
Percent of Household White	0.221***	0.220***
	[0.010]	[0.010]
Percent of Household Coloured	0.009	0.007
	[0.009]	[0.010]
Controls for Schooling	YES	YES
Controls for Age	YES	YES
District * Year Fixed Effects	YES	YES
Municipality Fixed Effects	YES	YES
Constant	-0.121	0.15
	[11,258.493]	[1.400]
Observations	49231	49231
Method	OLS	IV
R-squared	0.174	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4. Analysis of Individual Employment, Extensive Margin

	Dependent Variable: person is employed									
VARIABLES	COLUMNS									
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	0.047***	0.337***	0.025	0.053	0.080***	0.447***	0.078**	0.278*	0.081**	0.642***
	[0.017]	[0.102]	[0.023]	[0.106]	[0.024]	[0.111]	[0.035]	[0.160]	[0.033]	[0.156]
Dummy Variable =1 if Person is Male	0.100***	0.100***								
	[0.004]	[0.004]								
Dummy Variable =1 if Person is White	-0.005	-0.003	-0.02	-0.02	0.062**	0.061**	0.062*	0.061*	0.103**	0.101*
	[0.016]	[0.016]	[0.020]	[0.020]	[0.028]	[0.028]	[0.035]	[0.035]	[0.051]	[0.052]
Dummy Variable =1 if Person is Coloured	0.030*	0.028	0.036	0.035	0.018	0.017	0.026	0.027	0.005	0.004
	[0.018]	[0.018]	[0.022]	[0.022]	[0.030]	[0.030]	[0.038]	[0.038]	[0.052]	[0.053]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	0.683***	0.595	0.879***	0.789***	1.234***	1.191***	0.458*	0.862***	0.690*	1.518***
	[0.134]	[0.662]	[0.184]	[0.203]	[0.202]	[0.215]	[0.275]	[0.279]	[0.376]	[0.317]
Observations	57486	57486	28264	28264	29222	29222	14105	14105	15117	15117
R-squared	0.26		0.279		0.242		0.265		0.239	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 5. Analysis of Self-Employment

Dependent Variable: person is self-employed (=1)										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	-0.049**	-0.081	-0.013	-0.042	-0.107***	-0.17	-0.120**	0.067	-0.085*	-0.196
	[0.020]	[0.087]	[0.026]	[0.108]	[0.033]	[0.156]	[0.048]	[0.207]	[0.050]	[0.246]
Dummy Variable =1 if Person is Male	-0.060***	-0.060***								
	[0.004]	[0.004]								
Dummy Variable =1 if Person is White	0.504***	0.504***	0.521***	0.520***	0.401***	0.401***	0.365***	0.365***	0.458***	0.458***
	[0.015]	[0.015]	[0.017]	[0.017]	[0.028]	[0.028]	[0.034]	[0.034]	[0.053]	[0.053]
Dummy Variable =1 if Person is Coloured	-0.009	-0.008	-0.008	-0.008	0.02	0.02	-0.019	-0.021	0.098	0.099
	[0.017]	[0.017]	[0.020]	[0.020]	[0.034]	[0.034]	[0.042]	[0.042]	[0.063]	[0.063]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	0.589***	0.601***	0.635***	0.640***	0.448**	0.278	0.342	-0.051	0.599	0.207
	[0.135]	[0.145]	[0.198]	[0.240]	[0.190]	[0.191]	[0.327]	[0.285]	[0.471]	[0.285]
Observations	29767	29767	16733	16733	13034	13034	6651	6651	6383	6383
R-squared	0.293		0.291		0.32		0.343		0.335	
Standard errors in brackets										
* significant at 10%; ** significant at 5%; *** significant at 1%										

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 6. Analysis of Agricultural Employment

Dependent Variable: Person is employed in the agricultural sector (=1)										
s	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	-0.098***	-0.149*	-0.083***	-0.227**	-0.138***	0.127	-0.089*	-0.062	-0.163***	0.251
	[0.021]	[0.089]	[0.027]	[0.113]	[0.035]	[0.159]	[0.051]	[0.216]	[0.052]	[0.240]
Dummy Variable =1 if Person is Male	0.027***	0.027***								
	[0.005]	[0.005]								
Dummy Variable =1 if Person is White	0.021	0.02	0.056***	0.055***	-0.072***	-0.073***	-0.055	-0.055	-0.090*	-0.086
	[0.015]	[0.015]	[0.018]	[0.018]	[0.028]	[0.028]	[0.034]	[0.034]	[0.053]	[0.053]
Dummy Variable =1 if Person is Coloured	-0.099***	-0.099***	-0.062***	-0.060***	-0.177***	-0.182***	-0.186***	-0.187***	-0.153**	-0.160**
	[0.018]	[0.018]	[0.021]	[0.021]	[0.034]	[0.035]	[0.043]	[0.043]	[0.062]	[0.063]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	0.632***	0.505***	0.868***	0.87***	0.371*	-0.001	0.592**	0.248	0.56	0.325
	[0.123]	[0.128]	[0.196]	[0.204]	[0.202]	[0.226]	[0.250]	[0.288]	[0.399]	[0.307]
Observations	27425	27425	16098	16098	11327	11327	5806	5806	5521	5521
R-squared	0.389		0.445		0.374		0.416		0.381	
Standard errors in brackets										
* significant at 10%; ** significant at 5%; *** significant at 1%										

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 7. Analysis of Individual Employment, Intensive Margin

Dependent Variable: log of the number of hours a person worked in a month if the person is employed										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	0.012	0.024	-0.034	-0.033	0.078	0.102	0.084	-0.024	0.086	0.429
	[0.029]	[0.123]	[0.034]	[0.138]	[0.051]	[0.243]	[0.076]	[0.323]	[0.075]	[0.360]
Dummy Variable =1 if Person is Male	0.127***	0.127***								
	[0.006]	[0.006]								
Dummy Variable =1 if Person is White	0.037*	0.037*	0.080***	0.080***	-0.03	-0.03	-0.017	-0.017	-0.074	-0.075
	[0.022]	[0.022]	[0.024]	[0.024]	[0.044]	[0.044]	[0.054]	[0.054]	[0.082]	[0.082]
Dummy Variable =1 if Person is Coloured	-0.024	-0.024	0	0	-0.031	-0.031	-0.008	-0.006	-0.044	-0.044
	[0.025]	[0.025]	[0.027]	[0.027]	[0.053]	[0.053]	[0.065]	[0.066]	[0.096]	[0.096]
Controls for Age and Years of Schooling	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	3.309***	2.958***	3.467***	3.313***	2.845***	2.826***	3.629***	3.593***	2.015***	1.539**
	[0.209]	[0.227]	[0.232]	[0.252]	[0.336]	[0.366]	[0.444]	[0.458]	[0.681]	[0.699]
Observations	28829	28829	16250	16250	12579	12579	6426	6426	6153	6153
R-squared	0.232		0.264		0.217		0.253		0.23	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 8. Analysis of Wage Rates

Dependent Variable: log of the wage earned per hour if a person is employed.										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	-0.077	-0.228	-0.083	-0.283	-0.054	-0.23	-0.172	0.232	0.104	0.093
	[0.048]	[0.215]	[0.064]	[0.261]	[0.076]	[0.387]	[0.110]	[0.492]	[0.114]	[0.591]
Dummy Variable =1 if Person is Male	0.385***	0.385***								
	[0.011]	[0.011]								
Dummy Variable =1 if Person is White	1.021***	1.020***	1.202***	1.200***	0.763***	0.762***	0.714***	0.713***	0.928***	0.928***
	[0.037]	[0.037]	[0.045]	[0.045]	[0.067]	[0.067]	[0.082]	[0.082]	[0.125]	[0.125]
Dummy Variable =1 if Person is Coloured	0.055	0.056	0.052	0.054	0.07	0.072	-0.009	-0.015	0.242*	0.242*
	[0.041]	[0.041]	[0.049]	[0.050]	[0.076]	[0.076]	[0.093]	[0.093]	[0.144]	[0.144]
Controls for Age and Years of Schooling	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	1.524***	3.523***	3.708***	4.184***	2.017**	4.381***	3.353***	4.176***	2.590**	4.219***
	[0.410]	[0.416]	[0.620]	[0.588]	[0.898]	[0.958]	[0.949]	[1.065]	[1.024]	[1.060]
Observations	25288	25288	14583	14583	10705	10705	5483	5483	5222	5222
R-squared	0.414		0.402		0.434		0.472		0.44	

Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 9. Analysis of Income from Employment

Dependent Variable: log of the monthly income from employment by a person if the person is employed										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	-0.085*	-0.23	-0.119*	-0.302	-0.02	-0.131	-0.118	0.188	0.113	0.571
	[0.050]	[0.224]	[0.066]	[0.271]	[0.078]	[0.404]	[0.112]	[0.519]	[0.117]	[0.624]
Dummy Variable =1 if Person is Male	0.539***	0.538***								
	[0.011]	[0.011]								
Dummy Variable =1 if Person is White	1.127***	1.126***	1.339***	1.338***	0.834***	0.834***	0.803***	0.803***	0.951***	0.949***
	[0.038]	[0.038]	[0.047]	[0.047]	[0.069]	[0.069]	[0.085]	[0.085]	[0.129]	[0.129]
Dummy Variable =1 if Person is Coloured	0.041	0.043	0.05	0.052	0.065	0.066	0.012	0.007	0.236	0.239
	[0.043]	[0.043]	[0.051]	[0.051]	[0.079]	[0.080]	[0.096]	[0.097]	[0.150]	[0.150]
Controls for Age and Years of Schooling	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	7.207***	7.326***	6.962***	7.382***	5.859***	8.428***	7.164***	8.321***	7.208***	7.396***
	[0.484]	[0.433]	[0.579]	[0.520]	[0.918]	[0.991]	[1.039]	[1.051]	[1.170]	[1.095]
Observations	25848	25848	14866	14866	10982	10982	5616	5616	5366	5366
R-squared	0.425		0.399		0.435		0.475		0.442	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 10. Analysis of Income from Sources other than Employment

Dependent Variable: log of not employment-related income a person received in a month (remittences, pensions, transfers from friends or neighbors)										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Coverage in the MD in the year before	0.191***	0.036	0.148**	0.074	0.251***	0.027	0.372***	0.904	0.148	-0.224
	[0.056]	[0.206]	[0.071]	[0.263]	[0.083]	[0.302]	[0.137]	[0.551]	[0.110]	[0.329]
Dummy Variable =1 if Person is Male	-0.225***	-0.225***								
	[0.010]	[0.010]								
Dummy Variable =1 if Person is White	-0.046	-0.045	0.245**	0.245**	-0.382***	-0.378***	-0.352**	-0.362**	-0.497**	-0.496**
	[0.079]	[0.079]	[0.096]	[0.096]	[0.124]	[0.124]	[0.152]	[0.153]	[0.221]	[0.221]
Dummy Variable =1 if Person is Coloured	0.158**	0.156**	0.213***	0.213***	0.079	0.076	-0.002	0.003	0.176	0.169
	[0.067]	[0.067]	[0.081]	[0.082]	[0.103]	[0.103]	[0.137]	[0.137]	[0.157]	[0.157]
Controls for Age and Years of Schooling	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Constant	-3.055***	-2.658***	-0.435	-0.739	-1.663**	-2.011***	-2.799**	-1.394	-2.916***	-1.016
	[0.597]	[0.583]	[0.679]	[0.656]	[0.663]	[0.748]	[1.209]	[1.057]	[1.025]	[0.793]
Observations	94152	94152	42428	42428	51724	51724	22077	22077	29647	29647
R-squared	0.464		0.441		0.479		0.475		0.488	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] IV results for entire sample; [3] OLS Results for Males; [4] IV resutls for Males; [5] and [6] OLS and IV results, respectively, for females; [7] and [8] OLS and IV results for Women living in households with less than two children; [9] and [10] OLS and IV results for women living in households with 3 children or more.

Table 11. Analysis of Total Household Income

	Dependent Variable is the log of household income					
	[1]	[2]	[3]	[4]	[5]	[6]
Coverage in the MD in the year before	0.396***	0.63	0.656***	1.918**	0.408***	0.308
	[0.128]	[0.756]	[0.190]	[0.860]	[0.153]	[0.727]
Percent of Household that is Male	0.293***	0.293***	0.307***	0.308***	0.263***	0.263***
	[0.068]	[0.068]	[0.094]	[0.094]	[0.079]	[0.080]
Percent of Household that is White	0.657***	0.660***	0.601***	0.609***	0.267	0.263
	[0.147]	[0.147]	[0.169]	[0.169]	[0.247]	[0.249]
Percent of Household that is Coloured	0.184	0.184	0.202	0.196	0.239	0.238
	[0.154]	[0.154]	[0.176]	[0.176]	[0.231]	[0.231]
Percent of Household with No Schooling	-0.099	-0.099	-0.033	-0.036	-0.101	-0.101
	[0.067]	[0.067]	[0.091]	[0.091]	[0.079]	[0.079]
Percent of Household with High School Education	0.319***	0.318***	0.387***	0.378***	0.329***	0.330***
	[0.075]	[0.075]	[0.100]	[0.101]	[0.091]	[0.091]
Percent of Household with a degree or more	1.695***	1.693***	1.732***	1.725***	1.782***	1.783***
	[0.094]	[0.094]	[0.126]	[0.127]	[0.112]	[0.112]
Average age of the household	0.012***	0.012***	0.010***	0.010***	0.013***	0.013***
	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]
STD of Age for household	0.038***	0.038***	0.037***	0.037***	0.040***	0.040***
	[0.002]	[0.002]	[0.003]	[0.003]	[0.003]	[0.003]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES
Constant	5.358***	4.889***	6.223***	6.391***	4.691***	4.673***
	[0.686]	[0.446]	[1.420]	[1.084]	[0.418]	[0.425]
Observations	21593	21593	11207	11207	16560	16560
R-squared	0.123		0.147		0.119	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] Coverage is instrumented and entire sample used; [3] OLS Results for households with two or fewer children; [4] IV results for households with two or fewer children; [5] OLS results for households with three or more children; [6] IV results for households with three or more children.

Table 12. Analysis of Extreme Poverty

Dependent Variable: household has income of less than Rand 52 ($7.50) a month (=1)						
	[1]	[2]	[3]	[4]	[5]	[6]
Coverage in the MD in the year before	-0.034	-0.396**	-0.078**	-0.348**	-0.021	-0.302**
	[0.025]	[0.154]	[0.037]	[0.169]	[0.030]	[0.150]
Percent of Household that is Male	-0.023*	-0.023*	-0.037**	-0.037**	-0.015	-0.014
	[0.013]	[0.013]	[0.018]	[0.018]	[0.016]	[0.016]
Percent of Household that is White	0.174***	0.171***	0.191***	0.190***	0.167***	0.158***
	[0.029]	[0.029]	[0.033]	[0.033]	[0.050]	[0.050]
Percent of Household that is Coloured	-0.018	-0.018	-0.012	-0.011	-0.005	-0.006
	[0.031]	[0.031]	[0.034]	[0.035]	[0.046]	[0.047]
Percent of Household with No Schooling	0.031**	0.032**	0.002	0.003	0.042***	0.042***
	[0.013]	[0.013]	[0.018]	[0.018]	[0.016]	[0.016]
Percent of Household with High School Education	-0.069***	-0.067***	-0.076***	-0.073***	-0.077***	-0.075***
	[0.015]	[0.015]	[0.019]	[0.020]	[0.018]	[0.018]
Percent of Household with a degree or more	-0.212***	-0.210***	-0.196***	-0.194***	-0.232***	-0.230***
	[0.019]	[0.019]	[0.025]	[0.025]	[0.023]	[0.023]
Average age of the household	-0.006***	-0.006***	-0.006***	-0.006***	-0.007***	-0.007***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
STD of Age for household	-0.009***	-0.009***	-0.008***	-0.009***	-0.010***	-0.010***
	[0.000]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES
Constant	0.427**	0.538***	0.453	0.586**	0.494*	0.563***
	[0.186]	[0.149]	[0.281]	[0.248]	[0.259]	[0.201]
Observations	22665	22665	11776	11776	17383	17383
R-squared	0.138		0.146		0.142	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] Coverage is instrumented and entire sample used; [3] OLS Results for households with two or fewer children; [4] IV results for households with two or fewer children; [5] OLS results for households with three or more children; [6] IV results for households with three or more children.

Table 13. Analysis of Moderate Poverty

Dependent Variable: household has income of less than $1 a day per person (=1)						
	[1]	[2]	[3]	[4]	[5]	[6]
Coverage in the MD in the year before	-0.086***	-0.112	-0.090**	-0.357*	-0.062*	0.024
	[0.027]	[0.167]	[0.042]	[0.192]	[0.032]	[0.158]
Percent of Household that is Male	-0.014	-0.014	-0.015	-0.015	-0.015	-0.015
	[0.015]	[0.015]	[0.021]	[0.021]	[0.017]	[0.017]
Percent of Household that is White	0.032	0.032	0.047	0.046	-0.021	-0.018
	[0.031]	[0.032]	[0.037]	[0.037]	[0.052]	[0.053]
Percent of Household that is Coloured	-0.067**	-0.067**	-0.056	-0.055	-0.099**	-0.099**
	[0.033]	[0.033]	[0.039]	[0.039]	[0.049]	[0.049]
Percent of Household with No Schooling	0.011	0.011	-0.005	-0.004	0.009	0.009
	[0.014]	[0.014]	[0.020]	[0.020]	[0.017]	[0.017]
Percent of Household with High School Education	-0.115***	-0.114***	-0.122***	-0.120***	-0.116***	-0.116***
	[0.016]	[0.016]	[0.022]	[0.022]	[0.019]	[0.019]
Percent of Household with a degree or more	-0.427***	-0.427***	-0.421***	-0.419***	-0.460***	-0.460***
	[0.020]	[0.020]	[0.028]	[0.028]	[0.024]	[0.024]
Average age of the household	-0.012***	-0.012***	-0.011***	-0.011***	-0.012***	-0.012***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
STD of Age for household	0.001	0.001	0	0	0.002***	0.002***
	[0.000]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES
District * Year Fixed Effects	YES	YES	YES	YES	YES	YES
District Coverage * Population Density, Percent Male, Percent White, Percent Coloured and Avg Household Size in MD in 1996	YES	YES	YES	YES	YES	YES
Constant	0.954***	0.995***	0.980***	1.105***	1.227***	1.258***
	[0.209]	[0.178]	[0.300]	[0.248]	[0.265]	[0.210]
Observations	22665	22665	11776	11776	17383	17383
R-squared	0.184		0.191		0.173	

Standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

[1] OLS Results for entire sample; [2] Coverage is instrumented and entire sample used; [3] OLS Results for households with two or fewer children; [4] IV results for households with two or fewer children; [5] OLS results for households with three or more children; [6] IV results for households with three or more children.